APEC Climate Network

발간등록번호
11-1360000-000080-14

Asia-Pacific
Economic Cooperation

APCN SYMPOSIUM

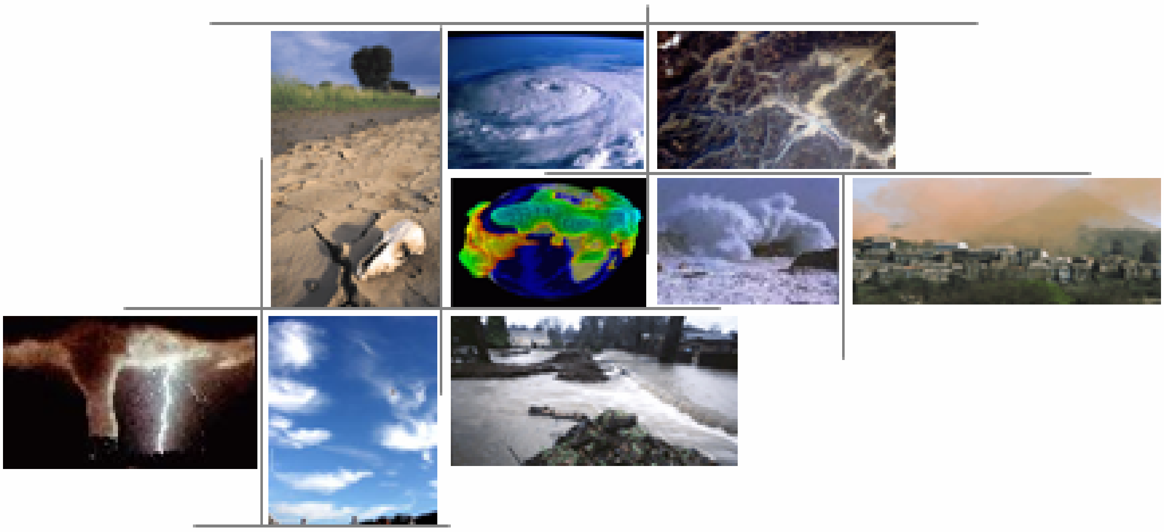
on the Multi-Model Ensemble for Climate Prediction

Second APCN Steering Committee Meeting and Third APCN Working Group Meeting

- Jeju Island, Republic of Korea, 7~10 October 2003

APEC Climate Network (APCN)

APEC Industrial Science and Technology Working Group (ISTWG)



Korea Meteorological Administration

2003

WMO

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on the Multi-Model Ensemble for Climate Prediction

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Industrial Science and Technology Working Group (ISTWG)

Korea Meteorological Administration

2003

ISBN 89-954715-0-6 93450

APEC#203-IT-04.1

Edited by Chung-Kyu Park, Climate Prediction Division, KMA

Published by KMA for APEC.

KMA (Korea Meteorological Administration)

460-18, Sindaebang-dong, Dongjak-gu, Seoul 156-720, Korea

APEC (Asia-Pacific Economic Cooperation)

35, Heng Mui Keng Terrace, Singapore 119616

Printed in the Republic of Korea

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APCN Symposium on the Multi-Model Ensemble for Climate Prediction/ Second APCN Steering Committee Meeting and Third APCN Working Group Meeting

Myung-Hwan Ahn

Administrator
Korea Meteorological Administration

Distinguished participants, Ladies and gentlemen,

It is my great pleasure to host the APCN Symposium in Jeju. This symposium is co-sponsored by World Meteorological Organization, and jointly held with the Second APCN Steering Committee Meeting and the Third APCN Working Group Meeting.

On behalf of the Korea Meteorological Administration, I would like to extend a warm welcome to all the participants, particularly leading scientists from all over the world, delegates from the APEC Member Economies and the European region, and the Steering Committee and Working Group members.

My special thanks should be addressed to Dr. Tomoyuki Ito, Director-General of the Climate and Marine Department of Japan Meteorological Agency (JMA), who is participating on behalf of Dr. Takeo Kitade, Director-General of JMA.

I would also like to express my sincere appreciation to Mr. Kenneth Davidson, Director of the World Climate Programme of WMO for his support to ensure the success of APCN, and Dr. Ming Ji from the US National Oceanic and Atmospheric Administration, Dr. Jagadish

Shukla from the Center for Ocean-Land-Atmosphere Studies of the United States, and Dr. Kilnam Chon from the Korea Advanced Institute of Science and Technology, for their participation and support.

We still remember the record-breaking natural disasters in the Asia-Pacific region during the 1997-98 El Nino, which resulted in enormous human and economic losses worldwide. As many parts of the world experienced serious natural disasters associated with a series of unusual weather and climate, the APCN project was proposed to the Third APEC Ministers Conference on Regional Science and Technology Cooperation held in Mexico in October 1998 for the purpose of establishing an early warning system for unusual climate through regional cooperation in the Asia-Pacific region.

It is indeed encouraging to note that APCN has made a steady progress for the past several years with the participation of 21 member economies. I would like to take this opportunity to express my sincere appreciation to all of you for your participation and cooperation since the beginning.

Now, while APCN is in an early stage yet, APCN is trying to provide the best multi-model ensemble climate prediction information, aiming at reducing the impact of natural disasters and contributing to the sustainable social and economic development in the Asia-Pacific region.

Distinguished participants, Ladies and gentlemen,

In this year again, we experienced unprecedented extreme climate events, such as extreme cold waves in Southwest Asia, record-breaking heat waves in Europe, and severe floods in many parts of the world. It is unfortunate that we could not foretell these large-scale extreme signals.

I personally believe, however, we can make it possible to predict the extreme climate signals through our joint effort, and also hope to improve the seasonal predictability up to that of medium-range weather forecasts in the near future. For this, I would like to assure you of the KMA's support to establish a Visiting Scientist Programme and Cooperative Research and Development Programme for better climate prediction.

As the occurrence of extreme climate becomes more frequent and severe, the regional cooperation is essential for the preparedness and countermeasures against unfavorable climate conditions. In this respect, I anticipate this meeting be the opportunity to bring our best wisdom together to step forwards and strengthen the cooperation.

Distinguished participants, Ladies and gentlemen,

APCN is intended to bring benefits to all of us. As the demands of regional cooperation are increasing for the prevention of natural disasters, your cooperation and continuous participation in APCN will lead to the improvement of climate prediction, and the APEC vision of regional prosperity and economic growth in the Asia-Pacific community will be realized someday through our continuous efforts.

Here, the Jeju island is a famous tourist resort for its natural beauty, and the Jeju islanders are also proud of their generosity and hospitality to visitors. KMA staffs will also do their best to make you feel comfortable. I hope we build-up our friendship throughout the meeting in this comfortable environment.

Finally, I would like to thank all the participants again, and wish you enjoy your stay in Jeju.

Kam-sa-ham-ni-da.

Keynote Address
Activities of the Japan Meteorological Agency for International Cooperation in Climate Information Services

Takeo Kitade

Director-General
Japan Meteorological Agency

1. Introduction

The 17th APEC ISTWG (Industrial Science and Technology Working Group) meeting held in Seattle in August 1999 approved the establishment of the Asia Pacific Climate Network (APCN) in order to reduce natural disasters related to unusual weather and climate and ultimately to contribute to the social and economic development of APEC members. Recognizing the importance of APCN, the Japan Meteorological Agency (JMA) has joined the APCN activities together with other APEC members and contributed to the multi-model ensemble experiment by providing the seasonal prediction output from the JMA’s model.

According to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, global warming is likely to lead to greater extreme events and increase the risk of natural disasters like drought and flood. The significance of climate information including climate monitoring and climate prediction, is increasing for the sustainable development in the Asia-Pacific region. It is convincing that the success of APCN will contribute to the reduction of the natural disasters and the protection of life and property.

2. Tokyo Climate Center (TCC) (Figure 1)

In April 2002, JMA established Tokyo Climate Center (TCC). The mission of TCC is to assist climate services of the National Meteorological and Hydrological Services (NMHSs) in the Asia-Pacific region with the aim of mitigating natural disasters and contributing to the sustainable development in the region. To accomplish this mission, TCC has two major areas of activities. The first area is to provide climate information including monitoring reports on extreme climate events and global climate system, Grid Point Values (GPVs) and maps of dynamical seasonal prediction and ENSO outlook from the TCC web site (http://okdk.kishou.go.jp/). The second one is to provide technical assistance to NMHSs in the region. NMHSs are responsible for the provision of climate information to users in their respective countries. TCC also supports capacity building for the NMHS in the Asia and Pacific region. In this regard, TCC held a training workshop on climate system monitoring, diagnosis and prediction in the Asia-Pacific region in December 2002. TCC will organize the workshop again this year.

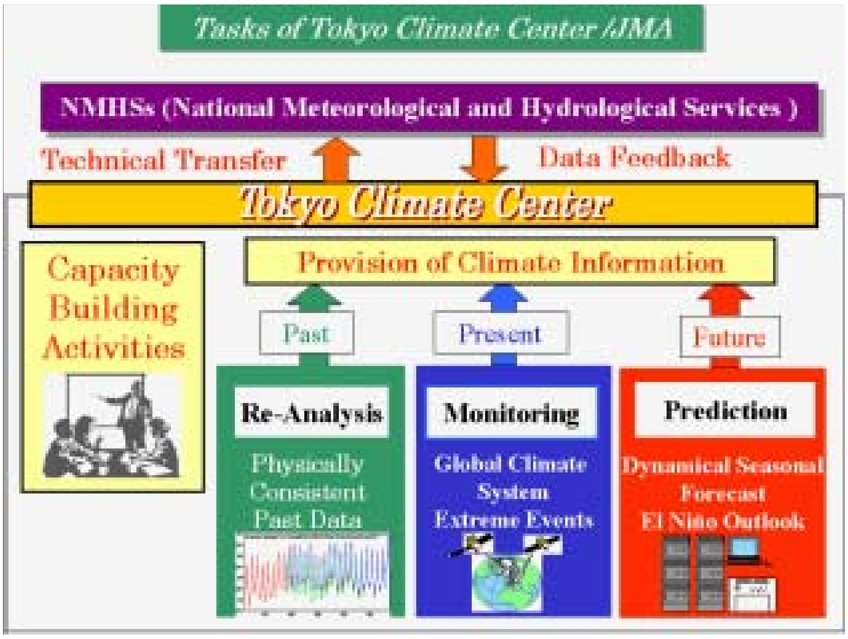


Figure 1

Concept for tasks of Tokyo Climate Center (TCC) /JMA.

3. Technical advancement in seasonal prediction model and climate system monitoring (Figure 2)

The quality of products from TCC is supported by technical development and increase of computer resources. Numerical model techniques for short-term weather forecast have been extendedly applied for predicting seasonal climate and re-analyzing a comprehensive past climate dataset.

JMA completed applying dynamical ensemble forecast techniques with the JMA's atmospheric model to all the ranges of the seasonal forecast in September 2003. The first application of dynamical ensemble predictions in JMA is the one-month dynamical forecast, which started in March 1996. This is basically the extended weather forecast, and its success is sustained by the growing performance of the JMA short-term numerical prediction model.

JMA began to conduct operational three-month dynamical ensemble forecasts once a month in March 2003. This means that the JMA numerical weather prediction stepped out into a different forecast regime where the signal of the prediction basically appear as the atmospheric response to SST anomalies. JMA began dynamical warm/cold-seasons ensemble prediction in September 2003. For this prediction, global SST anomalies for the model are given in a statistical way based on Nino3 (5°S - 5°N, 150°W - 90°W) SST, which is separately predicted with the El Nino prediction model, which is an atmosphere-ocean coupled model.

Our next goal in the seasonal forecast is to introduce an atmosphere-ocean coupled model. Specifically, our plan is to begin the seasonal forecast with a fully coupled model in 2012. A major task to achieve this goal is to reduce climate drift of the coupled model by resolving problems in both the atmosphere model and ocean model, for example, by improving cloud schemes which affect two aspects of radiation and precipitation.

We also have the plan to expand forecast periods to six-month and furthermore one-year, using the atmosphere-ocean coupled model.

Another technical topic is the Japan Reanalysis Project (JRA-25), which has been conducted by JMA and the Central Research Institute of Electric Power Industry of Japan (CRIEPI) since 2001. The main objective of JRA-25 is to make historical global objective analysis dataset for 1979-2004 in a consistent manner with a fixed state-of-the-art numerical weather prediction data assimilation system. The JRA-25 includes some characteristics distinct from ECMWF and NCEP/NCAR reanalysis by the adoption of the retrieved wind data around typhoons, the reanalyzed JMA satellite wind data over the Asia-Pacific region, and COBE (Centennial in-situ Observation-Based Estimates of variability of SST and marine meteorological variables) SST dataset based on Kobe Collection Data (2003). All of those characteristics will raise the quality of the JRA-25 climate dataset in the Asia-Pacific region. Heavy precipitation and severe wind associated with the typhoons or hurricanes are expected to be re-analyzed more precisely in JRA-25.

The JRA-25 dataset will be necessary for 1) consistent initial conditions and validation dataset for dynamical seasonal prediction, and 2) more accurate operational climate monitoring services in TCC/JMA. The dataset will be also useful for global warming study and other various research activities in climate research community. We plan to provide the products of JRA-25 for any interested parties to contribute to improvement of climate monitoring and analysis.

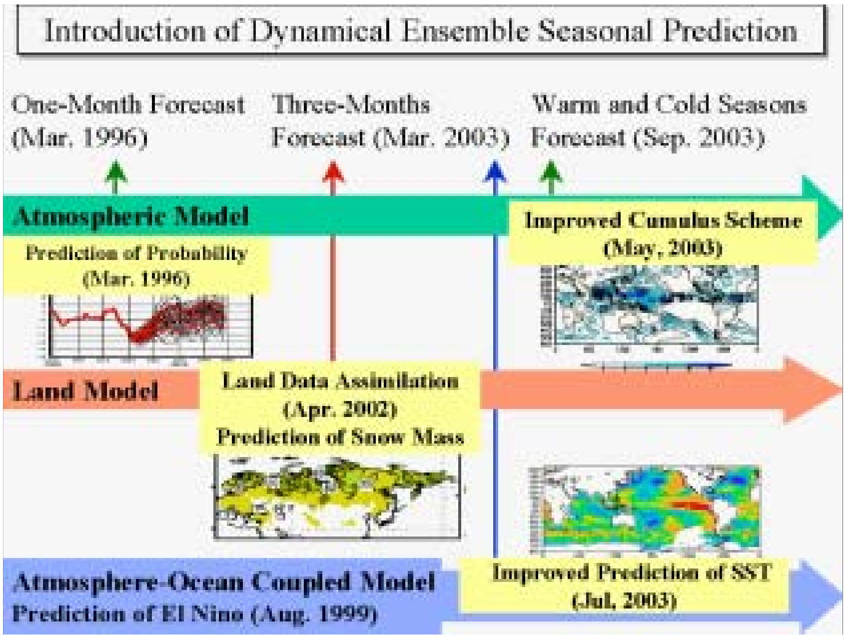


Figure 2 Schematic explanation on introduction of dynamical ensemble seasonal prediction in JMA.

4. Multi-Model Ensemble (MME) Technique

It is being recognized that the MME prediction technique is a promising tool in seasonal forecasting. Therefore, it is noteworthy that a number of NMHSs jointly make efforts to improve seasonal prediction with the MME approach and conduct related experiments under the framework of APCN. JMA has keen interest in the MME experiments and model comparisons of prediction performance on the APCN website.

On the other hand, I would like to emphasize the importance of the continuous improvement of each single model to raise the overall performance of the MME method. JMA has made much effort to improve the prediction model, but there are still a lot of outstanding issues to improve the models and we will continue to struggle for the better seasonal prediction model as before.

5. Summary

I reiterate that JMA will continue to cooperate with APCN to enhance the quality of climate information for APEC members. JMA will take two kinds of specific contribution to APCN.

The first one is to provide APCN with GPVs of the JMA operational seasonal prediction models from the TCC/JMA website. The second one is to improve the JMA's models without a break. I hope the latter contribution will really raise the quality of APCN's climate information products in comparison with other MME centers at present and in future.

JMA has been responsible for the provision of meteorological and climate information in Japan and has maintained high-level performance extended in the meteorological, climatological and oceanic observation, analysis and prediction. There is no doubt that large parts of the JMA's products are also helpful for NMHSs in the Asia and Pacific region, which are also responsible to provide appropriate meteorological and climate information and to promote its utilization in its own region.

We are pleased to continue cooperating with APCN members to promote climate information services all over the Asia-Pacific region.

Keynote Address

Chow Kok Kee

Director-General
Malaysian Meteorological Service

Distinguished guests,
Ladies and Gentlemen,

It is indeed my great honour to be invited to speak at this Asia Pacific Climate Network Symposium on multi-model Ensemble for Climate Prediction.

With the fast economic development, countries are becoming more and more sensitive to the climate and its changes. Any deviation from the norm could lead to significant economic impacts.

For example, the El Nino in 1997-1998 have resulted rampant forest fires in many areas. However, human interventions were not successful in putting off these fires immediately. The disaster had lead to great loss of biomass, food production and hence national economy. In addition, the particulate generated also posed a significant threat to the health of millions of residents that had no means to avert such aggrieved situation.

In many Asia Pacific countries, stable and sufficient crop, livestock and food production remain as their national priority. However, any interruption due to extreme weather will inadvertently lead to social distress or even security problems. At the moment, many of these countries still lack the skill for making simple climate forecast even at medium term. They are unable to make reasonable climate forecast at all. The IPCC third assessment report indicates that the poorest people in poorest countries will be the most affected by extreme events. Therefore, early warning and timely dissemination of climate forecast are crucial to reduce the losses.

In several Southeast Asian countries, no resource has been allocated to develop the climate forecast since it may involve intensive capital and human resource investment. Moreover, not many meteorologists are well trained to conduct such forecast.

We are indeed fortunate to have the Korean Meteorological Administration takes the lead in producing the ensemble climate forecast. The probabilistic forecasts at higher resolution are definitely very useful for Southeast Asian countries.

I consider having the products is only the first step towards good climate forecasts at the sub-regional and national levels. I suggest that the following action to be taken:-

a. Capacity Building

We need to build up the human resources at the national level. Regional seminars and symposiums similar to this one are crucial for meteorologists to understand the theoretical background and applications of forecast.

b. Verification

National meteorological services could contribute to the development of the ensemble climate forecast by carrying out verification. Such feedback will be useful for the future development of the models as well as better methodologies. Some forms of attachment or exchange of scientists will be useful for modelers to have a direct interaction with the national meteorological services.

c. User and product identification

National meteorological services should conduct their respective surveys or interactions with potential users with a view of designing the appropriate products. For example, the agriculture, health, water resources and power generation are some of the potential users. Different products may have to be tailor-made.

d. Networking

At national level, a good networking should be established among the meteorological services, users and academicians so as to foster the national development of climate forecast, user feedbacks and improvement of products. Networking at sub-regional level, for example, the ASEAN Sub-Committee on Meteorology & Geophysics or SCMG we used to call it, will facilitate exchange of experiences and products. I welcome the close cooperation between the KMA and SCMG. At regional level, obviously, a symposium like this will definitely enhance our capabilities.

e. Regional cooperation

Accurate climate predictions demand close interactions between climate centres and national meteorological services. Therefore, I would like to see more regional cooperation to be promoted with a view of enhancing the regional capabilities of all countries in the Asia Pacific area.

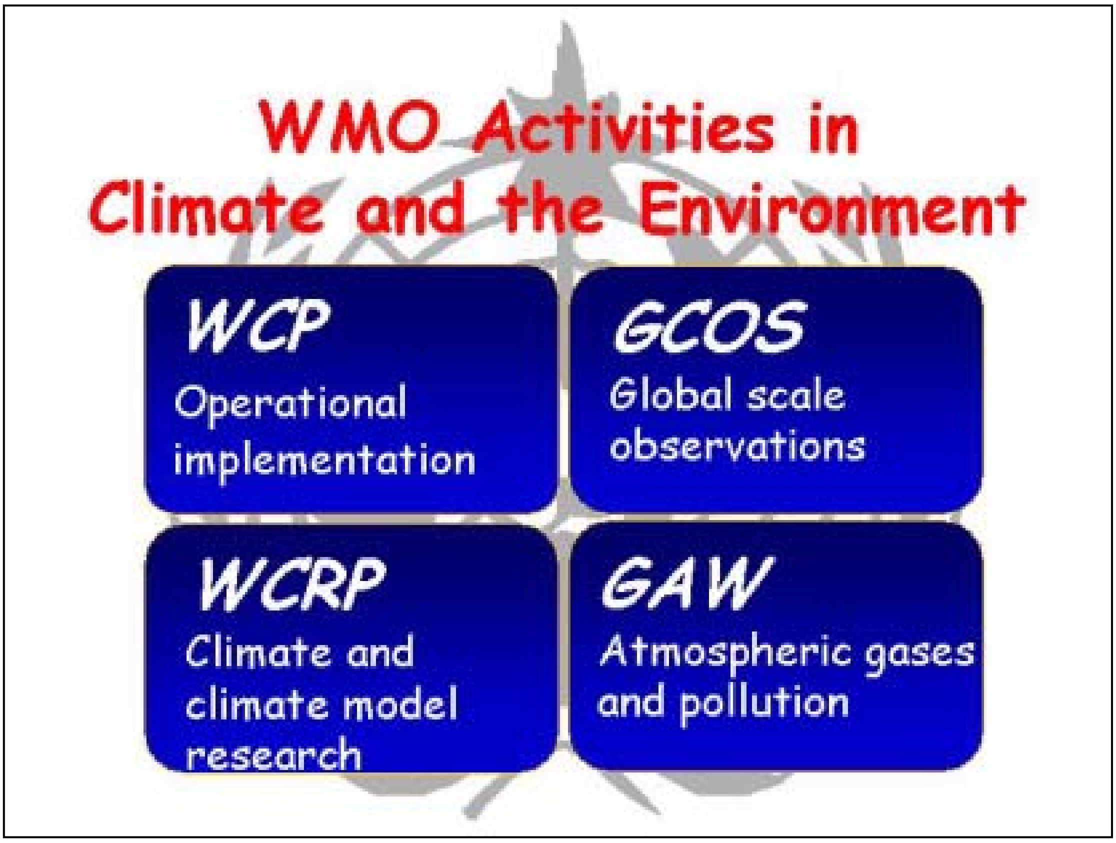
Once again, I like to thank the organizer for giving me the opportunity to speak at the symposium. I wish you having a successful deliberation in the next few days.

Thank you for your attention.

Keynote Lecture
WMO Activities in Climate and Environment

Kenneth Davidson

Director of World Climate Programme
World Meteorological Organization



World Climate Programme

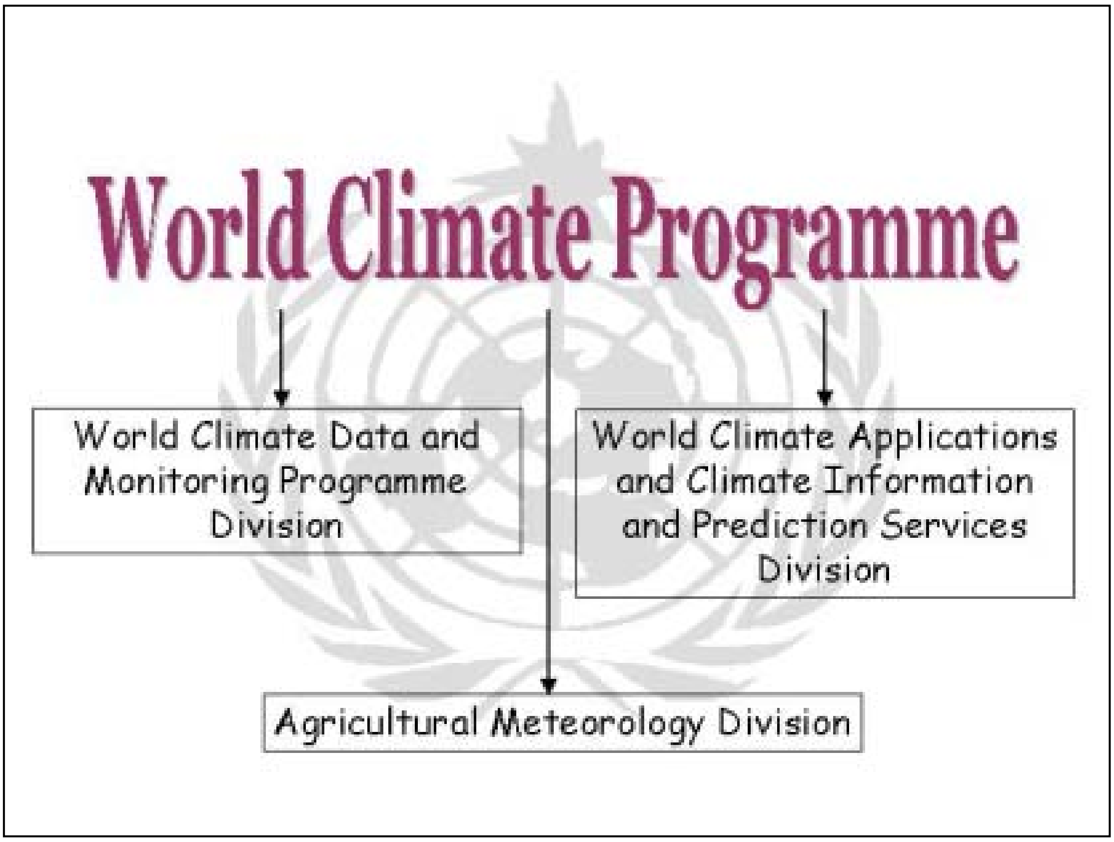
formed in 1979
following the 1st World Climate Conference

4 Components

WCAC, WCDMP, WCRP, WCIRP

World Climate Programme

- 1990—2nd WCC resulting in:
- Formation of GCOS
- New names for 3 components of WCP
- Strong support for IPCC
- 1994 creation of the CLIMATE AGENDA
- UNFCCC
- UNCCD
- UNCBD



World Climate Data and Monitoring Programme (WCDMP)

"Taking the pulse of the planet"

- To *Improve Capacity* of Members in:
  - Climate System Monitoring
  - Climate Data Rescue activities in light of recent technological developments
  - New Climate Database Management Systems
  - Development of methods for climate data homogenization and recording of metadata

Issues of Urgency

- Climate Monitoring
  - Elevate awareness of risks, for all time-period planning
  - Exploit distributed information
  - Use climate as a resource
- DARE
  - Deterioration of historical datasets needed for prediction
  - Potentially irreversible loss to science and society
- CDMS to replace CLICOM
  - CLICOM software, operating system, expertise becoming unavailable
  - Enhancements--CDMSs provide better support prediction, analysis and applications

Monthly, Seasonal, Interannual Monitoring and Climate Change Detection

Days with warm nights - Summer half of years 1976-1999

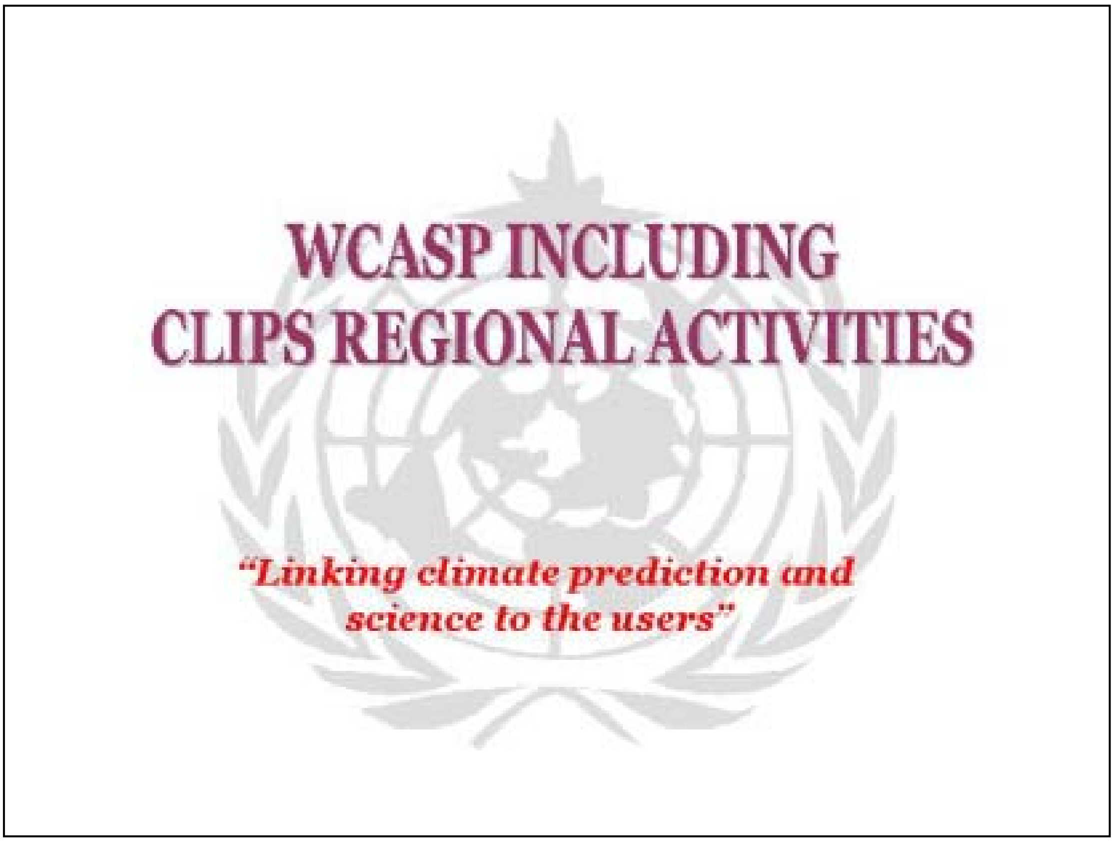
European Climate Assessment & Dataset < Warning: trends for selected subset of stations! >

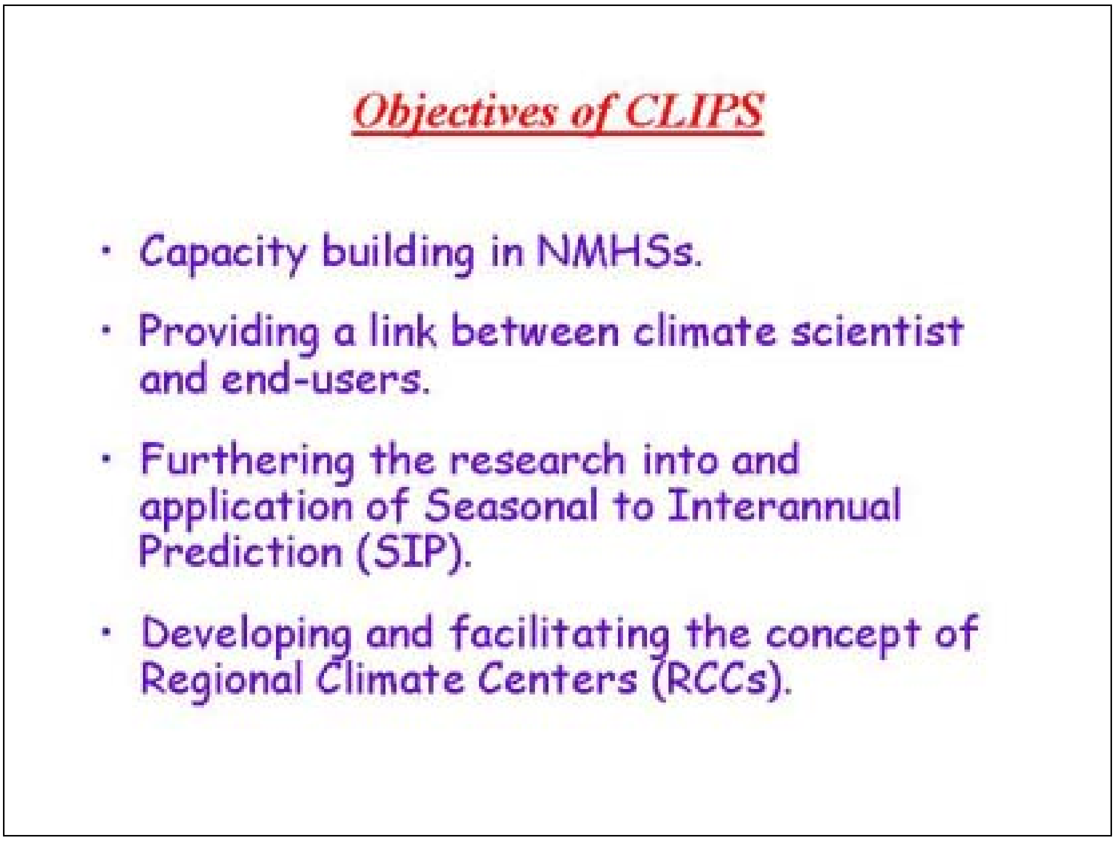
Data Rescue (DARE)

Definition: DARE is an ongoing process of

- Preserving all data at risk of being lost due to deterioration of the medium,
  and,
- Digitizing of current and past data into computer compatible form for easy access.

A major requirement: digitize deteriorating paper archives


WCASP INCLUDING
CLIPS REGIONAL ACTIVITIES
"Linking climate prediction and
science to the users"


Objectives of CLIPS
• Capacity building in NMHSs.
• Providing a link between climate scientist and end-users.
• Furthering the research into and application of Seasonal to Interannual Prediction (SIP).
• Developing and facilitating the concept of Regional Climate Centers (RCCs).

Activities

- Provide assistance to NHMSs in building their capacity to interact with various sectoral users of climate information through training workshops and seminars.
- Provide support in development of new methods and techniques in response to user needs and requirements for climate information, knowledge and services.
- Development of methodologies to assess the effects of climate, its variability and potential change on various socio-economic activities.
- Establish through workshops and other related activities, e. g. Climate Outlook Forums, a closer interaction with potential users of climate services.

Applications

WCASP has continued to implement activities related to:

1) Climate and Human Health through:
   - Supporting and participating in regional activities on health impacts of climate related severe events and climate variability and change;
   - Supporting work on establishing heat/health warning systems for various cities and preparing relevant guidelines;
   - Supporting work on establishing a Universal thermal climate index;
2) Urban and Building Climatology through:
   - Developing training syllabus, tools and other guidelines;
   - Promotion and support of activities related to development and use of renewable energies.

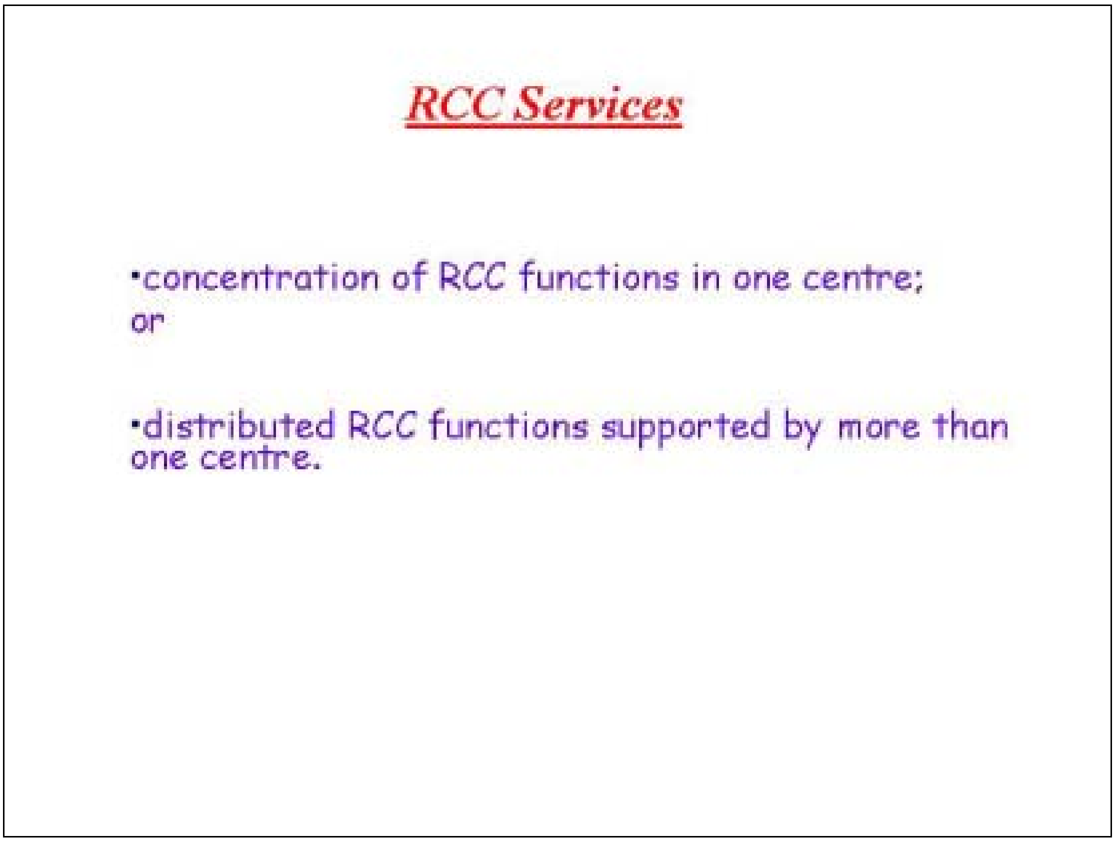
Future Plans

- Capacity building (CLIPS focal points);
- Application projects (development of pilot applications projects in various countries as follow-up to the capacity building);
- Regional Climate Centres;
- Collaboration (close coordination and cooperation between the NMHSs and sectoral organizations and institutions).

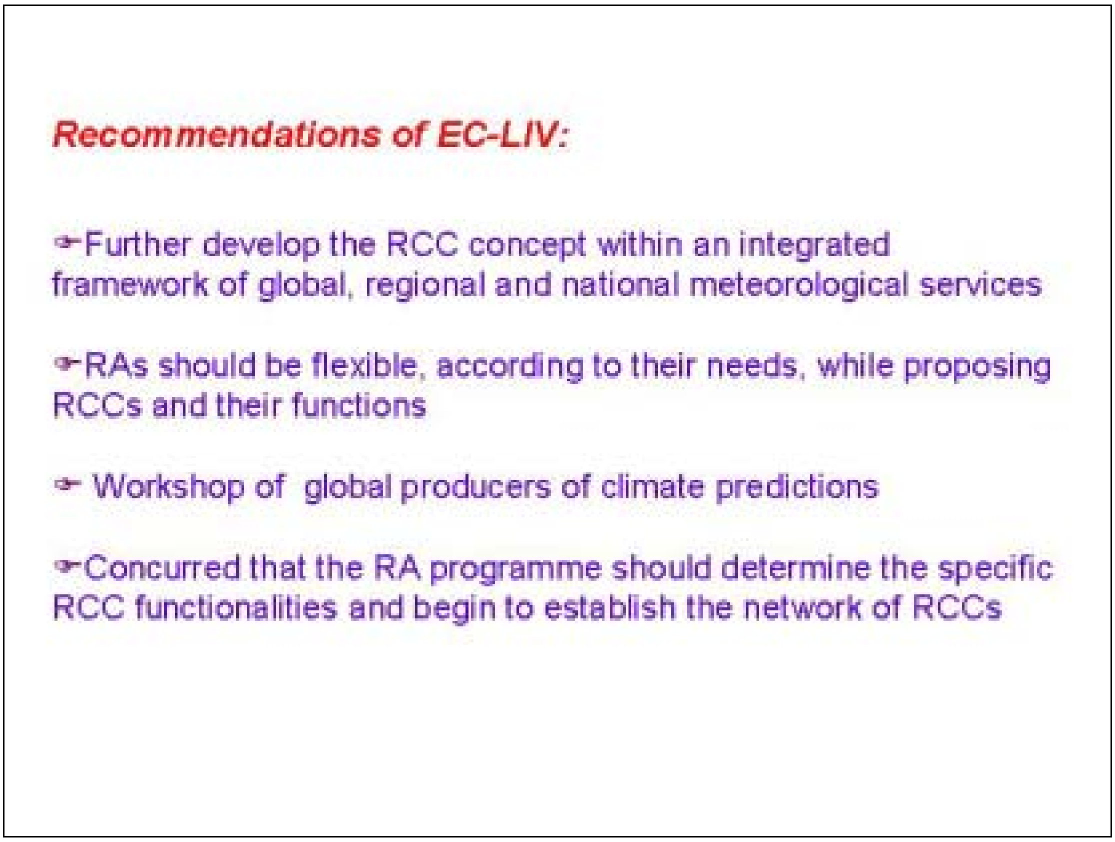
WMO Regional Climate Centres

Concept	Actions to date
Alternative structures	Moving it forward


Regional Climate Centres (RCCs)
To assist NMHSs in providing Seasonal to Inter-annual (SI) forecasts, climate analyses and monitoring, and data management
• Coalesced from concerns in CCl, CBS and RAs
• Inter-Commission Task Team developed the concept (CCl, CBS, CAS, RAs) (2001, 2002)
• Executive Council recommended the Regional Associations implement RCCs as needed, through CCl and CBS
• Regional Associations are considering the need for one or more RCCs
• The WCP is organizing a meeting with all Regional Associations, to clarify the process


RCC Services
•concentration of RCC functions in one centre; or
•distributed RCC functions supported by more than one centre.


Functions of RCCs
The requirements of NMHSs for RCC functions will vary from Region to Region. They are being considered within the following categories:
• Operational Activities
• Co-ordination Functions
• Data Services
• Training and Capacity building
• Research and Development


Recommendations of EC-LIV:
Further develop the RCC concept within an integrated framework of global, regional and national meteorological services
RAs should be flexible, according to their needs, while proposing RCCs and their functions
Workshop of global producers of climate predictions
Concurred that the RA programme should determine the specific RCC functionalities and begin to establish the network of RCCs

Examples of alternative structures

- Single, multi-functional RCC for all or some part of a region
- Several RCCs, each providing a unique focus ("distributed RCC")
- Services and products from several centres, linked and identified as one ("virtual RCC")
- Note: individual services and products may be provided through a contract with a commercial service, through the RCC.

Single, multi-functional RCC

- A single centre identified as an RCC
- Multi-functional
  - eg., climate predictions, alerts, regional database, data rescue, training
- Similar to NTPC, ASMC

Distributed RCC

- Several centres, each identified as an RCC, each providing unique services
  - Segregated by types of functions, climatic zones, economic associations
  - User must communicate with every centre that provides desired services
- Similar to DMC-Nairobi and ACMAD

Virtual RCC

- Several centres, each providing a suite of functions
  - Linked so that user only needs to seek information, but doesn't need to know the originator's address
  - Some services may be offered by more than one centre
- Analogous to WMO's international weather and climate information
  - from the centre of WMO Home page, click "Official Weather Forecasts and Warnings", or enter: http://www.worldweather.org

Process to gain approval of group's recommendations

- Review by President (with any assistance he requires)
- Modifications
- Review of concept by the RA's PR's, others
- Modification of TOR

Process to complete an action plan

- Development of Action Plan to gain designation and commence implementation
  - Nodes fill out their plans
  - Overall coordination by ...
- Formal confirmation of centres' commitments
- Regional Association approval and notification to CCl and CBS

Process to gain "RCC" designation

(proceed in pilot demonstration while following the formal designation process)

- Demonstration of RCC's capabilities, to CBS or CCl
- Introduction for designation at next session of CBS or CCl, jointly
- Modifications
- Recommendation by CBS to include in *Manual on the GDPS*, to Congress or EC

WMO IOC UNEP ICSU

Global Climate Observing System

GCOS Mission and Strategy

To ensure that the data required to meet the needs of users for climate information are obtained and made available for …

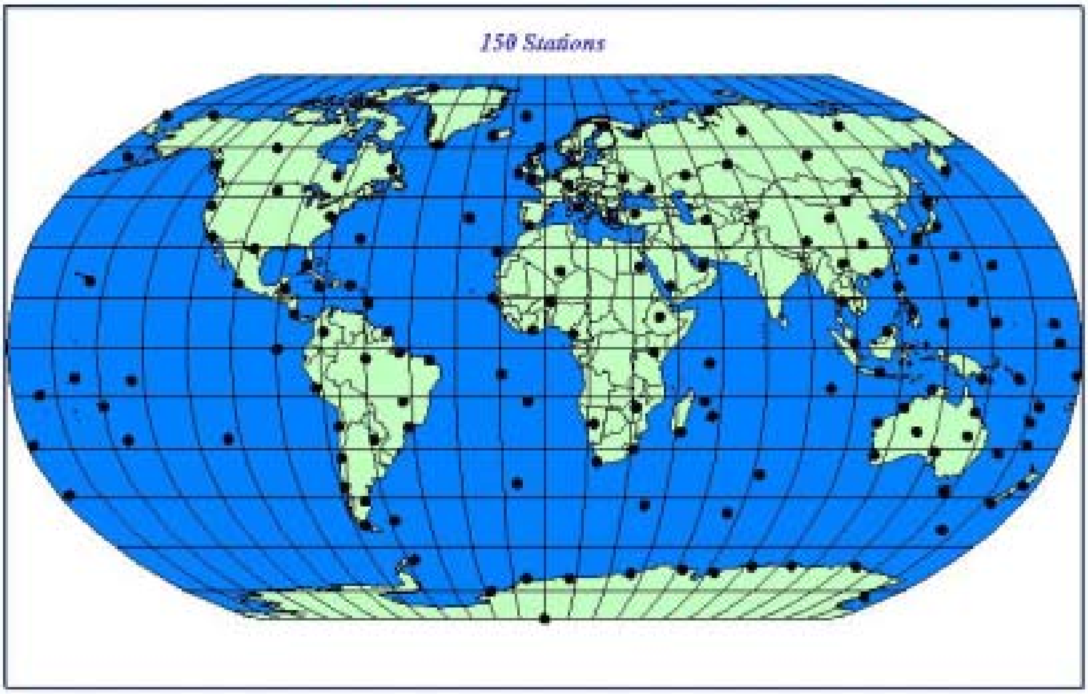
- Planning and Facilitating the Implementation of Climate Observing Systems to GCOS Standards based on advice from scientific panels and working with relevant technical bodies
- Engaging Intergovernmental and National Bodies
  - UNFCCC / COP / SBSTA
  - Intergovernmental bodies of GCOS Sponsors.
- Developing Strategies for Resource Mobilisation
  - Multi-governmental Voluntary Donor Fund

The GCOS is comprised of the climate components of the domain based observing systems including both satellite and *insitu* observations

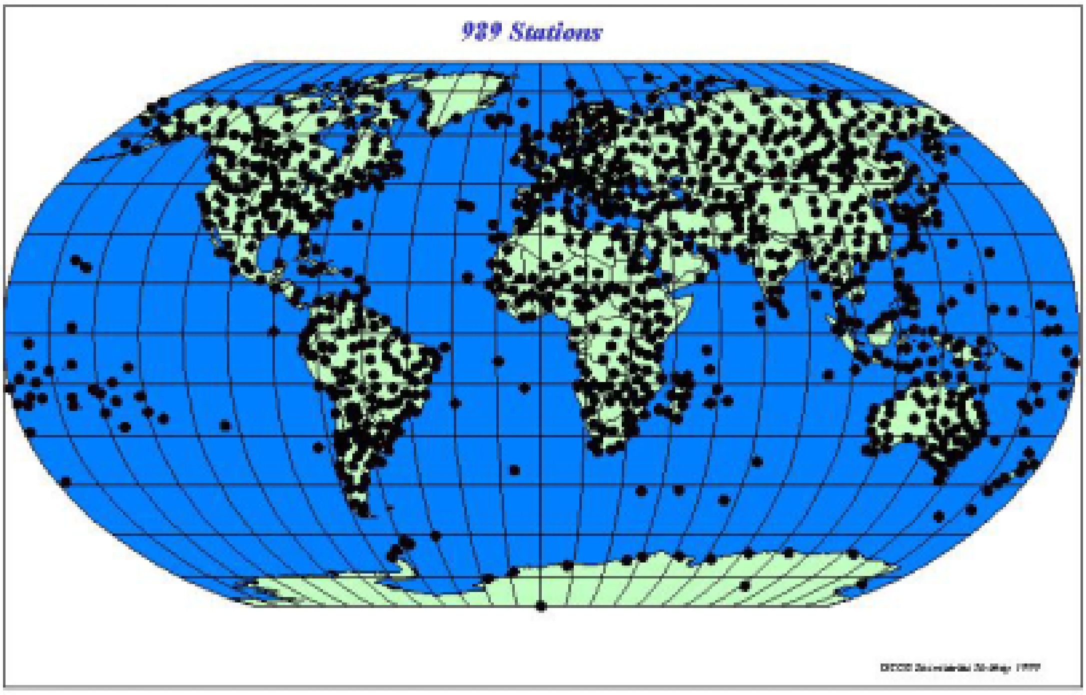
GCOS Networks

- **Atmosphere**
  - GCOS Upper Air Network (GUAN) (150 stations, 80 countries)
  - GCOS Surface Network (GSN) (989 Stations, 145 countries)
  - Global Atmosphere Watch (GAW) (22 global, 300+ regional stations)
- **Ocean**
  - Ship of Opportunity Program (SOOP) (~120 ships/27,000 XBTs, 7 countries)
  - Data Buoy Cooperation Panel (DBCP) components (~1300 drifting buoys, plus moored buoys, subsurface floats; 21 countries)
  - Voluntary Observing Ships (VOS) (~7000 ships, 52 members)
  - ENSO Observing System (TAO/Triton Array, tide gauges, VOS)
  - Automated Shipboard Aerological Programme (ASAP) (22 units, 9 members)
  - Global Sea-Level Observing System (GLOSS) (~300 global stations)
  - Argo (up to 3000 profiling floats, 14 countries)
- **Terrestrial**
  - Global Terrestrial Network for Glaciers (GTN-G) (~750 glaciers monitored)
  - Global Terrestrial Network for Permafrost (GTN-P)
  - Global Terrestrial Network for Ecology (GTN-E) (ILTER, Fluxnet, TEMS)
  - Global Terrestrial Network for Hydrology (GTN-H)

GCOS Upper Air Network (GUAN)



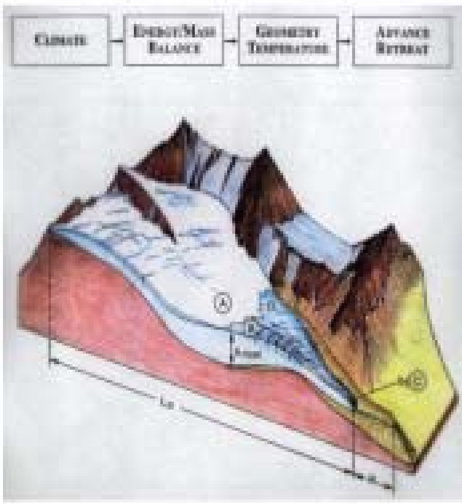
GCOS Surface Network (GSN)



GTN - Glaciers

World Glacier Monitoring Service (WGMS)

- WGMS
  - Collects and publishes glacier inventory and fluctuation data, including satellite observations
  - Assesses ongoing changes
  - Provides fast data access
- World Glacier Inventory
  - describes the spatial distribution
- Fluctuations of Glaciers / Mass Balance Bulletin
  - Document changes in time (in mass, volume, area and length of glaciers).



WCRP Climate

World Climate Research Programme

World Climate Research Programme

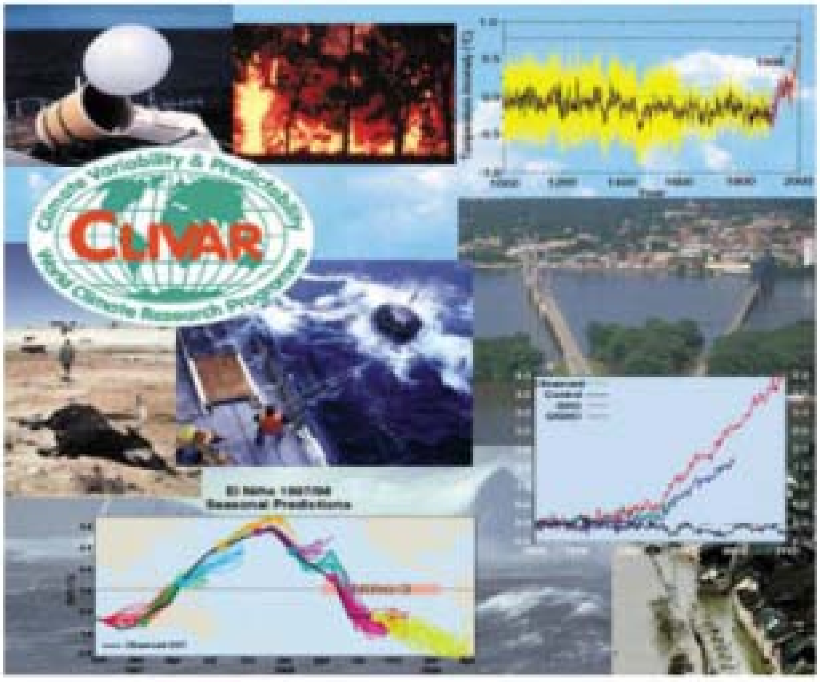
Sponsors

- World Meteorological Organization (WMO,1980+)
- International Council for Science (ICSU,1980+)
- Intergovernmental Oceanographic Commission (IOC/UNESCO,1993+)

Objectives

- To determine to what extent climate can be predicted
- To determine the extent of human influence on climate

Climate Variability and Predictability: CLIVAR



CLIVAR Questions (1)

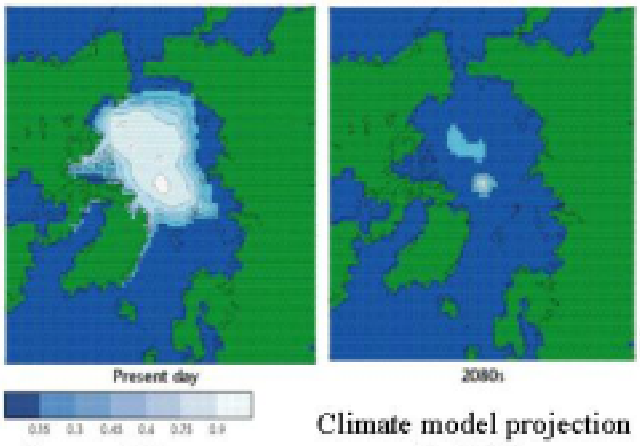
- Will there be an El Niño next year?
- Will the monsoon cause droughts or floods?
- What will the next winter be like in northern Europe; 'warm and wet' or 'cold and dry'?

CLIVAR Questions (2)

- How is the planet warming from human influences?
- How much sea-level rise will there be in the 21st century?
- Will there be more extreme weather events because of global warming?
- Could climate make a sudden switch?

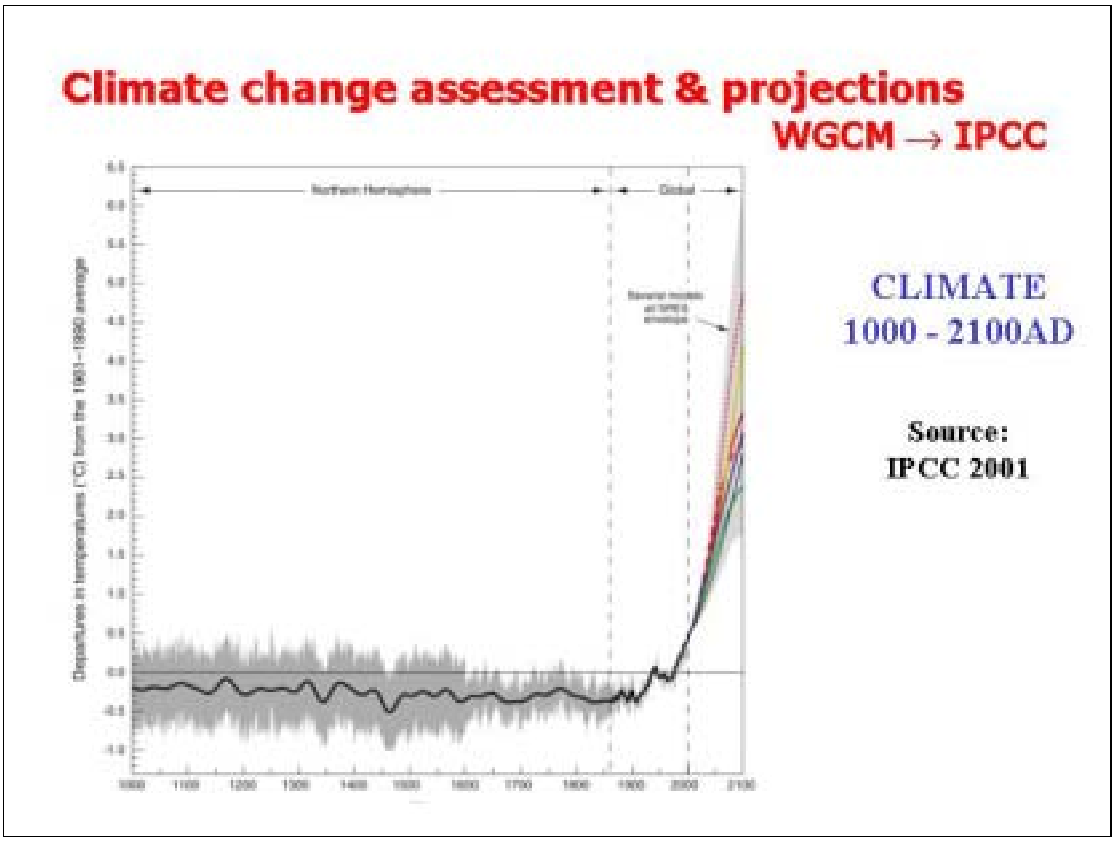
Climate and Cryosphere - key scientific questions

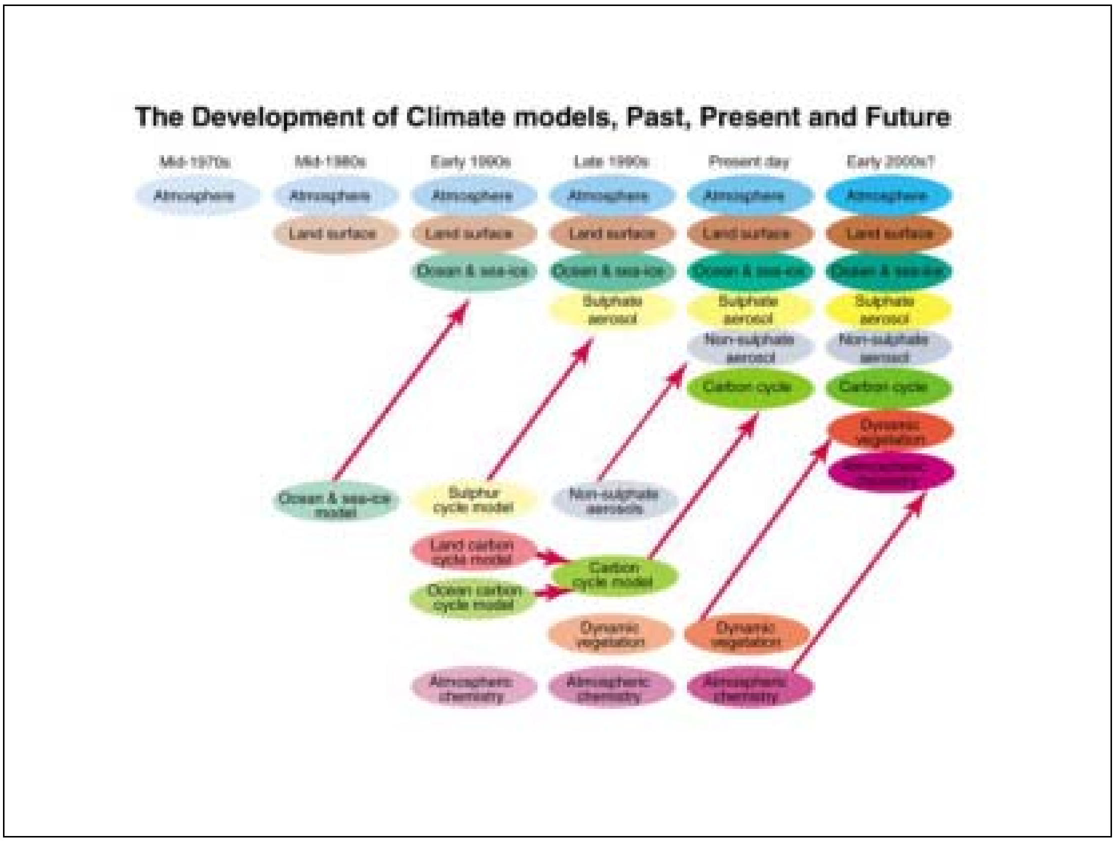
- What will be the nature of changes in ice (mass balance) in both polar regions in response to climate change?



Perennial Ice cover

Climate model projection for 2080s


Climate change assessment & projections
WGCM → IPCC
Northern Hemisphere
Global
CLIMATE
1000 - 2100AD
Source:
IPCC 2001


The Development of Climate models, Past, Present and Future
Mid-1970s
Mid-1980s
Early 1990s
Late 1990s
Present day
Early 2000s?
Atmosphere
Land surface
Ocean & sea-ice
Sulphate aerosol
Non-sulphate aerosol
Carbon cycle
Dynamic vegetation
Ocean & sea-ice model
Sulphur cycle model
Non-sulphate aerosols
Land carbon cycle model
Carbon cycle model
Ocean carbon cycle model
Atmospheric chemistry

WMO/GAW:
Global Atmosphere Watch

The GAW Mission

- *Systematic Global Monitoring* Of Chemical Composition of the Atmosphere.
- Support of *International Conventions and Assessment.*
- Development Of Air Pollution and Climate *Prediction*

Air Pollutants Measured

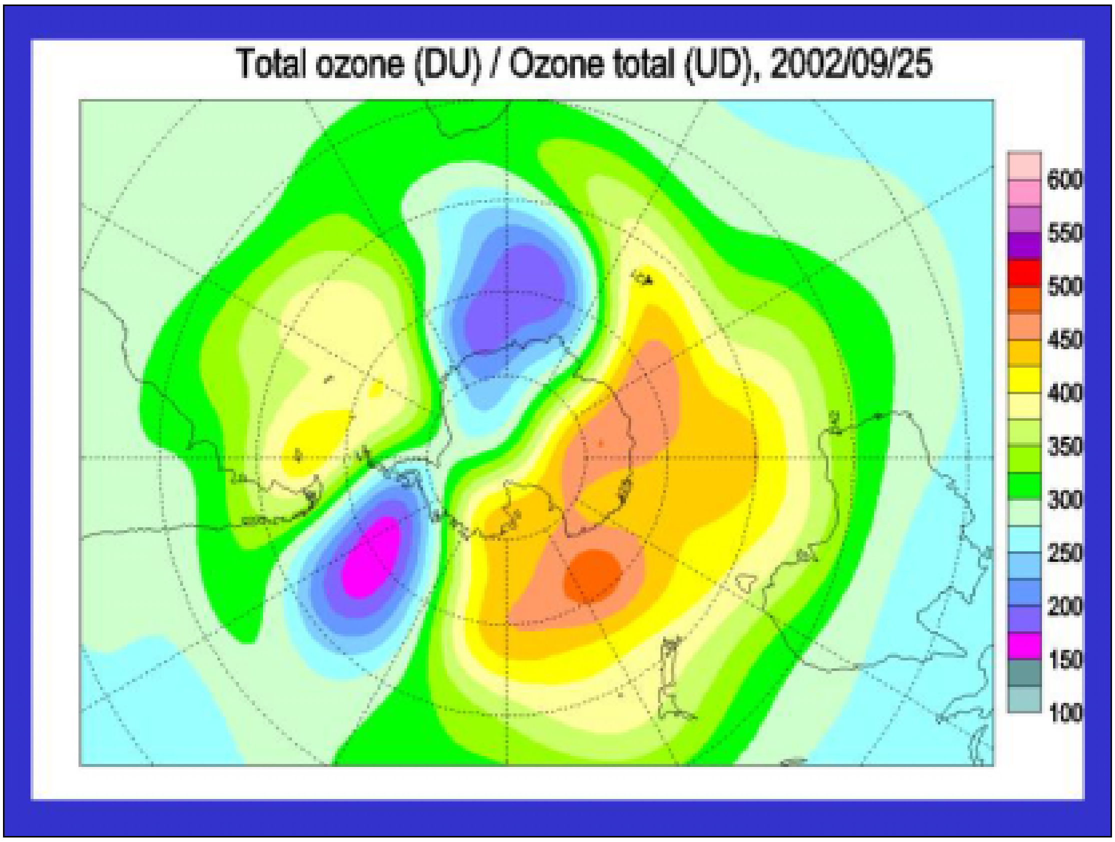
- Ozone and associated UV
- Greenhouse gases (CO_2, CH_4, N_2O, O_3, halocarbons)
- Aerosols (dust, haze etc.)
- Reactive gases (CO, VOC, NO_y, SO_2)
- Acid Rain

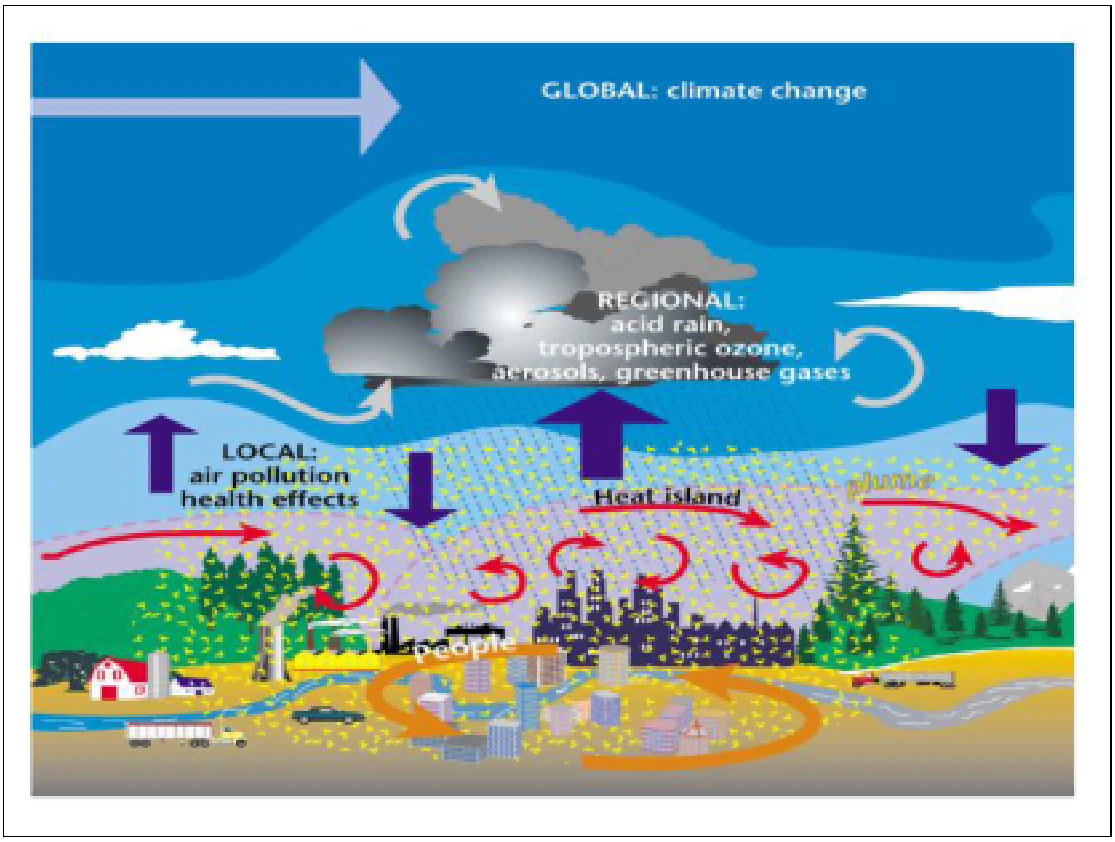
Monitoring Stations for Carbon Dioxide (CO_2)

Assessment And Synthesis

Stratospheric Ozone

- Support of WMO/UNEP Scientific Assessment of Ozone Depletion
- Organize and publish recommendations of the meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer
- Antarctic Ozone Hole Bulletins
- Arctic Ozone Depletion


Total ozone (DU) / Ozone total (UD), 2002/09/25
600
550
500
450
400
350
300
250
200
150
100


GLOBAL: climate change
REGIONAL:
acid rain,
tropospheric ozone,
aerosols, greenhouse gases
LOCAL:
air pollution
health effects
Heat island
People

Keynote Lecture
Predictability of Seasonal Means from Multiple Models and Observations

Jagadish Shukla and Timothy Delsole

George Mason University
Center of Ocean-Land Atmosphere Studies

We live in a phase in which the predictability of monthly and seasonal means is model dependent. This is not the case for weather predictability, in which virtually all operational weather prediction models indicate predictability to about 2 weeks. A critical issue in studying long-term predictability is that model errors lead to significant prediction errors. There does not appear to exist a universally accepted framework for accounting for prediction errors in predictability theory. Thus, the problem of quantifying predictability of long-term forecasts is confounded by the problem of accounting for significant errors in the forecast models. We need a methodology for extracting the maximum predictability from a given forecast model, regardless of its errors, so that the state of the art in long-term predictability can be quantified.

The purpose of this paper is to discuss a systematic and comprehensive procedure for extracting predictability from a set of observations and forecasts. This procedure, which is based on information theory, clarifies the fundamental definition of predictability and the role of imperfect forecast models in assessing predictability. A fundamental metric in this framework is mutual information (Cover and Thomas 1991).

This quantity can be used to measure the degree to which forecasts are related to the observed behavior of the climate system. Furthermore, the state can be decomposed into components that optimize mutual information. Hence, decomposition of mutual information provides a basis set for identifying predictable components of a forecast model, and for filtering out those components that are unpredictable. If all variables are normally distributed, then this decomposition can be accomplished by applying Canonical Correlation Analysis (CCA) to the forecast and verification fields.

The above methodology suffers from a practical problem, namely that it is sensitive to sampling errors and hence requires long data sets for its application. However, it can be proven rigorously (for Gaussian variables) that the above procedure is formally equivalent to an alternative procedure whose sampling properties are much better behaved. The alternative procedure is to first extract the predictable patterns from each forecast model based on Canonical Correlation Analysis between forecast fields and boundary conditions (and/or initial conditions). A selection criteria for choosing the number of canonical patterns is proposed, based on the results of cross-validation experiments. The selection procedure usually yields one to two predictable patterns per model. The small number of predictable patterns suggests that the variability of predictability is controlled by a few degrees of freedom, in which case predictability can be analyzed statistically in short time series. After extracting the predictable patterns, the associated time series can serve as predictors in a statistical prediction procedure.

In principle, the above methodology accounts for the entire probability distribution of the forecast model. In practice, however, the Gaussian assumption mandates a linearity assumption. Nevertheless, even under the Gaussian assumption, the above methodology corrects the entire probability distribution of a forecast model.

In the paper, we present the results of applying the above methodology on multiple atmospheric general circulation models, integrated with observed sea surface temperatures, to determine the predictability of winter seasonal surface temperature over North America. We show that different models clearly exhibit different degrees of predictability even at the same location, with some models showing essentially no predictability. Moreover, the above methodology very often enhances the predictability, although this enhancement never exceeds the predictability of purely empirical forecast models for the models used in this work. These results prove without doubt that certain monthly and seasonal means of importance to society are predictable. Morever, these results clearly demonstrate that dynamical models can be improved to enhance their estimates of predictability, if by no other means than by statistical corrections.

References

Cover, T. M., and J. A. Thomas, 1991: *Elements of Information Theory*. Wiley, 576 pp.

Keynote Lecture
NOAA Intra-Seasonal-to-Interannual Prediction (ISIP) Program

Ming Ji

NOAA/Office of Global Programs

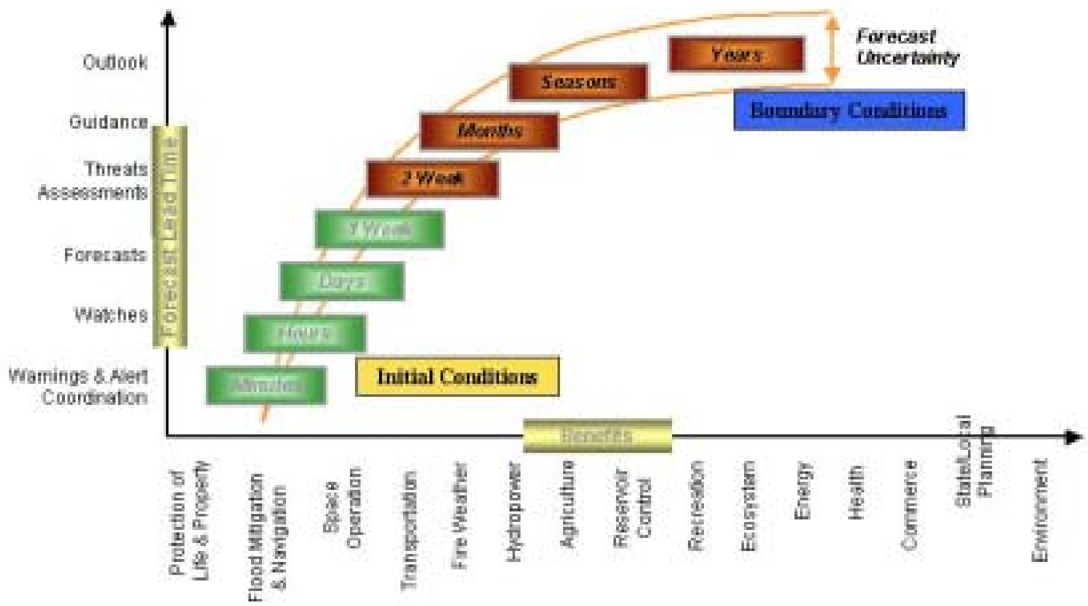
ISIP Requirements

- NOAA Strategic Plan
  - Improve long-range climate, weather and water predictions
- US CCSP deliverables addressed by NOAA ISIP
  - Climate Variability and Change
  - Global Water Cycle
- Requirements ("pull") from Users and Customers
  - Operational Climate Prediction Centers
  - Climate and Water Service Providers
  - Place based R&D Applications Research (e.g., RISA)
  - End users (e.g., Resource managers and policy/decision makers)

ISIP Goals

- **Provide the Nation with a seamless suite of climate forecasts and application products to manage risks and opportunities of climate impacts due to intra-seasonal to interannual climate variations**
  - **The "Seamless Suite" of NWS forecast guidance (week-2 to interannual)**
  - **Multi-model ensemble based forecast system(s)**
  - **Regional/sectoral application products for decision support (resource and risk management)**
  - **International predictions, assessments and applications**

Seamless Suite of Forecasts

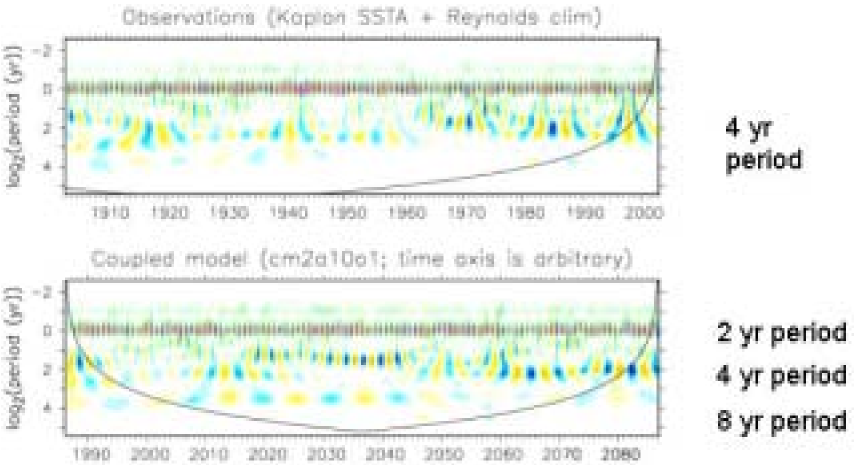


Integrated Program Structure

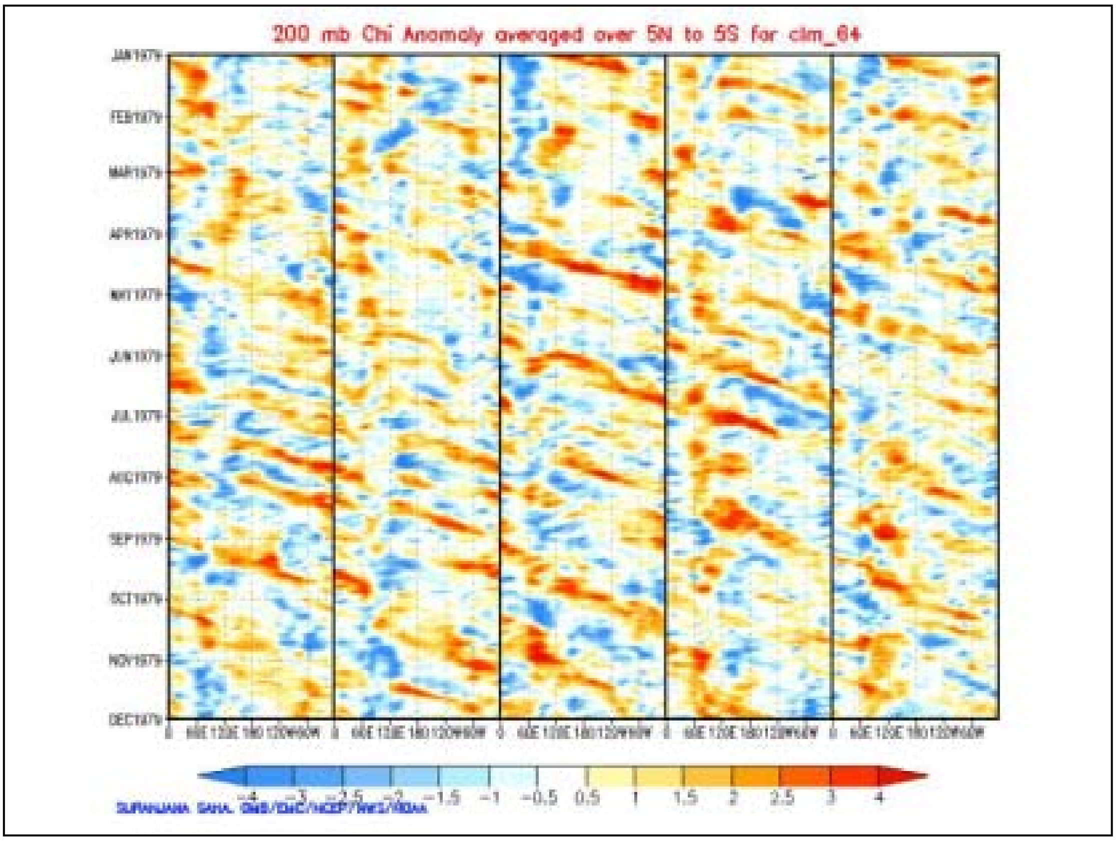
1. **Model Development**
   (High-end centers: EMC, GFDL, NASA/GMAO, NCAR)
2. **Experimental Prediction**
   (Incl. Multi-model Ens. Fcst System Development)
3. **Forecast and Application Products Development**
4. **Applied Research**
   (e.g., process and predictability studies, diagnostics, data analysis, attribution, model development)

El Nino: the *sine qua non* of Climate Models

100 years of NINO3 wavelet analysis



GFDL's model development allows assessment of: the sensitivity of ENSO characteristics to model biases; impacts of global warming on ENSO; experimental new seasonal and longer timescale forecast products from a fully coupled Earth System model.



Program Structure (2)

1. **Model Development**

   (Requirement for Environmental Modeling Program)

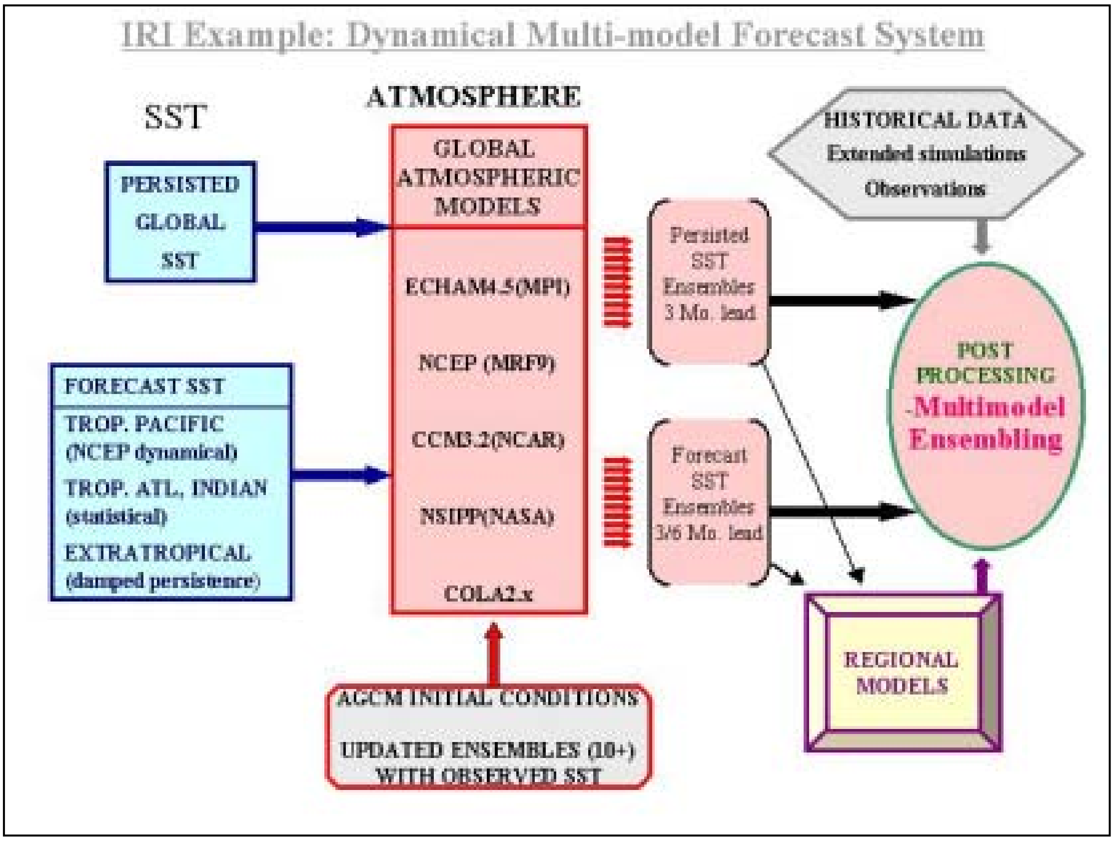
2. **Experimental Prediction**

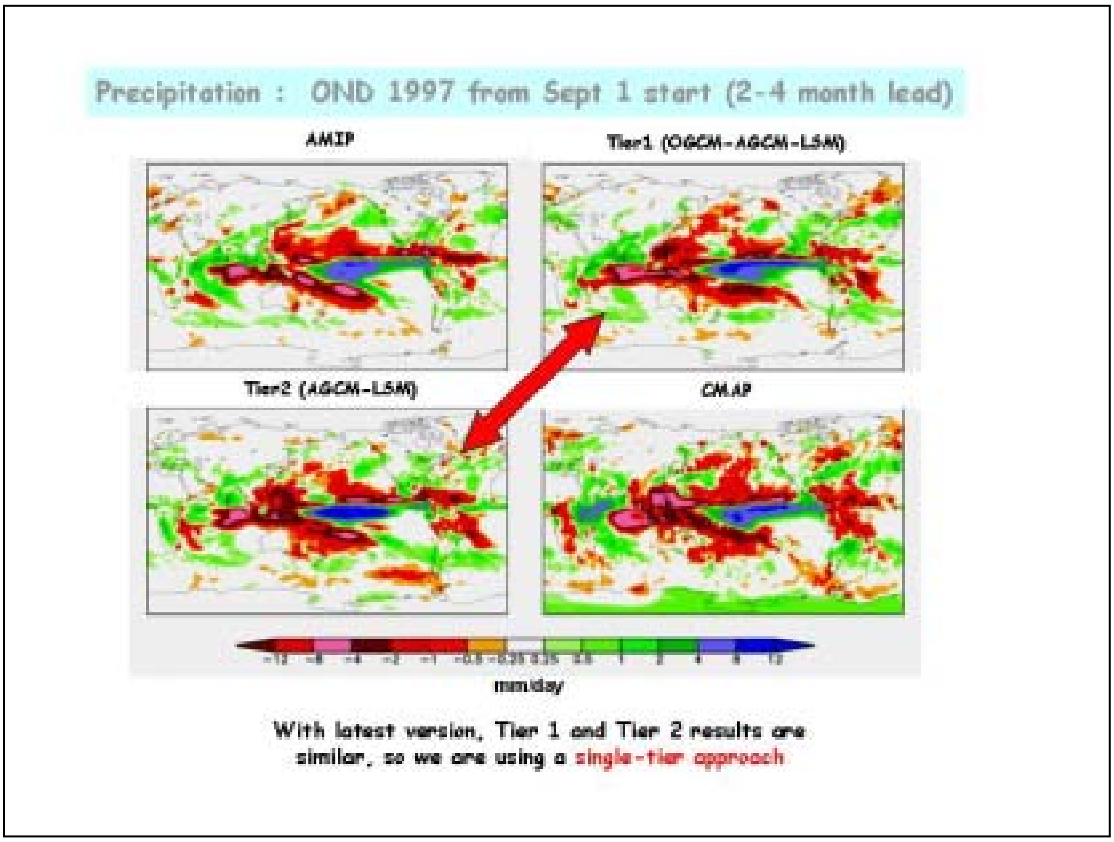
   (Incl. Multi-model Forecast System Development)

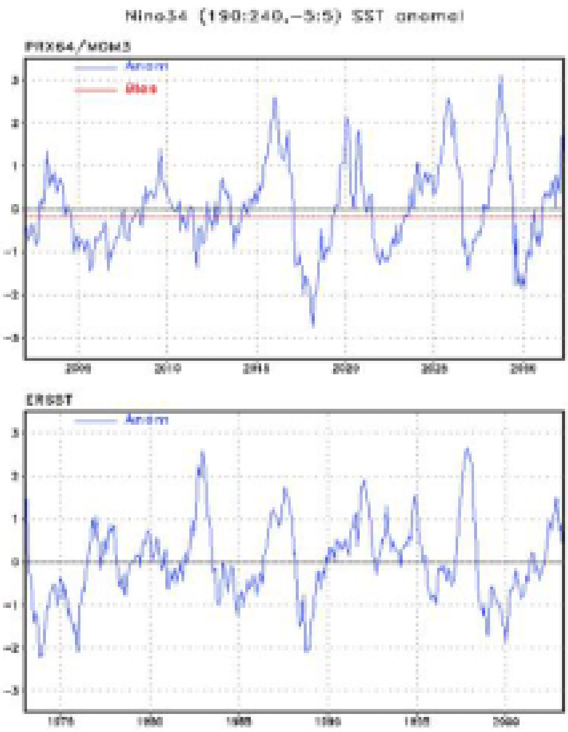
3. **Applications and Products Development**

4. **Research**

   (e.g., process and predictability studies, diagnostics, data analysis, attribution, model development)

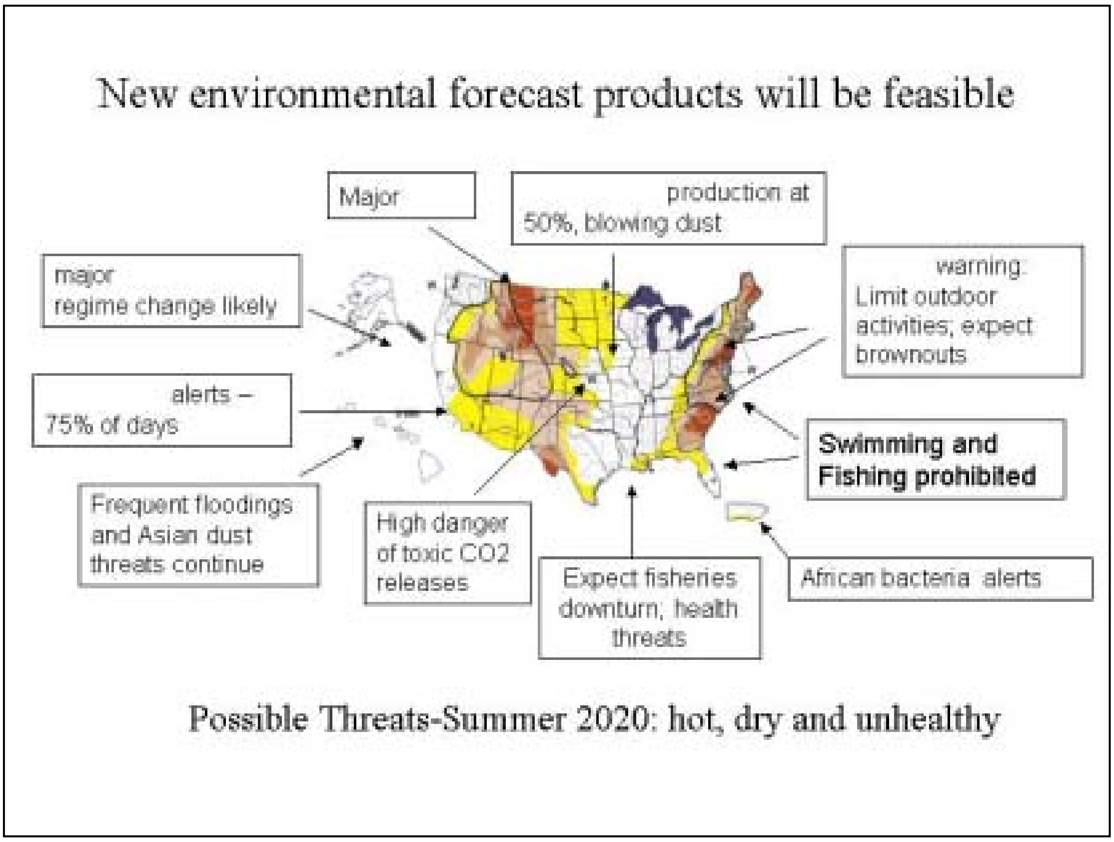

IRI Example: Dynamical Multi-model Forecast System
SST
ATMOSPHERE
PERSISTED GLOBAL SST
FORECAST SST
TROP. PACIFIC (NCEP dynamical)
TROP. ATL, INDIAN (statistical)
EXTRATROPICAL (damped persistence)
GLOBAL ATMOSPHERIC MODELS
ECHAM4.5(MPI)
NCEP (MRF9)
CCM3.2(NCAR)
NSIPP(NASA)
COLA2.x
AGCM INITIAL CONDITIONS
UPDATED ENSEMBLES (10+) WITH OBSERVED SST
HISTORICAL DATA
Extended simulations
Observations
Persisted SST Ensembles 3 Mo. lead
Forecast SST Ensembles 3/6 Mo. lead
POST PROCESSING
Multimodel Ensembling
REGIONAL MODELS

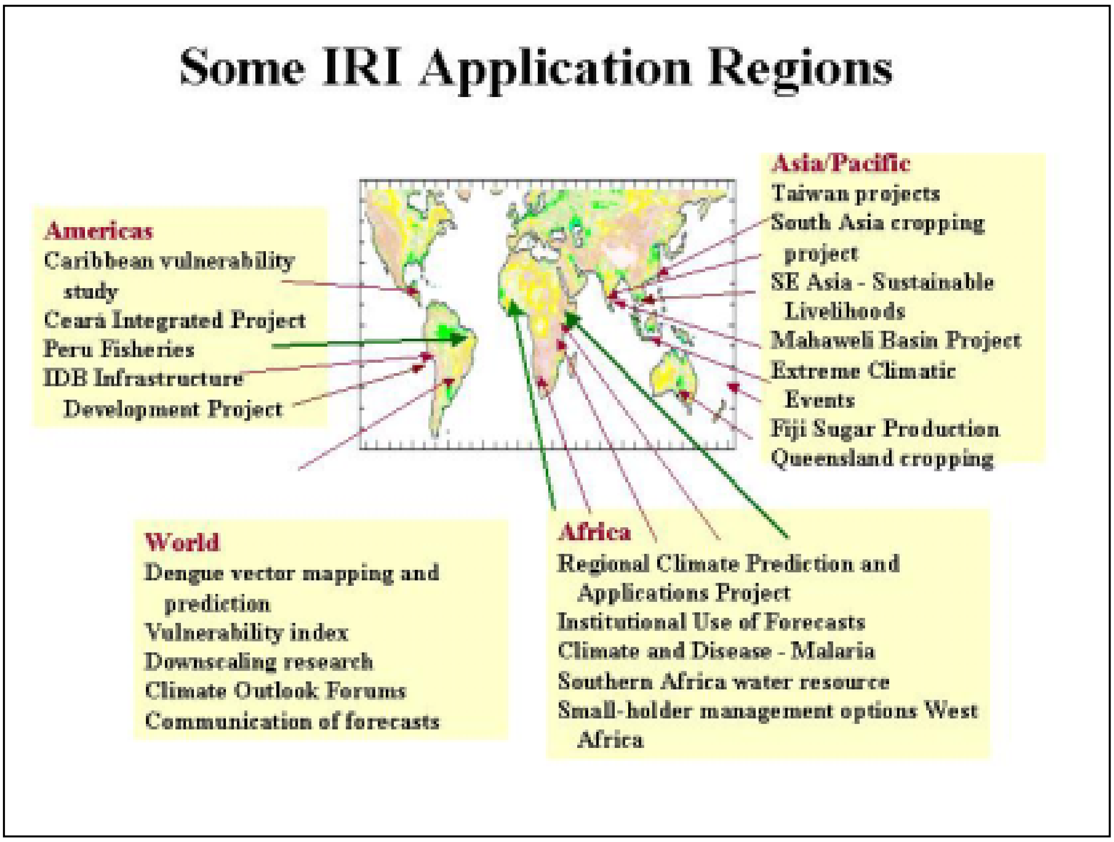

Precipitation : OND 1997 from Sept 1 start (2-4 month lead)
AMIP
Tier1 (OGCM-AGCM-LSM)
Tier2 (AGCM-LSM)
CMAP
mm/day
With latest version, Tier 1 and Tier 2 results are similar, so we are using a single-tier approach



Program Structure (3)

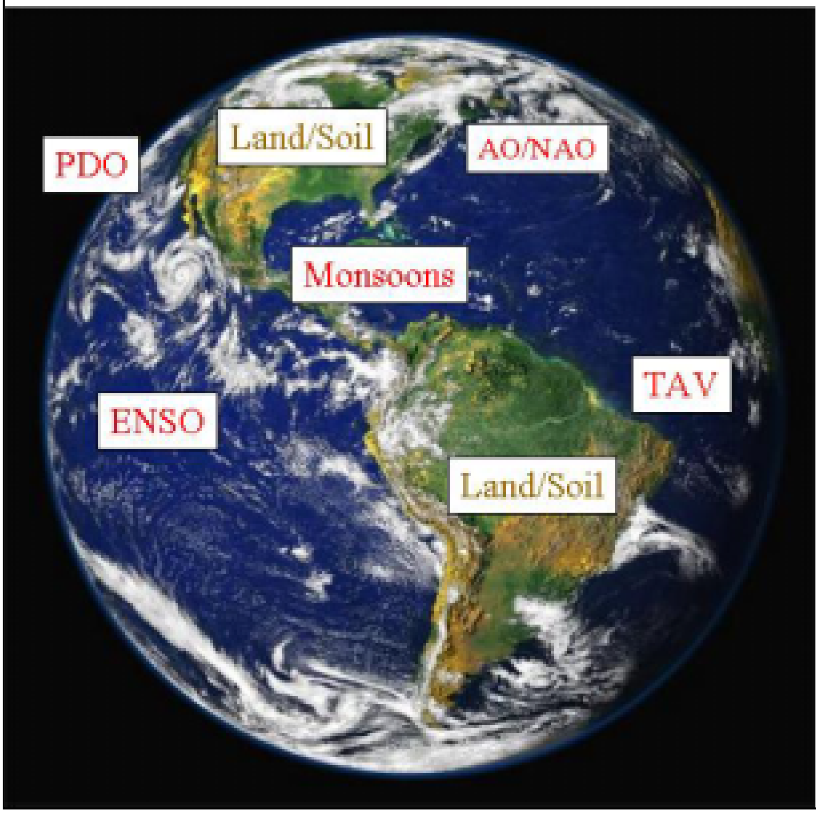
1. Model and Forecast System Development
2. Experimental Prediction
3. Diagnostics and Attribution
4. Development of Application Products
    - Subseasonal forecast products
    - Agriculture, Fire Wx, applications
    - Water resource applications
    - International forecasts and applications
5. Research and datasets development


New environmental forecast products will be feasible
Major
production at 50%, blowing dust
major regime change likely
warning: Limit outdoor activities; expect brownouts
alerts – 75% of days
Swimming and Fishing prohibited
Frequent floodings and Asian dust threats continue
High danger of toxic CO2 releases
Expect fisheries downturn; health threats
African bacteria alerts
Possible Threats-Summer 2020: hot, dry and unhealthy


Some IRI Application Regions
Asia/Pacific
Taiwan projects
South Asia cropping project
SE Asia - Sustainable Livelihoods
Mahaweli Basin Project
Extreme Climatic Events
Fiji Sugar Production
Queensland cropping
Americas
Caribbean vulnerability study
Ceará Integrated Project
Peru Fisheries
IDB Infrastructure Development Project
World
Dengue vector mapping and prediction
Vulnerability index
Downscaling research
Climate Outlook Forums
Communication of forecasts
Africa
Regional Climate Prediction and Applications Project
Institutional Use of Forecasts
Climate and Disease - Malaria
Southern Africa water resource
Small-holder management options West Africa

Program Structure (4)

1. Model Development
2. Multi-model f'cst system and experimental prediction
3. Application Products Development
4. Research (Integrated PACS-GAPP programs)
    - **Predictability and Process studies (e.g., NAME)**
    - **Regional Reanalysis and LDAS products**
    - **Attribution on weather and climate extremes**
    - **Land and hydrology model development for climate prediction and water resource applications**
    - **Climate model diagnostics consortium**
    - **ODASI consortium (Requirements for obs. system)**
    - **Regional modeling consortium**

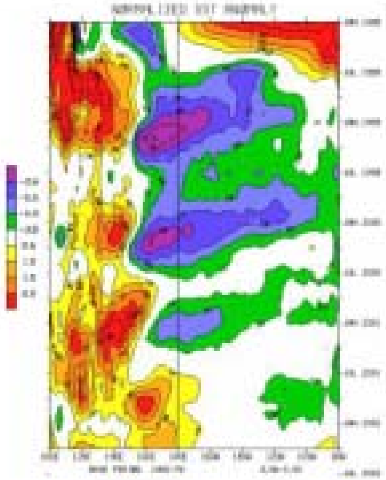


Patterns of Natural Climate Variability and Source of Predictability

Drought and climate variability

Are the tropical oceans playing an important role?

Evolution of tropical Pacific Sea Surface Temperatures

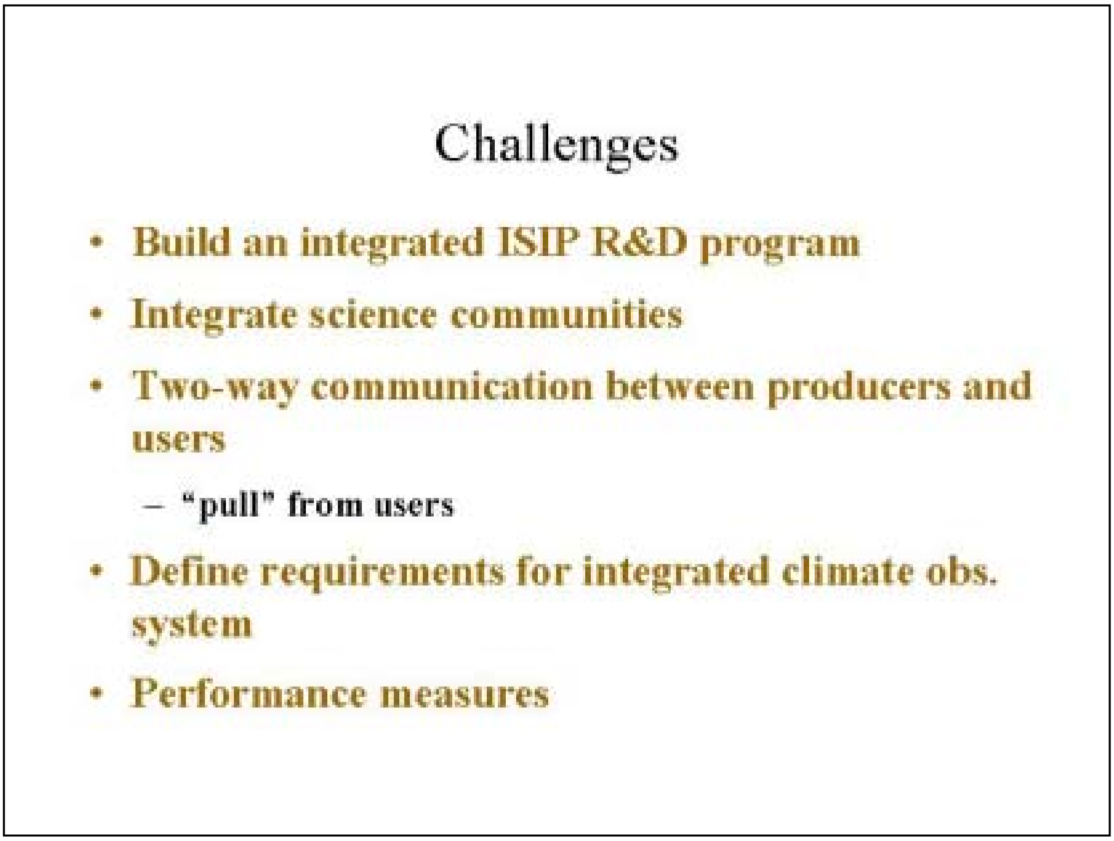


Two key features:

- Prolonged La Niña conditions 1998-2002
- Long-term warming of Indian Ocean-west Pacific "warm pool"

ISIP Products by Category

- National Guidance Products
  - Attribution on all time scales
  - Nowcasting of Trends
  - Subseasonal probabilistic forecast of extremes
  - Global and regional reanalysis products
  - Best practice for climate forecasts
- Regional/sectoral Application Products
  - Water resource availability
  - Fire weather
  - Agriculture applications
  - River forecasts, costal runoff
- Other
  - Trainings and workshops
  - International applications (place based)
  - Information briefings for Fed. Gov. (White House, Congress)
  - Requirements for climate obs. system


Challenges
• Build an integrated ISIP R&D program
• Integrate science communities
• Two-way communication between producers and users
– "pull" from users
• Define requirements for integrated climate obs. system
• Performance measures

Keynote Lecture
Advanced Network
for Climate Information Exchange

Kil-Nam Chon[1,2]

Chair of Asia-Pacific Advanced Network [1]
Korean Advanced Institute of Science and Technology [2]

APAN Asia-Pacific Advanced Network

Table of Contents

Part I : APAN (Asia Pacific Advanced Network)

- History
- Research and Education Networks - Global Network
- Member
- APAN Link Information
- APAN Organization Chart
- APAN Working Group List

Part II : APAN-APCN Collaboration

- Bandwidth
- Internet
- AUP – Research vs Non-Commercial
- Access for Meetings
- Outreach

APAN Asia-Pacific Advanced Network

Part I : APAN (Asia Pacific Advanced Network)

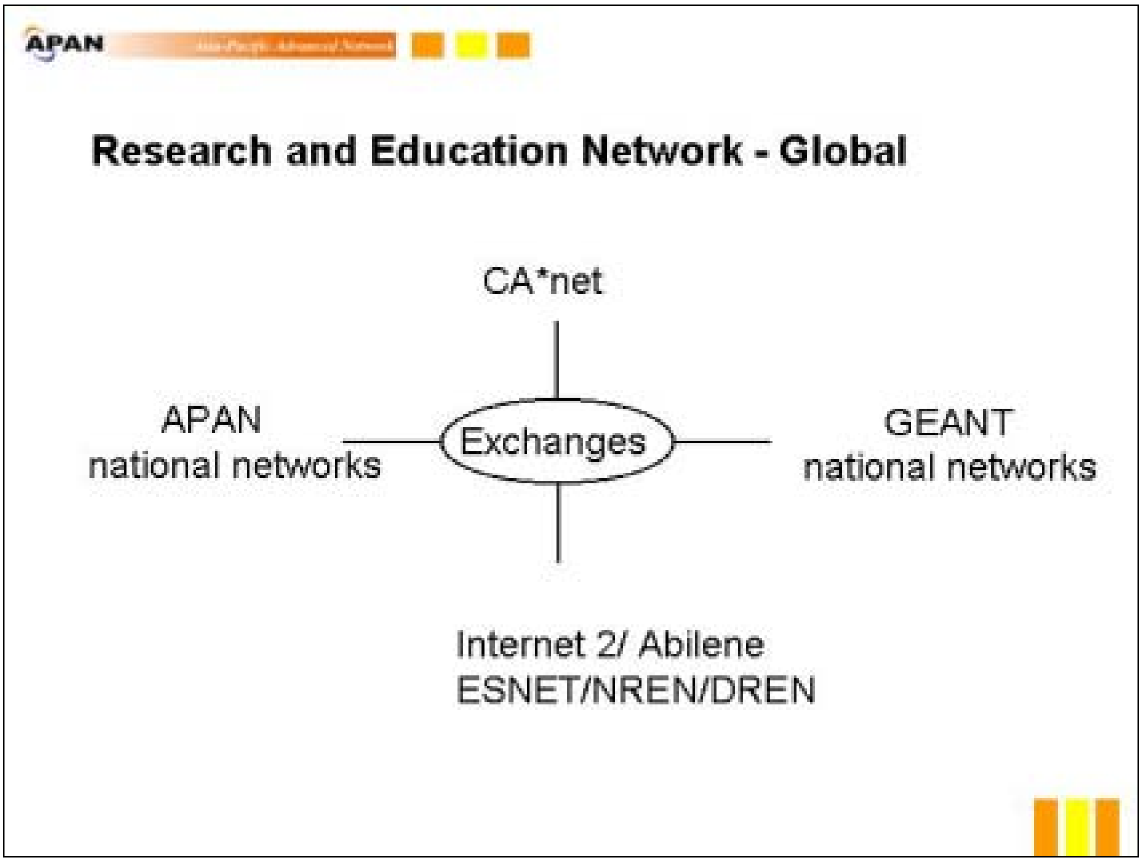
Mission Statement

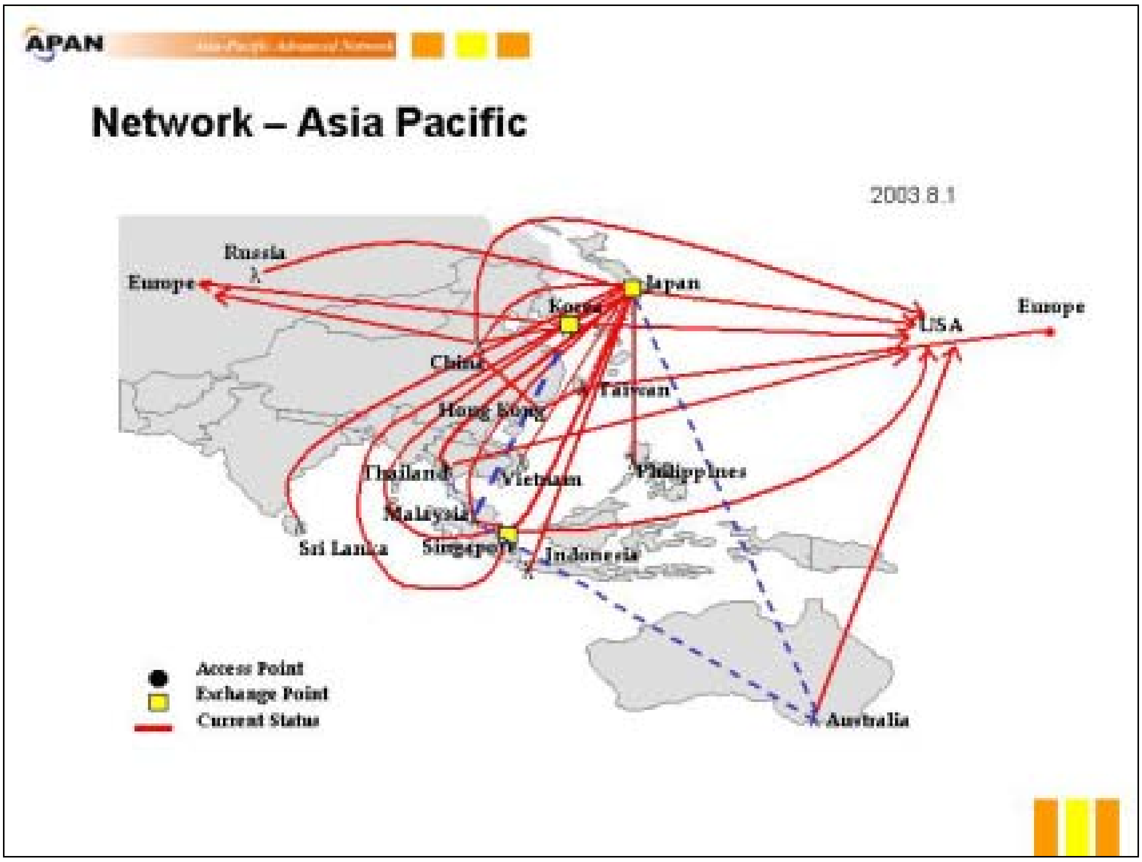
- to coordinate and promote R&D activities on networking including technology, applications, and services.
- to provide an advanced networking environment for research and education communities in the Asia-Pacific region.

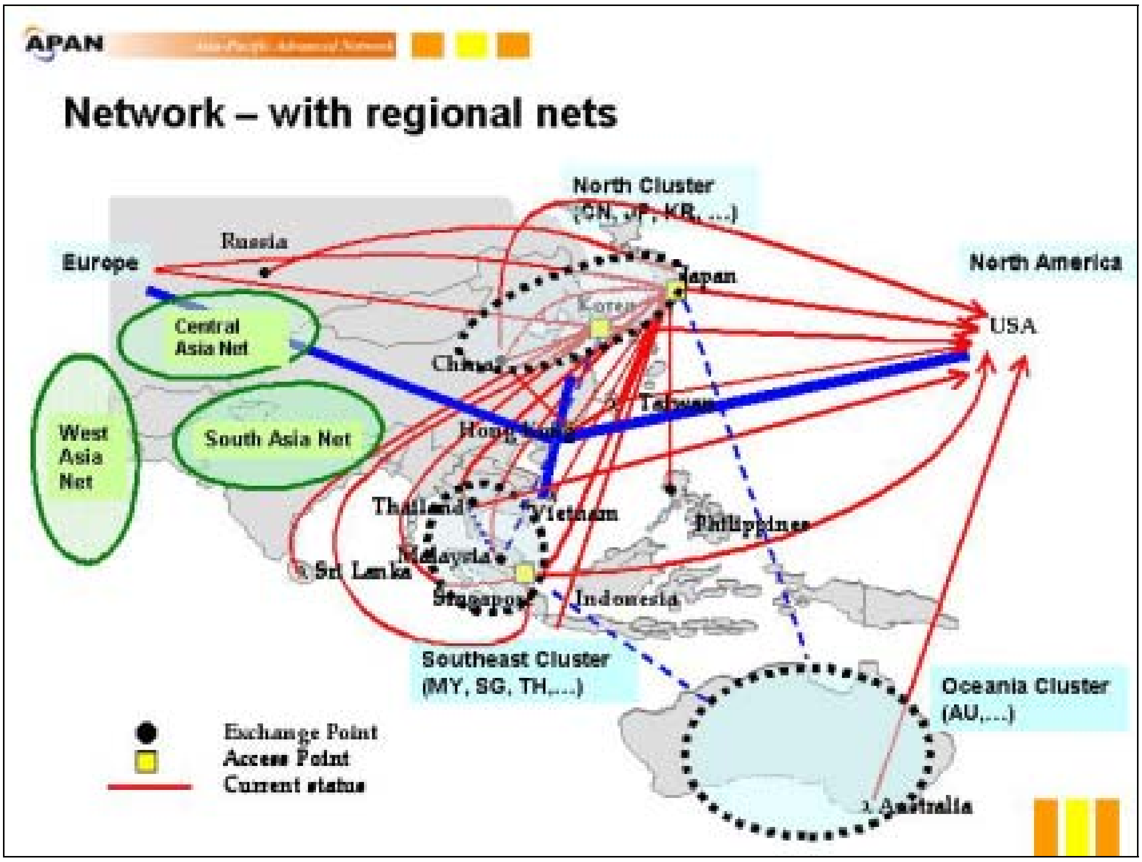
APAN Asia-Pacific Advanced Network

History

	Global	Asia-Pacific
1970s	User community coordination (High Energy Physics, NATO,..)	
1980s	Academic Networkshop	AsiaNet PCCS/Joint Workshop
1987	Coordination Committee for Intercontinental Research Networking	
1990s	Internet Initiatives (HPIIS, TEN,…)	Internet Initiatives (APAN, APII, AI3,...)
1996	Next Generation Internet Initiatives (APAN, Internet 2, CA*net, DANTE/TEN34)	
2000s	Internet Initiatives (Cyber Infrastructure, GRID, IEEAF,.)	Internet Initiatives (TEIN, CJK, ...)


APAN
Research and Education Network - Global
CA*net
APAN
national networks
Exchanges
GEANT
national networks
Internet 2/ Abilene
ESNET/NREN/DREN


APAN
Network – Asia Pacific
2003.8.1
Russia
Europe
Japan
Korea
USA
Europe
China
Taiwan
Hong Kong
Thailand
Vietnam
Philippines
Malaysia
Sri Lanka
Singapore
Indonesia
Australia
Access Point
Exchange Point
Current Status



APAN

Member

Primary Members

APAN-AU Consortium	APAN-CN Consortium
HARNET	APAN-JP Consortium
APAN-KR Consortium	APAN-MY Consortium
SingaREN	APAN-TW Consortium

Associate Members

ASTI (PH)	LEARN (LK)
APAN-TH Consortium	TransPac/Indiana University

Affiliate Members

ACFA	APBioNet	APNG
APRTC	APRU	CGIAR
IDRC	Pacific Wave	PRAGMA

Liaison Members

Canada :	CANARIE
Europe :	DANTE
	TERENA
USA:	Internet 2

Industry Member

CISCO	JUNIPER

APAN Asia-Pacific Advanced Network

APAN Link Information -1

Countries	Network	Bandwidth(Mbps)	Availability	AUP/Remark
AU-JP	AARNet	155	2003/2004	R&E
AU-US	AARNet	310	Now	R&E
CN	IEEAF	10.6 Gbps	2003/2004	R&E
CN-HK	CERNET/HARNET	2	Now	R&E
CN-HK	CSTNET	155	Now	R&E
CN-JP	CERNET	10	Now	R&E
CN-UK	CERNET	45	Now	R&E
CN-US	CERNET	10	Now	Research
CN-US	CERNET	200	Now	R&E
CN-US	CSTNET	55	Now	Research
HK-US	HARNET	45	Now	R&E
HK-TW	HARNET/TANET	10	Now	R&E
JP-CN	APII/CERNET	2.5 Gbps	2003	R&E (through Hong Kong)
JP-ID	AI3(ITB)	2/1.5	Now	R&E
JP-KR	APII	2Gbps	Now	Research (APII)
JP-LK	AI3(ICT)	1.5/0.5	2003/2004	R&E
JP-MY	AI3(USM)	1.5/0.5	Now	R&E
JP-PH	AI3(ASTI)	1.5/0.5	Now	R&E
JP-PH	MAFFIN	2	Now	Research
JP-SG	AI3(SICU)	1.5/0.5	Now	R&E
JP-SG		1~2 Gbps	2003/2004	R&E
JP-TH	AI3(AIT)	1.5/0.5	Now	R&E
JP-TH	SINET (ThaiSarn)	2	Now	R&E
JP-US	TransPac	1.2 Gbps	Now	R&E, 5Gbps in 2003Q4

APAN Asia-Pacific Advanced Network

APAN Link Information -2

Countries	Network	Bandwidth(Mbps)	Availability	AUP/Remark
JP-VN	AI3 (IOIT)	1.5/0.5	Now	R&E
KR	IEEAF	10.6 Gbps	2003/2004	R&E
KR-CN		1~2 Gbps	2004	R&E
KR-FR	KOREN/RENATER	34	Now	Research (TEIN)
KR-MY	TEIN	45	2003/2004	R&E
KR-SG	APII(KOREN)	8	Now	R&E
KR-US	KOREN/KREONet2	155	Now	R&E
LK-JP	LEARN	3	Now	R&E
MY-SG	TEMAN (SingaREN)	2	Now	R&E
MY-TH	TEMAN/ThaiSarn	8~45	2003/2004	R&E
SG	IEEAF	10.6Gbps	2003/2004	R&E
SG-US	SingaREN	90	Now	R&E
TH-US	Uninet	155	Now	R&E
TW-HK	ASNET/TANET2	155	Now	R&E
TW-JP	ASNET/TANET2	155	Now	R&E
TW-US	ASNET/TANET2	622	Now	R&E
TW-UK	ASNET/TANET2	155	Now	R&E, Through US
US-JP	IEEAF	10.6Gbps	Now	R&E

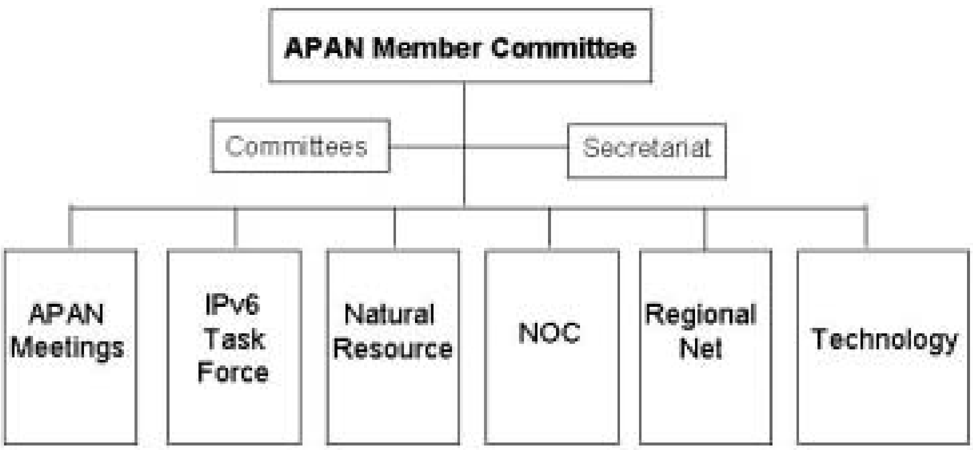
APAN Asia-Pacific Advanced Network

APAN Link Information – Non APAN Links

Non APAN Links				
Countries	Network	Bandwidth(Mbps)	Availability	AUP
IN-CH	LHC	155	2004	Research (HEP)
IN-US/UK	ERNET	16	Now	R&E
JP-(US)-EU	SINET	155	Now	R&E / No Transit
JP-US	SINET	5 Gbps	Now	R&E / No Transit

APAN Asia-Pacific Advanced Network

APAN Organization Chart



APAN Asia-Pacific Advanced Network

APAN Working Group List

Technology

- Application Technology Area
  - Education WG
  - Grid WG
  - P2P WG
  - Security
- Network Technology Area
  - IPv6 WG
  - Measurement WG
  - Multimedia WG

Natural Resource

- Agriculture WG
- Earth Monitoring WG
- Earth System WG

APAN Asia-Pacific Advanced Network

Part II : APAN-APCN Collaboration

Bandwidth

Variety of Bandwidth / Growing Rapidly

Intercontinental : 1.5 Mbps ~ 10 Gbps

North Asia (CJK) : ~ 2 Gbps

South East Asia : ~ 150 Gbps

South Asia : ~ 2 Mbps

Central Asia : ~ 8 Mbps

APAN

Internet – Best Effort

Internet is Best Effort Network

APAN

Internet – Connectivity

Once you are connected to the Internet,

you will be able to reach to all.

APAN Asia-Pacific Advanced Network

AUP – Research vs Non-Commercial

Accepted User Policy (AUP) should be considered.
Some networks may accept your traffic, but other networks may not accept your traffic.

APAN Asia-Pacific Advanced Network

Access for Meetings

There are several ways to access for meetings

Telephone Conference
Video Conference
Access Grid
(and more)

APAN Asia-Pacific Advanced Network

Outreach (case study)

North Asia : Mongolia

- network (ERDEM Net) with 16 universities
- 2 Mbps satellite link to USA

APAN Asia-Pacific Advanced Network

Central Asia : Kazakstan (and others)

Virtual Silk Highway Project by NATO

- Satellite link (8Mbps) to Europe
- Domestic research & education network (KazRENA)

APAN Asia-Pacific Advanced Network

Southeast Asia : Philippines

-ASTI (Advanced Science and Technology Institute)

-Multiple International Links

APAN Asia-Pacific Advanced Network

South Asia : Sri Lanka

- Domestic Research & Education Network, LEARN

- 3 Mbps international link

APAN Asia-Pacific Advanced Network

West Asia (middle east): Lebanon

EUMED connect project for Meditevranean

- NCSR (National Council for Scientific Research)
- Domestic Research Network
- Links to Europe and Other Connections

APAN Asia-Pacific Advanced Network

Remark :

Coordinated Committee for
Intercontinental Research Networking (CCIRN)

APAN Asia-Pacific Advanced Network

Reference

APAN	www.apan.net
APCN	www.apcn21.net
CCIRN	www.ccirn.org
DANTE	www.dante.net
EUMED connect	www.dante.net/EUMEDconnect
Internet 2	www.internet2.edu
Virtual Silk Highway Project	www.silkproject.org

Current Status of APCN

Chung-Kyu Park

Climate Prediction Division
Korea Meteorological Administration

1. INTRODUCTION

There is growing recognition that the international exchange of climate information is essential for minimizing natural disasters and economic impacts. Action is needed to develop climate early warning systems and climate information networks at the regional scale to improve monitoring and prediction of climate variations.

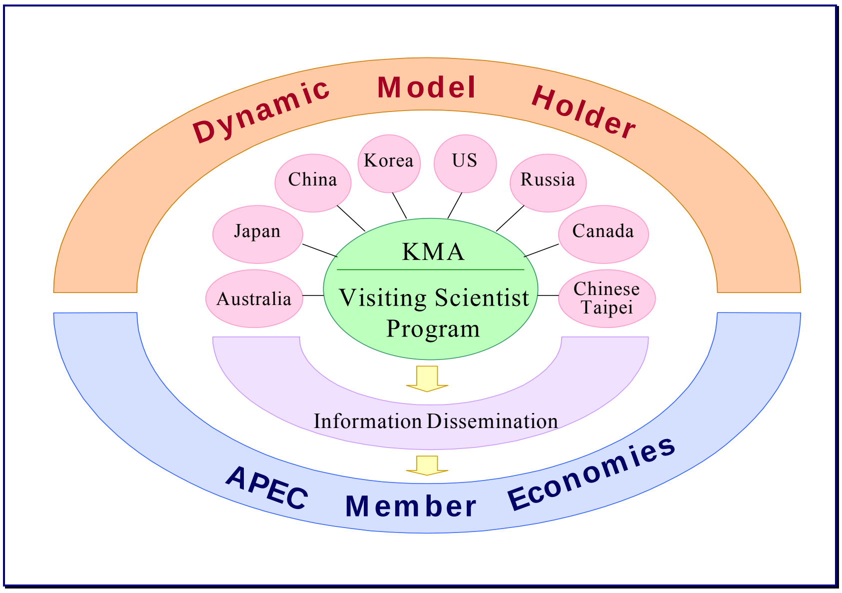
The Korea Meteorological Administration (KMA) has been carrying out the APEC Climate Network (APCN) project for the real-time exchange of climate prediction information among the APEC member economies in order to reduce the effects of natural disasters and to provide benefit to industries and socio-economic activities in the Asian-Pacific region through international cooperation. The APCN project is focused on global climate monitoring and prediction aimed at integrated preventive strategy development.

2. APCN MULTI-MODEL ENSEMBLE SYSTEM

APCN is aimed at producing reliable seasonal predictions to user communities, based on a well-validated multi-model ensemble system (MMES). The APCN produces real-time seasonal forecasts and disseminates the forecast products to member economies to assist in the management of climate risks in the Asian-Pacific region.

The dynamic multi-model ensemble forecast system has been constructed to form the basis of optimum global climate prediction. The dynamic ensemble seasonal prediction data have been collected from NMHSs and research institutes equipped with infrastructure to produce the dynamic seasonal prediction information. The APCN-MMES is based on the output of global climate models developed and at least partially validated in operational seasonal-forecast mode at different institutes of several APEC member economies.

The participating organizations and institutes involved in the real-time multi-model ensemble experiments to build-up the infrastructure for joint operational seasonal forecast are: the Meteorological Service of Canada, China Meteorological Administration, Institute of Atmospheric Physics of China, Central Weather Bureau of Chinese Taipei, Japan Meteorological Agency, Korea Meteorological Administration, Meteorological Research Institute of Korea, Russian Federal Service for Hydrometeorology and Environmental Monitoring, Main Geophysical Observatory of Russia, National Aeronautics and Space Administration, National Centers for Environmental Prediction of USA, and the International Research Institute for Climate Prediction of USA.



APCN multi-model ensemble system

3. INFRASTRUCTURE

The APCN Working Group has been formed to facilitate the exchange of regional climate information, particularly climate forecast information, among APEC member economies and discuss various issues relevant to the implementation of the APCN. The APCN Working Group consists of representatives from the individual APEC member economies.

The APCN Steering Committee has been organized, consisting of leading scientists in the fields of climate modeling and prediction, and other areas of interest to the seasonal prediction. The role of the APCN Steering Committee is to provide guidelines on research and development activities involved in dynamic climate forecast and orchestrate the individual efforts in operational centers and research institutes within the framework of APEC. The functions of the Committee are also to discuss strategies for acquiring the necessary funding for the operation of APCN.

The APCN Secretariat located in KMA is responsible for the processing of dynamic ensemble prediction data and making it available to the participating members. The multi-model ensemble products are distributed through the provision of access to the APCN web site (http://www.apcn21.net). The APCN Secretariat is also responsible for keeping APCN records and official papers, distributing them to the members and interested parties as required, as well as providing administrative arrangements for meetings and other activities.

4. APCN SCIENCE PLAN

The APCN project's primary goal is to provide reliable climate information for the Asian-Pacific region, satisfying the requirements of member economies. The project can only be realized through effective collaboration between scientists and forecasters in the participating institutes. The existence of several teams of specialists and organized scientific research in seasonal forecasts will be of considerable benefit to the project.

The APCN project will be carried out in two phases: the experimental phase and the implementation phase. Included in the experimental phase are activities for establishing the scientific basis for multi-model ensemble forecasts and the enhancement of necessary infrastructure, followed by the generation of multi-model ensemble based on the prediction information provided by participating members and dissemination of climate monitoring and forecast information to participating members in the implementation phase.

The science plan under the APCN project include: (1) the development of a multi-model ensemble system for seasonal prediction, (2) the ongoing research and development of the science and methodologies underpinning seasonal prediction, and (3) the development of sophisticated application methods for exploiting the available skill of seasonal predictions. The MMES will be based on an ensemble of seasonal predictions produced by participating climate prediction centers in the Asian-Pacific region.

The forecast system includes procedures for model output collection, bias correction, statistical downscaling, super-ensemble methods for blending the predictions of different models, and verification. The project will also assess the economic value of MMES and develop methods for applying MMES in the industrial sectors. Basic research related to climate predictability including the model sensitivity to initial and boundary conditions and the applicability of various downscaling methods will also be undertaken.

Participating institutes are requested to provide global 20-year hindcasts and real-time forecasts. The hindcasts, which will be used to develop the MMES, should be made, as far as practicable, the same way that the real-time forecasts will be made. That is, they should not use any data that would be unavailable if the forecast was being made in real-time. The data format and other specifications will be, as far as practicable, identical to the protocols established for SMIP2/HFP.

The core facilities for undertaking the research and development will be located in the APCN Secretariat situated in KMA. A lead scientist for each component will be identified by the APCN Steering Committee. These lead scientists will recruit scientists from the NMHSs and participating institutes from APEC member economies, to assist in defining, guiding, and carrying out the research in each component. Overall scientific guidance will be provided by the APCN Steering Committee.

5. LESSONS LEARNED

(a) Training of the models and bias correction

The results of the multi-model ensemble prediction is better than any single model performance, but yet to be further improved by developing more systematic approaches in the areas related to the training of the models and bias correction.

The design of an optimal weighting function for a long-term forecast is a key for the development of multi-model ensemble system. A preliminary experiment indicates that the weighted multi-model ensemble forecast based on pattern correlation coefficient between forecast and observation derived from previous years exceeds the predictability of the simple average of all the members available. It is recommended that for better predictability the weighting coefficient be derived using much larger samples, and the models participating in the multi-model ensemble be kept unchanged. Otherwise, the time-consuming and high-cost processes of computing model statistics must be repeated. An organized research team should carry out the research project to develop science and technologies involved in optimal method of blending various model outputs.

The training of models for statistical downscaling should also be performed using well-designed hindcast data with sufficient sample size. Preliminary studies also indicate the skill score can be improved by statistical bias correction prior to applying multi-model ensemble techniques.

(b) Boundary forcing

The preliminary results of the multi-model ensemble predictions provide a hope for the improvement of seasonal dynamic ensemble prediction. However, the results are far from satisfactory for the operational purpose yet due to a number of drawbacks in the current experimental APCN-MMES.

In the current prediction system, the persistence of SST anomalies is used because the single model prediction has not been able to provide us with reliable SST prediction information with confidence, whereas the impact of SST boundary forcing specified by persistent anomalies is critical particularly when the SST anomaly pattern changes rapidly.

The SST prediction information must be incorporated in the multi-model ensemble seasonal prediction and the training of the models. More stable and possibly more reliable SST prediction information can be produced from the multi-model ensemble of predictions provided by individual dynamical and statistical SST prediction models.

(c) Climatology

Currently, in the experimental multi-model ensemble prediction the anomalies are computed based on the model climatology obtained from the AMIP type multi-year simulation instead of using historical prediction data. The inconsistency between two climatologies may contaminate the forecast anomaly fields by introducing spurious errors.

(d) Daily forecast data

The calculation of the probability of heavy precipitation episodes using daily forecast data provides useful information for various regions. Particularly, the high resolution model is superior in the realization of storm development and monsoon rainband. It is desirable to archive daily time-series data of key forecast variables from individual ensemble members for further research.

(e) Data exchange

The optimum number of ensemble members from individual models needs to be decided based on the results of research on predictability and the infrastructure of participating institutes, taking into account the time constraints on data acquisition and processes.

It is necessary to build-up a systematic channel for producing and exchanging long-range prediction information in a standardized format among the participating institutes, parallel to research efforts to improve the predictability. A standardized data format can help to reduce data processing.

The provision of adequate computer resources and development of a well-organized network, and availability of adequate human resources are essential element for the successful development of MMES.

6. SUMMARY

The practical importance of climate forecasts for the protection of life and property, together with concerns about environmental change, have led to the initiation of the APCN project. The project’s most important challenge is to provide accurate and reliable climate information for member economies in the Asian-Pacific region. The major aspect of APCN-MMES is the development of new techniques for providing forecast information to the user community.

The new techniques include the downscaling method to make a seasonal forecast at a target region. The range of seasonal forecasts and detailed climate information required and provided must be developed through dialogue between the scientists involved in research projects and the forecasters in NMHSs.

The results of the project will benefit both public and private meteorological and hydrological institutions in the Asia-Pacific region in several ways. Those institutions without the capacity to produce climate predictions will be able to access optimized, high-cost global climate predictions. The predictions should enable national and international disaster prevention offices to respond more effectively to natural disasters and mitigate economic losses in the case of extreme climate events.

7. RECOMMENDATIONS FOR FUTURE CONSIDERATION

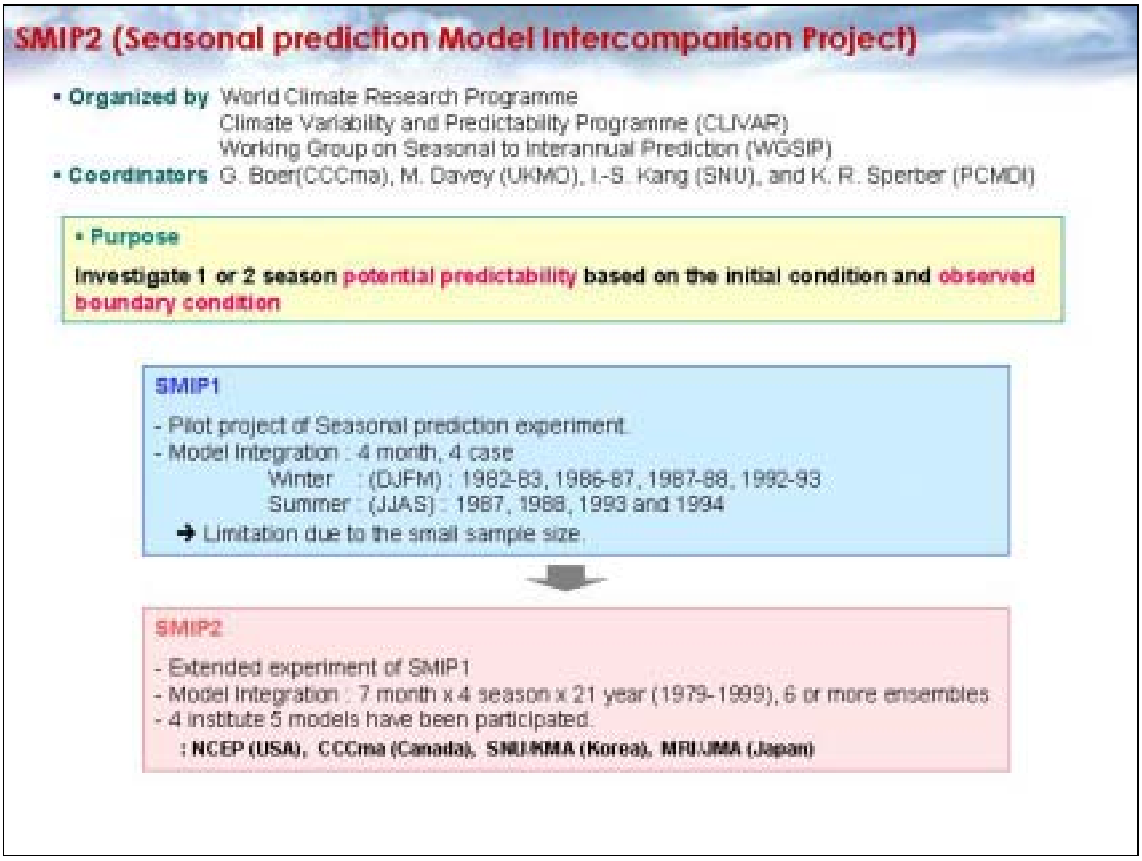
Special attention is needed to develop the long-range forecast and verification techniques on global hydrological cycle monitoring and prediction, aimed at integrated preventive strategy development. Considering the current level of understanding and the size of the tasks involved in producing reliable seasonal prediction information, these tasks should be properly distributed until credibility is established, whereas extensive and organized research efforts should be supported for establishing the scientific basis and the enhancement of necessary infrastructure.

To encourage and assemble the regional activities related to long-range forecasting, WMO is requested to set up a strategic plan to orchestrate individual research efforts in operational centers and research institutes. It is highly recommended to designate a World Climate Center (WCC) which can process the global climate prediction information based on the products obtained from global producers and disseminate the optimized forecast information to RCCs for downscaling on behalf of WMO.

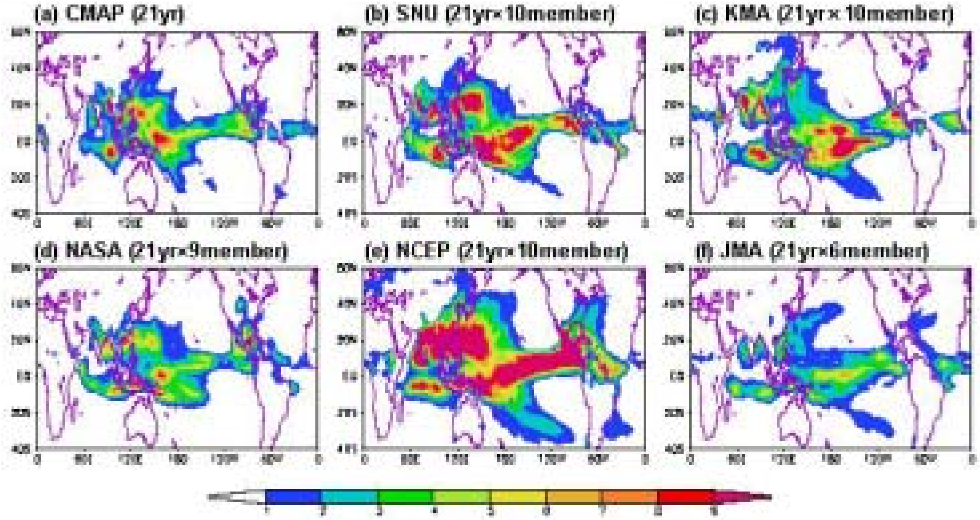
Seasonal Predictability of SMIP and SMP/HFP

In-Sik Kang
Jin-Ho Yoo, Kyung Jin, June-Yi Lee

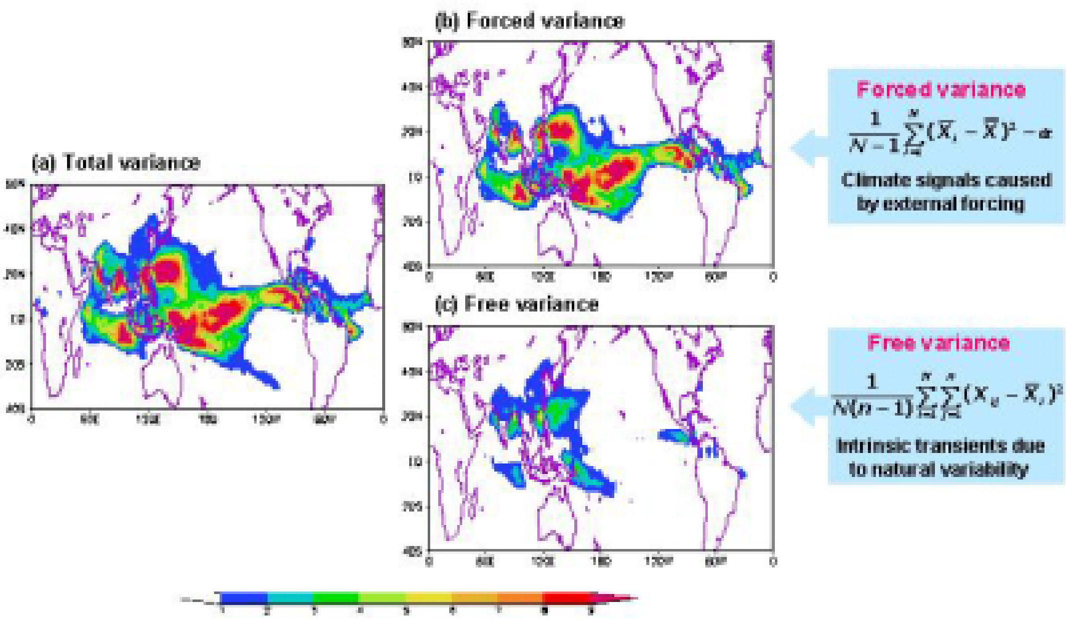
Climate Environment System Research Center
Seoul National University

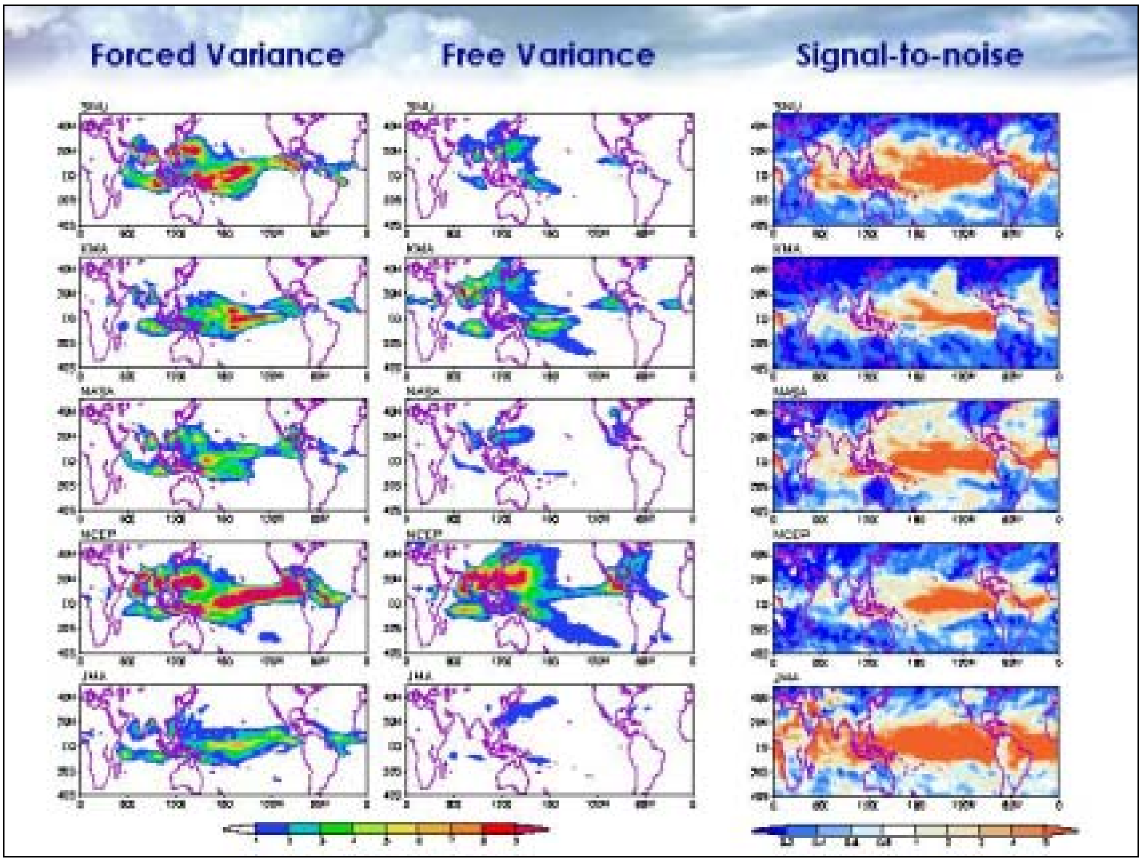


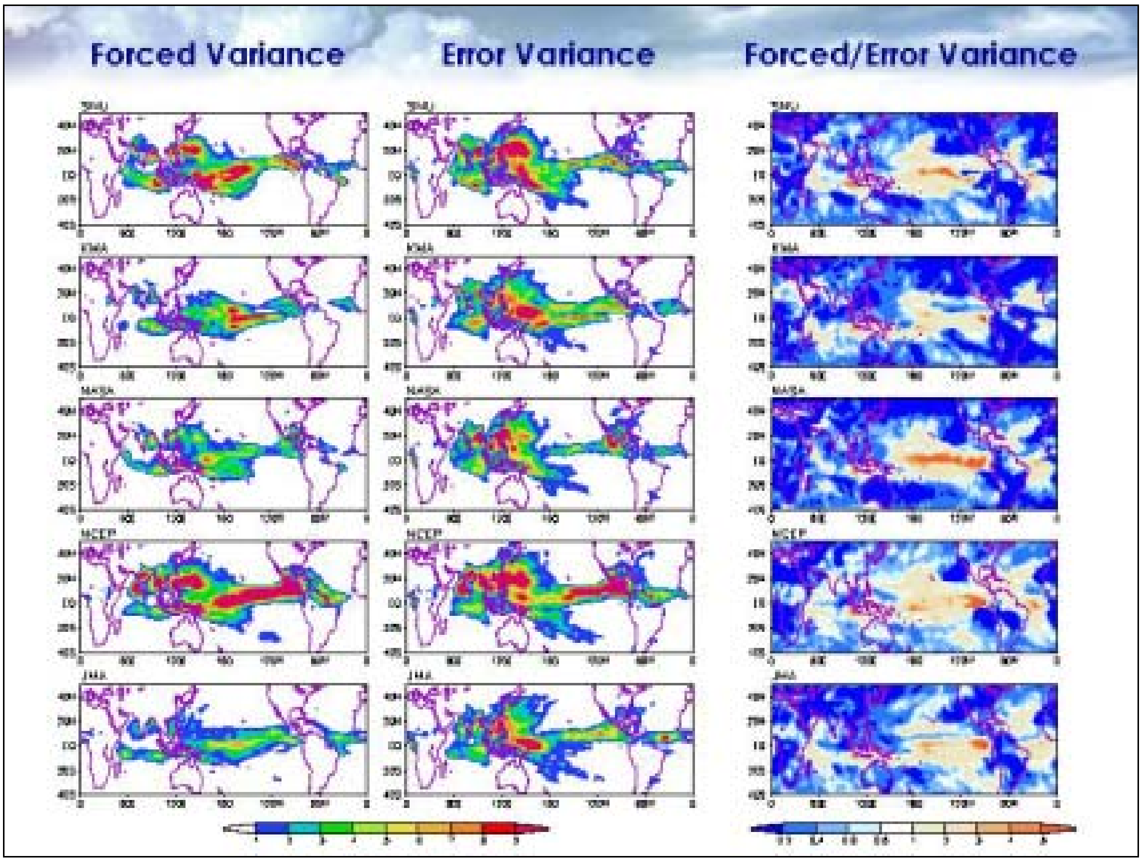
Total Variance of JJA Precipitation Anomalies

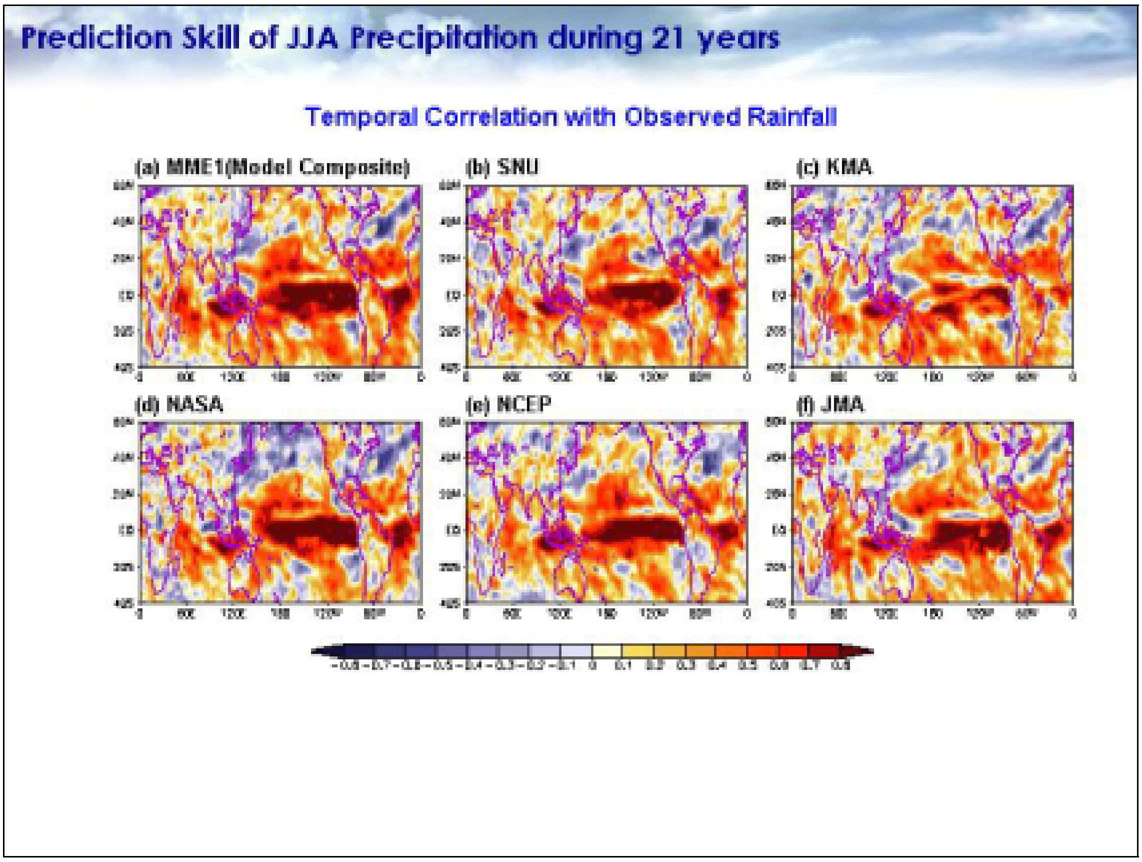


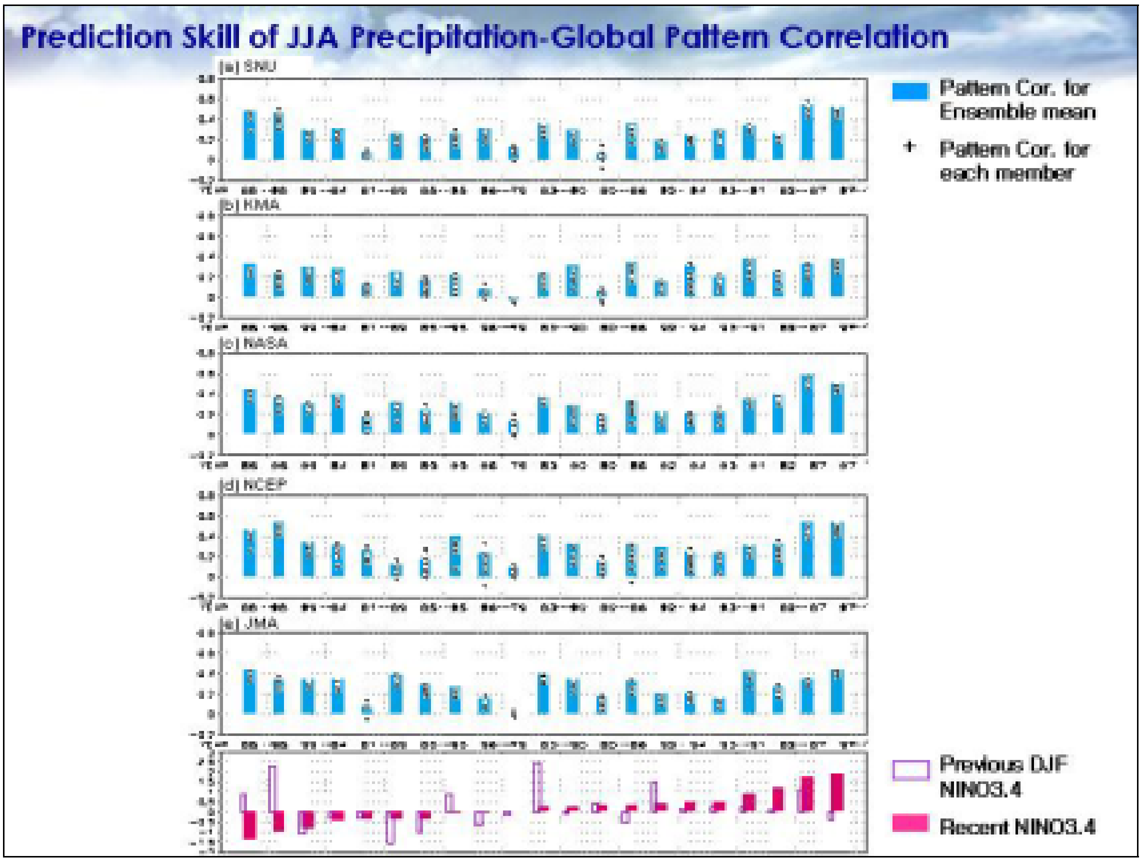
Analysis of Variance of JJA Precipitation Anomalies (SNU case)

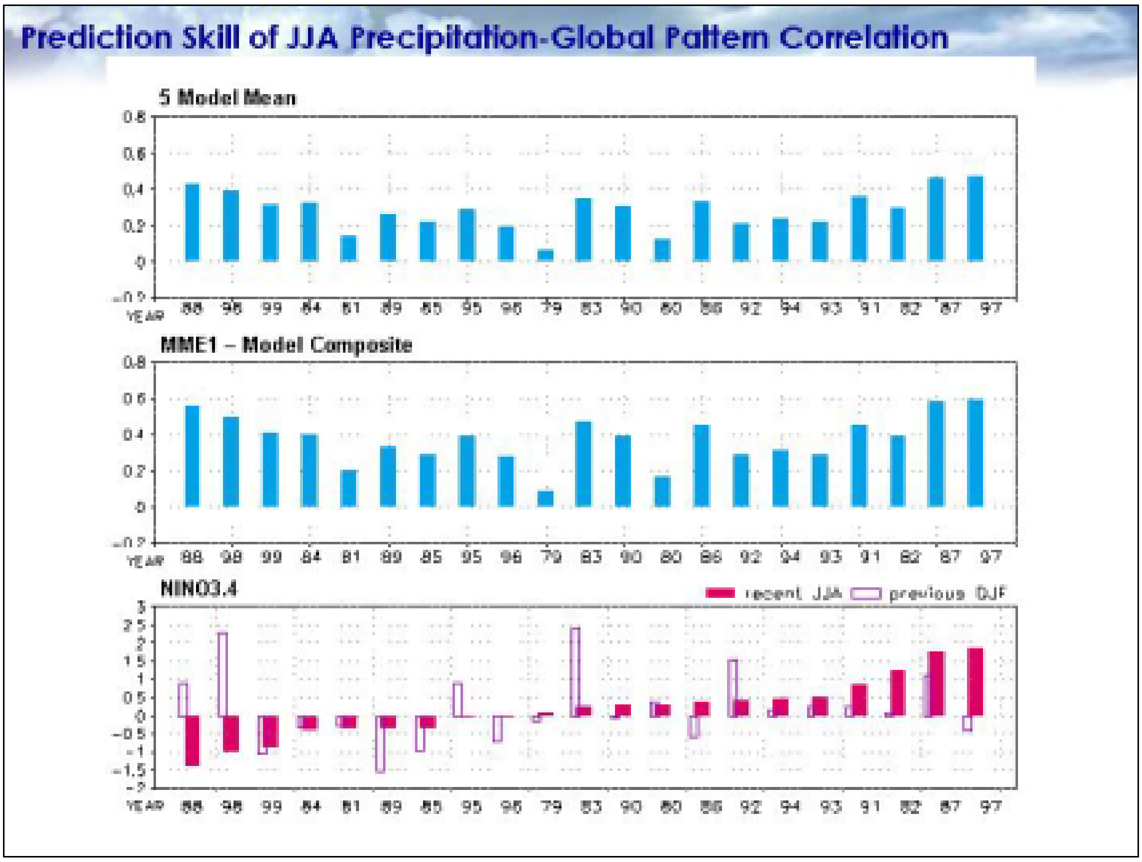


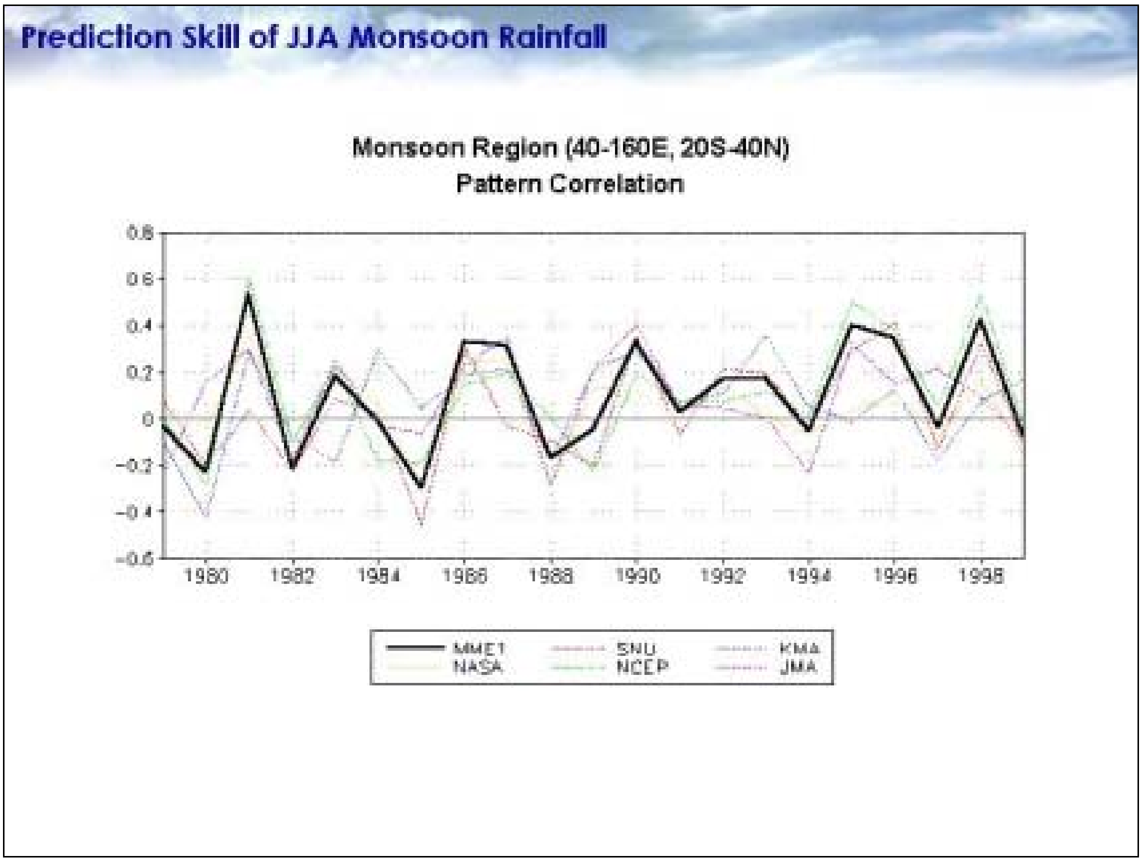

Forced Variance
Free Variance
Signal-to-noise
SNU
KMA
NASA
NCEP
JMA

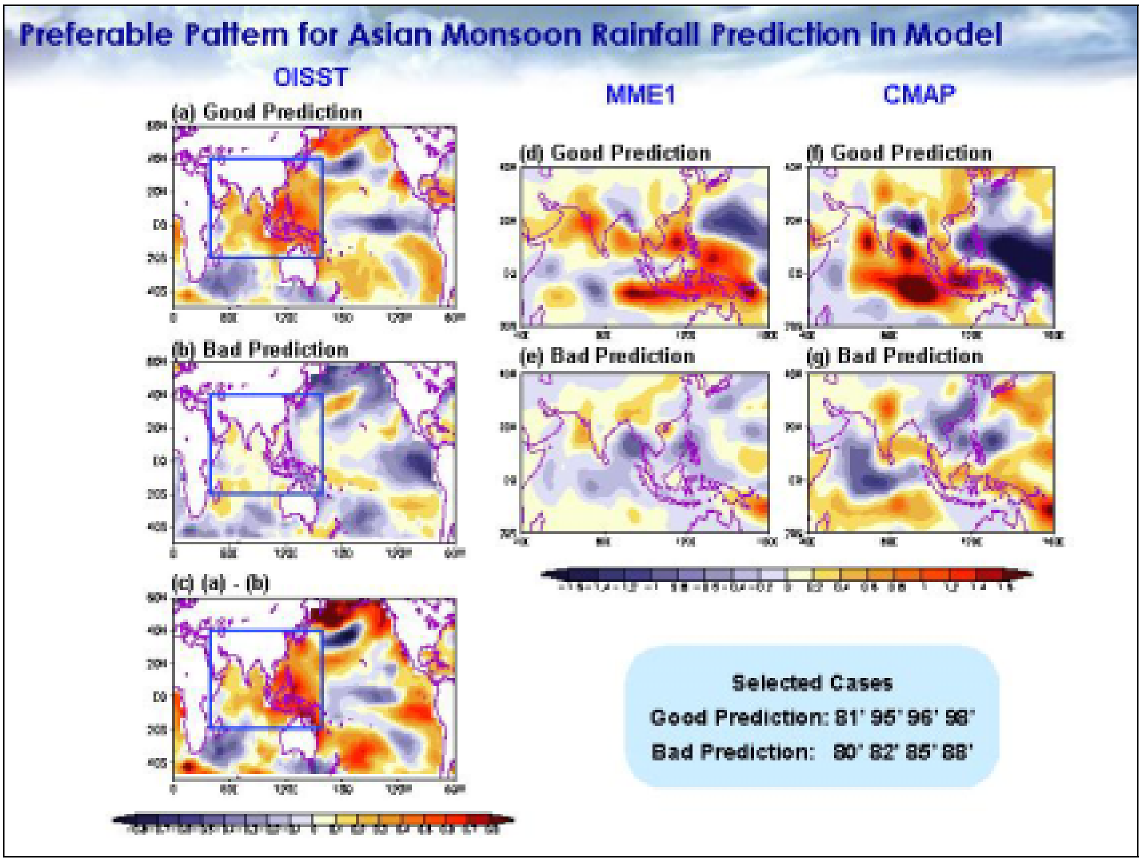

Forced Variance
Error Variance
Forced/Error Variance
SNU
KMA
NASA
NCEP
JMA

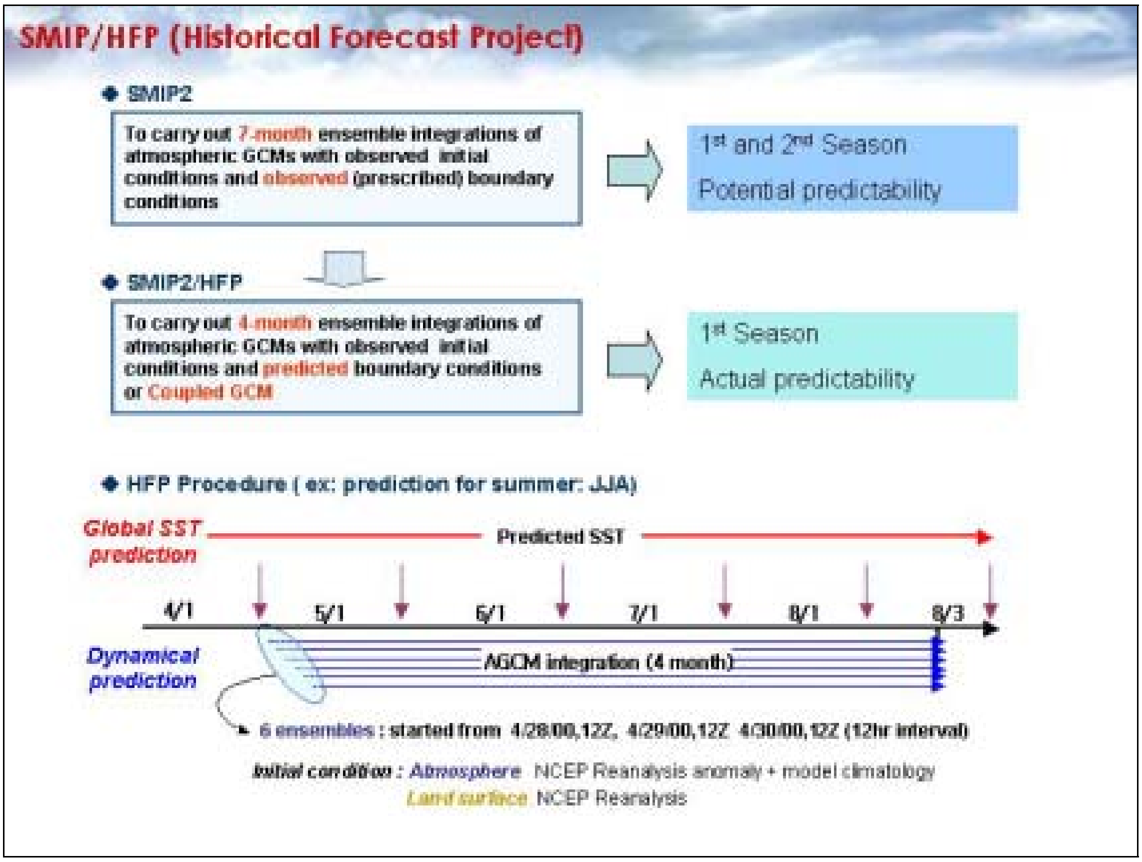

Prediction Skill of JJA Precipitation during 21 years
Temporal Correlation with Observed Rainfall
(a) MME1(Model Composite)
(b) SNU
(c) KMA
(d) NASA
(e) NCEP
(f) JMA

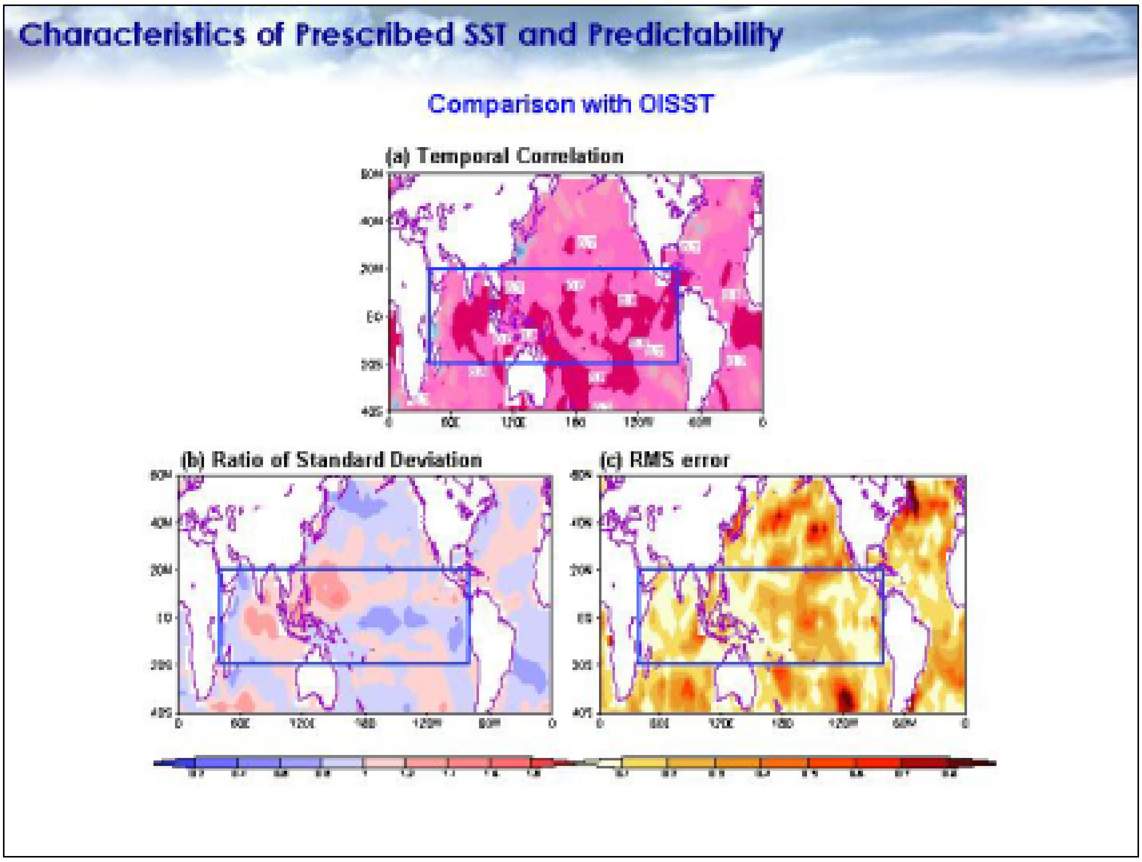

Prediction Skill of JJA Precipitation-Global Pattern Correlation
(a) SNU
(b) KMA
(c) NASA
(d) NCEP
(e) JMA
Pattern Cor. for Ensemble mean
+ Pattern Cor. for each member
Previous DJF NINO3.4
Recent NINO3.4

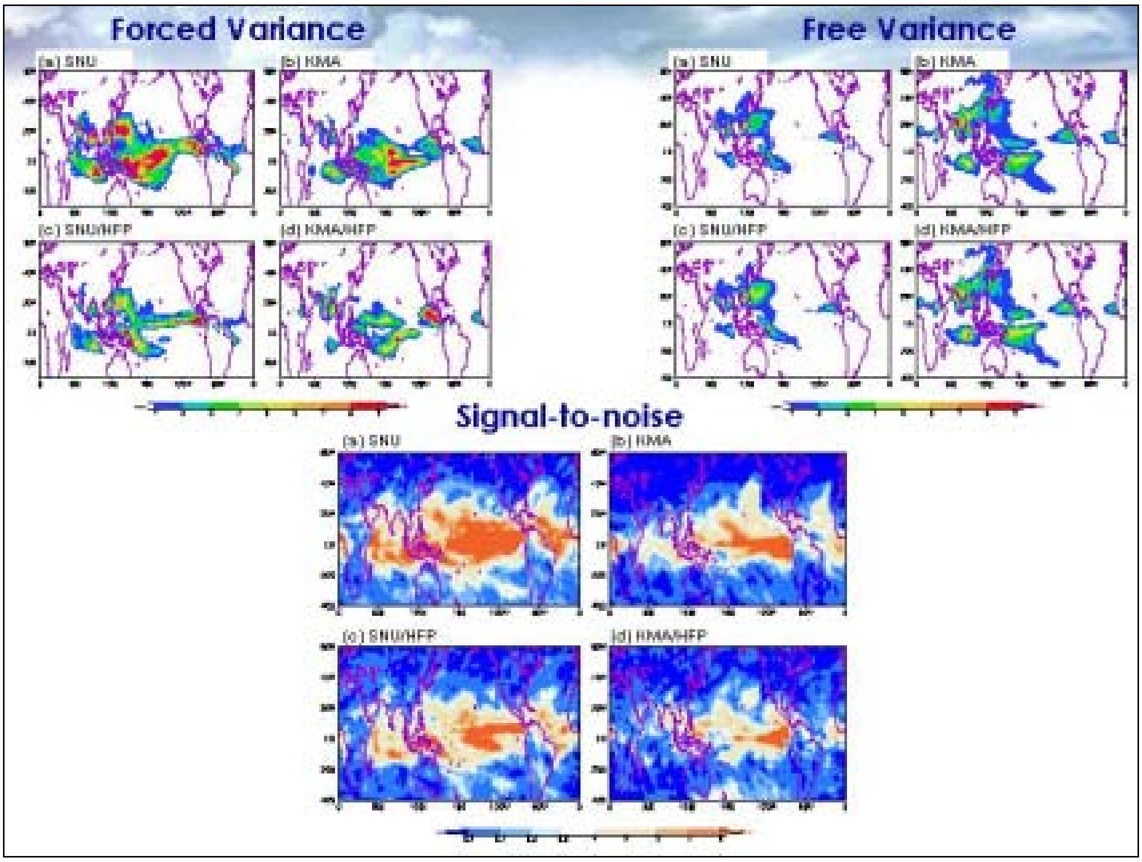

Prediction Skill of JJA Precipitation-Global Pattern Correlation
5 Model Mean
YEAR 88 98 99 84 81 89 85 95 96 79 83 90 80 86 92 94 93 91 82 87 97
MME1 – Model Composite
YEAR 88 98 99 84 81 89 85 95 96 79 83 90 80 86 92 94 93 91 82 87 97
NINO3.4
recent JJA
previous DJF
YEAR 88 98 99 84 81 89 85 95 96 79 83 90 80 86 92 94 93 91 82 87 97

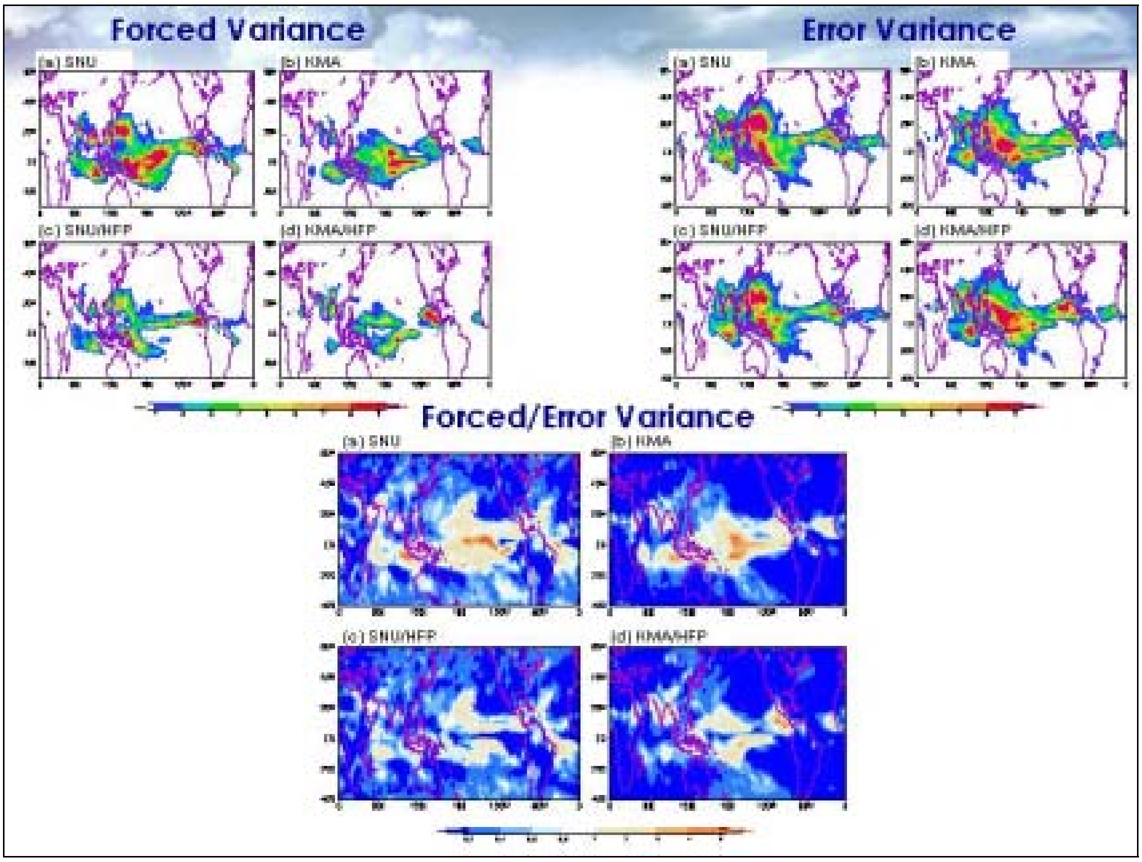

Prediction Skill of JJA Monsoon Rainfall
Monsoon Region (40-160E, 20S-40N)
Pattern Correlation
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998
MME1
NASA
SNU
NCEP
KMA
JMA

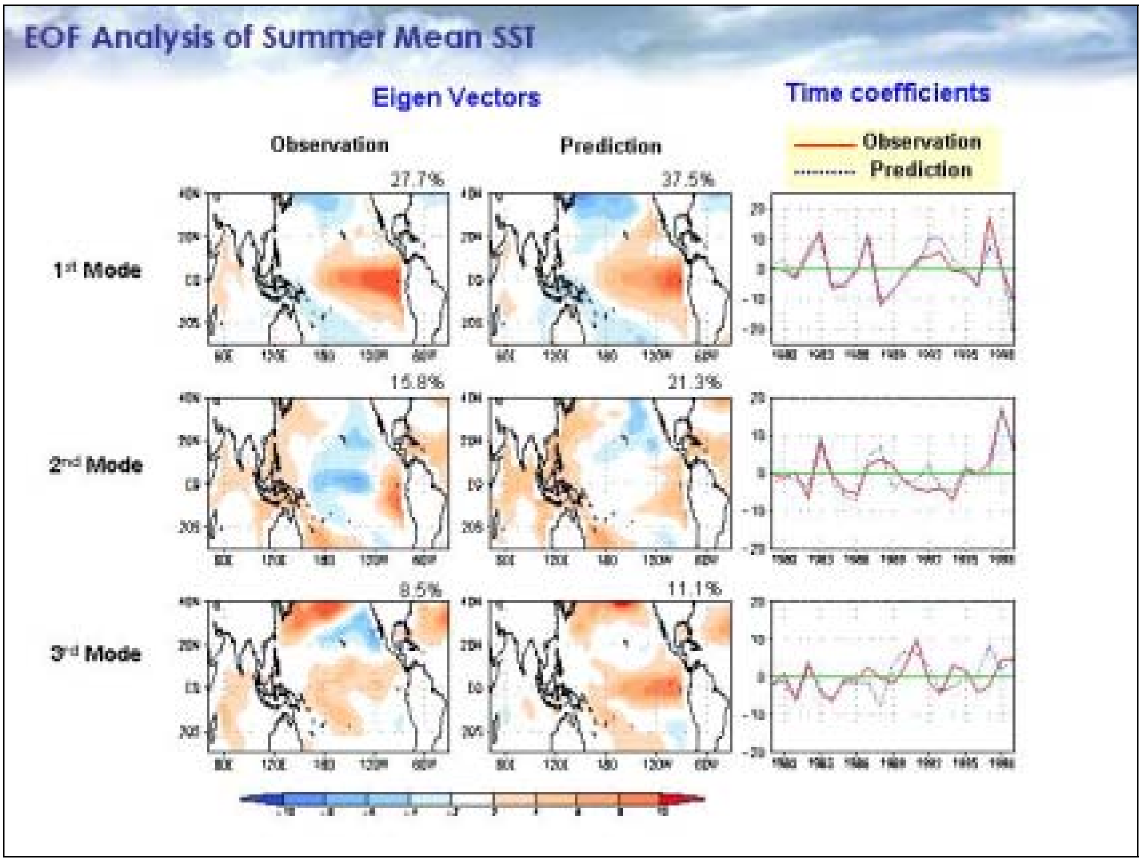

Preferable Pattern for Asian Monsoon Rainfall Prediction in Model
OISST
MME1
CMAP
(a) Good Prediction
(b) Bad Prediction
(c) (a) - (b)
(d) Good Prediction
(e) Bad Prediction
(f) Good Prediction
(g) Bad Prediction
Selected Cases
Good Prediction: 81' 95' 96' 98'
Bad Prediction: 80' 82' 85' 88'

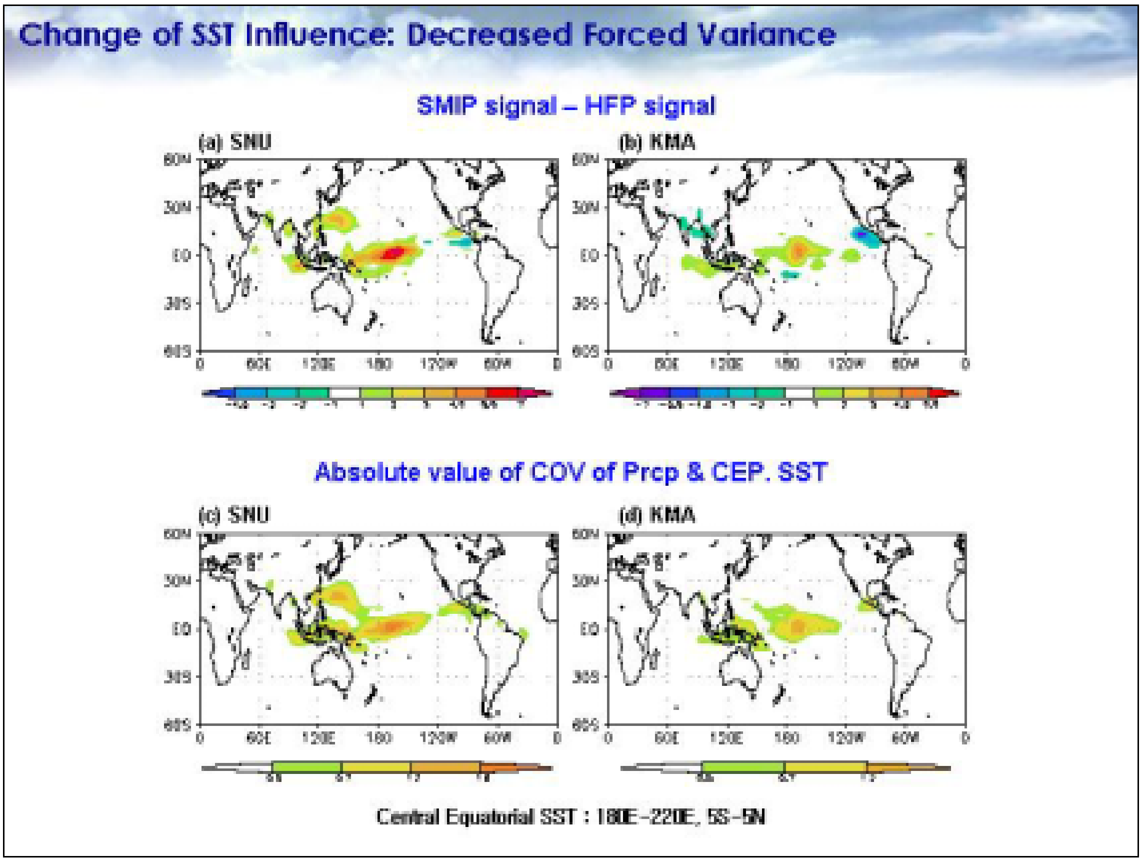

SMIP/HFP (Historical Forecast Project)
SMIP2
To carry out 7-month ensemble integrations of atmospheric GCMs with observed initial conditions and observed (prescribed) boundary conditions
1st and 2nd Season
Potential predictability
SMIP2/HFP
To carry out 4-month ensemble integrations of atmospheric GCMs with observed initial conditions and predicted boundary conditions or Coupled GCM
1st Season
Actual predictability
HFP Procedure (ex: prediction for summer: JJA)
Global SST prediction
Predicted SST
4/1
5/1
6/1
7/1
8/1
8/3
Dynamical prediction
AGCM integration (4 month)
6 ensembles : started from 4/28/00,12Z, 4/29/00,12Z 4/30/00,12Z (12hr interval)
Initial condition : Atmosphere NCEP Reanalysis anomaly + model climatology
Land surface NCEP Reanalysis

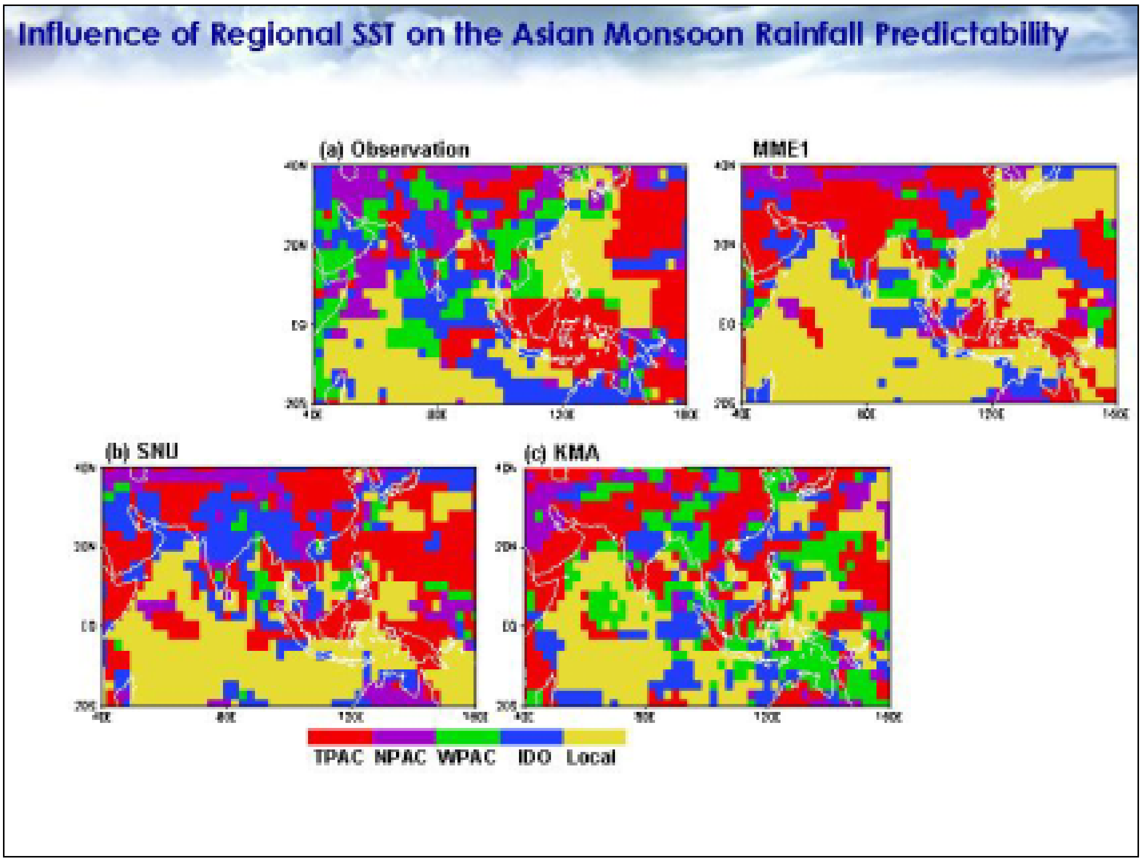

Characteristics of Prescribed SST and Predictability
Comparison with OISST
(a) Temporal Correlation
(b) Ratio of Standard Deviation
(c) RMS error


Forced Variance
Free Variance
Signal-to-noise
(a) SNU
(b) KMA
(c) SNU/HFP
(d) KMA/HFP


Forced Variance
Error Variance
(a) SNU
(b) KMA
(c) SNU/HFP
(d) KMA/HFP
Forced/Error Variance

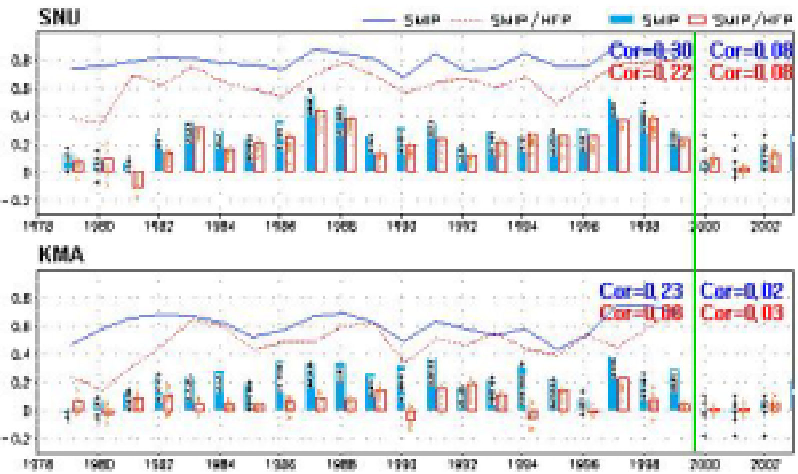

EOF Analysis of Summer Mean SST
Eigen Vectors
Time coefficients
Observation
Prediction
1st Mode
2nd Mode
3rd Mode
27.7%
37.5%
15.8%
21.3%
8.5%
11.1%


Change of SST Influence: Decreased Forced Variance
SMIP signal – HFP signal
(a) SNU
(b) KMA
Absolute value of COV of Prcp & CEP. SST
(c) SNU
(d) KMA
Central Equatorial SST : 180E-220E, 5S-5N


Influence of Regional SST on the Asian Monsoon Rainfall Predictability
(a) Observation
MME1
(b) SNU
(c) KMA
TPAC NPAC WPAC IDO Local

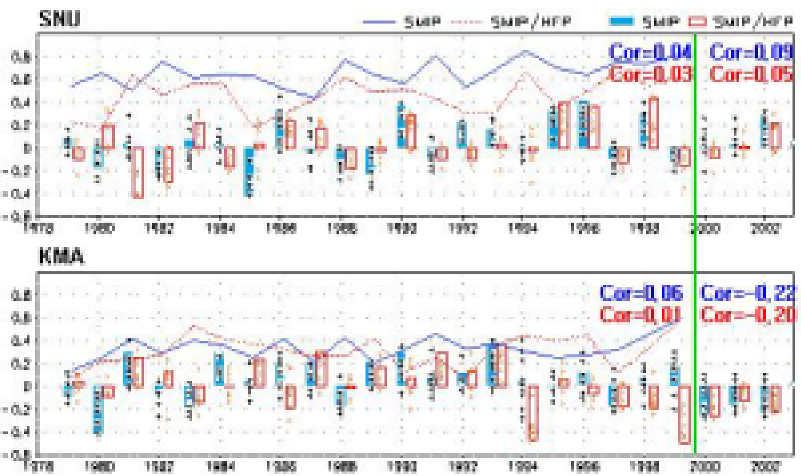
Prediction skill of JJA Precipitation during 1979-2002

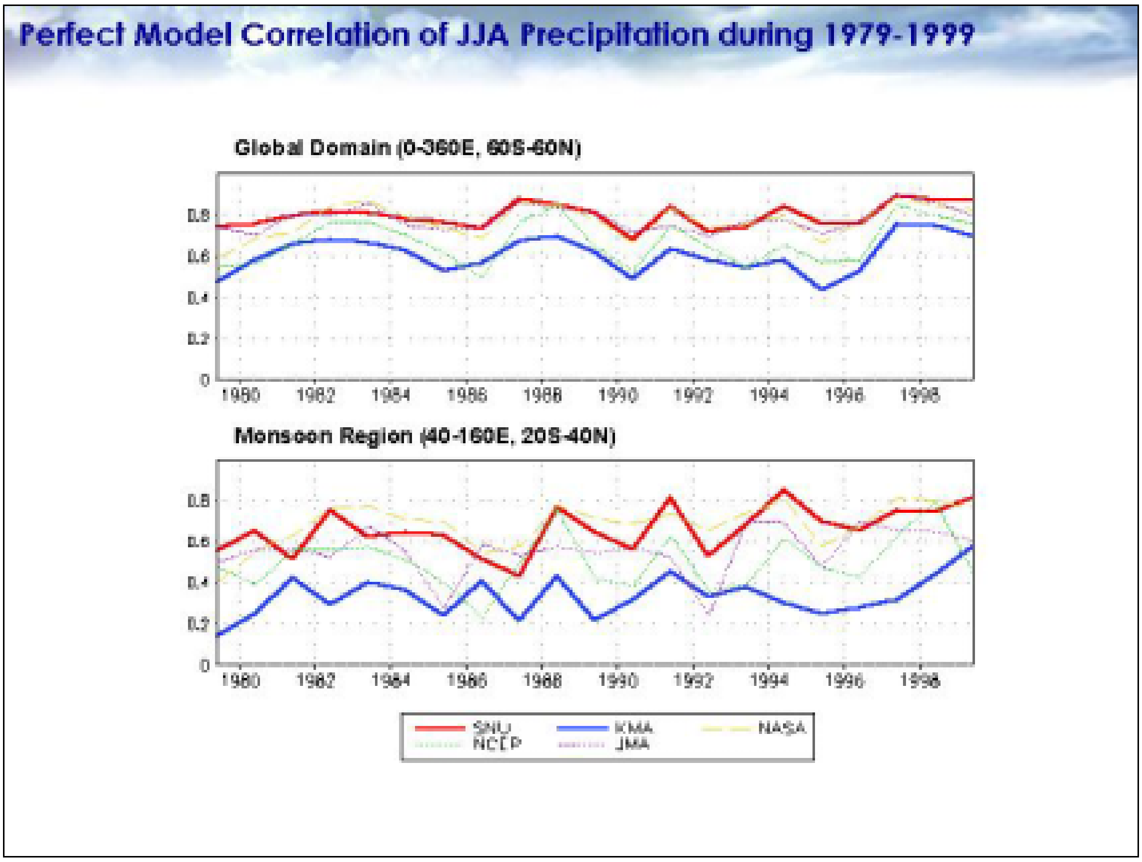
Global Pattern Correlation (0-360E, 60S-60N)

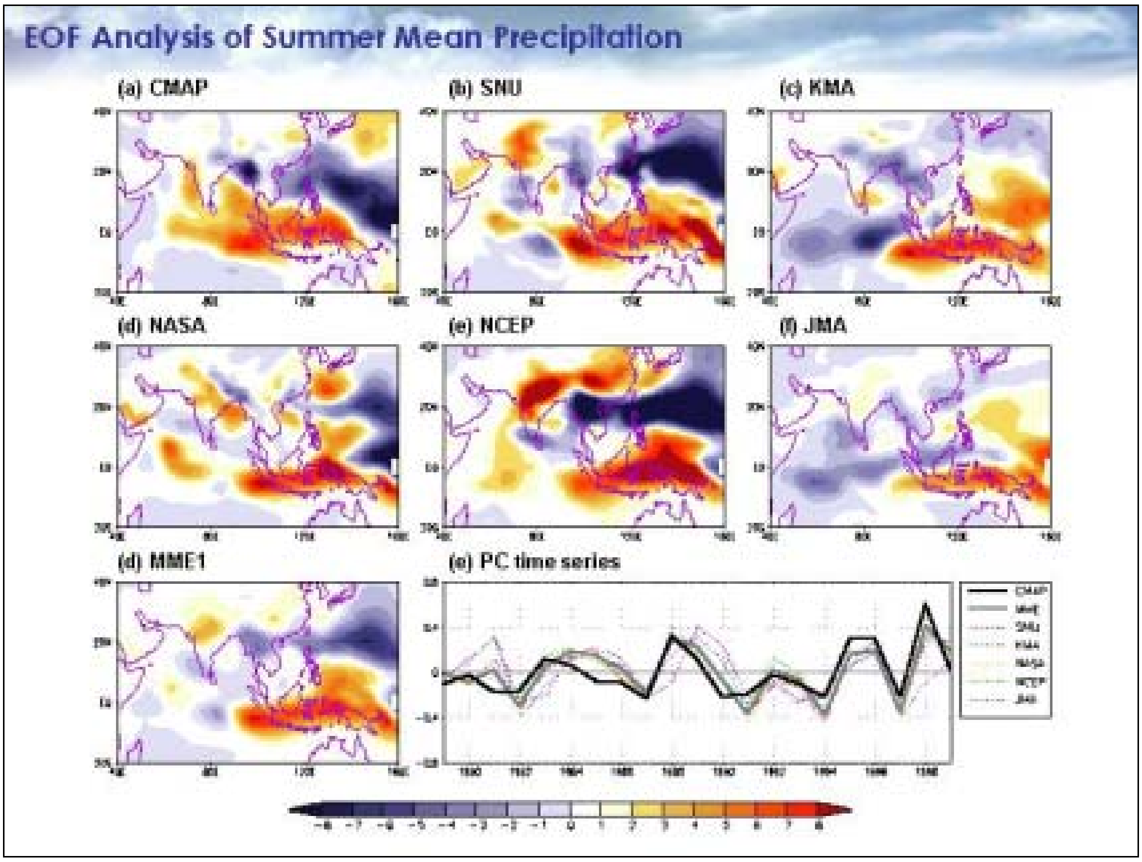


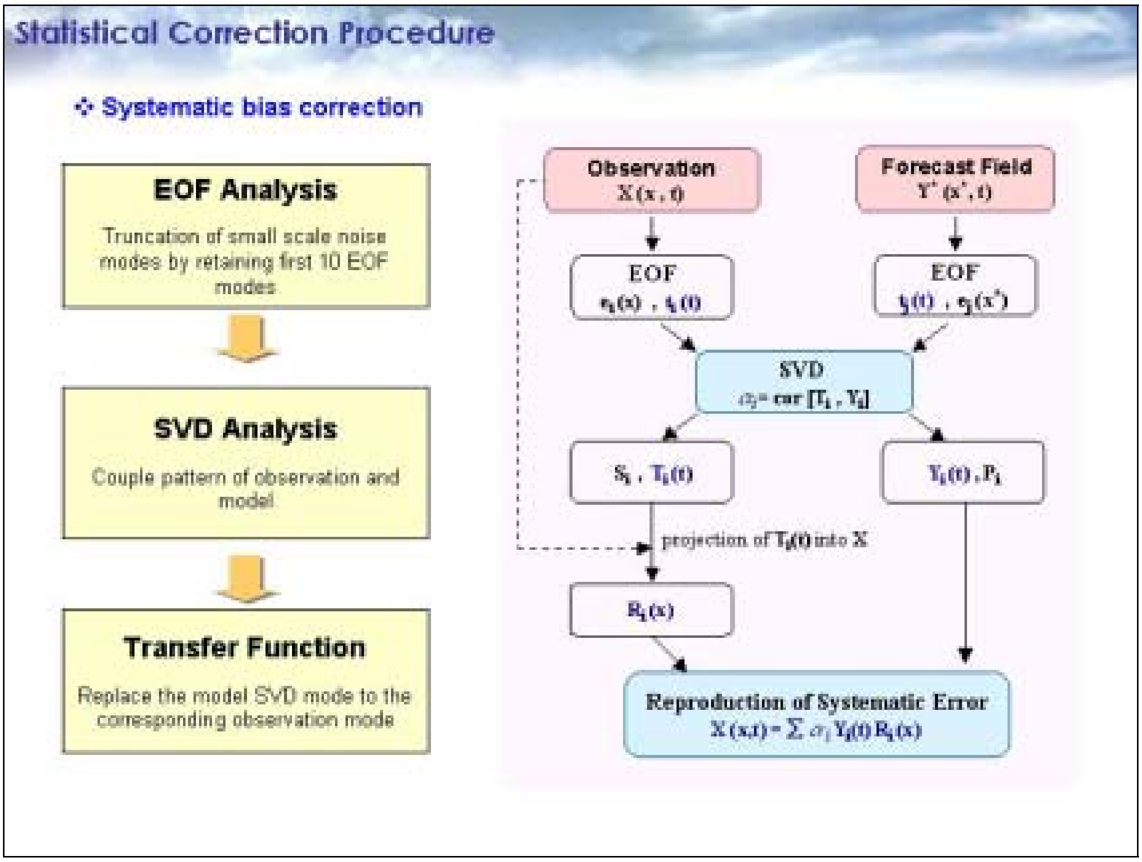
Prediction skill of JJA Precipitation during 1979-2002

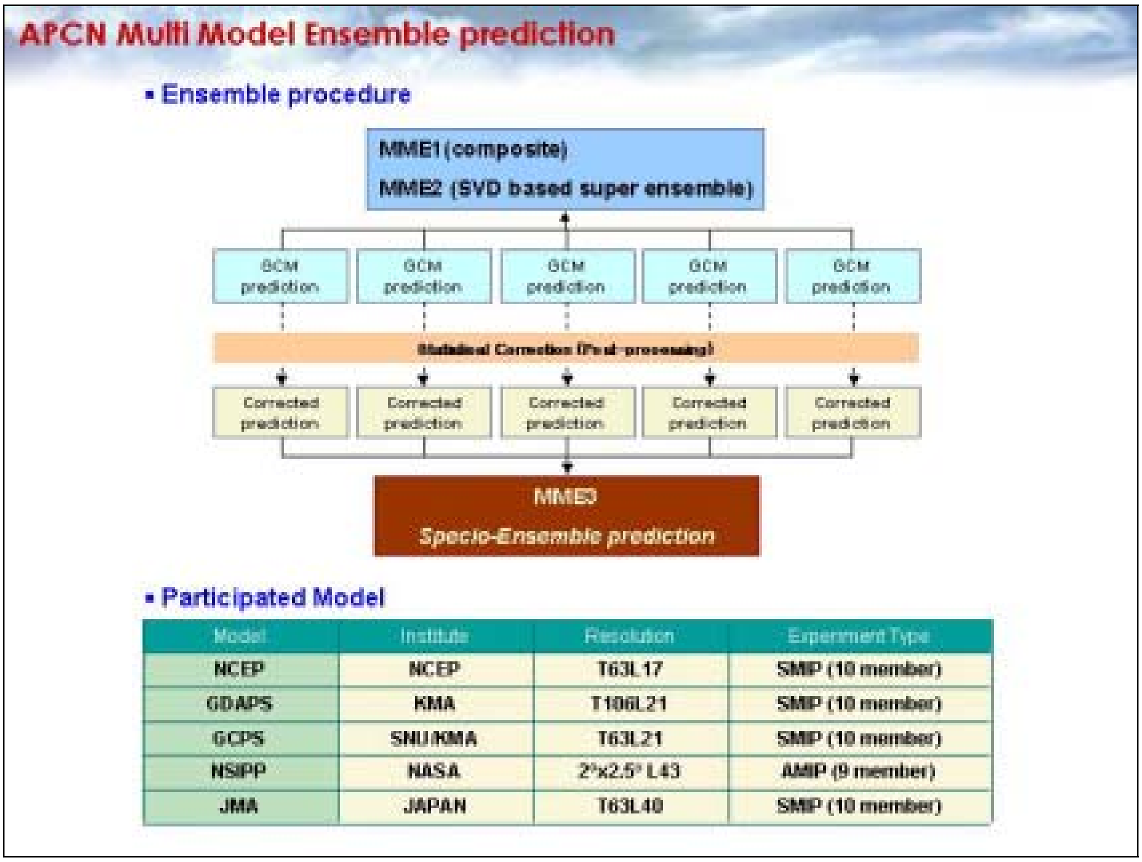
Monsoon Pattern Correlation (40-160E, 20S-40N)




Perfect Model Correlation of JJA Precipitation during 1979-1999
Global Domain (0-360E, 60S-60N)
Monsoon Region (40-160E, 20S-40N)
SNU
KMA
NASA
NCEP
JMA


EOF Analysis of Summer Mean Precipitation
(a) CMAP
(b) SNU
(c) KMA
(d) NASA
(e) NCEP
(f) JMA
(d) MME1
(e) PC time series

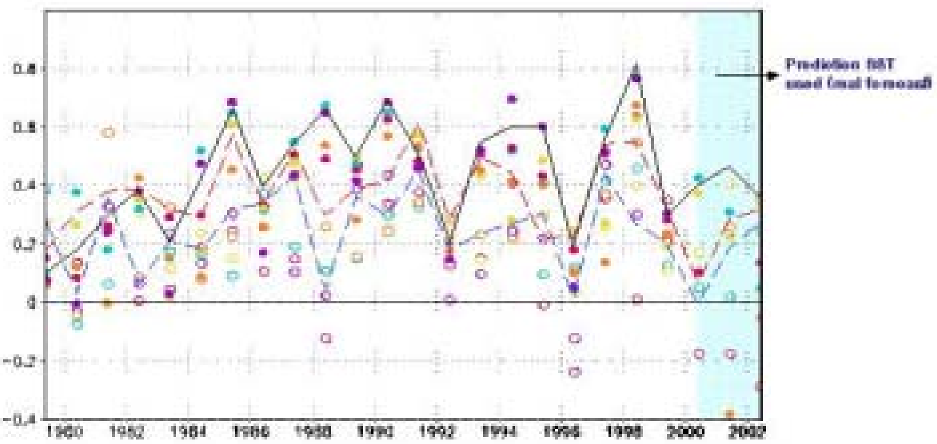




Model	Institute	Resolution	Experiment Type
NCEP	NCEP	T63L17	SMIP (10 member)
GDAPS	KMA	T106L21	SMIP (10 member)
GCPS	SNU/KMA	T63L21	SMIP (10 member)
NSIPP	NASA	2°x2.5° L43	AMIP (9 member)
JMA	JAPAN	T63L40	SMIP (10 member)

Prediction skill of APCN Multi Model predictions

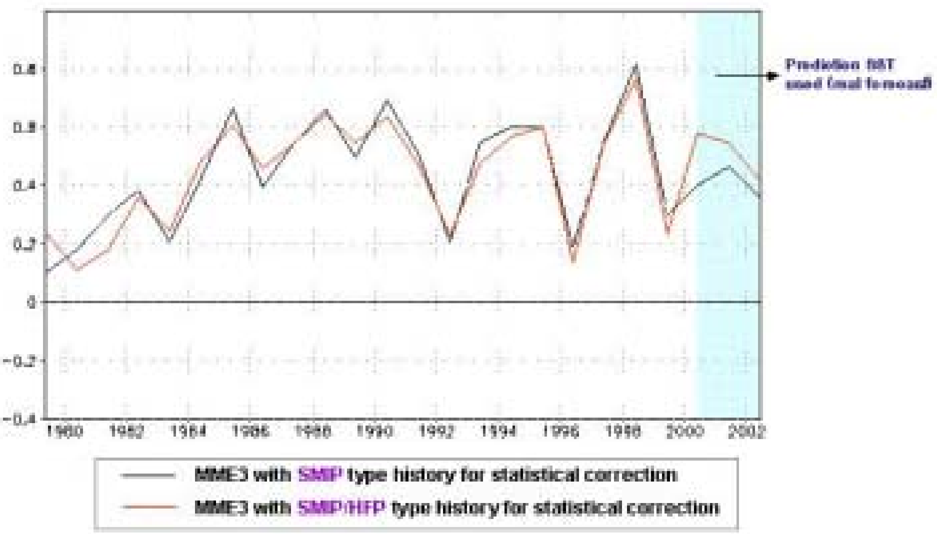
Pattern correlation precipitation over monsoon region (40E-160E, 20S-40N)



		MME3	MME2	MME1	SNU	KMA	NASA	NCEP	JMA
Avg. Skill	79-99	0.45	0.39	0.25	0.20	0.15	0.25	0.26	0.21
					0.42	0.39	0.35	0.32	0.40
	00-02	0.41	0.22	0.15	0.10	-0.21	0.31	0.31	N/A
					0.26	0.15	0.31	-0.22	N/A

SMIP/HFP history after statistical correction

MME3 with 5 models (only SNU & KMA are different : SMIP vs SMIP/HFP)



Prediction dataset has inconsistency in SST boundary condition. During 1979-1999, observed SST was used for SMIP type simulation. However, the forecast after 2000 used predicted SST in real forecast mode. Thus, SMIP/HFP can be more skillful for later stage due to consistency in boundary condition for statistical correction based on previous forecast history.

DEMETER: Development of an European Multi-Model Ensemble System for Seasonal to Interannual Climate Prediction

F. J. Doblas-Reyes, R. Hagedorn, T. N. Palmer

European Centre for Medium-Range Weather Forecasts

Introduction

Seasonal weather forecasts are of potential value for a wide cross section of society, for personal, commercial and humanitarian reasons. Dynamical seasonal forecasts have been made operationally using ensemble systems with perturbed initial conditions (Stockdale et al. 1998). However, if uncertainties in initial conditions were the only perturbations represented in a seasonal-forecast ensemble, then the resulting measures of predictability would not be reliable, the reason being that the model equations are also uncertain. One approach to this problem relies on the fact that global climate models have been developed somewhat independently at different climate research institutes. An ensemble comprising such quasi-independent models could therefore be thought of as providing a sampling of possible model equation sets. This is referred to as a multi-model ensemble (Palmer et al. 2000). A multi-model ensemble-based system for seasonal-to-interannual prediction has been developed in the European project DEMETER (Development of a European Multi-Model Ensemble Prediction System for Seasonal to Inter-annual Prediction). The DEMETER system comprises seven global atmosphere-ocean coupled models, and has been designed to study the multi-model concept by creating an extensive hindcast dataset. The comprehensive evaluation of this hindcast dataset demonstrates the enhanced reliability and skill of the multi-model ensemble over a more conventional single-model ensemble approach. In addition, innovative applications of seasonal ensemble forecasts for malaria and crop yield prediction have been carried out. The “end-to-end” strategy followed in DEMETER (Pielke and Carbone 2002) deals with several scientific aspects as communication across disciplines, downscaling of climate simulations, and use of probabilistic forecast information in the applications sector, illustrating the economic value of seasonal-to-interannual prediction for society as a whole. Some examples of the ability of multi-model ensembles to produce more reliable, skilful and useful probability seasonal forecasts are described in this paper.

Experiment and data

The DEMETER project[1] has been funded under the European Union Vth Framework Environment Programme to assess the skill and potential economic value of multi-model ensemble seasonal forecasts. The principal aims of DEMETER are to advance the concept of multi-model ensemble prediction by installing a number of state-of-the-art global coupled ocean-atmosphere models on a single supercomputer, to produce a series of multi-model ensemble hindcasts with common archiving and common diagnostic software, and to assess the utility of multi-model hindcasts in specific quantitative applications, notably health and agriculture.

The DEMETER prediction system comprises the global coupled ocean-atmosphere models of the following institutions: CERFACS (European Centre for Research and Advanced Training in Scientific Computation, France), ECMWF (European Centre for Medium-range Weather Forecasts), INGV (Istituto Nazionale de Geofisica e Vulcanologia, Italy), LODYC (Laboratoire d’Océanographie Dynamique et de Climatologie, France), Météo-France (MetFr, France), Met Office (UKMO, UK) and MPI (Max-Planck Institut für Meteorologie, Germany). In order to assess seasonal dependence on forecast skill, the DEMETER hindcasts have been started from 1st February, 1st May, 1st August, and 1st November. The atmospheric and land-surface initial conditions are taken from the ECMWF Re-Analysis[2] (ERA-40) dataset. The ocean initial conditions are obtained from ocean-only runs forced by ERA-40 fluxes except in the case of MPI that used a coupled initialization method. Each hindcast has been integrated for 6 months and comprises an ensemble of 9 members. Hindcasts have been produced for the period 1958-2001, for the exact period covered by each different model see Table 1.

[1] A complete description of the project and its main results can be found on the DEMETER website: http://www.ecmwf.int/research/demeter

[2] http://www.ecmwf.int/research/era

	Period	Number of years
ECMWF	1958-2001	44
MetFr	1958-2001	44
UKMO	1959-2001	43
INGV	1969-2001	33
MPI	1973-2001	29
LODYC	1974-2001	28
CERFACS	1980-2001	22

Table 1: Period and number of years of the hindcasts produced by each one of the global coupled models participating in DEMETER.

In its simplest form, the multi-model ensemble is obtained by merging the ensemble hindcasts of the seven single-model ensembles, thus comprising 7x9 uniformly weighted ensemble members. The performance of the DEMETER system has been evaluated from a comprehensive set of hindcasts over a substantial amount of years, with the main focus in 1980-2001 (Palmer et al., 2003), using ERA-40 as verification dataset for all the variables but for precipitation, for which the GPCP[3] data set has been used as a reference.

To enable a fast and efficient post-processing and analysis of this complex data set, much attention was given to the definition of a common archiving strategy for all models. A large subset of atmosphere and ocean variables, both daily data and monthly means has been stored into the ECMWF's Meteorological Archival and Retrieval System (MARS). A significant part of the DEMETER dataset (monthly averages of a large subset of surface and upper-air fields) is now freely available for research purposes through a public online data retrieval system installed at ECMWF[4]. The data available for downloading comprise a variety of gridded monthly mean fields from all ensemble members together with the corresponding verification from ERA-40. Geopotential height, temperature, wind and specific humidity are provided on three tropospheric pressure levels. Total precipitation, low-level wind, 2-metre temperature and mean sea level pressure are also available. A tool to plot these fields before retrieving them in gridded form is also provided. The data can be retrieved in both GRIB and NetCDF format. This dataset should prove useful for scientists and potential users of seasonal forecasts wishing to assess seasonal predictability using a truly state-of-the-art multi-model ensemble system, for regions and variables of interest. The dataset will also be valuable for training and education purposes.

Given the large amount of data generated, a comprehensive verification system to evaluate the forecast quality of all DEMETER single-model ensembles as well as the multi-model DEMETER ensemble system has been developed at ECMWF. The system runs periodically to monitor hindcast production, to control the data quality (and the archival) and

[3] The GPCP dataset can be found at http://orbit-net.nesdis.noaa.gov/arad/gpcp/

[4] Monthly data can be retrieved in GRIB and NetCDF from http://www.ecmwf.int/research/demeter/data

to calculate a common set of verification diagnostics based upon WMO standards. The basic set of diagnostics (performed in cross-validation mode) can be accessed on-line[5]. It comprises: global maps and zonal averages of the single-model bias, time series of specific climate indices, standard deterministic and probabilistic measures of forecast quality and a comparison of single-model ensembles skill with that of multi-model ensembles. Some additional features, such as ocean diagnostics, will be added soon.

Multi-model versus single-model seasonal forecast skill

An assessment of the skill of sea surface temperature (SST) over the tropical Pacific suggests that both the multi-model ensemble and the single models perform at levels comparable with other state-of-the-art ENSO prediction models and much better than persistence. Figure 1 shows the time series of the multi-model seasonal mean SST anomalies for the period March to May (February start date, 1-month lead time) averaged over the region Niño 3.4 (5ºN-5ºS, 170ºW-120ºW). The multi-model ensemble contains always the verification and reproduces satisfactorily the interannual variability of the reference. As a measure of performance, the correlation of the ensemble mean (0.94) and the ranked probability skill score (RPSS) for tercile categories (0.70) are above the values obtained for a persistence hindcast (0.88 and 0.07, respectively). Similar results are obtained for other seasons. The predictability of the SSTs induces a high skill in other variables over the tropics, as shown in Figure 2 for precipitation. Here the multi-model seasonal mean precipitation anomalies for the four start dates (1-month lead time) averaged over the tropical Pacific (10ºN-10ºS, 160ºE-90ºW) is displayed. The interannual variability is well represented, as in the case of the 1982/83, 1987/88 and 1997/98 ENSO events. Different skill measures indicate that the multi-model ensemble-mean skill is close to the best single-model skill almost every year and is the most skilful when performance is averaged over all years. Table 2 shows the correlation and RPSS for tercile categories for the multi-model ensemble and the seven single-model ensembles. All the scores are positive and statistically significant. Besides, a superior performance of the multi-model ensemble is noticed in the case of the probabilistic measure.

[5] http://www.ecmwf.int/research/demeter/verification

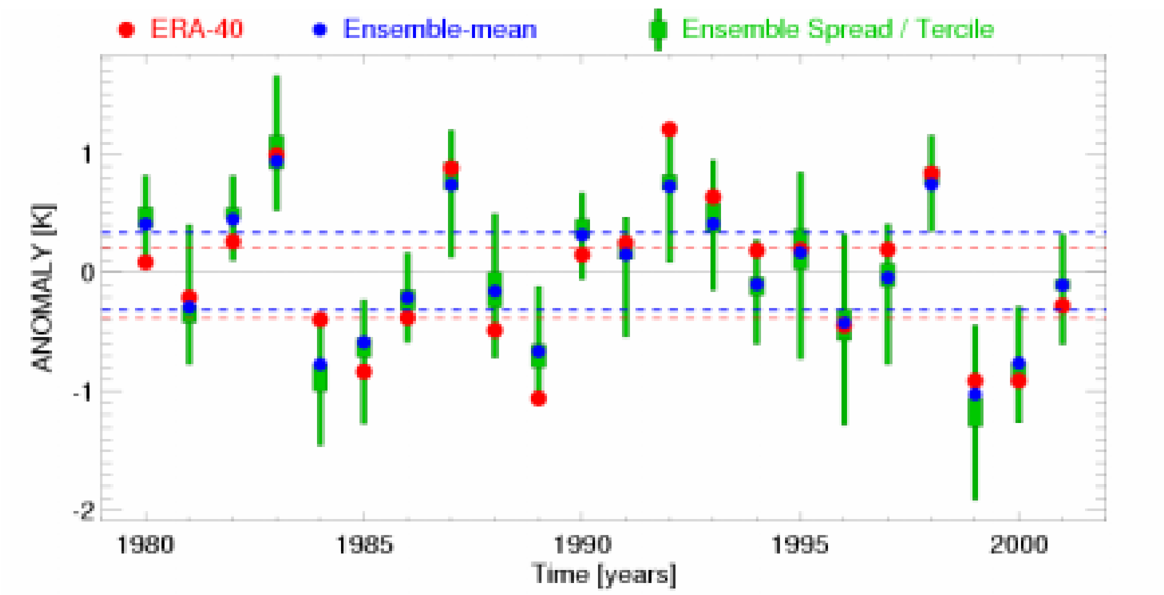


Figure 1: Time series of the 1-month lead boreal spring (February start date, average from March to May) sea surface temperature multi-model hindcasts averaged over the Niño 3.4 area. The range of multi-model ensemble values is depicted using a box-and-whisker representation, with each whisker containing a third of the ensemble members. The blue dots represent the ensemble mean, the ERA-40 values being displayed by red dots. The horizontal dashed lines around the solid zero line indicate the tercile boundaries of the ERA-40 (red) and hindcast data (blue).

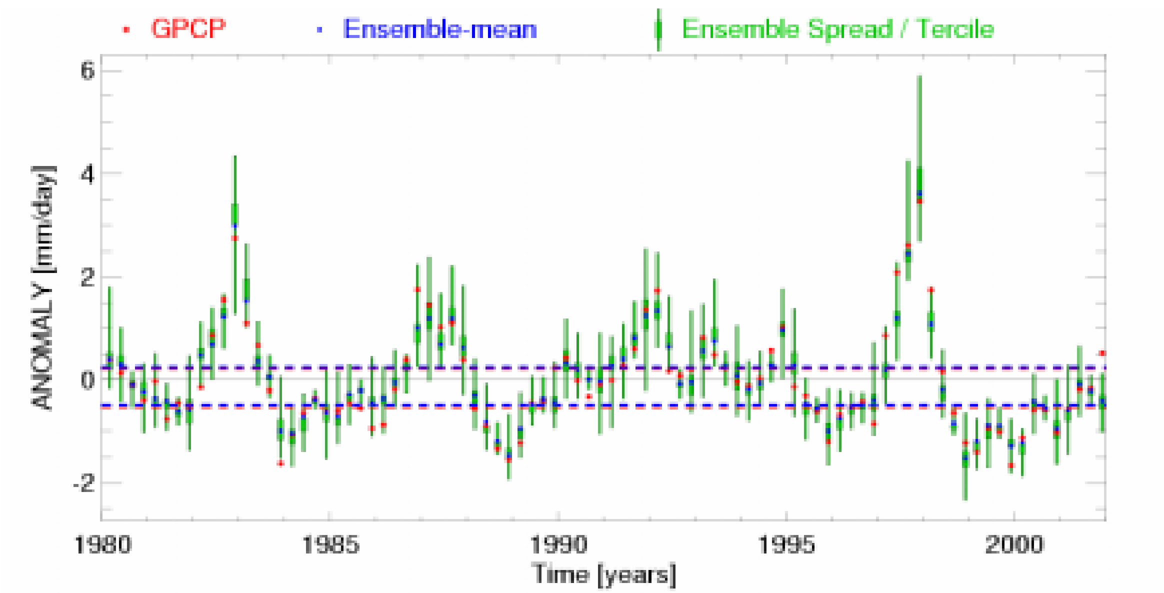


Figure 2: As in Figure 1, but for the 1-month lead seasonal mean precipitation anomaly (all start dates) averaged over the tropical Pacific area.

Forecast system	Multi-model	ECMWF	MetFr	UKMO	INGV	MPI	LODYC	CERFACS
Correlation	0.95	0.93	0.93	0.92	0.92	0.86	0.95	0.94
RPSS	0.64	0.58	0.54	0.58	0.60	0.39	0.59	0.59

Table 2: Correlation and RPSS (tercile categories) for the different forecast systems used in DEMETER for the seasonal mean precipitation anomalies averaged over the tropical Pacific for the four start dates (1-month lead time) during the period 1980-2001.

In general, the identity of the most skilful single-model ensemble varies with the region and the year. However, in most of regions the multi-model ensemble proves to be the most skilful forecast system. In order to assess the higher performance of the multi-model ensemble, different probabilistic skill measures were computed (Brier skill score and ROC area under the curve) for four events: anomalies above (below) the upper (lower) tercile boundary and anomalies above (below) the mean. Figure 3 depicts the Brier skill score for the 2-metre temperature seasonal anomalies for the four start dates computed over eight different regions (Northern extratropics, tropical band, southern extratropics, North America, Europe, West Africa, East Africa, South Africa) for the single-model ensembles versus the multi-model ensemble. The superiority of the multi-model approach is overwhelming because most of the points (99.5%) are found below the diagonal, which indicates a higher Brier skill score for the multi-model. In addition, most of the skill scores for the multi-model are positive compared to a majority of negative values for the single-model ensembles. The figure also displays the number of times that the multi-model skill score beats each single-model ensemble. Using the decomposition of the Brier score in terms of reliability and resolution (Murphy 1973), reliability and resolution skill scores have also been computed and are displayed in Figure 3b and c. They demonstrate that the increased skill of the multi-model ensemble with regard to the single-model ensembles is due to an improvement in both terms of the Brier score. Therefore, the multi-model approach not only generates more reliable predictions, but also increases their resolution. Similar results are found using the ROC area as skill measure. The greater probabilistic skill of the multi-model ensemble compared with the single-model skill also leads to increased potential economic value. For instance, it has been found that for the predictions described, the potential economic value of the multi-model ensemble outperforms that of most of the single-model ensembles by 15% to 50%, depending on the range of cost/lost ratio considered.

In spite of the clear improvement of the multi-model ensemble performance with regard to the single-model ensembles, an important question arises. Is the improvement in the multi-model ensemble merely due to the increased ensemble size resulting from collecting all members of the single-model ensembles? In order to separate the benefits that derive from combining models of different formulation to those derived simply from the accompanying increase in ensemble size, a 54-member ensemble hindcast has been generated with the ECMWF model alone for the period 1987-1999 using the May start date. Figure 4 shows the RPSS for tercile categories of summer 1-month lead (May start date) seasonal precipitation over the tropical band (30ºN-30ºS) for the 54-member single-model ensemble (blue bars) and the 54-member multi-model ensemble (red bars).

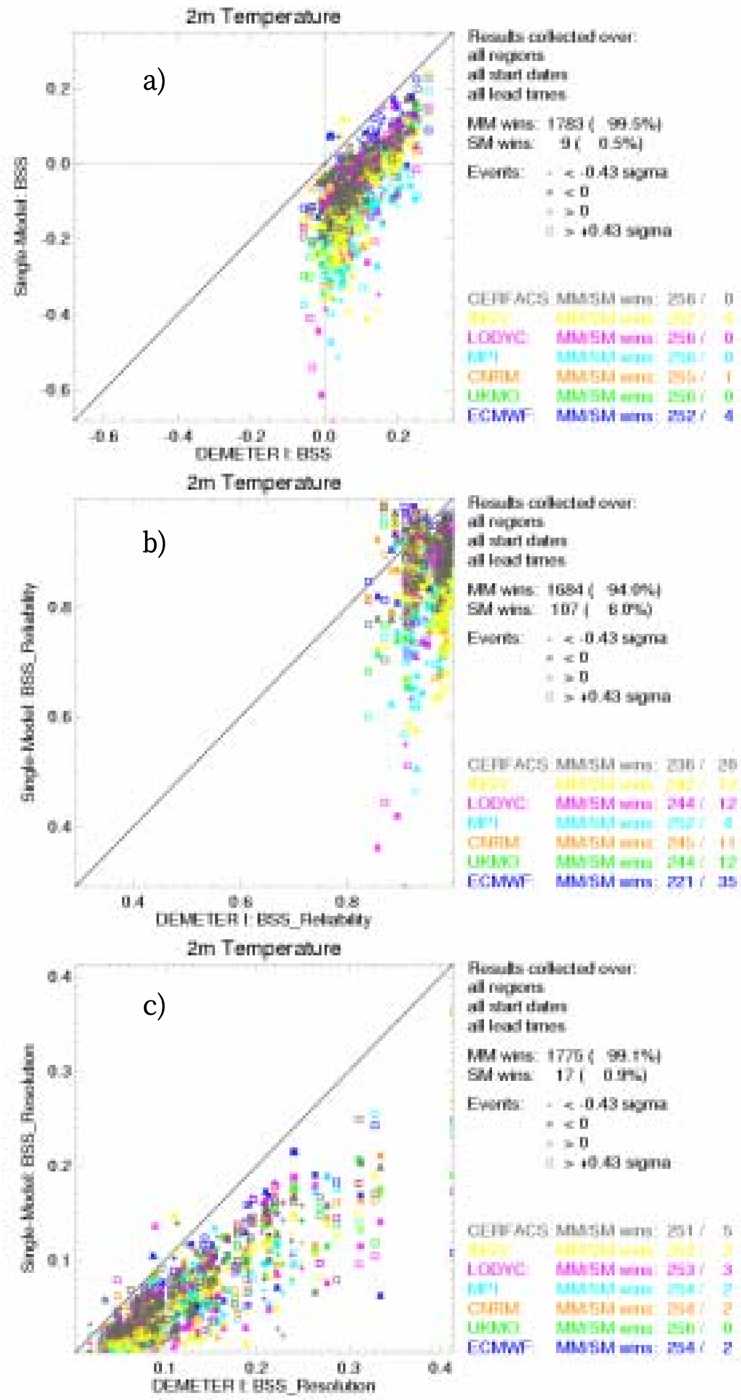


Figure 3: a) Brier skill score of the seasonal mean 2-metre temperature for the single-model ensembles versus the corresponding skill score for the multi-model ensemble for the period 1980-2001. All start dates, two lead times (1-month and 3-month lead time), four events (positive and negative anomalies, anomalies above 0.43 times and below -0.43 times the model standard deviation) and eight regions have been plotted. The number and proportion of times in which the multi-model ensemble is better than the single-models is also shown, as well as the number of times the multi-model ensemble beats each single-model ensemble. Plots b) and c) are similar to a), but for the reliability and resolution skill scores, respectively.

The multi-model ensemble for this example was constructed by randomly selecting 54 members out of the 63 available from the 7 single-model ensembles. Values for the ECMWF model 9-member ensemble are also shown (green bars). As expected, the single-model skill increases with ensemble size, as seen when comparing the blue and green bars on the right part of the plot. However, the multi-model ensemble outperforms the 54-member single-model ensemble skill. In addition, the multi-model skill score is positive not only on average, but also every year. Similar results are found for other variables and regions. As mentioned above, it has been found that most of the improvement is due to an increase in reliability.

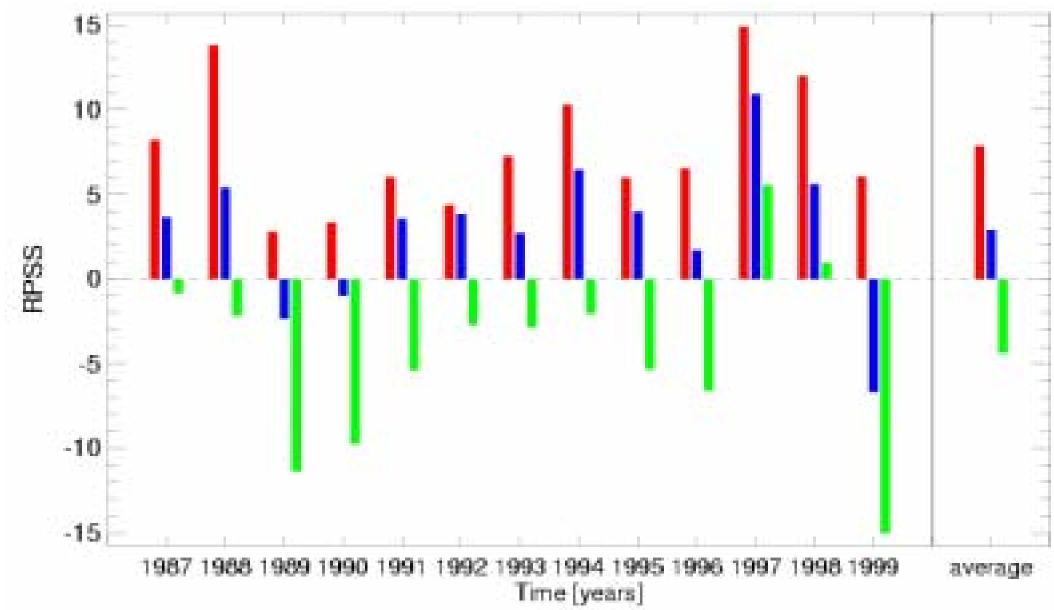


Figure 4: Ranked probability skill score (RPSS) based on tercile categories for summer (May start date, 1-month lead time) seasonal mean precipitation over the tropical band for the 54-member multi-model ensemble (red), as well as for the ECMWF ensemble with 54 (blue) and 9 members (green). The average for the period 1987-1999 is shown on the right end of the plot.

To further discriminate between the improvement in skill attributed to an increase in either ensemble size or number of models, Figure 5 shows the RPSS (based on tercile categories) for summer seasonal mean precipitation over the tropical band for different model combinations. In the first column, the vertical black bar indicates the range of values that the single-model ensembles cover and the black dot corresponds to their average. In the remaining columns, the RPSS values for all multi-model ensembles that can be constructed by combining 2-6 single-model ensembles are depicted in red. For each multi-model combination a single-model ensemble of the same ensemble size was constructed and its value displayed in blue. An increase of the RPSS with the ensemble size can be appreciated in both cases, although the increase is larger for the multi-model than for the single-model ensemble for more than 3 models (27 ensemble members). For four or more models the multi-model skill is always above the skill of any combination obtained with the large single-model ensemble. This result emphasizes the superiority of the multi-model approach above single-model ensembles in a probabilistic prediction framework.

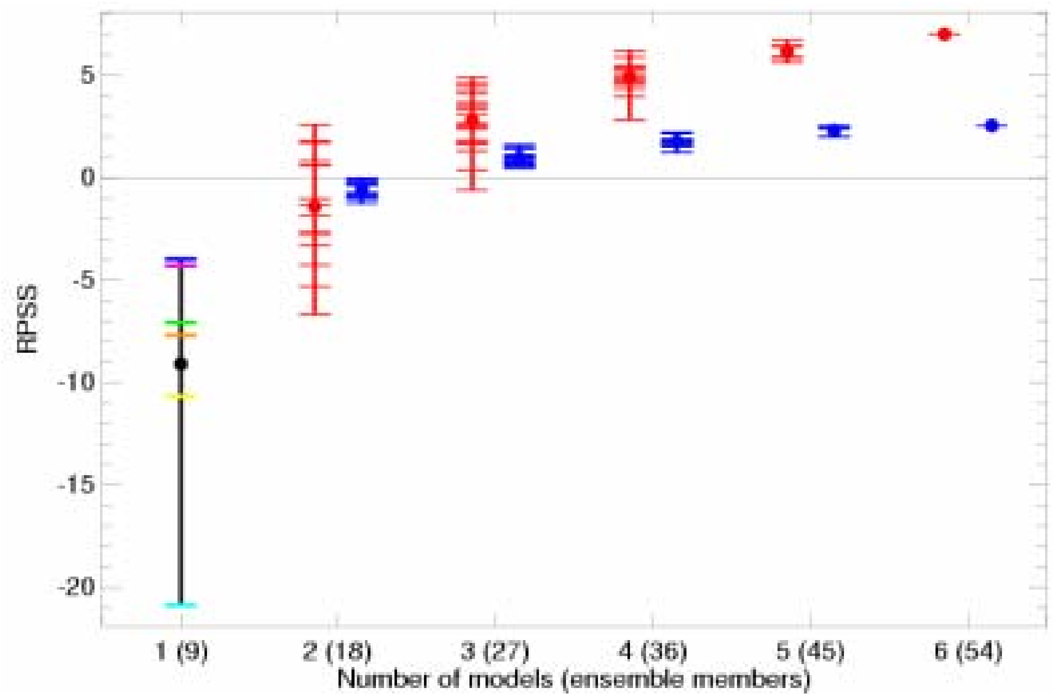


Figure 5: Ranked probability skill score (RPSS) based on tercile categories for summer seasonal mean precipitation over the tropical band for different model combinations. In the first column, the vertical black bar indicates the range of values covered by six single-model ensembles (each model represented with a different color) while the black dot corresponds to their average. RPSS values for all multi-model ensembles that can be constructed by combining 2-6 single-model ensembles are depicted in red in the remaining columns. A single-model ensemble of the same ensemble size was constructed for each multi-model combination and the RPSS displayed in blue.

User applications

The DEMETER project has application partners in agronomy and tropical disease prediction. These users have quantitative application models requiring weather information as input. The models can be directly linked to the output of individual members of a prediction ensemble. The net result is a probability forecast, not of weather or climate, but of a variable directly relevant to the user. As such, the design of DEMETER was based on the concept of an "end-to-end" system, in which users feed information back to the forecast producers.

Quantitative application models of the sort used in DEMETER have been derived using data from specific meteorological stations. By contrast, the output from global climate models represents averages over a relatively coarse grid. As such, the statistics of model variables, especially precipitation in regions of steep orography, can differ substantially from the statistics of station data. It is therefore necessary to perform some form of downscaling analysis to the climate model output, either by some statistical/empirical scheme, or by embedding a high-resolution limited-area model into the climate model.

Crop simulation models that estimate crop growth and crop yield, as a function of environmental conditions and management practices, are important tools for decision-makers. The EU Joint Research Centre (JRC) Crop Growth Monitoring System uses a crop model called WOFOST, and performs crop yield forecasting through a regression analysis comparing simulated crop indicators at the time of issuing the forecast and historical yield series for the main crops at national and European level. Until now, the statistical model used crop growth indicators only dependent on meteorological conditions known at the time of issuing the forecast. The objective is to create improved crop growth indicators based on seasonal predictions from the DEMETER system, which brings additional information for the remaining of the crop season. In the new end-to-end system the crop model is run forced by the downscaled output of the multi-model ensemble to generate the required crop indicators for the end of the season. Therefore, a PDF of the crop yield can be derived. Based on the PDF spread, the end-user can directly quantify the benefits and risks of his climate-sensitive decisions. Figure 6 shows the wheat yield hindcasts carried out over four years (1995-1998) for France and Germany (the largest European wheat producers) as well as for Denmark and Greece using the multi-model ensemble downscaled data. This plot depicts the quartiles of the ensemble PDF using a box-and-whisker representation, where the blue dot corresponds to the median. The red dot indicates the wheat yield obtained when ERA-40 is used to force the crop model. As an external reference, the black horizontal lines display the Eurostat official yields gathered by the European Commission. Some disagreement between Eurostat and ERA-40 yields is observed, especially in the case of France. This may be due to the crop model not taking into account the impact of pests or the conditions at harvest. The multi-model ensemble shows a high skill in predicting the ERA-40 values (the red dot is always contained within the range of predicted wheat yield values), although a slight negative bias can be noticed. Similar results are obtained for other countries.

The other application used in DEMETER concerns predictions of malaria incidence in Eastern and Southern Africa. Malaria is a disease of extreme importance given the large amount of people at risk in tropical areas. A typical lag in the peak case numbers compared with the peak in the rainfall of between 2 and 4 months is observed. This implies that some predictability of malaria incidence could be obtained if a dynamical malaria model is fed with current weather conditions as well as future climate variability information. These predictions are obviously of great benefit to malaria early warning systems, which incorporate vulnerability assessment, seasonal climate forecasts, weather monitoring and case surveillance for unstable areas in Africa (Thomson et al. 2000).

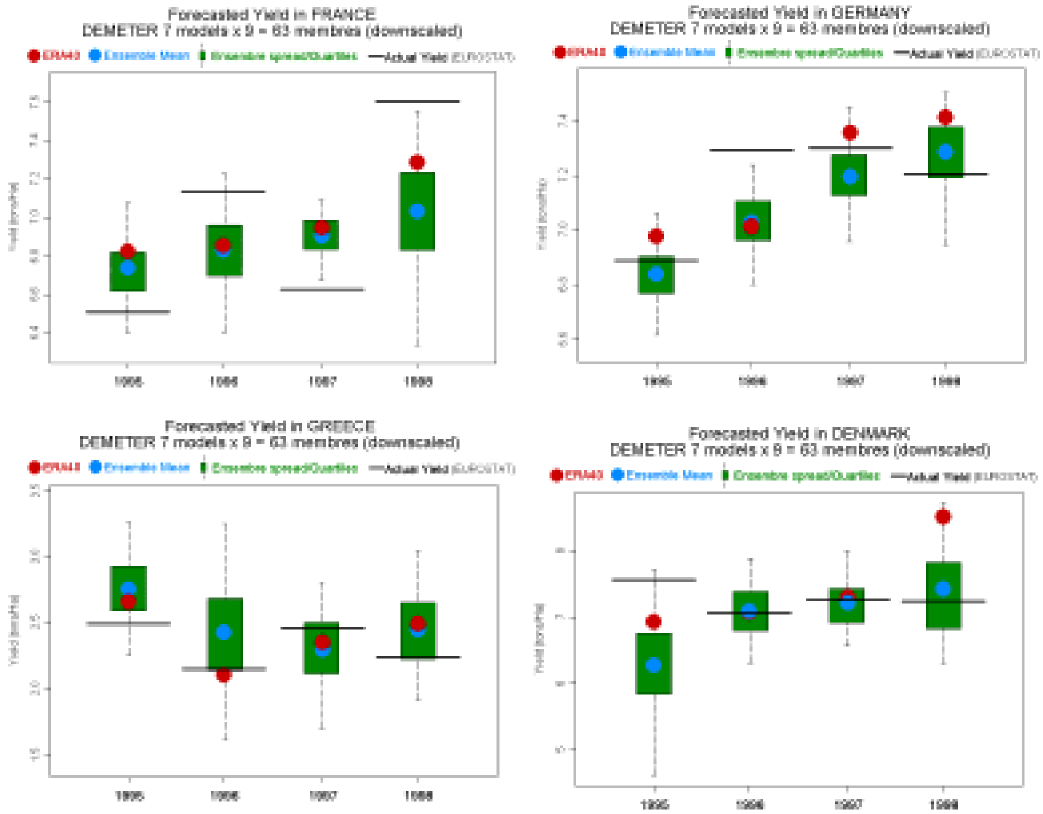


Figure 6: Time series of wheat yield predictions (February start date) for France, Germany, Denmark and Greece over the period 1995-1998. The range of multi-model ensemble values is depicted using a box-and-whisker representation, with each whisker containing a fourth of the ensemble members. The blue dots represent the ensemble median, the wheat yield obtained using ERA-40 data being displayed by red dots. The horizontal black lines correspond to the yields recorded by the EU official body Eurostat.

A numerical biological model describing malaria processes has been run using ERA-40 as well as multi-model ensemble bias-corrected data. The model simulates the population dynamics of cohorts of mosquitoes, and thus predicts the behavior of the total mosquito population. Figure 7 presents the seasonal average of monthly malaria incidence (proportion of cases accumulated over a month) for the point 0º 35ºE (Kenya) for the period 1987-1999. The incidence obtained when forcing the malaria model with ERA-40, which is considered as a reference given the lack of clinical cases reports, is shown in red. As before, a box-and-whisker representation has been used to represent the predicted incidence PDF. Each whisker and the central box contain a third of the ensemble members, while the blue dot corresponds to the ensemble mean. The interannual variability of the reference malaria incidence is predicted with success, the reference value never being out of the multi-model ensemble range. In addition, the prediction of the onset and duration of intense malaria events is remarkably precise. The correlation and RPSS for these predictions are displayed in Table 3.

Once again, the multi-model ensemble performs as well as the best single-model ensemble proving that the advantage of the multi-model approach is transferred through the applications models to the prediction of useful variables. These promising results require further research in which the malaria model is forced with downscaled seasonal prediction data for larger areas.

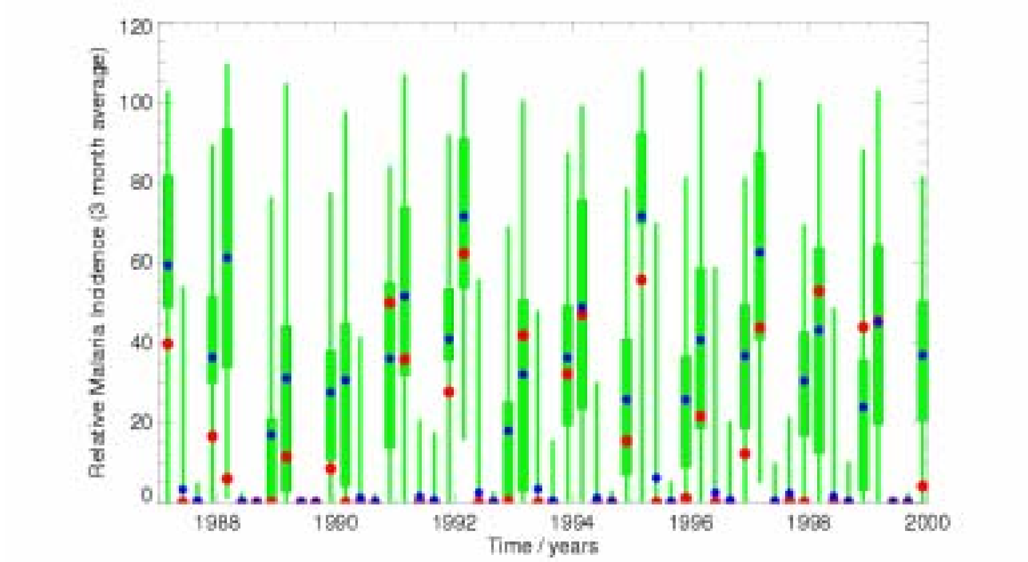


Figure 7: Time series of the seasonal average of malaria monthly incidence (all start dates) for the point 0º 35ºE over the period 1987-1999. The range of multi-model ensemble values is depicted using a box-and-whisker representation, with each whisker containing a third of the ensemble members. The blue dots represent the ensemble mean, the malaria incidence obtained using ERA-40 data being displayed by red dots.

Forecast system	Multi-model	ECMWF	MetFr	UKMO	INGV	MPI	LODYC	CERFACS
Correlation	0.50	0.34	0.52	0.36	0.35	0.03	0.29	0.51
RPSS	0.30	0.24	0.23	-0.01	0.27	-0.25	0.26	0.23

Table 3: Correlation and RPSS (tercile categories) of the different forecast systems used in DEMETER for the seasonal-mean monthly malaria incidence at 0º 35ºE for the four start dates (1-month lead time) during the period 1987-1999.

Summary

As part of the European Union-funded DEMETER project, a multi-model ensemble system based on 7 European global coupled ocean-atmosphere models has been installed and validated in hindcast mode using the ECMWF Re-Analysis ERA-40 data. Results indicate that the multi-model ensemble is a viable pragmatic approach to the problem of representing model uncertainty in seasonal-to-interannual prediction, and will lead to a more reliable and skilful forecasting system than that based on any one single model. A key result is that multi-model ensemble probability scores are, on average, better than those from any of the single-model ensembles, this improvement not only being a consequence of the increase in ensemble size. As a result of the success of DEMETER, real-time multi-model ensemble forecasting is now being established as part of the operational seasonal forecast suite at ECMWF. At the time of writing, plans are well established for the ECMWF, Met Office and Météo-France coupled systems to be included in this multi-model mix. It is possible that other DEMETER models may be included at a later stage.

In addition, visitors to the DEMETER web site can download (in GRIB or NetCDF format) gridded data from a large data set comprising monthly mean fields for a large number of variables from the DEMETER hindcasts, including ERA-40 verification. We thus encourage scientists and potential users of seasonal forecasts to perform their own analysis of the DEMETER data (perhaps to assess skill for specific regions and variables of interest not covered in our standard analysis). More generally, we offer this DEMETER data set for education and training purposes, both in the developed and developing worlds.

The DEMETER project has applications partners in agronomy and in tropical disease prediction. Their dynamical models have been directly linked to the output of individual members of the multi-model ensemble, after correction of the bias and downscaling onto a finer grid than the one used in the coupled models. As such, the design of DEMETER was based on the concept of a quantitative “end-to-end” system, in which users can also feed information back to the forecast producers. Preliminary results from the application models prove that the non-negligible multi-model seasonal potential economic value can be transformed into actual economic and social valuable information in the framework of the end-user problem.

In future research it is hoped to use a successor system to DEMETER to explore the use of multi-model ensembles not only for seasonal-to-interannual timescales, but also for decadal timescales for which scientific evidence of predictability has emerged in recent years. For this purpose, it is planned to ensure that the model components used for seasonal-to-decadal ensemble prediction, are, as far as practicable, identical to those used for century-timescale anthropogenic climate change. In this way, the reliability of century-timescale climate change projections can be assessed by running essentially the same ensemble systems on timescales for which verification data exists. This is one of the main tasks of the recently approved EU-funded project ENSEMBLES.

Acknowledgements

The DEMETER project has been funded by the European Union under the contract EVK2-1999-00197. Pierre Cantelaube (JRC, Ispra, Italy) has kindly produced the plot in Figure 6 and Dr. Moshe Hoshen carried out the integrations with the malaria model.

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A Comparison of Multi-Model Ensemble Prediction Techniques

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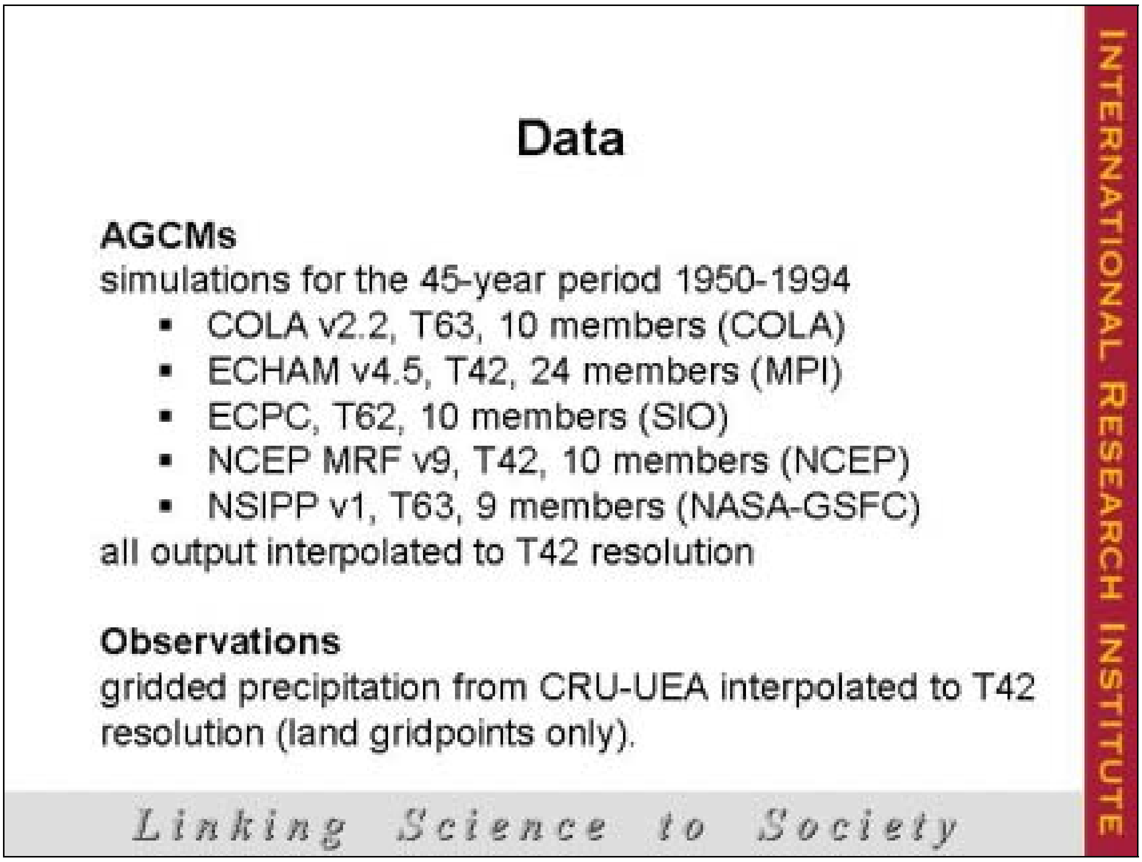
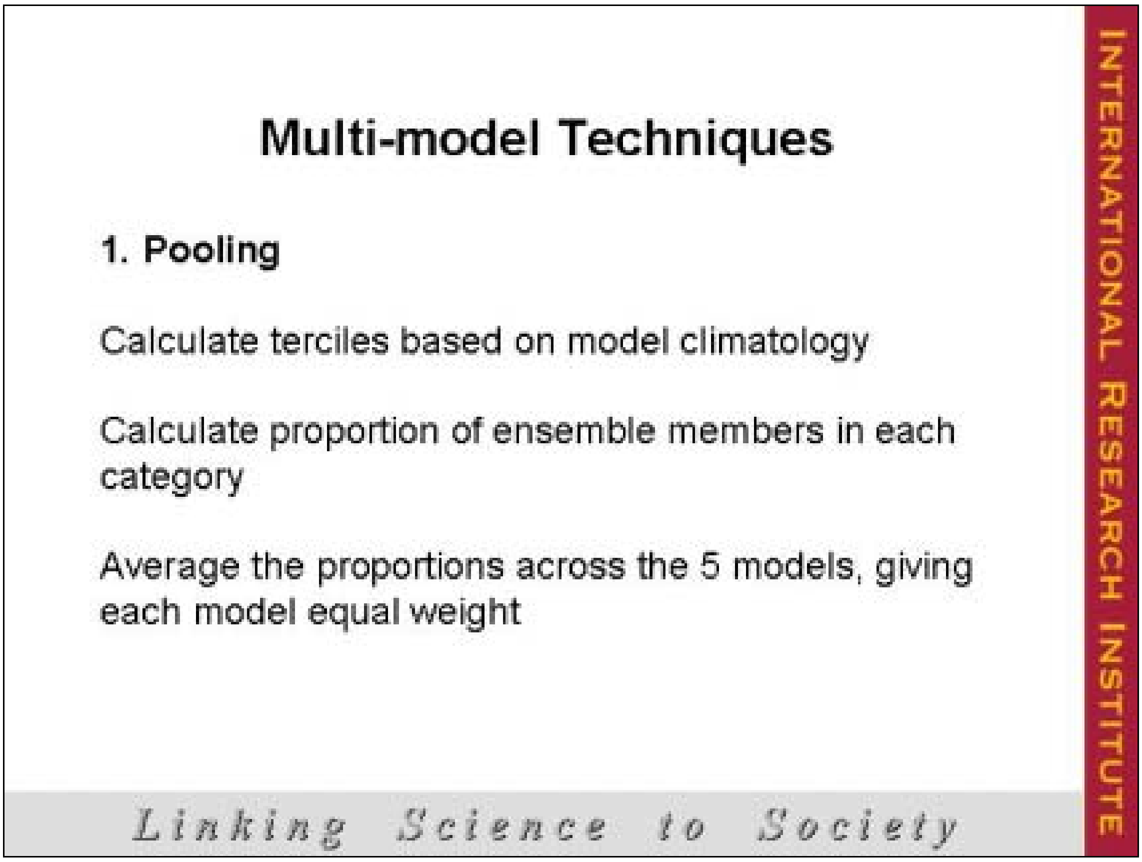
International Research Institute for Climate Prediction




Multi-model Techniques
1. Pooling
Calculate terciles based on model climatology
Calculate proportion of ensemble members in each category
Average the proportions across the 5 models, giving each model equal weight
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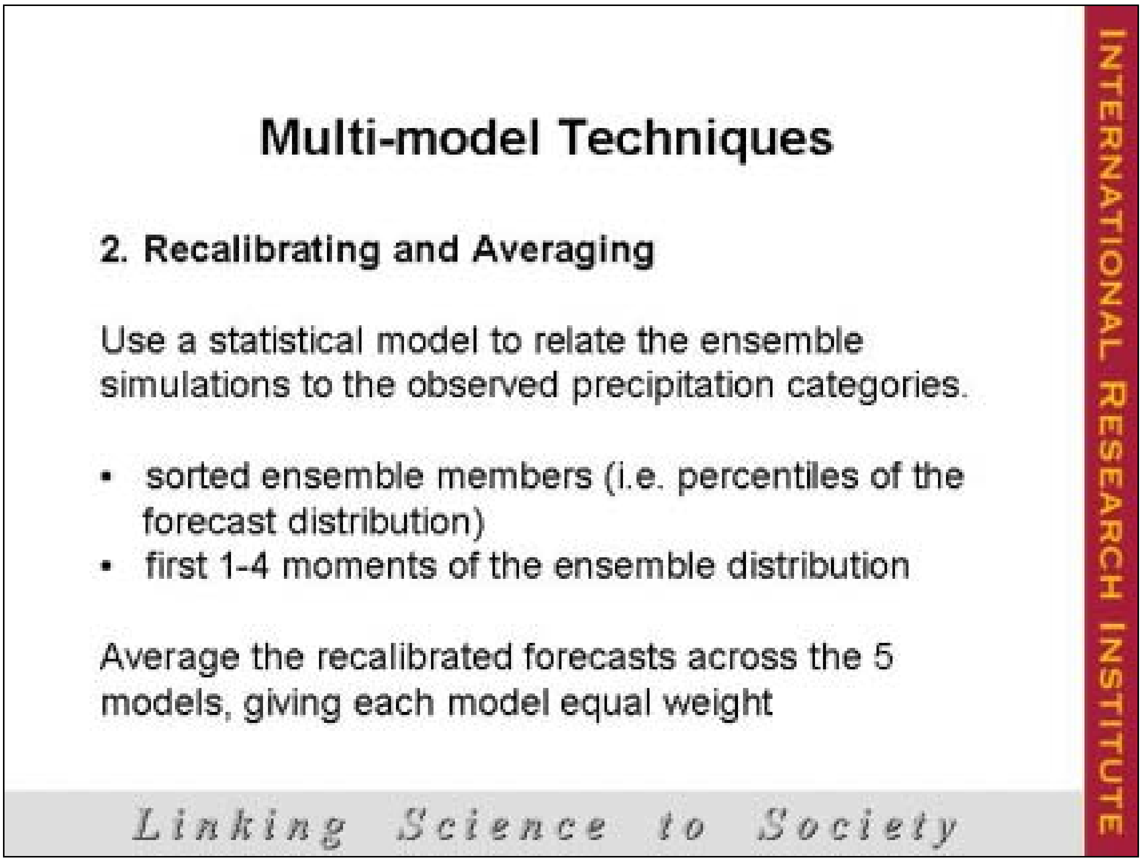
Multi-model Techniques
2. Recalibrating and Averaging
Use a statistical model to relate the ensemble simulations to the observed precipitation categories.
• sorted ensemble members (i.e. percentiles of the forecast distribution)
• first 1-4 moments of the ensemble distribution
Average the recalibrated forecasts across the 5 models, giving each model equal weight
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Multi-model Techniques

3. Combining

Use a statistical model to relate the ensemble simulations of all five models to the observed precipitation categories

- sorted ensemble members (i.e. percentiles of the forecast distribution)
- first 1-4 moments of the ensemble distribution

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Canonical Covariate Analysis

Canonical techniques involve calculating linear combinations (weighted sums) of variables. The weights are defined to achieve specific objectives:

- PCA – weighted sums maximise *variance*
- CCA – weighted sums maximise *correlation*
- CVA – weighted sums maximise *discrimination*

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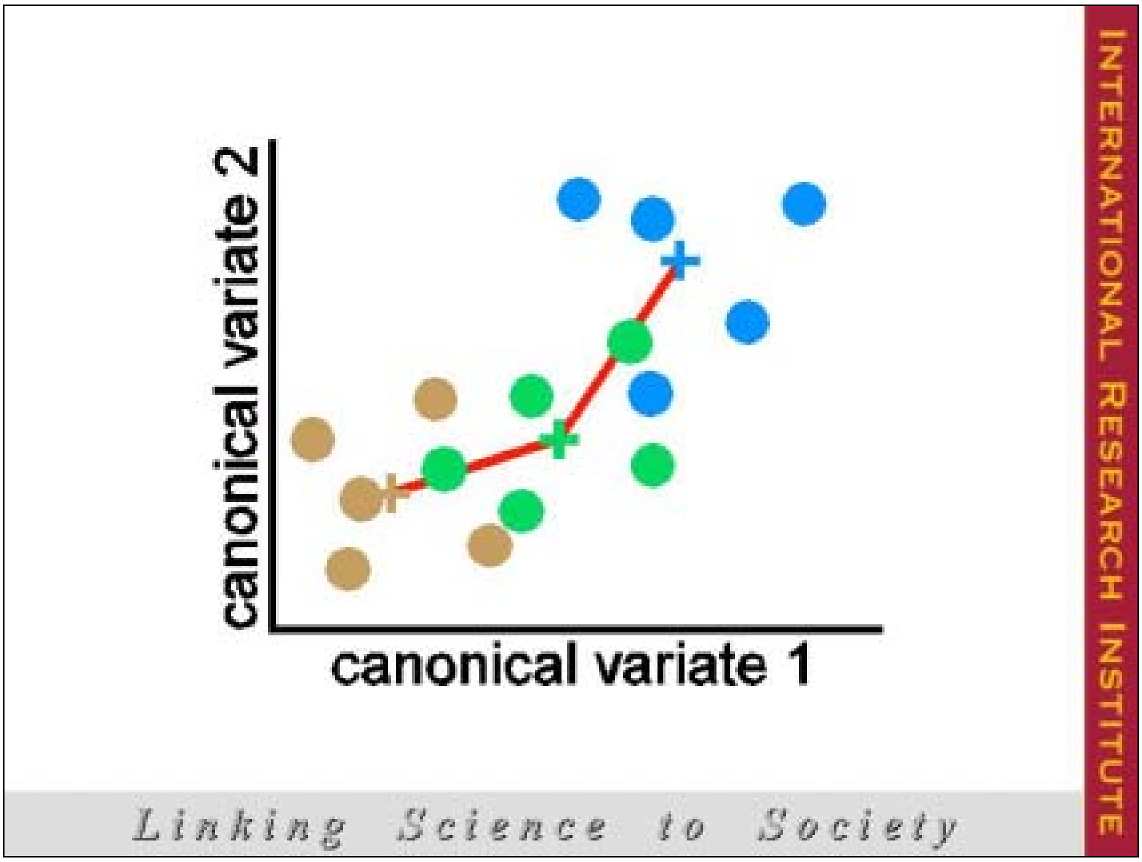

Cross-validation

A 15-year sliding cross-validation window was used. Only the middle year was predicted at each step.

The window was lopped so that the training period was 30 years in each case.

Climatologies, model parameters and verification categories were recalculated at each step.

A large cross-validation window was used to avoid biases resulting from recalculation of the climatologies, and to test the procedure in the context of realistic sample sizes.

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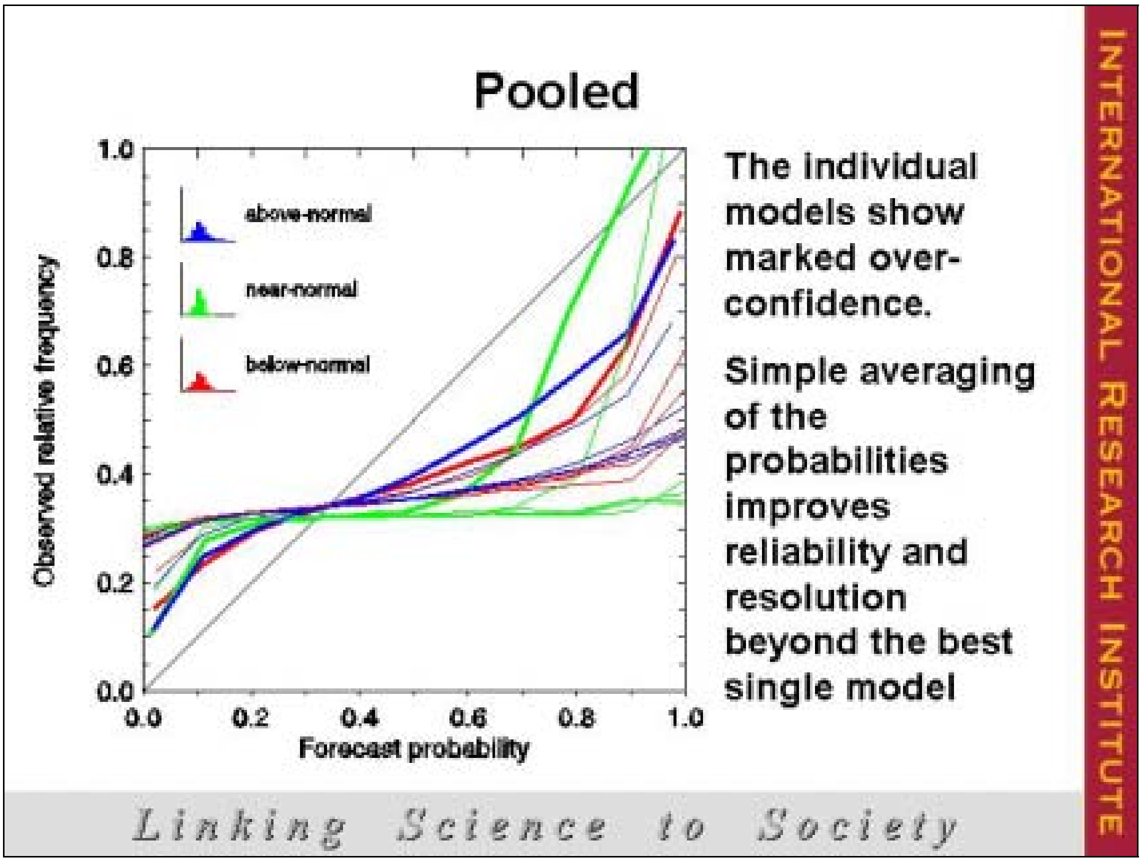
Pooled
1.0
0.8
0.6
0.4
0.2
0.0
Observed relative frequency
above-normal
near-normal
below-normal
0.0
0.2
0.4
0.6
0.8
1.0
Forecast probability
The individual models show marked over-confidence.
Simple averaging of the probabilities improves reliability and resolution beyond the best single model
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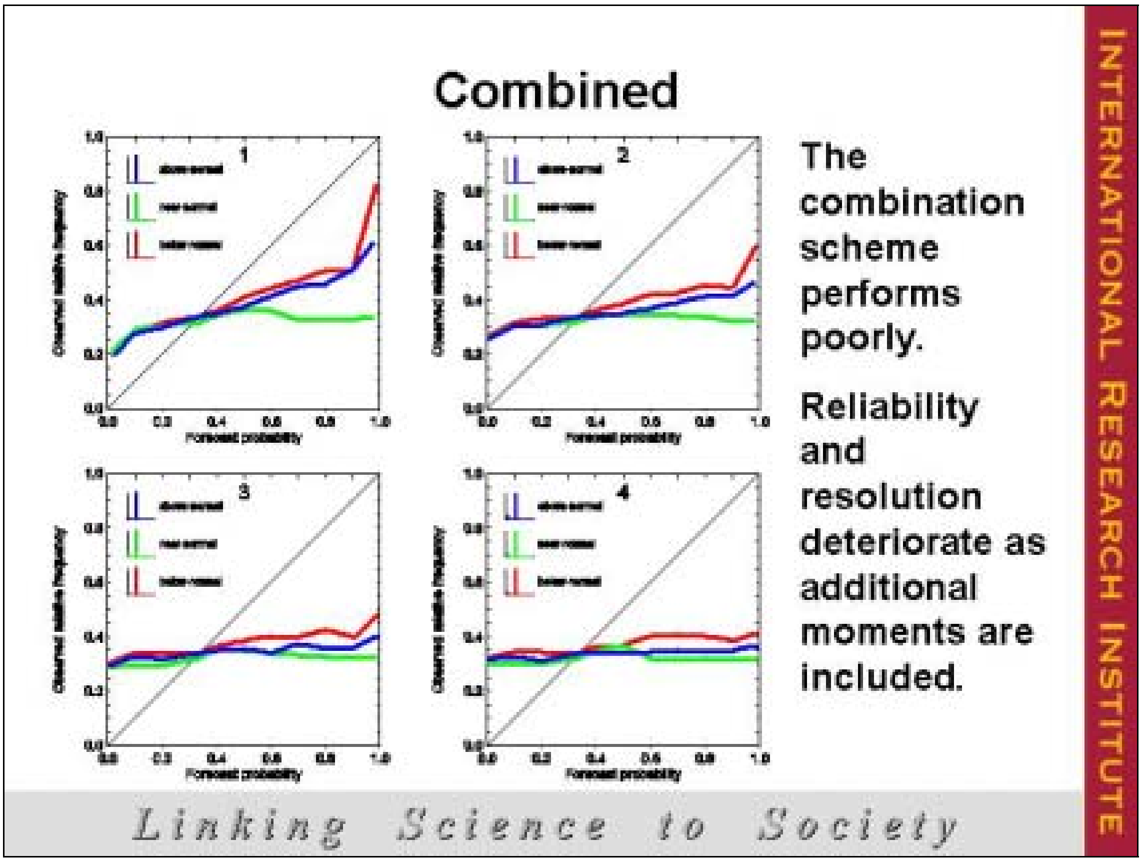
Combined
1
2
3
4
The combination scheme performs poorly.
Reliability and resolution deteriorate as additional moments are included.
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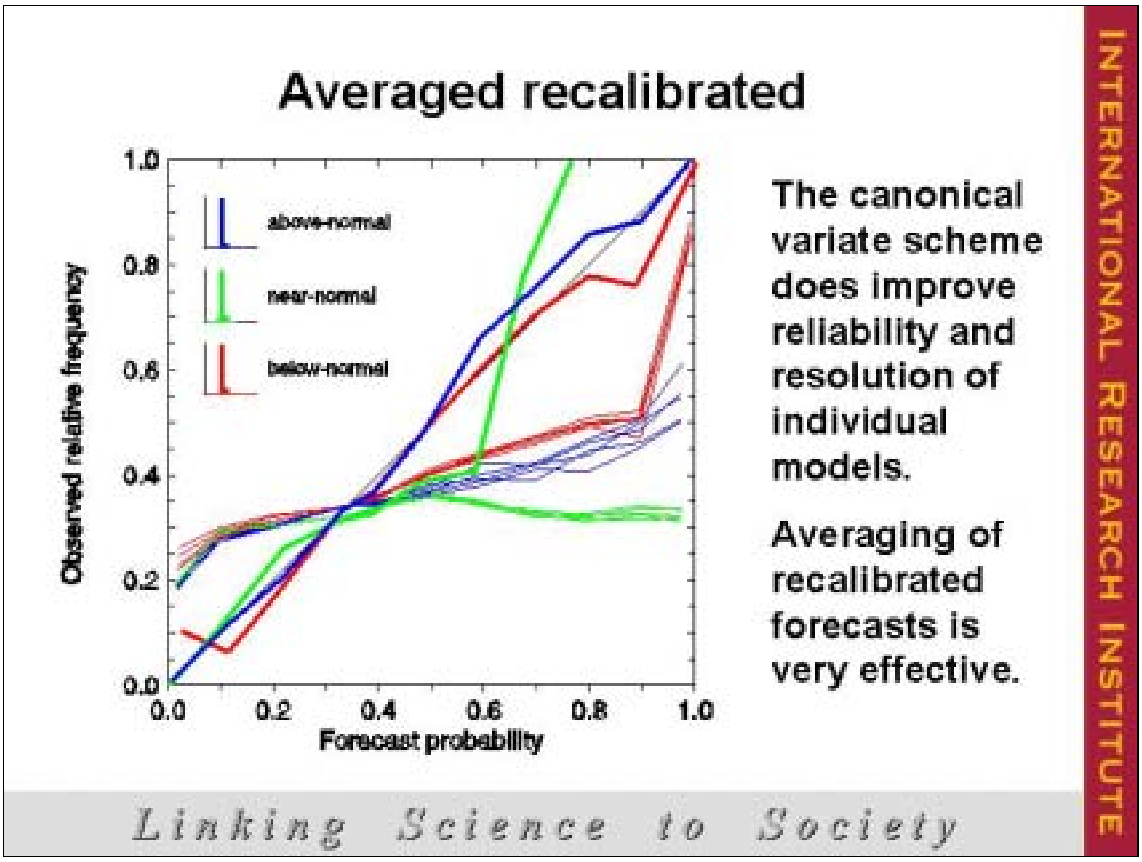
Averaged recalibrated
1.0
0.8
0.6
0.4
0.2
0.0
Observed relative frequency
above-normal
near-normal
below-normal
0.0
0.2
0.4
0.6
0.8
1.0
Forecast probability
The canonical variate scheme does improve reliability and resolution of individual models.
Averaging of recalibrated forecasts is very effective.
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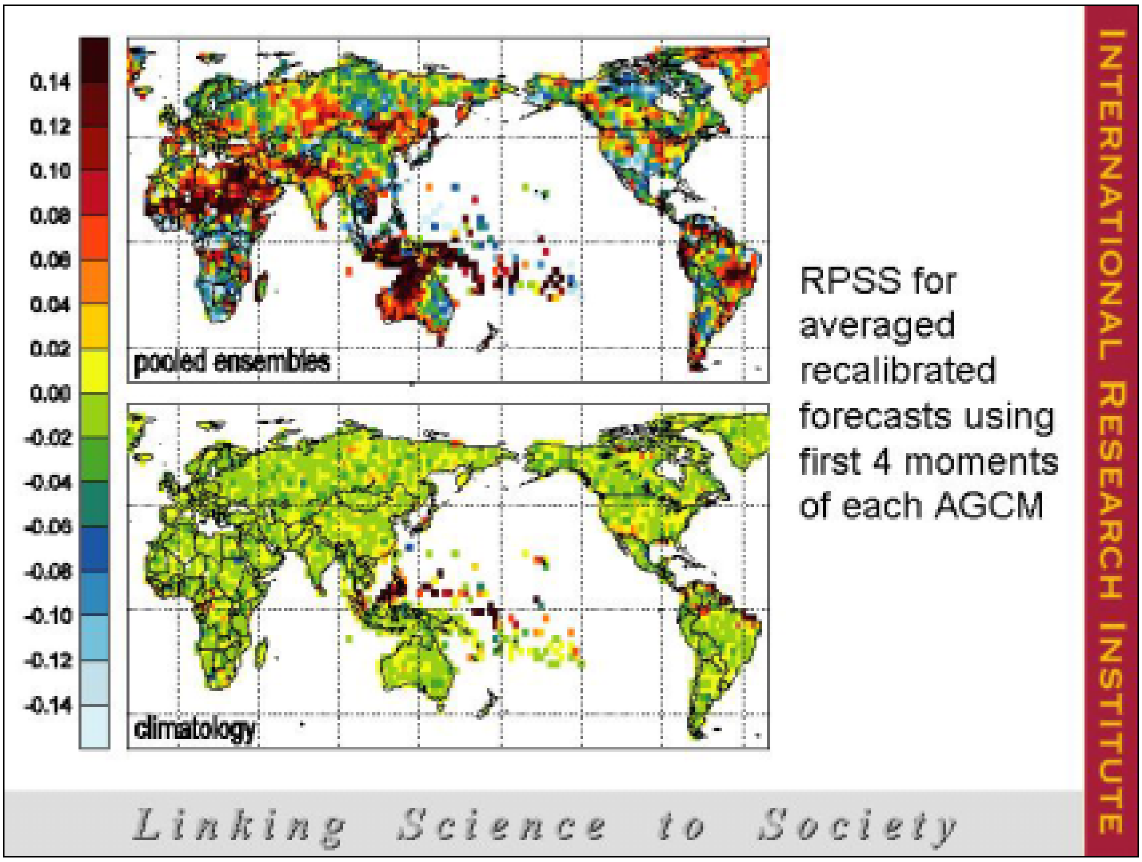
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
pooled ensembles
climatology
RPSS for averaged recalibrated forecasts using first 4 moments of each AGCM
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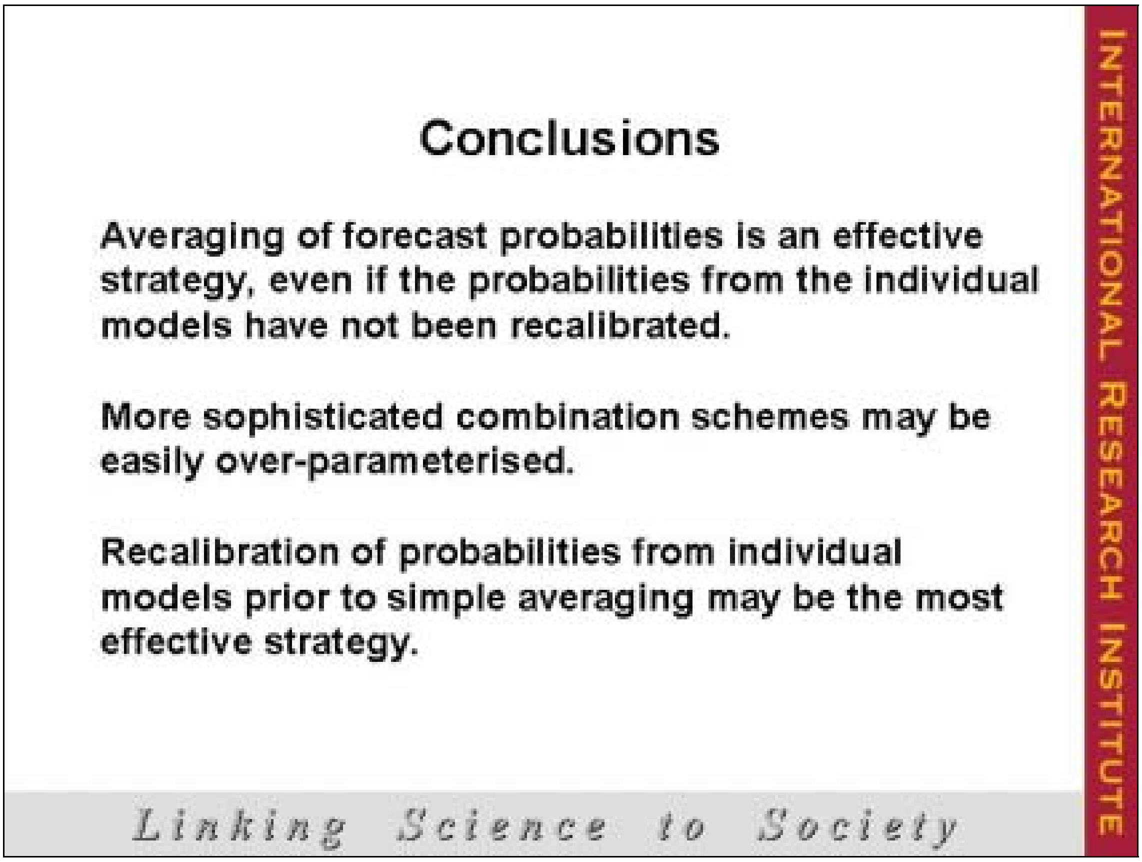
Conclusions
Averaging of forecast probabilities is an effective strategy, even if the probabilities from the individual models have not been recalibrated.
More sophisticated combination schemes may be easily over-parameterised.
Recalibration of probabilities from individual models prior to simple averaging may be the most effective strategy.
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Multi-Model Ensembles, Climate Variation and Climate Change

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Introduction

The “sensitivity to initial conditions” that characterizes forecasts of the complex atmosphere/ocean system limits the skill of deterministic forecasts (type 1 forecasts using the terminology of Lorenz) even for a perfect forecast model. Hindcasts, i.e. forecasts based on past information, are used to develop and to assess the skill of modern forecast systems. In the case of multi-model ensembles (MME) of forecasts, hindcast information is used to devise statistical combinations of model results to provide additional skill (if such exists).

The situation is somewhat different for decadal and longer timescale forecasts, including “forecasts” of climate change, which are largely independent of initial conditions (hence type 2 forecasts). An analogy may nevertheless be made between the “sensitivity to initial conditions” in the case of deterministic (type one) forecasts and the “sensitivity to numerics and parameterizations” in the case of (type two) climate forecasts/simulations. Only a comparatively small amount of observational information is available to produce hindcasts at longer timescales. Ensemble methods may still be considered although the approach is necessarily somewhat different.

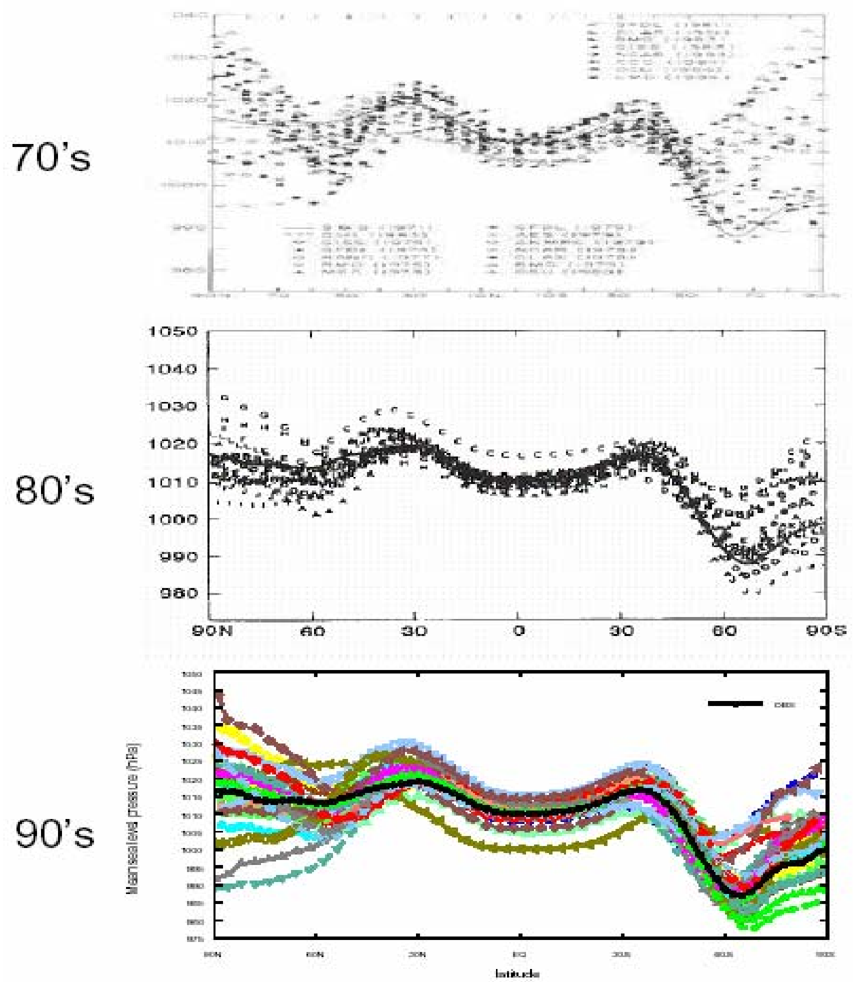


Figure 1. Modelled mean sea-level pressure (hPa) from Gates (1987) top, Boer et al., (1991) middle, and Gates et al., (1999) bottom.

MIPs and MMEs

Climate model intercomparison projects (MIPs) have existed for some time and new projects continue to arise. The purposes of model intercomparison is: (1) to document the ability of models to simulate and predict the current climate and its variations; (2) to identify deficiencies, especially those that are common to a group of models; (3) on the basis of these deficiencies to formulate hypotheses concerning their causes; (4) to give attention to, and draw inferences concerning, the effects of numerical methods, model resolution, and parameterizations employed in models; (5) to suggest numerical experiments to clarify the causes and potential solution to model deficiencies; and (6) to document model evolution and improvement.

We may add a further purpose, namely to provide multi- model ensembles of results that may be use to devise and test MME approaches to the prediction of climate on many timescales. Thus SMIP2 provides seasonal forecasting results that can potentially be used by the APCN while CMIP provides a MME that may be used for climate investigations.

Sensitive dependence

The sensitive dependence on initial conditions that constrains deterministic type one prediction of the atmosphere to the two week "predictability limit" is well known. Since initial conditions cannot be error free the accompanying loss of predictability cannot be overcome even with a perfect forecast model. This has led short term forecasters to turn attention to ensemble forecasts which attempt to reveal the probability of the range of possible results.

The presumption in type two climate simulation is that basic climate parameters, such as the climatological distribution of mean temperature, precipitation, etc., are deterministic for given external boundary conditions. MIPs are intended to identify those model deficiencies that prevent accurate simulation of these deterministic climate quantities. This has proved to be difficult, however, as indicated by the scatter of results in Figure 1 which gives the zonally averaged distribution of northern winter mean sea level pressure from three MIPs which roughly characterize models of the decades of the 1970's, 80's and 90's (from Gates, (1978), Boer et al., (1992), and Gates et al., (1999) respectively). The diagram also indicates that there has been a remarkable increase in the number of participating AGCMs from something like 8 in the early 1980s, to 14 in the middle panel in the early 1990s, to over 30 models in the bottom panel in the AMIP intercomparison.

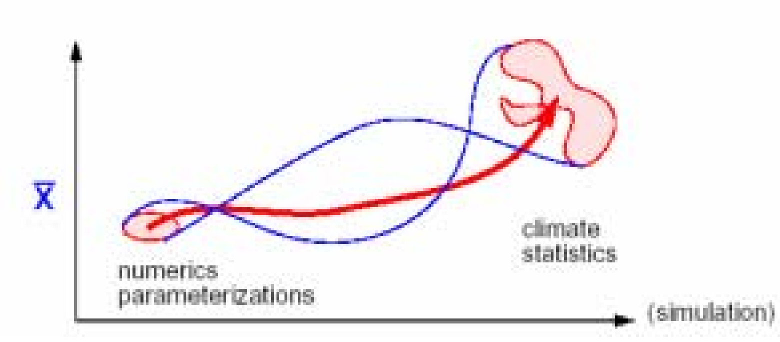


Figure 2.

The difficulty in simulating basic quantities like mslp in Figure 1 suggests that the sensitive dependence on initial condition error that restricts deterministic weather prediction has an analog in the sensitive dependence of climate statistics on errors and deficiencies in model numerics and parameterization as illustrated schematically in Figure 2. Thus even for the simulation of mean climate or of forced climate variation and change, which does not depend critically on initial error, there is an inherent uncertainty and chaotic nature to the results which arise due to the non-linear workings of the imperfectly modelled system. Thus, just as there is a predictability limit associated with weather forecasts there is an "simulation limit" associated with climate prediction.

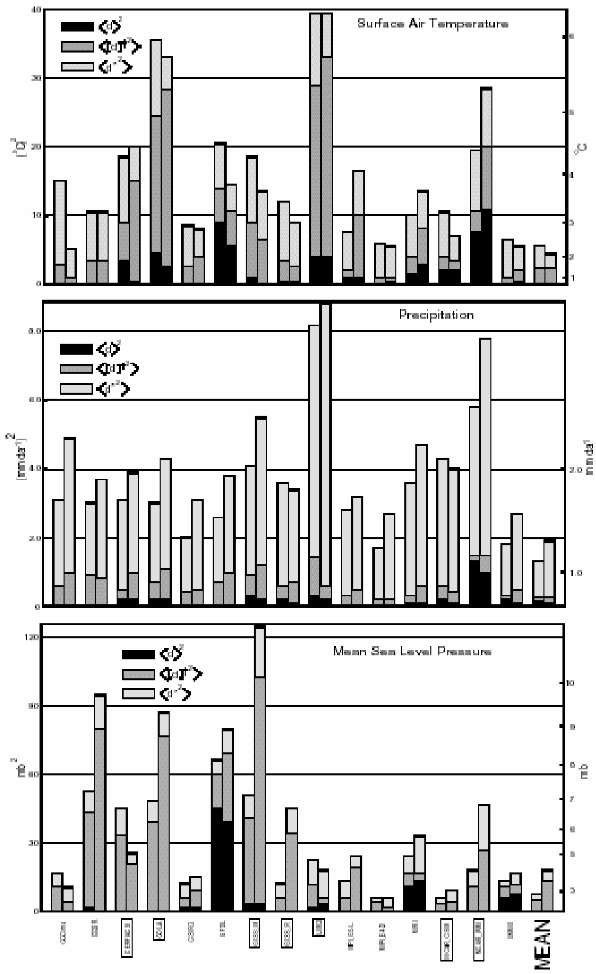


Figure 3. Mean square differences from observation-based climatology or each model and for the "mean model". DJF on left and JJA on right.

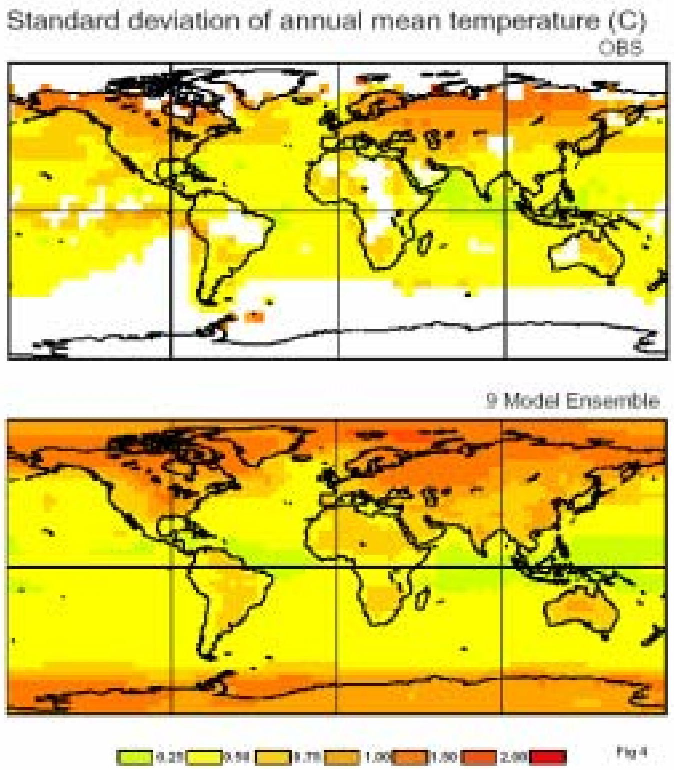
Ensembles

Weather forecasts attempt to improve deterministic predictions by increasing resolution, improving model parameterizations and by reducing initial errors. The sensitive dependence on initial conditions suggests ensemble approaches for which multiple forecasts are made using a range of initial conditions meant to capture the distribution of initial conditions that are consistent with available observations. These multiple forecasts are used to estimate the probability of a range of results and/or combined to improve the deterministic forecast. Model deficiencies add a further layer of error to the initial condition error but, since many short range forecasts are produced and verified, there is a large sample of results that may be examined and statistically combined.

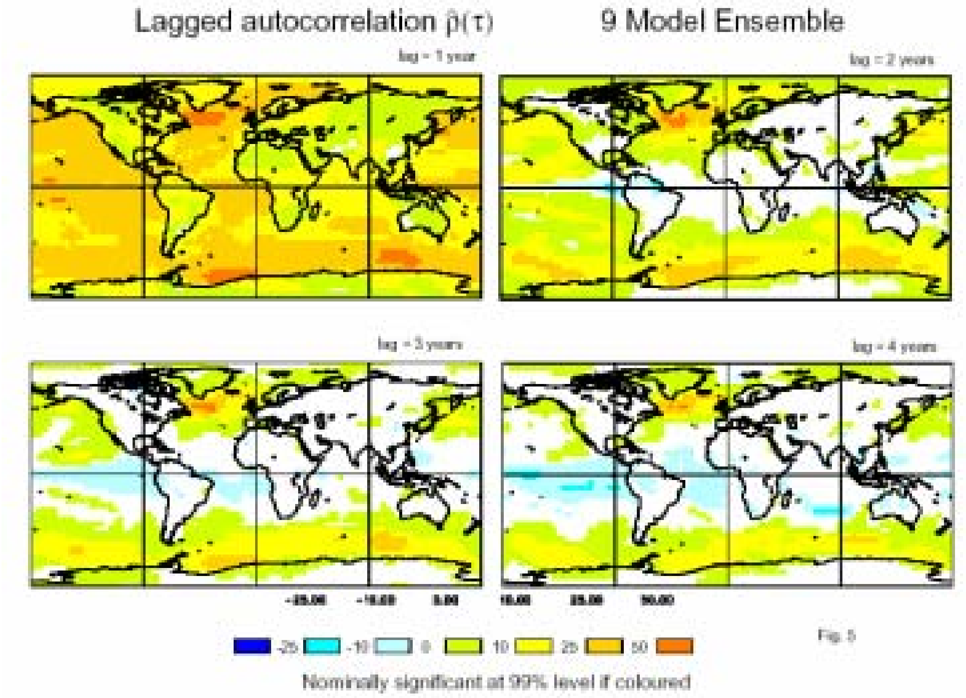
Climate and its forced variation is nominally independent of initial conditions error but in its place numerical and parameterization deficiencies introduce uncertainty and into the results. We may nevertheless once again appeal to ensemble approaches. Here, however, uncertainty is introduced not due to inherently erroneous initial conditions but by the imperfect numerics and parameterization approaches used in current climate models.

MMEs and climate

MME approaches may be applied to the simulation of current climate and climate variation as well as to climate predication. Ensemble methods for short range prediction use the available body of forecasts and analyses to statistically combine forecasts. However, this is not possible for the kinds of climate statistics produced when simulating current climate and a basic question is how to combine the kinds of simulations in Figure 1 to produce a better result. Lambert and Boer (2001) show that this is possible in a climate context and that the simple ensemble mean of results from a collection of coupled models from the Climate Modelling Intercomparison Project (CMIP) is generally closer to the observed climate than the result of any individual model. This is illustrated in Figure 3 where the “mean model” typically has as good or better mean square differences from observations (and other second order statistics) than any particular model. Thus, while the simulation results of models are improving only slowly, as implied by Figure 1, even the simplest multi-model ensemble approach appears to hold promise.



For climate change experiments, we may take the scatter in the results again as analogous to the scatter of the results of an ensemble of weather forecasts. Interpreting the scatter as giving information on the probability distribution of possible climate change for a given forcing change, such as an increase in greenhouse gas concentrations, assumes that the models may be considered as a random sample from some idealized population of climate models which represent current knowledge and abilities to model climate.



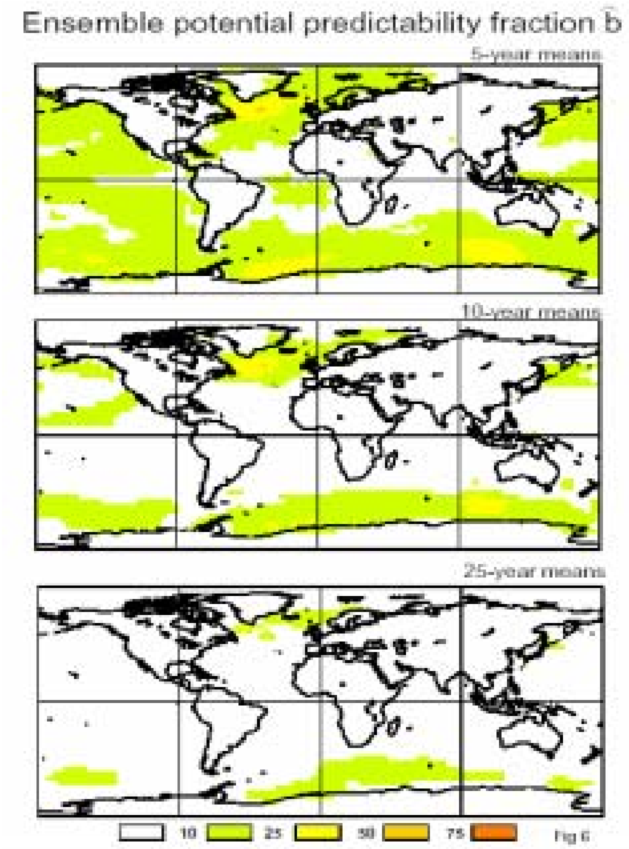
Climate variability

Pooling the results of a range of climate model results offers the possibility of better estimating mean climate statistics, as indicated in Figure 3, but also other statistics as well. As an example we use the CMIP MME to estimate the variability of surface temperature as shown in Figure 4. The results compare well to “observation-based” results where data is available indicating once again the utility of even simple applications of the MME approach. Provided we are justified in pooling model results together, the resulting large data set means that higher order statistics are well estimated. For instance, the lagged autocorrelation structure of the annual mean temperature in Figure 5 shows how temperatures decorrelate with time depending on location, with rapid decorrelation over land, slow decorrelation over high latitude oceans, and evidence of long timescale oscillatory behaviour over tropical oceans.

Long timescale variability and predictability

Long timescale prediction and predictability is investigated almost entirely in the context of perfect model approaches since there is a profound lack of data with which to perform hindcasts. One way of investigating the possibility of long timescale prediction is to ask if there is a long timescale "potentially predictable" component of the variance that is distinct from that which would be obtained by averaging white noise. If some appreciable fraction of the variance passes this test, there may be a signal that can be predicted. One possibility is that the ocean simply damps white noise forcing and if this is the case, a simple AR1 statistical forecast is the best that can be done.

We base calculations on a MME of annual mean temperatures from the CMIP models. There are nine models entering the ensemble with differing amounts of data. All the results have been carefully detrended. We calculate a "potential predictability" variance fraction for 5, 10 and 25 year means. The result is shown in Figure 5 where regions with values greater than 10% are coloured as being of interest. We may also show that the variance structure is inconsistent with an AR1 process almost everywhere. The large amount of data in the MME means that we may nominally estimate the statistics and perform tests with high statistical confidence. The result is that long timescale variability, that is not simply the average or damping of noise, is found especially at high latitudes over oceans. The implication is that long timescale prediction may be possible in these regions.



Summary

The analogy between the "sensitivity to initial conditions" in the case of deterministic forecasts and the "sensitivity to numerics and parameterizations" in the case of climate forecasts/simulations argues for the application of MME methods for climate. The applicability of these methods depends, however, on the assumption that the models used may be considered as a representative sample from a population of models of the climate system. Simple pooling of results under this assumption can be shown to provide better estimates of at least some observed climate statistics. The pooled results may be used to estimate higher order statistics such as long timescale lagged autocorrelations, variability and "potentially" predictable variance fractions.

Multi-Model Synthetic Superensemble Prediction System

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The Superensemble approach is a recent contribution to the general area of weather and extended range forecasting, developed at the FSU, and this technique is discussed extensively in a series of publications. Recent papers of that are by Krishnamurti and Sanjay (2003), Kharin and Zwiers (2002), and Yun (2003). Superensemble algorithm is embraced as a tool for making both of deterministic and probabilistic predictions. The Superensemble algorithm entails the division of a time line into two parts, called training phase and forecast phase. During training phase the forecast of member models are fit as a linear combination to observations with the objective of minimization of residual error variance. In general, the Superensemble approach yields forecast with considerable reduction in forecast error compared to the error in the member models, the bias-corrected ensemble mean forecast and the ensemble mean forecast.

A major component of Superensemble forecast initiative is training of forecast data set. The superensemble prediction skill during the forecast phase could be degraded if the training was executed with either a poorer analysis or poorer forecasts. That means that the prediction skill is improved when higher quality training data set is deployed for the evaluation of the multi model bias statistics.

Despite the continuous improvement of both dynamical and empirical models, the predictive skill of extended forecasts remains quite low. The multi model Superensemble is one emphasized way to improve weather predictions. In the context of seasonal climate forecasts, we had noted that the multi-model bias-removed ensemble demonstrated a skill slightly below that of climatology, whereas the superensemble provided a skill slightly above that of climatology. For a further improvement to the superensemble method we suggest synthetic superensemble algorithm, developed by Yun (2003).

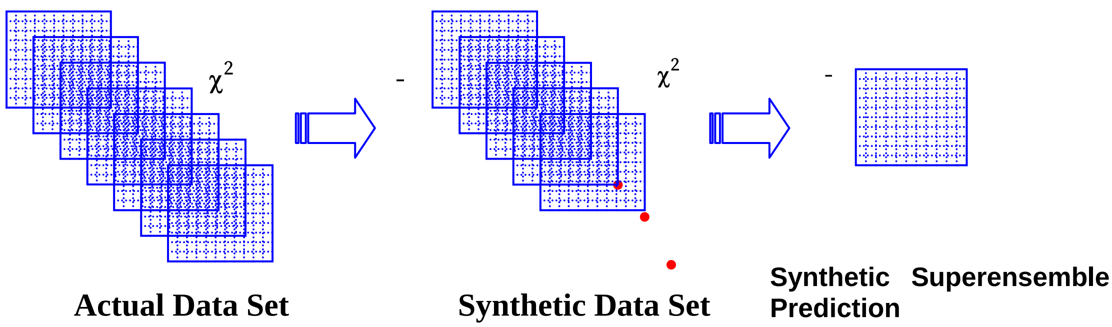

Fig. 1 Extended range forecast using synthetic data sets. To generate the synthetic data sets, EOF- and Fourier analysis and random process are used as a statistical method.

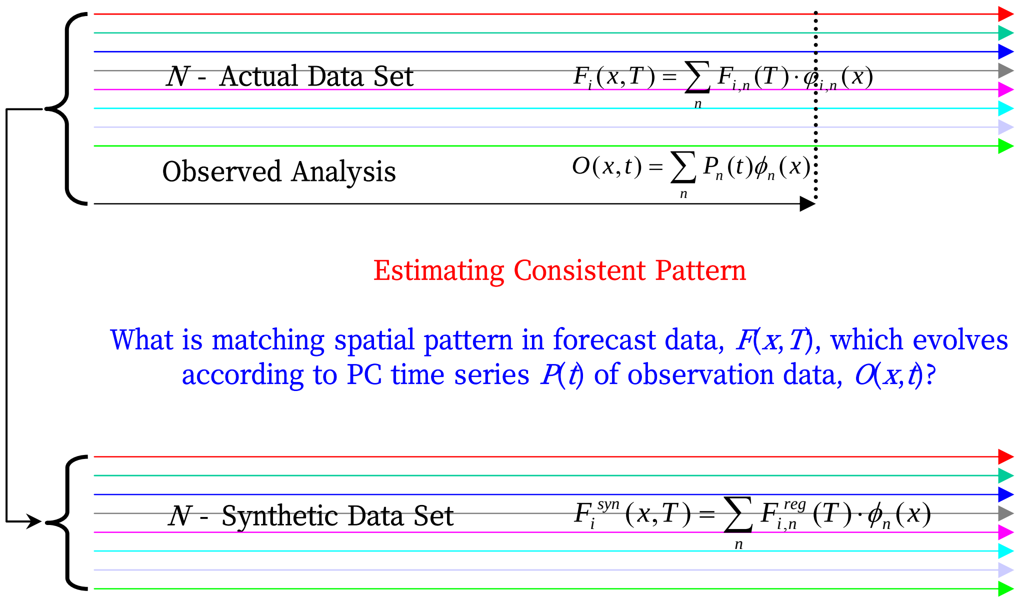

Fig 2. Scheme of synthetic data processor. Synthetic data set is generated form actual data set by finding consistent pattern among observation and forecast data.

Once EOFs of observation data (time series) are found, the time series of observation can be written as a linear combination of EOFs.

Introduction of Synthetic Data Processor

The synthetic superensemble algoritm is an alternative method to obtain high quality forecast data set and to improve the prediction skill of extended forecast. In order to do so, we generate synthetic data set which is derived from a combination of the past observations and forecasts. Synthetic data set is created by finding consistent spatial pattern between observation and forecast data set. It is a linear regression problem in EOF space. A set of such synthetic forecasts is then used for the creation of a superensemble forecast.

$$O(x,t) = \sum_n P_n(t)\phi_n(x) \qquad (1)$$

PC time series, P(t), in equation (1) represents how EOFs (spatial patterns) evolve in time. PCs are independent of each other. Now we are interested in knowing the spatial patterns of forecast data which evolve in a consistent way with EOFs of observation. That means what is matching spatial pattern in forecast data, F(x,t), which evolves according to PC time series P(t) of observation data? We can answer such a question by finding concurrent patterns among observation and forecast data. Patterns of two variables are called concurrent when they have the common evolution history. The procedure of finding consistent pattern can be written a regression problem in EOF space. And the forecast data set can be written as a linear combination of EOFs

$$F_i(x,T) = \sum_n F_{i,n}(T)\cdot\varphi_{i,n}(x) \qquad (2)$$

Index i and n in equation (2) indicates the number of forecast models and the number of EOF modes, respectively. $\varphi(x)$ and F(t) are the EOFs and the corresponding PC time series of F(x,t). Then a regression relationship is sought between the observation PC time series and a number of PC time series of forecast data.

$$P(t) = \sum_n \alpha_{i,n}F_{i,n}(t) + \varepsilon(t) \qquad (3)$$

With equation (3) we want to express observation time series, P(t), as a linear combination of predictor time series, F(t) in EOF space. And the regression coefficients, αn, are found that the residual error variance, E(ε2), is minimized. Once the regression coefficients αn are found, we can write PC time series of synthetic data set

$$F_i^{reg}(T) = \sum_n \alpha_{i,n}F_{i,n}(T) \qquad (4)$$

Synthetic data set is reconstructed with EOFs and PCs

$$F_i^{syn}(x,T) = \sum_n F_{i,n}^{reg}(T) \cdot \phi_n(x) \qquad (5)$$

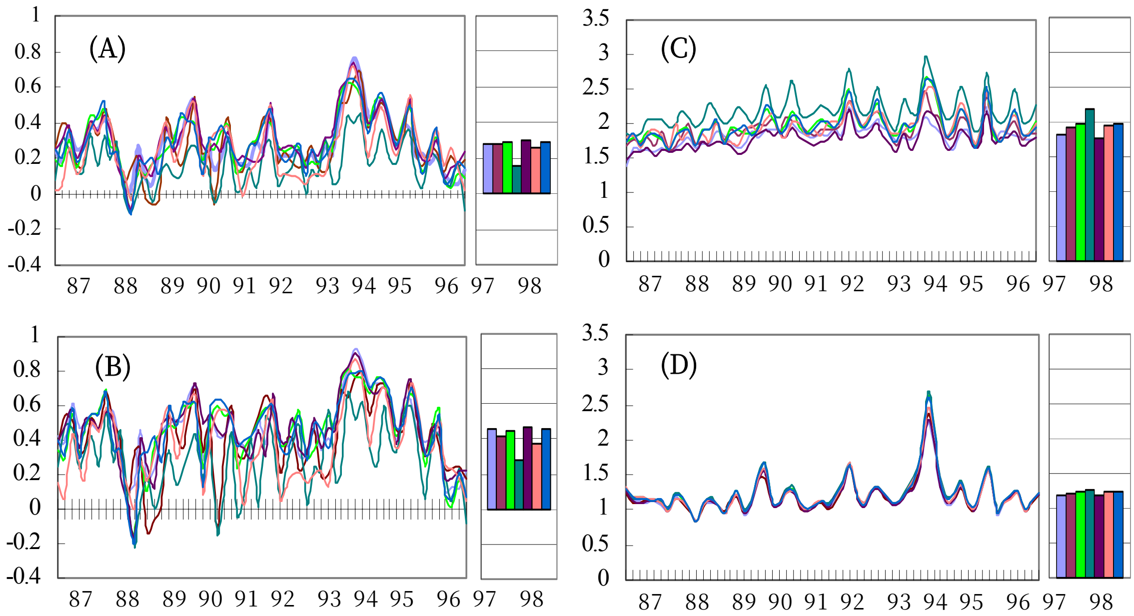

Fig. 3 Globally averaged ACC and RMS error of the actual (DEMETER models) and synthetic data set of precipitation. Forecasts of DEMETER models are averaged over 2-4 months forecasts. (A): ACC of DEMETER global precipitation forecasts. (B): ACC of synthetic data set. (C): RMS of DEMETER global precipitation forecasts. (D): RMS of synthetic data set. Bars in diagram indicate from left ECMWF, UKMO, Meteo France, MPI, LODYC, INGV, and CERFACS DEMETER models. Units of RMS is mm/day.

How good is the performance of synthetic forecast data set? Fig. 3 illustrates the ACC and RMS error of actual and synthetic data set, which are produced from DEMETER (Development of a European Multi-Model Ensemble System for Seasonal to Inter-Annual Prediction) forecasts (Palmer, 2003). DEMETER system comprises seven global atmosphere-ocean coupled models, each running from an ensemble of nine different initial conditions. The synthetic data procedure generates obviously high quality synthetic data and improves predictive skill more than 20% compared with actual data set. This generated synthetic data set is used as an input data of synthetic superensemble model.

In Fig. 4, our preliminary results shown that the proposed synthetic algorithm increases predictive skill of extended forecasts clearly better than the DEMETER actual data set. The forecast produced by synthetic ensemble and superensemble generally outperforms the both of ensemble mean and model forecast.

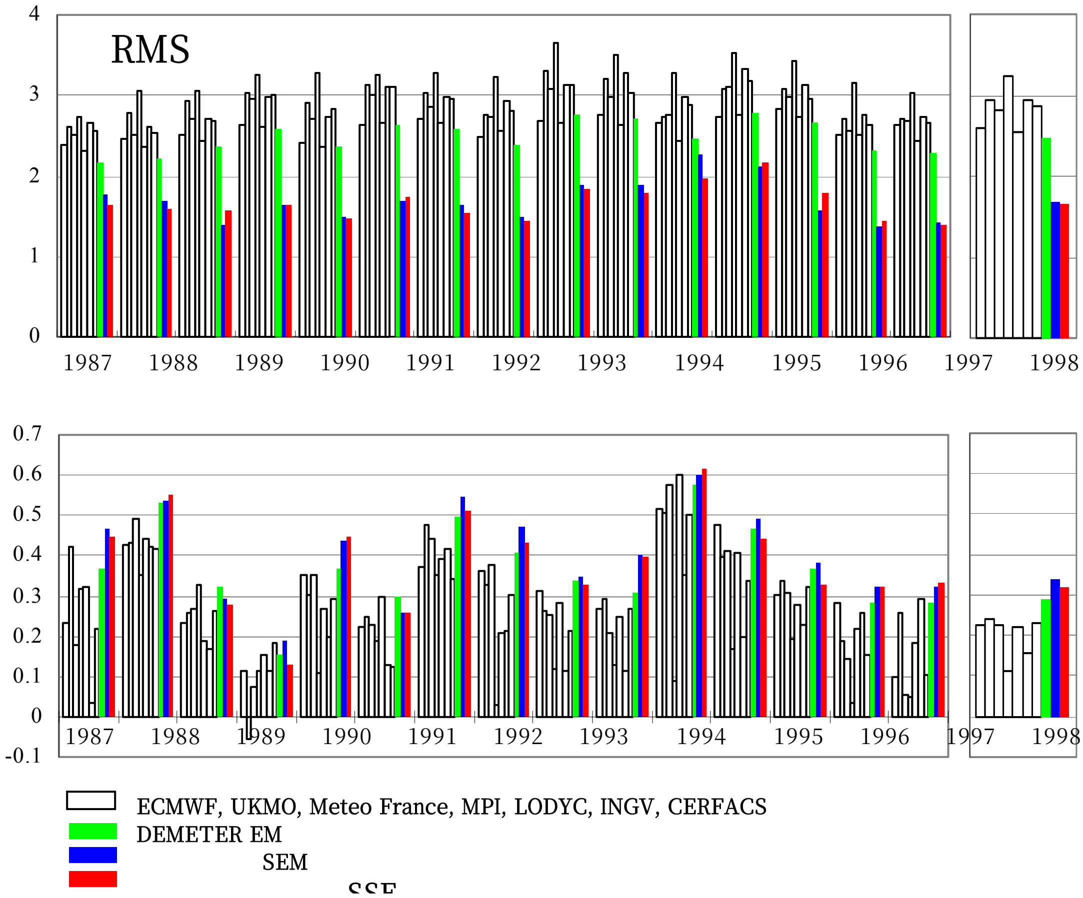

Fig. 4 Cross-validated JJA mean RMS and ACC skill of synthetic superensemble for region of 0°-60°N. Synthetic data set is generated from DEMETER over 2-4 months averaged precipitation forecasts. EM, SEM and SSF indicate ensemble mean, synthetic ensemble mean and synthetic superensemble forecast, respectively. Units of RMS is mm/day.

A post-processing algorithm based on synthetic multi-model solutions toward observed fields during a training period is one of the best solutions for extended range prediction. Our study shows that the proposed synthetic technique further reduces the forecast errors below those of the conventional superensemble technique and increases the predictive skill of extended forecasts.

Acknowledgement: DEMETER data was provided by ECMWF

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Multi-Model Superensemble Prediction System in METRI/KMA

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Korea Meteorological Administration

1. Introduction

Ensemble prediction was first introduced into meteorology by Leith (1974) and Epstein (1969). It consists of (1) estimating the probability distribution of the true state of the atmosphere around the control analysis, (2) sampling that probability distribution, and (3) running the forecast model from all the sample points. The ensemble strategy will work only if the models are good enough that model-related errors do not dominate the final error fields. Since Lorenz (1963, 1969) it has been recognized that perfect numerical weather forecasts will always be unattainable; even the smallest of errors in the initial conditions will grow inexorably, eventually rendering any single deterministic forecast useless. Rather than pinning unrealistic hopes upon the accuracy of a single numerical forecast, ensemble forecast adopts an alternative approach; generate multiple, individual numerical forecasts from different initial conditions and different numerical model configurations (Leith, 1974).

Ensemble prediction systems mostly use a single model with a set of perturbed initial conditions to take account of the analysis uncertainty. This approach essentially assumes that the model is perfect, and that forecast uncertainty is due only to initial condition errors (Yun, 2002). Recently, new approaches to ensemble forecasting, called Multi-Model Superensemble, is made by Krishnamurti et al. (1999, 2000). From these studies, superensemble-based forecasts were quite superior in comparison to participating member models and the bias-removed ensemble mean.

In Meteorological Research Institute under Korea Meteorological Administration (METRI/KMA) a dynamical ensemble seasonal prediction system using METRI Atmospheric General Circulation Model (METRI AGCM) had been accomplished since 2000 (Figure 1). Since then, various ways to improve the model performance had been applied to METRI AGCM with physical parameterization processes. New surface albedo parameterization, modification of cloud optical depth, insertion of aerosol optical depth, series of tests of cumulus convection schemes, and reconstruction of initial/boundary condition with some model code errors have improved the model simulation of vertical atmospheric temperature distribution and atmospheric and surface variables, which are related with cloud-physical processes (Sporyshev et al., 2002).

As a continuous effort, recently, a research project to develop a METRI multi-model superensemble seasonal prediction system is being implemented with cooperation of universities in Korea. A description of the METRI superensemble prediction system is presented in section 2. Verification to evaluate a prediction skill of METRI superensemble prediction system is described in section 3.

2. METRI Superensemble Prediction System

The METRI superensemble system comprises four AGCM models (CCSR, CAMII, CCM3, and METRI AGCM) using same initial and boundary conditions with same integration period (Figure 2). Each model performs a 10-member ensemble by a time-lagging method of 12 hour atmospheric initial datasets with persistent sea surface temperature (SST) anomaly boundary conditions for a period of four months. In this study linear and non-linear METRI superensemble system was constructed on the basis of the hindcast experiment conducted for 24 winter seasons of 1979 to 2002. The hindcast experiment has been started from 27th October initial conditions with 10 ensemble members of 12 hour time lag. The persistent October SST is used as boundary condition for four month integrations. We gives in this study seasonal predictability of 500 hPa geopotential height, 850 hPa temperature, and precipitation with a particular emphasis on East Asia region.

3. Verification

We apply a variety of verification measures to determine the quality of two kinds of seasonal predictions, continuous predictand and categorical forecast.

3.1 Verification based on continuous predictand

The prediction conducted from the METRI superensemble system is a continuous variable. In practice, however, the prediction and observation of continuous atmospheric variables are made using a finite number of discrete values. So, it is convenient and useful to treat the verification of continuous predictand in a continuous framework (Wilks, 1995). The mean squared error (MSE) is a common accuracy measure for continuous predicatand, and is the average squared difference between the prediction and observation pairs. This MSE can apply to both the time-domain and the space-domain pairs.

$$MSE(t) = \frac{1}{M}\sum_{m=1}^{M}(f_{m,t} - o_{m,t})^2 \quad \text{for space-domain pairs}$$

$$MSE(m) = \frac{1}{T}\sum_{t=1}^{T}(f_{m,t} - o_{m,t})^2 \quad \text{for time-domain pairs}$$

Here ($f_{m,\,t}$, $o_{m,\,t}$) is the m th of M pairs and the t th of T pairs of predictions and observations, respectively. Clearly, the MSE is zero if the predictions are perfect and increases as discrepancies between the predictions and observations become larger.

A skill score, relative accuracy of a set of forecasts to some set of reference forecasts, can easily be constructed using the MSE. For the MSE using the climatology as the reference forecasts, at each grid point of the forecast domain the skill score (SS) becomes

$$SS(m) = 1 - \frac{MSE(m)}{MSE_{clim}(m)} = 1 - \frac{MSE(m)}{s_o^{\,2}} = r_{fo}^{\,2} - \left[r_{fo} - \frac{s_f}{s_o} \right]^2 - \left[\frac{\overline{f} - \overline{o}}{s_o} \right]^2$$

and is interpreted as a percentage improvement over the climatology. The SS for the MSE can be rearranged (Murphy, 1988) and be regarded as consisting of a contribution due to the correlation between the predictions and observations, and penalties relating to the conditional and unconditional biases of the predictions. Thus, if the predictions are completely reliable and unbiased, the SS is exactly the square of correlation coefficient between the predictions and observations.

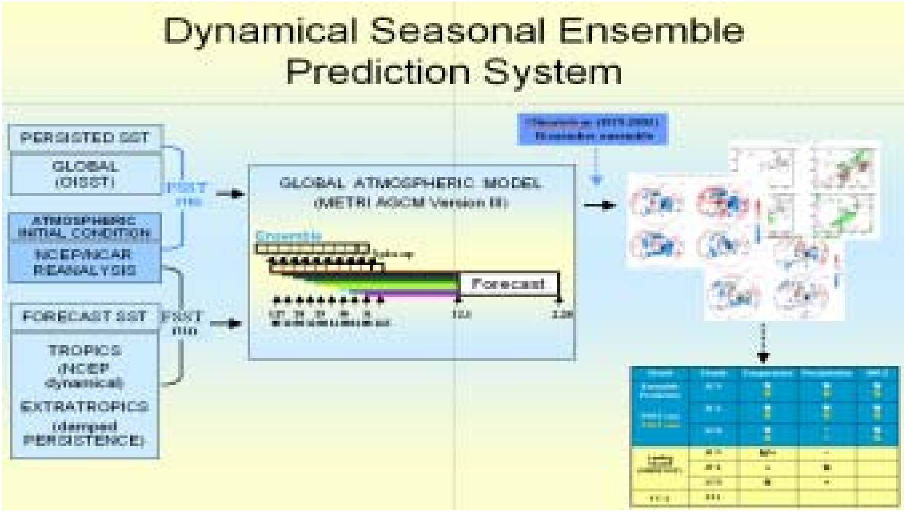


Figure 1. Dynamical seasonal ensemble prediction system in METRI.

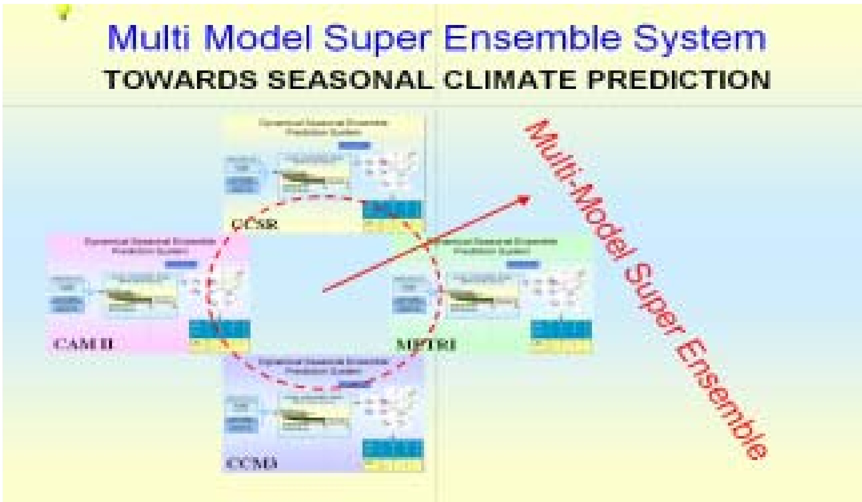


Figure 2. Multi Model Superensemble seasonal prediction system in METRI.

		Observed			
		above	normal	below	
forecast	Above	$\mathbf{N_{11}}$	$\mathbf{N_{12}}$	$\mathbf{N_{13}}$	F_1
	normal	$\mathbf{N_{21}}$	$\mathbf{N_{22}}$	$\mathbf{N_{23}}$	F_2
	below	$\mathbf{N_{31}}$	$\mathbf{N_{32}}$	$\mathbf{N_{33}}$	F_3
		O_1	O_2	O_3	N(=24)

Figure 3. A contingency table for the 3×3 categorical forecast verification.

Acknowledgement.

This study was performed as a project of ‘Development of superensemble long-range prediction system’ from Meteorological Research Institute/Korea Meteorological Administration.

Evaluation of the APCN Multi-Model Ensemble Prediction System

Woo-Sung Lee

APEC Climate Network Secretariat

Contents

- Objectives
- Participating Models
- Verification
  - Climatology
  - Variability
  - Predictibility
- Summary

APEC Climate Network

Objectives

❖ Is multi-model ensemble prediction superior to single model prediction ?

Multi-model Ensemble

Reduce bias in model formulation	Reduce bias in initial condition

❖ Where do we stand ?

Performance of the APCN MME System in terms of

- climatology
- variability
- Predictability

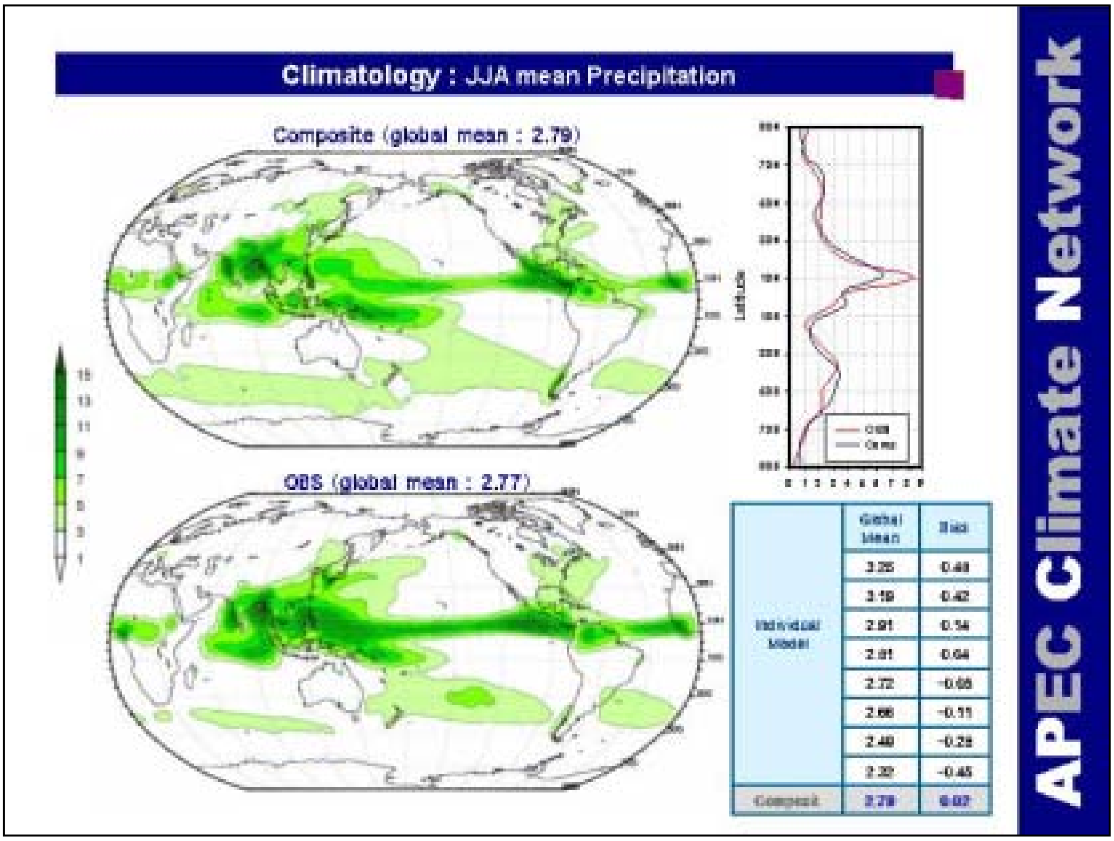
APEC Climate Network

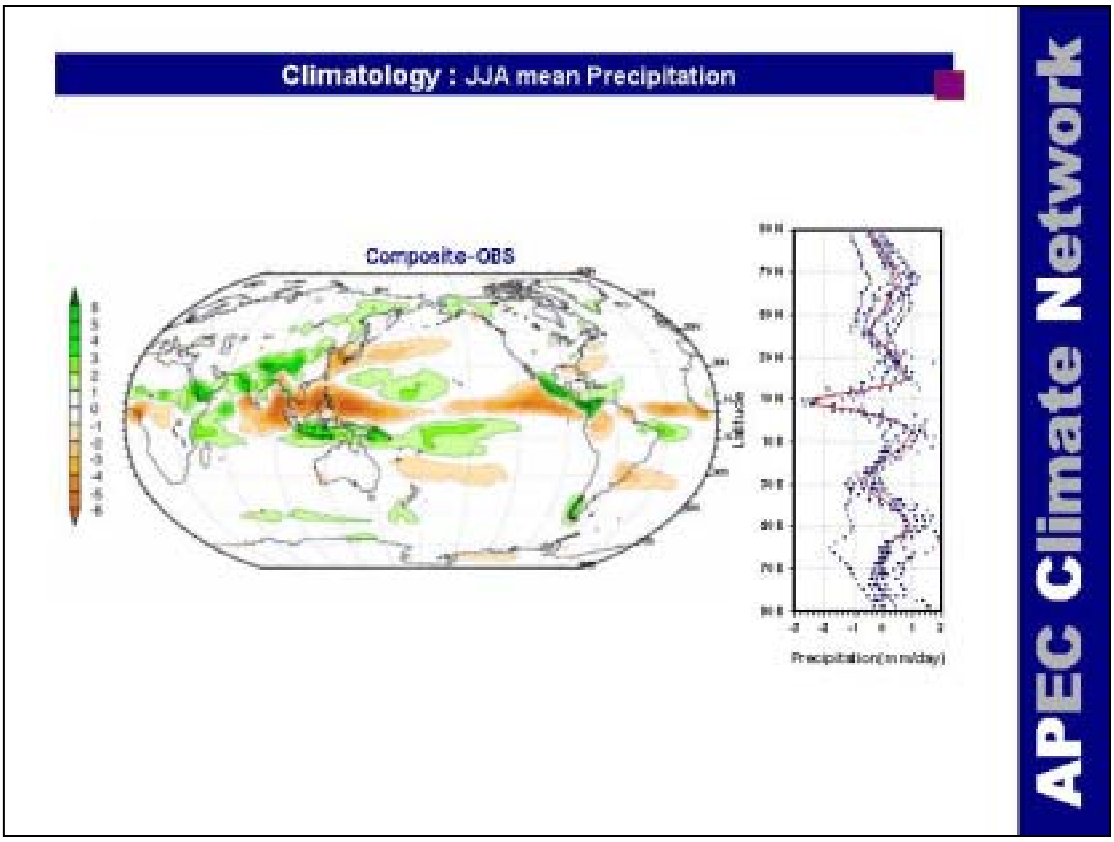
Participating Models

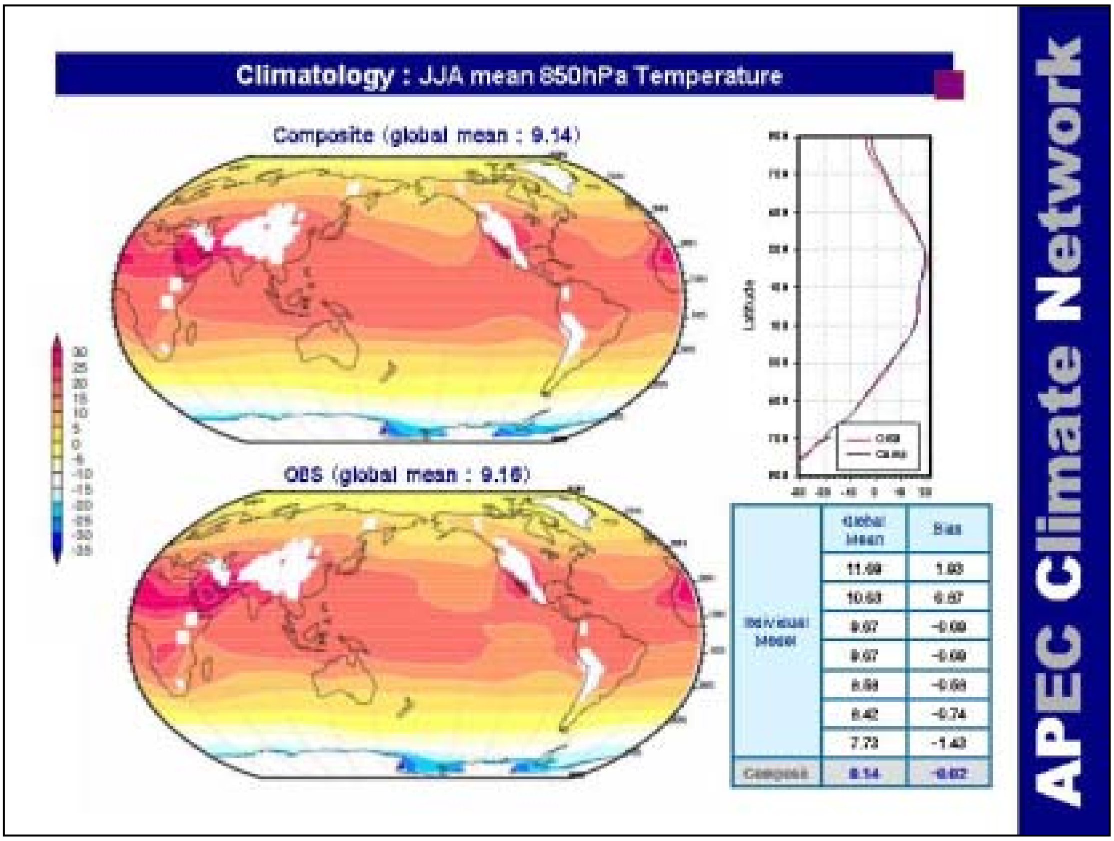
Member Economies	Acronym	Organization	Model Resolution	Seasonal Prediction Data			Hindcast Data	
				2001	2002	2003	SMIP	AMIP
China	NCC	National Climate Center / China Meteorological Administration	T63L16	□	□□□			
	IAP	Institute of Atmospheric Physics	4° x 5° L2		□□□	□□□		
Chinese Taipei	CWB	Central Weather Bureau	T42L18	□	□□□	□□□		1979–1999
Japan	JMA	Japan Meteorological Agency	T63L40			□□□	1979–1999	
Korea	GDAPS/KMA	Korea Meteorological Administration	T106L21	□	□□□	□□□	1979–1999	1979–1995
	GCPS/KMA	Korea Meteorological Administration	T63L21	□	□□□	□□□	1979–1999	1979–1999
	METRI/KMA	Meteorological Research Institute / Korea Meteorological Administration	4° x 5° L17	□	□□□	□□□		
Russia	MGO	Main Geophysical Observatory	T42L14	□	□□□	□□□	1979–1999	
USA	NCEP	Climate Prediction Center / National Centers for Environmental Prediction	T62L17	□	□□□	□□□	1979–1999 ([illegible])	
	NSIPP/NASA	National Aeronautics and Space Administration	2° x 2.5° L34	□	□□□	□□□		1979–2000

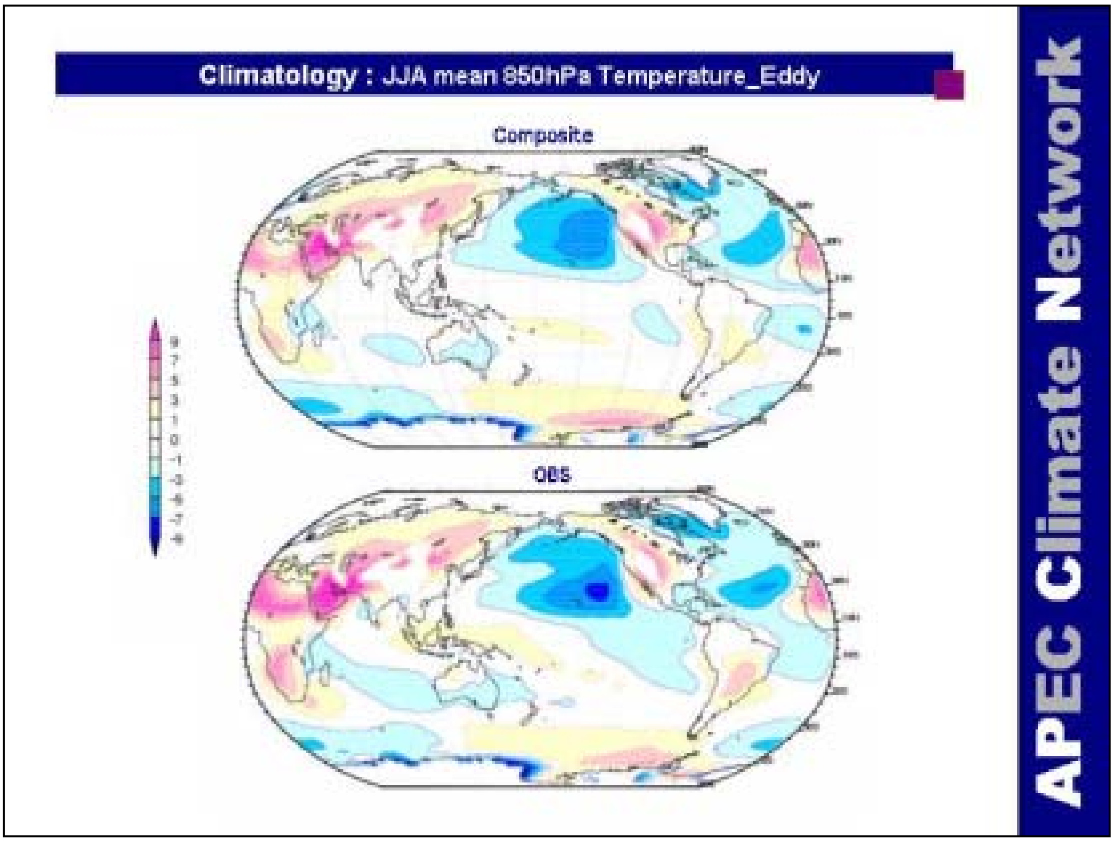
Variable	Name	Reference
Precipitation	CMAP/NCEP	Xie and Arkin, 1997
850hPa Temperature	NCEP/NCAR reanalysis	Kalnay et al. 1996
500hPa GPH		

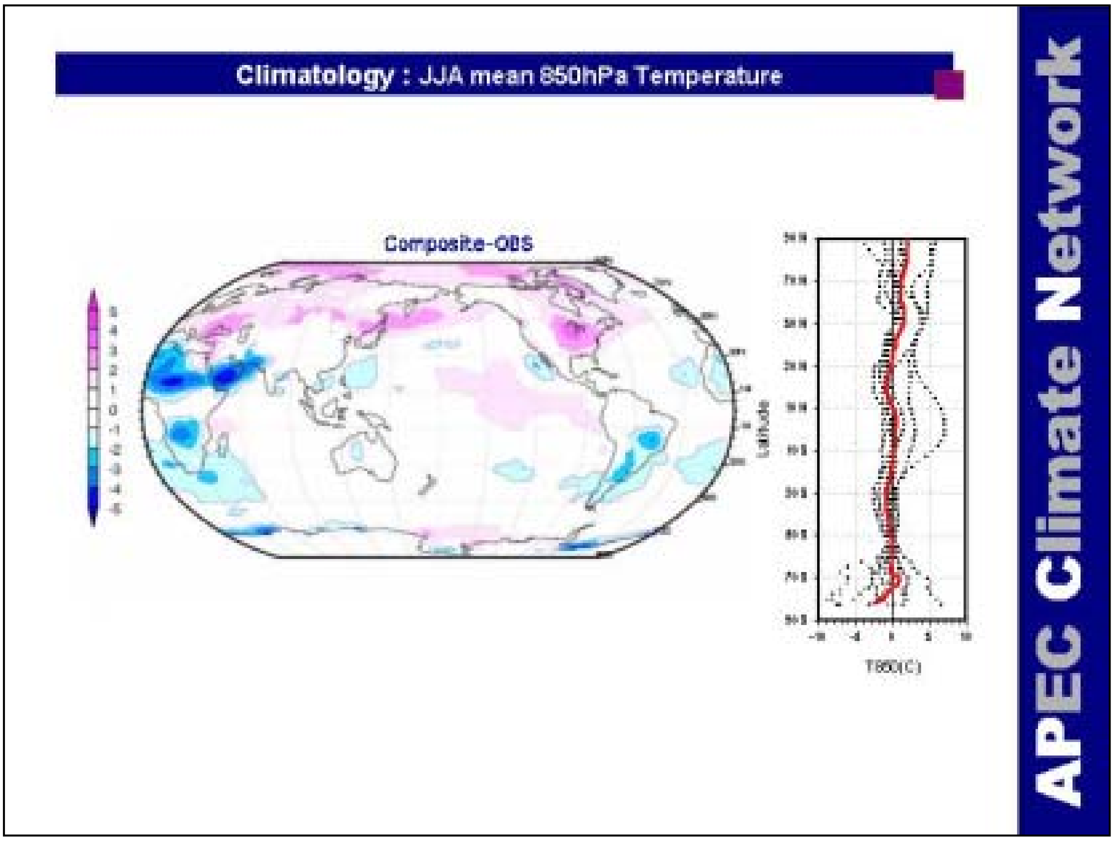
APEC Climate Network

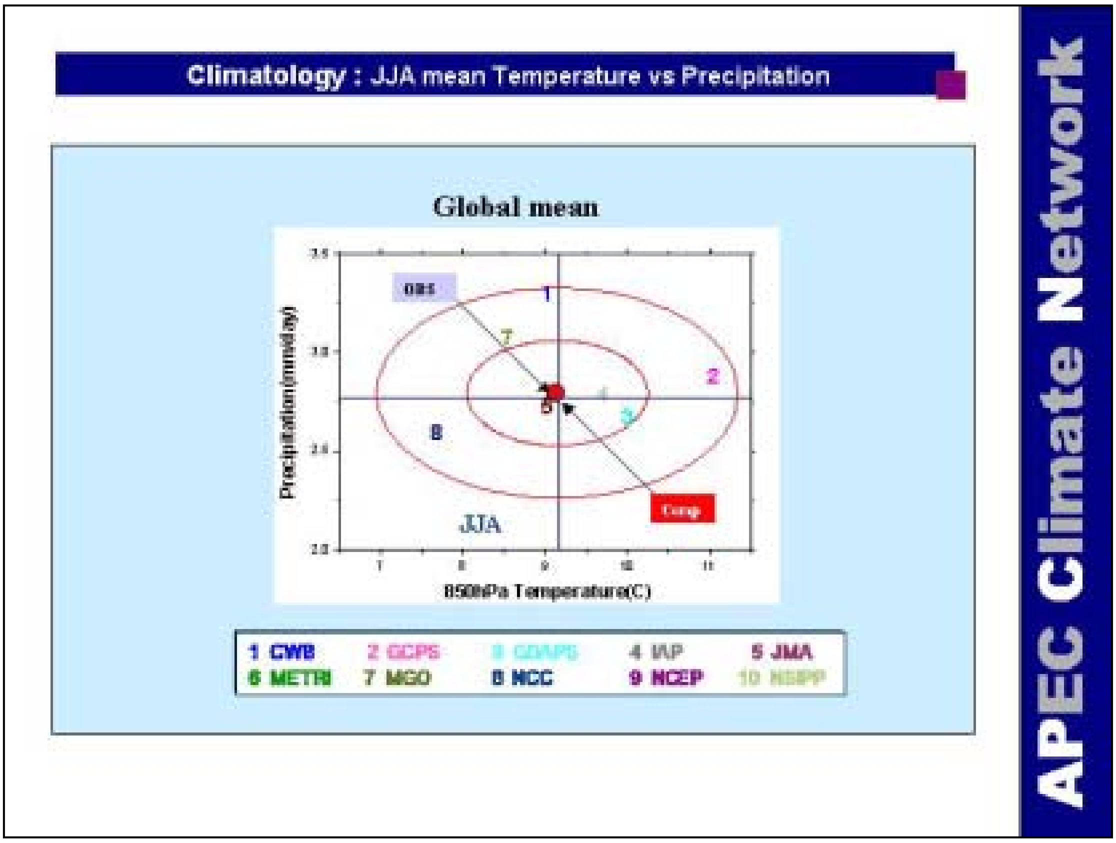

Climatology : JJA mean Precipitation
Composite (global mean : 2.79)
OBS (global mean : 2.77)
Latitude
OBS
Comp
Global Mean
Bias
Individual Model
3.25 0.48
3.19 0.42
2.91 0.14
2.81 0.04
2.72 -0.05
2.66 -0.11
2.48 -0.29
2.32 -0.45
Composit 2.79 0.02
APEC Climate Network

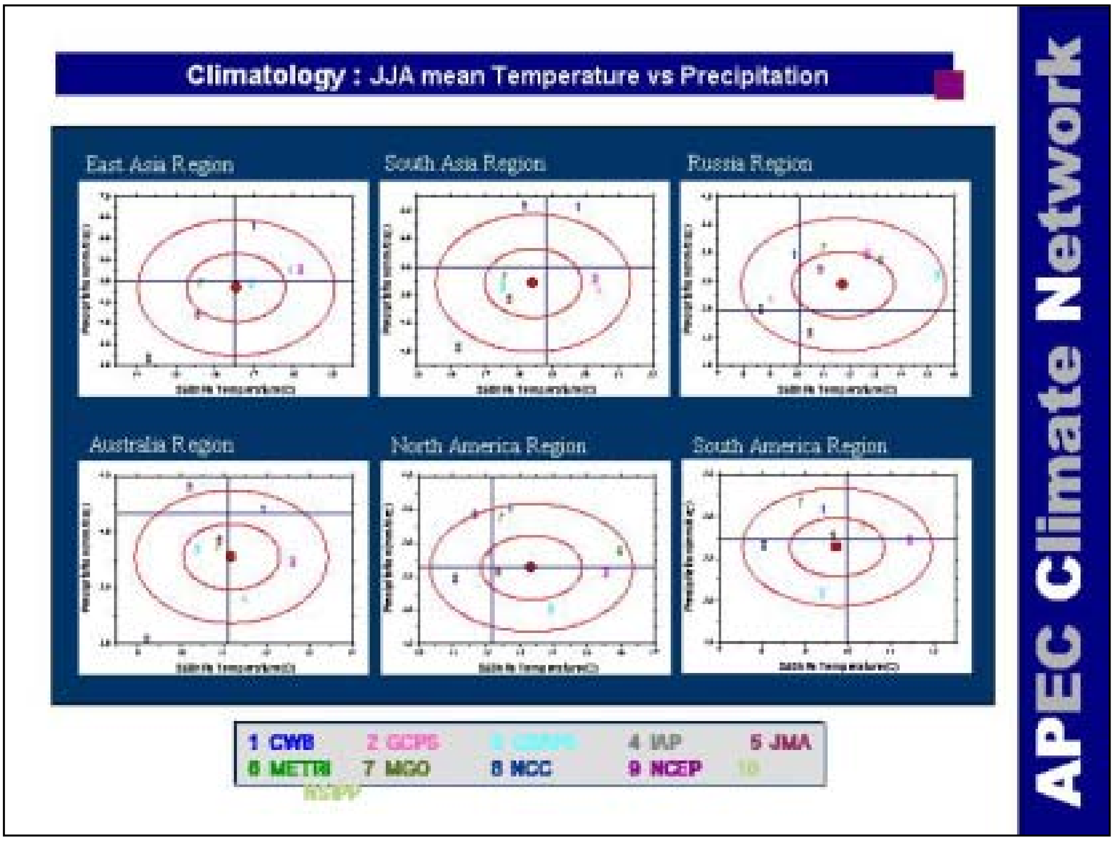

Climatology : JJA mean Precipitation
Composite-OBS
Latitude
Precipitation(mm/day)
APEC Climate Network

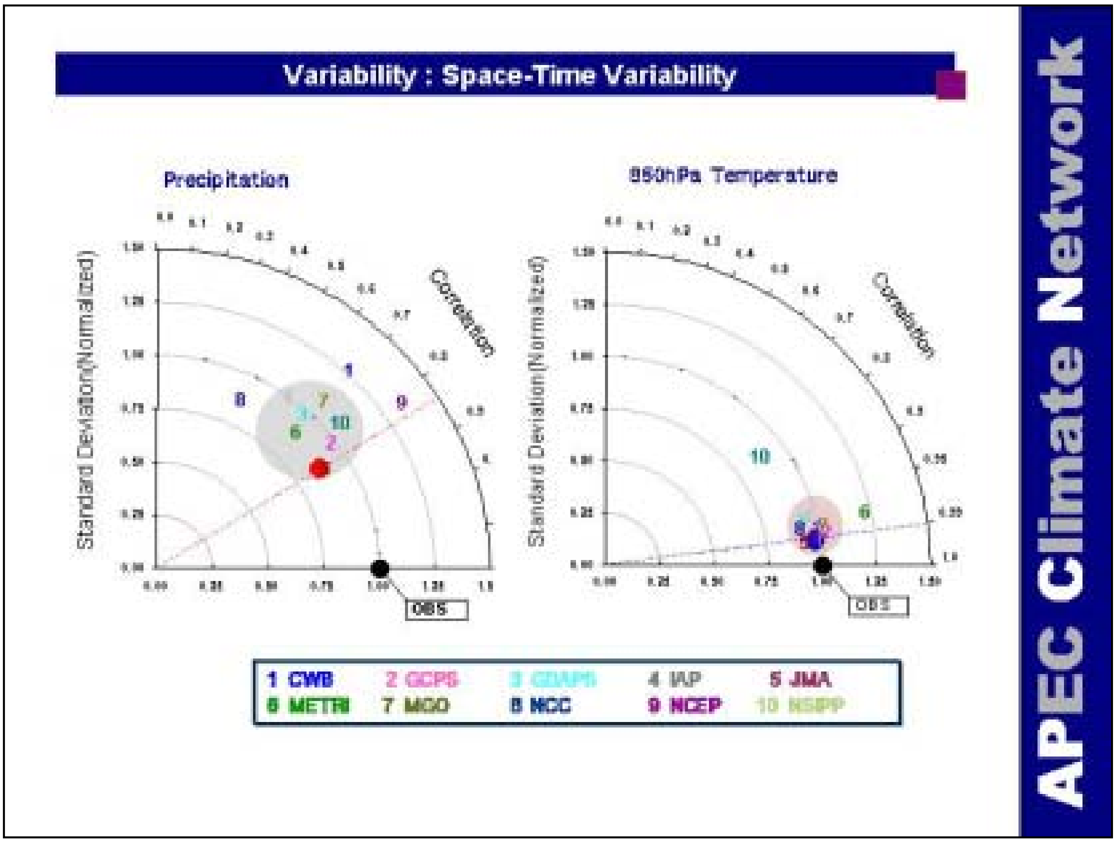

Climatology : JJA mean 850hPa Temperature
Composite (global mean : 9.14)
OBS (global mean : 9.16)
Latitude
Global Mean
Bias
Individual Model
Composite
APEC Climate Network

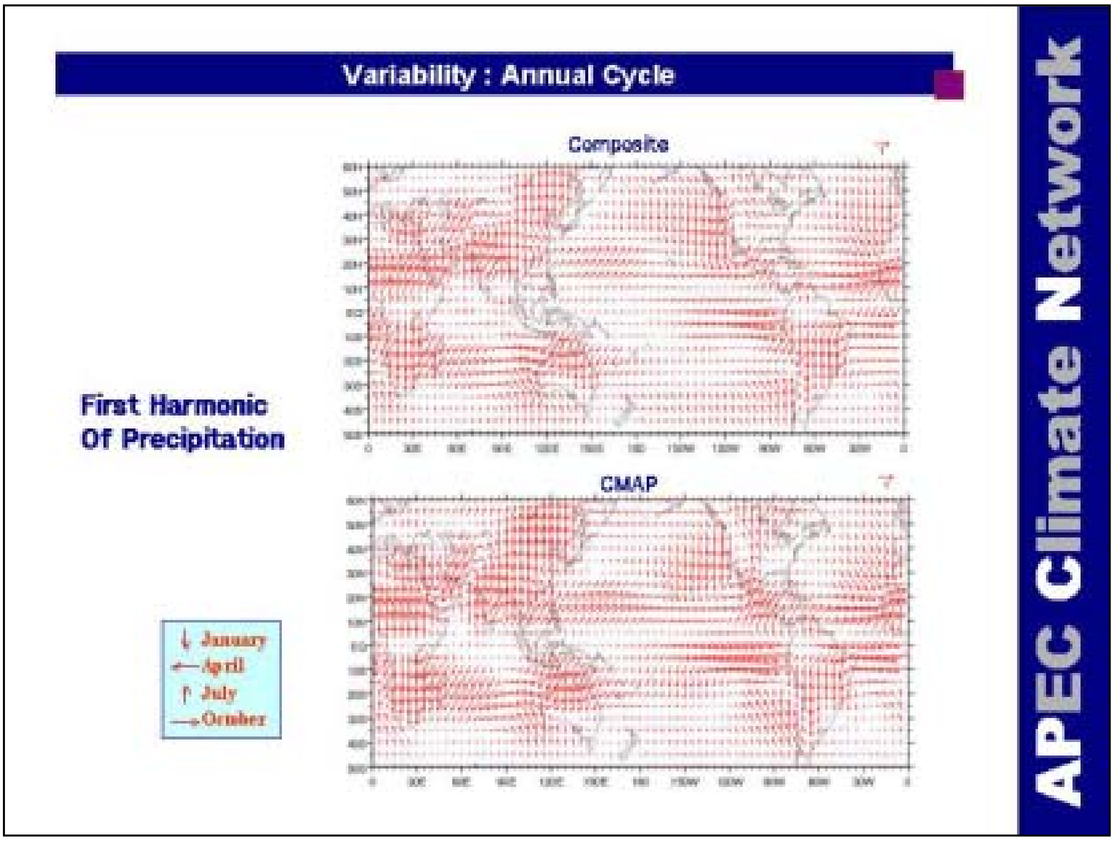

Climatology : JJA mean 850hPa Temperature_Eddy
Composite
OBS
APEC Climate Network

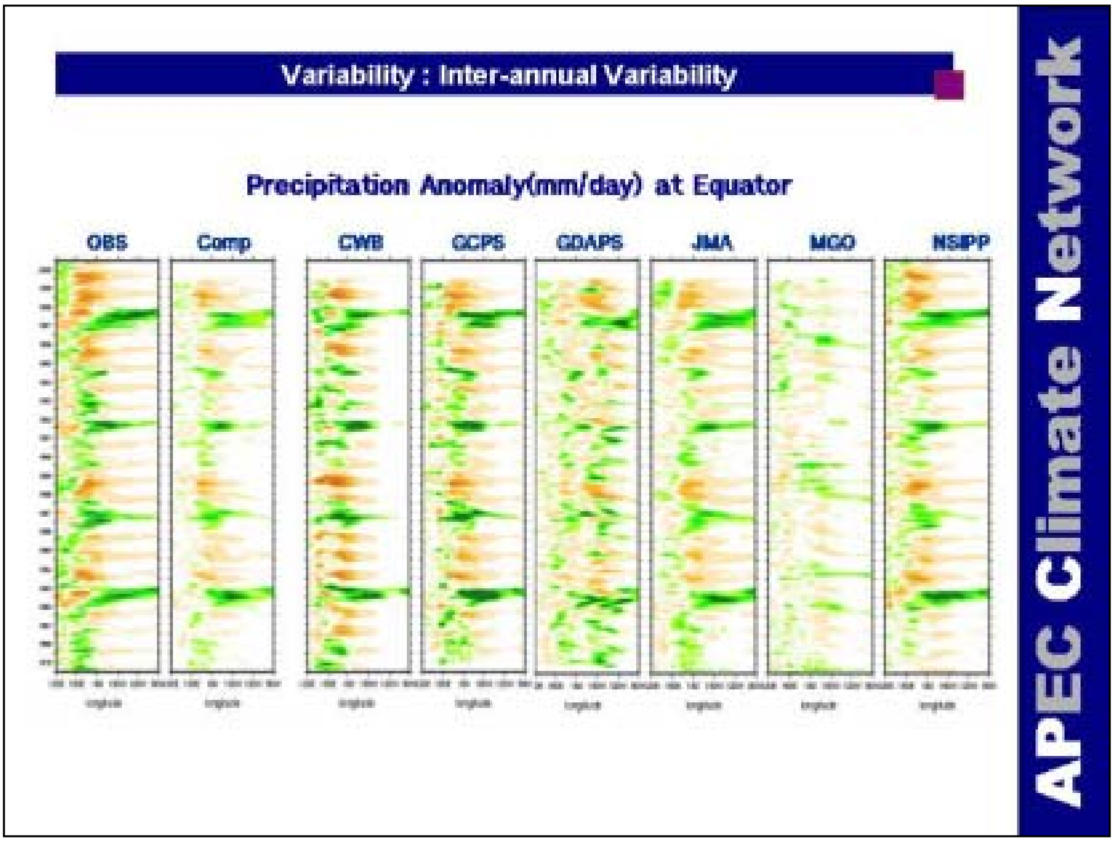

Climatology : JJA mean 850hPa Temperature
Composite-OBS
Latitude
T850(C)
APEC Climate Network


Climatology : JJA mean Temperature vs Precipitation
Global mean
OBS
Comp
JJA
Precipitation(mm/day)
850hPa Temperature(C)
1 CWB
2 GCPS
3 GDAPS
4 IAP
5 JMA
6 METRI
7 MGO
8 NCC
9 NCEP
10 NSIPP
APEC Climate Network


Climatology : JJA mean Temperature vs Precipitation
East Asia Region
South Asia Region
Russia Region
Australia Region
North America Region
South America Region
1 CWB
2 GCPS
4 IAP
5 JMA
6 METRI
7 MGO
8 NCC
9 NCEP
NSIPP
APEC Climate Network


Variability : Space-Time Variability
Precipitation
850hPa Temperature
Standard Deviation(Normalized)
Correlation
OBS
1 CWB
2 GCPS
3 GDAPS
4 IAP
5 JMA
6 METRI
7 MGO
8 NCC
9 NCEP
10 NSIPP
APEC Climate Network


Variability : Annual Cycle
First Harmonic
Of Precipitation
Composite
CMAP
January
April
July
October
APEC Climate Network


Variability : Inter-annual Variability
Precipitation Anomaly(mm/day) at Equator
OBS
Comp
CWB
GCPS
GDAPS
JMA
MGO
NSIPP
APEC Climate Network

Multi-Model Ensemble Technique

MME I Simple composite

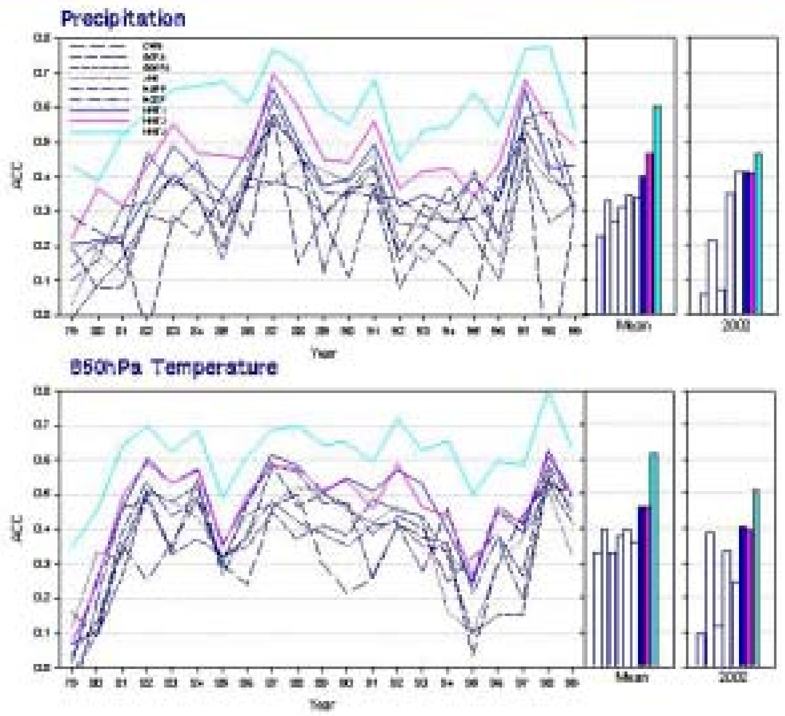
MME II Singular Value Decomposition

MME III Composite after statistical downscaling bias correction (Coupled Pattern Projection Method).

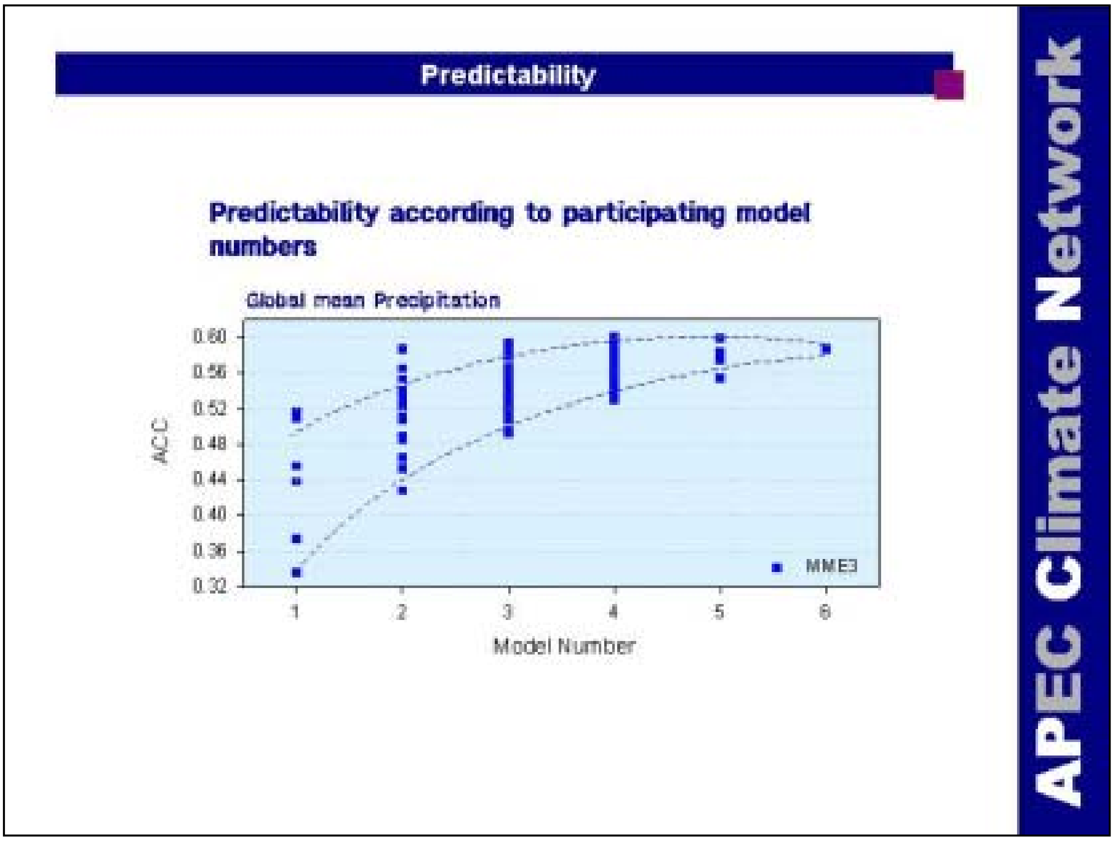
Used Model	CWB, NSIPP GCPS, NCEP, JMA, GDAPS
Period	• 21-year hindcasts from 1979 to 1999 • 2001/2002/2003 summer forecasts
Variable	Precipitation, 850hPa Temperature

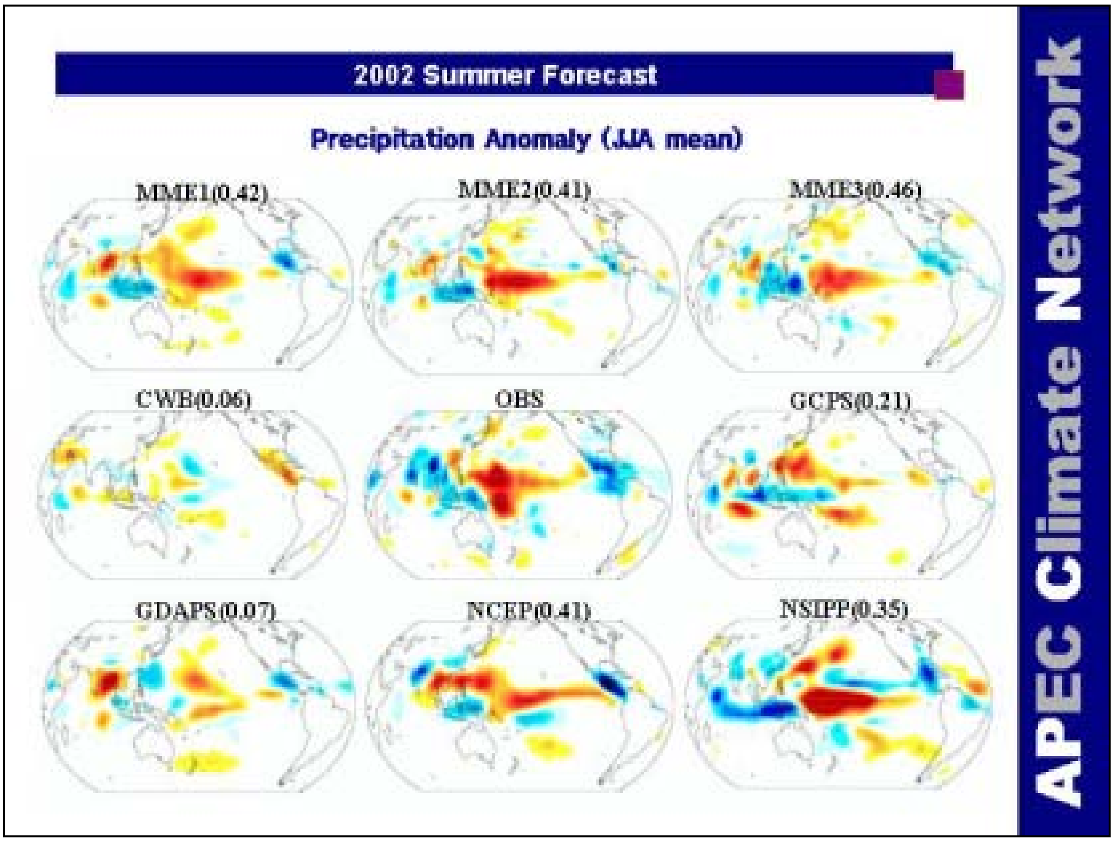
APEC Climate Network

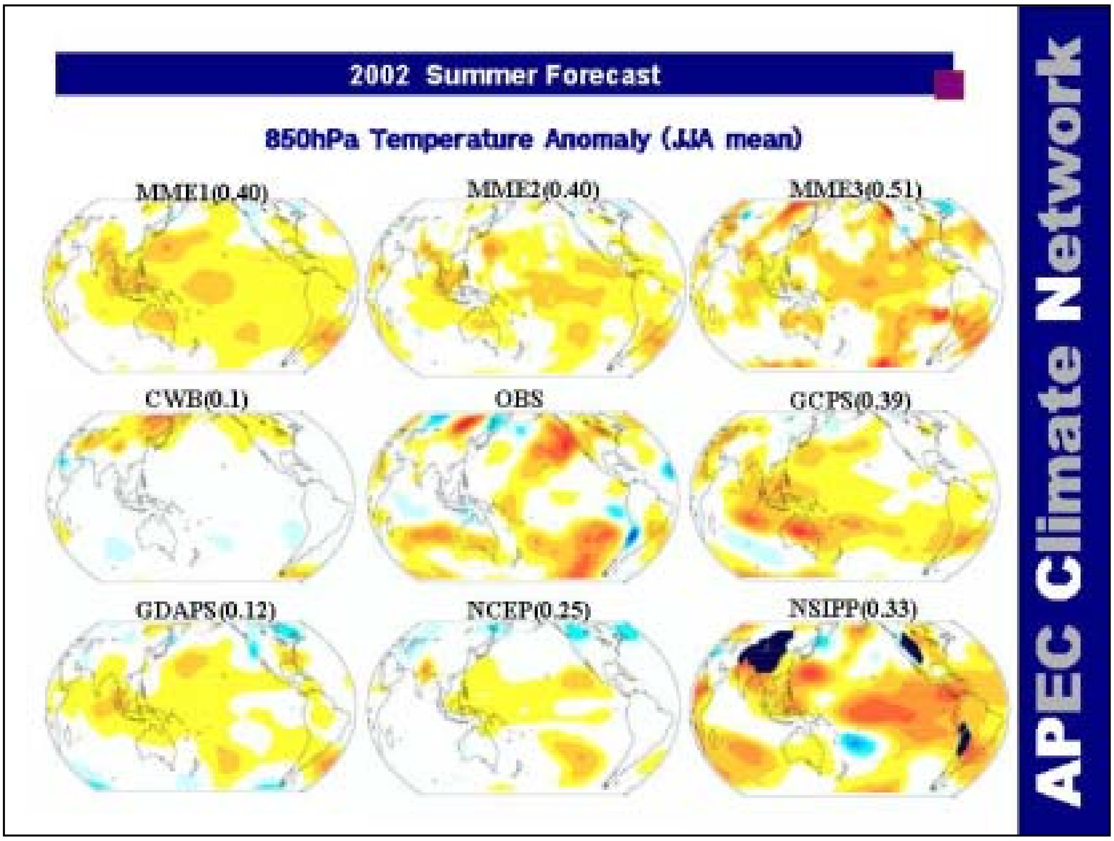
Pattern Correlation : 1979-1999 Hindcast, 2002 JJA forecast



APEC Climate Network


Predictability
Predictability according to participating model numbers
Global mean Precipitation
ACC
0.60
0.56
0.52
0.48
0.44
0.40
0.36
0.32
1
2
3
4
5
6
Model Number
MME3
APEC Climate Network

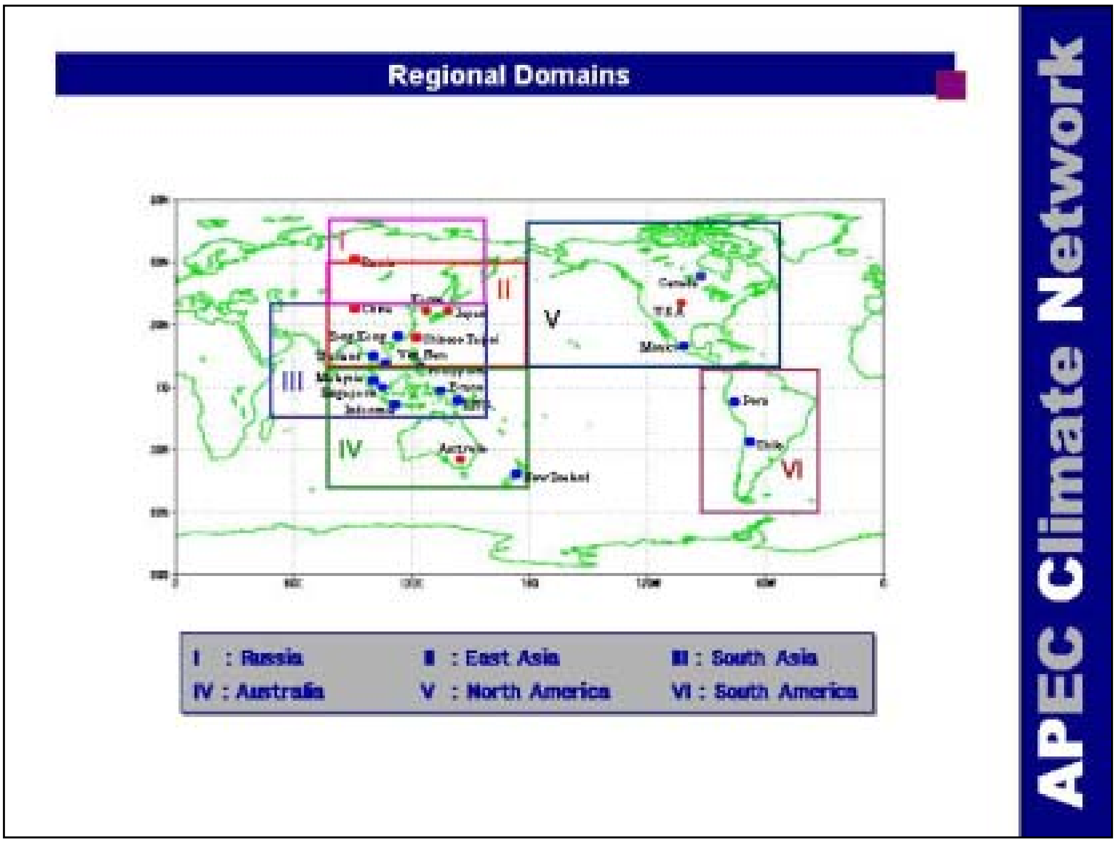

2002 Summer Forecast
Precipitation Anomaly (JJA mean)
MME1(0.42)
MME2(0.41)
MME3(0.46)
CWB(0.06)
OBS
GCPS(0.21)
GDAPS(0.07)
NCEP(0.41)
NSIPP(0.35)
APEC Climate Network



Summary and Suggestion

- The APCN participating models reproduce the major features of the observation, but there is a considerable diversity among model results.
- APCN MME System provides superior performance to any single model prediction in term of climatology, variability and predictability.
- Statistical bias correct of individual models prior to multi-model ensemble(MME3) enhances predictability compare to simple model composite(MME1) or SVD superensemble(MME2)
- Difference between the MME performance in the cross-validation during the hindcast period and in the independent predictions appear to rise from the uncertainty of boundary forcing, currently specified by persistent conditions in the operational forecast.

APEC Climate Network


Regional Domains
APEC Climate Network
I : Russia
II : East Asia
III : South Asia
IV : Australia
V : North America
VI : South America

Ten-year Simulations and the Seasonal Predictions for Flooding Seasons in China by using the Nested Regional Climate Model (RegCM_NCC)

Ding Yihui
Shi Xueli, Liu Yiming, Liu Yan, Li Qingquan

National Climate Center
China Meteorological Administration

A modified version of the NCAR/RegCM2 has been developed in the National Climate Center, China Meteorological Administration, through a series of sensitivity experiments, and multi-year simulations and hindcasts, with a special emphass on adequate choice of physical parameterization schemes suitable for the East Asian monsoon climate. This regional climate model is nested with the NCC/IAP T63 coupled GCM to make the experimental seasonal prediction in China and East Asia. Two-year (2001 and 2002) prediction results are encouraging.

Firstly, the sensitivity study on the main physical parameterization schemes used in the RegCM2 has been made in connection with climate simulations of seasonal rain belts and the 1991, 1994 and 1998 extreme flooding events in China. Four physical processes have been studied of significantly affecting the simulation results in the model through a comparative testing experiment: the land surface process, convective precipitation, cloud-radiation transfer process, and boundary layer process and large-scale topography. Among them, the most sensitive physical processes for precipitation simulations are believed to be the cloud-radiation transfer processes and convective precipitation representation. These two processes are not independent from each other. The total cloud amount and their vertical partition greatly depends on the cumulus parameterization scheme. On the other hand, the convective precipitation is considerably affected by cloud-radiation transfer process through the feedback mechanism with changing the atmospheric heating fields, surface fluxes and atmospheric stability. In the East Asia monsoon region, the cloud type and vertical configurations have the prominent features. The observation indicates that major seasonal cloud band such as the Meiyu and Baiu are usually characterized by an elongated low-and mid-level cloud bands with a number of convective cloud clusters or meso-scale cloud systems embedded within it (Niniomiya and Murakami, 1987). Therefore, a more realistic cloud parameterization scheme suitable for representation of interaction of this mixed type of clouds is desirable.

The precipitation episodes in an extreme flooding event in East Asia is significantly modulated by intraseasonal oscillations with the peak period ranging from 20 day to 90 day, mostly 20-30 days (Wang and Xu, 1997). The occurrence of propagation of the ISO is associated with the cloud-precipitation and surface processes feedback mechanism. Therefore, cloud parameterization and radiative transfer schemes not only play a crucial role in simulation of rainfall amounts, patterns and intensity, but also are fundamental for simulations of repeated occurrence of rain episodes under modulation of the ISO.

The parameterization schemes of land surface processes may exert an important effect on precipitation and surface temperature in pattern and magnitude. The surface temperature is very sensitive to the surface process parameterization schemes. Our experiments have shown that a finer vertical resolution of soil layer, especially in the plant root zone (0.5-2 m), is necessary for improved climate simulation. In the East Asian region, the inclusion of the Tibetan Plateau in regional climate models is indispensable for a realistic simulation of the East Asian monsoon activity and the seasonal rain belt. However, in doing so, extensive areas of the apparent spurious heavy precipitation over the steep sloping regions usually occur in the model. They can be mostly eliminated with adequate methods. Therefore, the thermal and dynamic effects of the Tibetan Plateau can be well represented in an expanded domain of the model. For better simulations of diurnal variations and vertical distributions of meteorological variables in the middle and lower troposphere, an improved representation of the boundary layer process is also very important.

Based on our sensitivity experiments for above four key physical processes in the RegCM2, we have found that the mass flux scheme (MFS) and Bett-Miller scheme (BM) for convective precipitation are more suitable for the simulations of precipitation in the East Asia region. The radiation transfer scheme used in CCM3 GCM may be used in the regional climate modeling, but with a rather systematic error and uncertainty. A further improvement needs to be done in the future. The modified land surface process models of the BATS type (LMPI and LMPII) show a better performance in the East Asian regional simulations. They will be used in the RegCM2 together with the original BATS. Likewise, the TKE scheme for boundary layer processes will be used in the RegCM2 as an additional option. Due to use of a larger domain including the entire Tibetan Plateau, the treatment schemes of large-scale terrain feature will be included in the RegCM2. Incorporating all the above modifications and new additional options into the RegCM2, a modified version of the RegCM2 has been developed on which based a ten-year regional model climatology and hindcasts in China have been made.

The initial results of the use of the nested regional climate model (RegCM_NCC) developed in China National Climate Center in the climate simulation and seasonal predictions in China has been presented. Overall, the simulational performance and predictive skills are encouraging. The ten-yr East Asian climate simulation is in many ways successful. Our discussions of simulation results were focused on the precipitation aspect, due to a great concern of floods and droughts in summer in the East Asian monsoon region. The geographical patterns and the seasonal march of precipitation in China, starting dates and durations of regional rainy seasons (the presummer rainy season in China, the Meiyu in the Yangtze-Huaihe River Basins and the rainy season in North China), and flooding years (e.g. 1991, 1994 and 1998), the associated large-scale monsoonal circulation features and evolution were well simulated. The feature of the inter-annual variability of precipitation was mostly captured. On the other hand, two major deficiencies have been identified. One problem is the ending dates of regional rainy seasons. For example, the ending of the Meiyu is too early and the ending of the rainy season in North China is very late, until late September. Our diagnostic analysis in Part I has shown that one of the major reasons behind this unrealistic simulation is possibly due to inappropriate cloud-radiation transfer schemes. In the Yangtze-Huaihe River Basins, the model produced too little cloudiness while in North China excessive cloudiness was generated. Therefore, the realistic simulation of the Meiyu and Baiu is a great challenge (Sasaki et al., 2000). The second major difficiency is the overestimation of summer rainfall amounts, in particular in South China. Our sensitivity study has shown that this is caused by selecting different convective precipitation parameterization schemes. The Kuo’s scheme generally produces underestimated rainfall amounts. The overestimate of rainfall amounts in the ten-yr simulation is made possibly due to use of the MSF scheme which generally can produce relatively large rainfall amount. The three-year comparative experiment have shown (Figures 6 and 7) that the Betts-Miller can produce a more reasonable rainfall amount in China.

The ten-yr hindcast driven by the NCC/IAP T63 coupled model has shown some skill of predicting the major seasonal rain belts. The best predicted regions with high ACC are located in the eastern part of West China, Northeast China and North China where the CGCM has maximum prediction skills as well. This fact may reflect the importance of the large-scale forcing. One significant improvement of the prediction derived form RegCM_NCC is the increase of ACC in the Yangtze River valley where the CGCM have a very low, even a negative ACC. The real-time experimental seasonal predictions for 2001-2003 summer have preliminarily shown their role not only in more detailed presentation of precipitation patterns and major seasonal rain belts as a downscaling technique, but also in adding some new informations as a predictive tool compared to the driving CGCM. More experimental seasonal prediction needs to be done in the future to continuously improve its predictive capability, through reducing systematic errors and uncertainties.

The improved prediction of seasonal march of the summer monsoon and its associated rainfall amount, and patterns of the major seasonal rain belts in East Asia has long become a focus of the operational dynamical seasonal prediction in this region. However, in the Asian seasonal monsoon region, as discussed previously, the skill of the dynamical seasonal predictions with the AGCM or CGCM is relatively low. The nested regional climate model is capable to provide a more detailed and realistic detail of the monsoon activity and related monsoon rain belts. To achieve this goal, much work should be done in the future of improvement of representation of physical and dynamical processes in the models, a longer term hindcasts (at least 20 years) and validation, initialization of soil temperature and moisture, and the increase of spatial and temporal resolution (McGregor, 1997). The regional climate modeling in the East Asian monsoon region is a very difficult work, due to the unique climate features and the complex interaction of local forcing and remote or large-scale forcing. The East Asian summer monsoon climate is characterized by the following prominent features (Ding, 1994): (1) the earliest onset of the Asian summer monsoon over the South China Sea (SCS) and the Indo-China Peninsula occurring around mid-May or even earlier, with a sudden change in low-level and high-level winds, OLR, height and rainfall fields before and after the onset, which is characterized by the wind switch from low-level easterlies and high-level westerlies to low-level westerlise and high easterlies, the rapid growth of convection and rainfalls, and the eastward retreat of the subtropical high; (2) the seasonal march of the climatological summer monsoon displays a distinct stepwise northward and northeastward advance. Over East Asia, two abrupt northward jumps and three stationary periods have been identified; and (3) the noted East Asian rainy seasons such as the presummer rainy season in South China, the Meiyu/Baiu in China and Japan, and Changma in Korea occur normally during the stationary periods of the northward advance of the summer monsoon, but with a great inter-annual variability. In connection with these features, three controlling factors and related physical mechanisms are believed to be responsible for the sudden onset and prominent seasonal march of the East Asian summer monsoon: (a) The land-sea thermal contrast and effect of the elevated heat source of the Tibetan Plateau is a pre-condition for the abrupt onset of the Asian summer monsoon in the SCS and Indo-China

Peninsula through the rapid reversal of the meridional temperature gradient; (2) the arrival of the intraseasonal oscillations (ISO) provides a triggering mechanism, with the several phase-locking wet ISO phase; (3) the intrusion of mid-latitude troughs into the northern SCS and central and northern Indo-china Peninsula is another triggering mechanism to induce the convective activity through release of the potential instability, thus enhancing the monsoon trough there through the feedback process of meso-scale convective systems; and (4) the interaction of cold air from mid-and high latitudes and the monsoonal airflow plays a key role in determing the seasonal march of major East Asian rain belts and their precipitation patterns that are quite different from the climate conditions in the South Asian monsoon region where the weather and climate regions is basically controlled by the tropical processes during the summer monsoon season. The simulations of regional climate models have been generally successful for (2), while the simulations of (1) and (3) have relatively low skills. The reasons are manifold. First, in regional climate models currently used for the East Asian climate simulations and predictions, the physical parameterization schemes are in many respects inadequate, especially for the cloud-radiation transfer and the land surface process schemes. The new schemes in these aspects should better describe the land-sea thermal contrast and the effect of elevated heat sources of the Tibetan Plateau, otherwise the abrupt onset of the East Asian summer monsoon and formation of the seasonal rain belts are unlikely to be well simulated and predicted. In addition, the ISO formation and propagation are closely related to cloud-radiation-land surface feedback processes. So, its realistic simulation and prediction also depends upon the performance of cloud-radiation-land surface processes parameterization schemes. The ISO is very essential in modulation of monsoon rainfall espisodes and triggering occurrence of a rainy episode.

The realistic representation of interaction of cold air and tropical monsoonal airflow in the model needs a larger domain, so that the model can appropriately cover the mid-and high latitude and the tropical regions. This requirement will make the domain a continental scale. In addition, the seasonal prediction of tropical cyclones in the western North Pacific, including its frequency, landing number and preferred paths, is also desirable. Therefore, a regional ocean model and oceanic data initialization in this oceanic region should be developed and coupled with the nested regional climate model in the future.

Impact of Soil Moisture on Seasonal Predictability in the Northern Eurasia

V.P.Meleshko and T.V.Pavlova

Voeikov Main Geophysical Observatory

Introduction

Prediction on seasonal time scales rests on the conception that there are slower components in the surface boundary conditions that through interaction mechanism can transfer predictable signal to the atmosphere. The SST anomalies are the major slow component of climate system that has been proved to be an important for atmospheric prediction on seasonal and larger time scales. It has been shown in modeling studies that SST anomalies affect tropical and some regions of winter mid latitude atmosphere, and they appear to be predictable up to a few seasons. However, the impact of SST anomalies on atmosphere is rather small in the summer mid latitudes or do not manifest itself in the some regions of mid latitudes. Meanwhile some studies indicate that another slow component, soil moisture, dominates over the SST in mid latitude summer, and control some near surface variables /Koster, and Suarez, 1999, 2001/. This implies that the proper use of soil moisture data in the forecast system may increase seasonal forecast skill. Systematic data on soil moisture, however, are not available from existing the observational network. This problem might be resolved in near future through the enhancement of existing observing system and improvement of land data assimilation technique. The purpose of the study is to evaluate the potential for improvement of seasonal prediction of the surface air temperature and precipitation in the northern Eurasia, when the soil moisture is initialized in the prediction system.

Model description

The numerical experiments were conducted using Voeykov Main Geophysical Observatory (MGO) climate model, which includes an atmospheric GCM coupled to a energy and water balance model of the continents /Shneerov et al., 1997, Shneerov et al., 2002/. The atmospheric GCM with different spectral resolution (T30L14 and T42L14) were used in the study. Both versions incorporate similar parameterization of major physical processes and its feedbacks:

- terrestrial and solar radiation with diurnal cycle and computation of varying radiative properties of clouds;
- prediction of layer and convective clouds with random overlapping;
- Tiedtke parameterization of deep and shallow convection;
- dependency of turbulent transfer of heat, moisture and momentum on stability profile using similarity assumption;
- gravity wave drag forcing due to topography.

The land surface is assumed non-homogeneous in each grid sell. It consists of mixture of different types of vegetation and bare soil. Roughness of the land surface depends on vegetation type and topography. Four soil layers of 3 m depth are considered in the model. These account for soil water storage and desiccation, and heat exchange between soil layer and the atmosphere. The water holding capacity of the total soil layer varies regionally and it defines the soil moisture memory. Evolution of soil moisture is determined by transpiration processes, hydraulic conductivity, surface and ground runoff. Land surface heat and water balance components are validated against available observation over the major watersheds of the world with particular attention to watersheds of the northern Eurasia.

Experiment design

The study is performed under assumption that the AGCM coupled to land surface processes and the observing system, which provides full set of variables in the atmosphere and on the land, are perfect /Meleshko et al., 2001/. To evaluate variability of the soil moisture generated by the MGO AGCM T30L14 and to examine its impact on the variability of surface air temperature and precipitation in the northern Eurasia, two multi-year simulations were conducted with SST prescribed from observation for the period 1949-1999. In the first run the atmospheric and land components of the model were coupled. In the second run the soil moisture was prescribed. The land hydrology was decoupled from the atmosphere and this allowed evaluation of impact of soil moisture anomalies on variability of surface air temperature and precipitation. The prescribed monthly soil moisture is model climatology computed from the first multiple run. Taking into account that cryosphere plays an important role in the soil moisture memory, and coupling of the land hydrological processes and the atmosphere varies over different regions of the northern Eurasia, the analysis was conducted for major watersheds.

To assess the enhancement of potential predictability of surface air temperature and precipitation in the northern Eurasia when initialized soil moisture is used, multiple simulations were conducted using MGO AGCM T42L14 with observed SST for period 1979-1999. Here potential predictability implies the largest attainable level of predictability on assumption that model is perfect. The atmosphere, soil water and temperature are initialized, and SST boundary condition is exactly determined in the course of the AGCM integration /*Anderson et al., 1999*/.

The result of this run was adopted as the perfect state of the global atmosphere and land surface. Further, two sets of ensemble predictions were performed for the same time period 1979-1999. Each ensemble incorporates six members obtained from slightly perturbed initial states of the atmosphere using breeding technique.

The first set of ensemble predictions of 10-days and monthly means of different quantities up to 4 months used initialized soil moisture that were obtained from perfect model simulation. In the second set of ensemble predictions, soil moisture anomalies were suppressed by use of soil moisture climatology computed from the perfect model simulation. Comparing two sets of ensemble runs, one can determine whether improvements in prediction of surface air temperature and precipitation could be achieved ever some watersheds of the northern Eurasia. Of particular importance is the development of prediction capability of near surface variables including soil moisture in upper soil layer spanning from spring to summer. Since snow cover in spring significantly effects interaction between land surface and the atmosphere, predictions were conducted from four dates of each year and spanning four months: 1st April, 1st May, and 1st June for period 1979-1999. The following seven watersheds located in different climatic zones of the northern Eurasia were selected for prediction analysis: Baltic system, Dnepr-Don, Pechora-N.Dvina, Volga-Ural, Ob, Enisey, and Lena.

Results of experiments

The impact of soil moisture anomalies on the predictability of the atmosphere depends on a number of factors and two of them appear to be most important. That is extension and magnitude of the soil moisture anomaly and intensity of interaction between land surface and the atmosphere, mainly through evaporation process and vertical transport of water vapor in the atmosphere. These determine persistency of soil moisture anomaly and its influence on variability of some near surface atmospheric variables in the warm season when interaction between the land surface and the atmosphere is large.

Assessment of soil moisture memory over watersheds from March to September derived from computation of lagged temporal correlation of soil moisture anomalies within soil layers of different depths showed that high persistency of correlation up to four months was found over four watersheds (Baltic, Dnepr-Don, Volga-Ural and Ob). Over three other watersheds (Pechora-N.Dvina, Enisey and Lena) the soil memory becomes very short from April to June due to effect of snow cover, its subsequent melt and runoff. Thus, the latter three watersheds appear to have low potential for enhancement of predictability in spring and beginning of summer.

Simulation of the atmosphere coupled to land surface model show that land surface processes significantly affect magnitude of the surface air temperature anomalies over some watersheds in summer. Simulation with soil moisture climatology, as initial condition, indicates that the 10-day mean anomalies become reduced over five watersheds by 20-50%. The impact of soil moisture anomalies on surface air temperature is negligible over two watersheds adjacent to North Atlantic. Similar percentage effect is obtained for monthly mean anomalies of temperature. The influence of soil moisture anomalies on precipitation variability is not so apparent over watersheds in comparison with that on surface air temperature variability. This concerns both 10-days and monthly precipitation variability.

Temporal co-variances between sol moisture, temperature and precipitation indicate that the land surface soil moisture does not affect essentially on the atmosphere over the northern watersheds (Baltic, Pechora-N.Dvina, Enisey and Lena) during the summer. And this is due to relatively cold condition in these regions and this results in weak land feedback on the atmosphere. However, over three other watersheds (Dnepr-Don, Volga-Ural and Ob) land produces noticeable influence on the atmosphere beginning from May.

The ensemble simulations, starting from April with initialized soil moisture and soil moisture taken from climatology did not show essential differences in skill of predictions for monthly and 10-days means of surface air temperature and precipitation over the northern Eurasia. But the differences become apparent, if prediction starts from June. For this reason analysis of results was concentrated on simulations from the latter date.

In analyzing the results of simulation it is important to note that predictability of atmospheric regimes usually does exceed one month in the middle latitudes. It was found that some improvement in predictability over Russia was achieved for monthly mean surface air temperature for the 10-days means in prediction up to 20 days when soil moisture was initialized. But no significant differences were observed in predictability of monthly and 10-days means of precipitation when different initial conditions for soil moisture were used. The regions producing the largest and minimal impact on surface air temperature is considered in detail.

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Recent GFDL Activities in Model Development and Climate Assessment using Ensemble Approaches

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The recent history of model development efforts at GFDL is reviewed. The current activities are focused on the design and implementation of a flexible modeling system that supports multiple physical parameterizations and dynamical cores. This system makes use of an `exchange grid' formulation that facilitates the coupling of atmospheric, oceanic and land components,all of which can have different grid structures. The principal numerical and physical schemes incorporated in the present version of this modeling system are described.

The capability of the model in reproducing various observed climatological fields is assessed by summarizing the performance measures (which include spatial correlation, root-mean-square error, and standard deviations from spatial means) in compact diagrams. These statistics are compared with those derived from previous GFDL models, as well as models developed at other centers. These evaluations indicate that the current GFDL model can simulate many atmospheric fields with a good degree of fidelity.

Results are presented from a ten-member ensemble integration of a recent version of the GFDL atmospheric GCM subjected to month-to-month variations of the global SST field from 1950 to present. It is seen that the simulated ensemble-mean geopotential height anomaly patterns in the Pacific-North American sector bear a considerable resemblance to the observations during prominent warm El Nino events (in particular, the 1982/83 and 1997/98 episodes). The comparison between model and observations is less favorable during weaker

events and La Nina episodes. The strength of the SST forcing in
the tropical Pacific also exerts notable influences on the degree of variability (or `spread') among individual members of the ensemble. The stronger El Nino events are associated with a smaller spread between the ten samples, thus yielding a stronger ensemble-mean signal.

The impact of El Nino on precipitation anomalies in various tropical and subtropical regions is studied using both model output and observational data. The observed correlations between El Nino and rainfall fluctuations over India, southeast Asia, northern Australia and southern United States are mimicked by the current GFDL model. These relationships leads to a higher degree of potential predictability in these regions, as demonstrated by computing the relative magnitudes of `external' (due to fluctuations of ensemble means) and `internal' (due to spread among members of the ensemble) variances at individual sites.

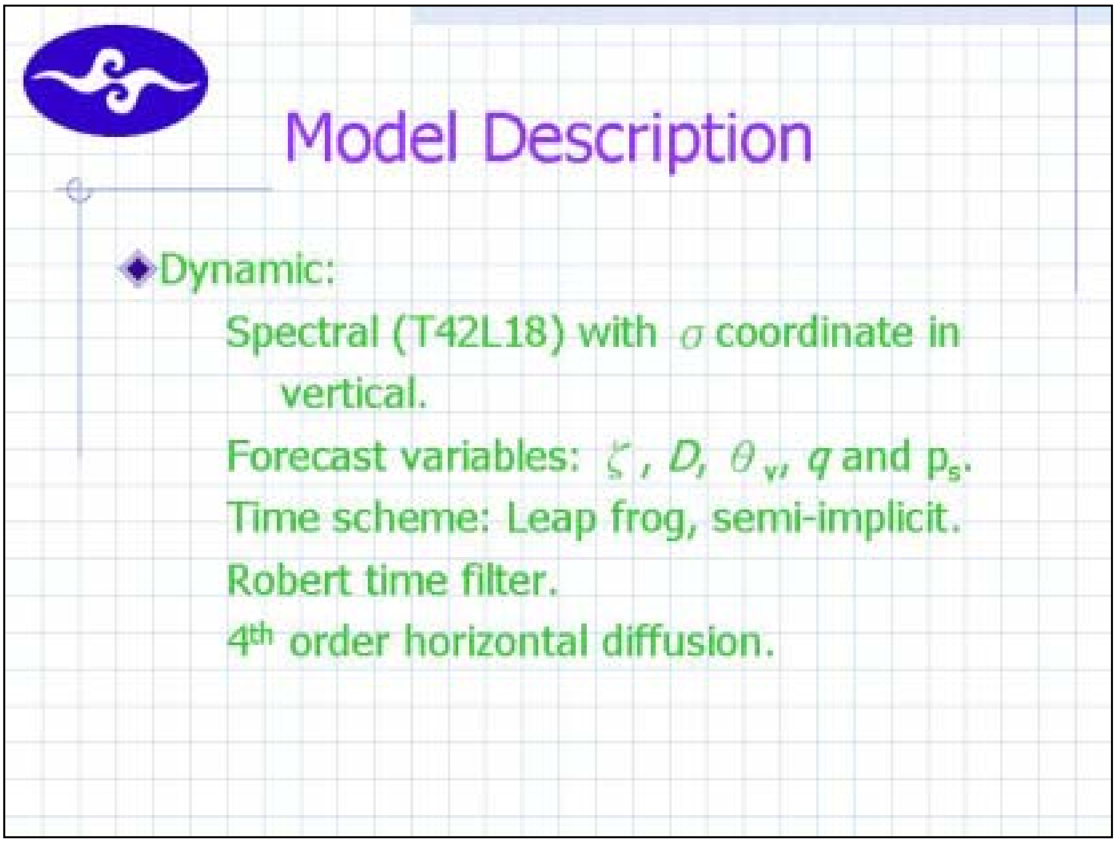
A description is given on the collaborative efforts between GFDL and various research and operational centers. Updated ensemble integrations are routinely performed by incorporating the most recent SST observations. These GFDL products are shared with similar output from other members of the NOAA Seasonal Diagnostics Consortium. The main goals of this project are to advance our understanding of seasonal predictability, and to seek attribution of observed seasonal climate anomalies on a near real-time basis. Sample results from this endeavor are presented, including the hindcasting of the global surface temperature anomaly of the 2002/03 winter by various participating models, and the comparison of skill of these models in replicating the observed historical temperature variations during the 1951-95 period.

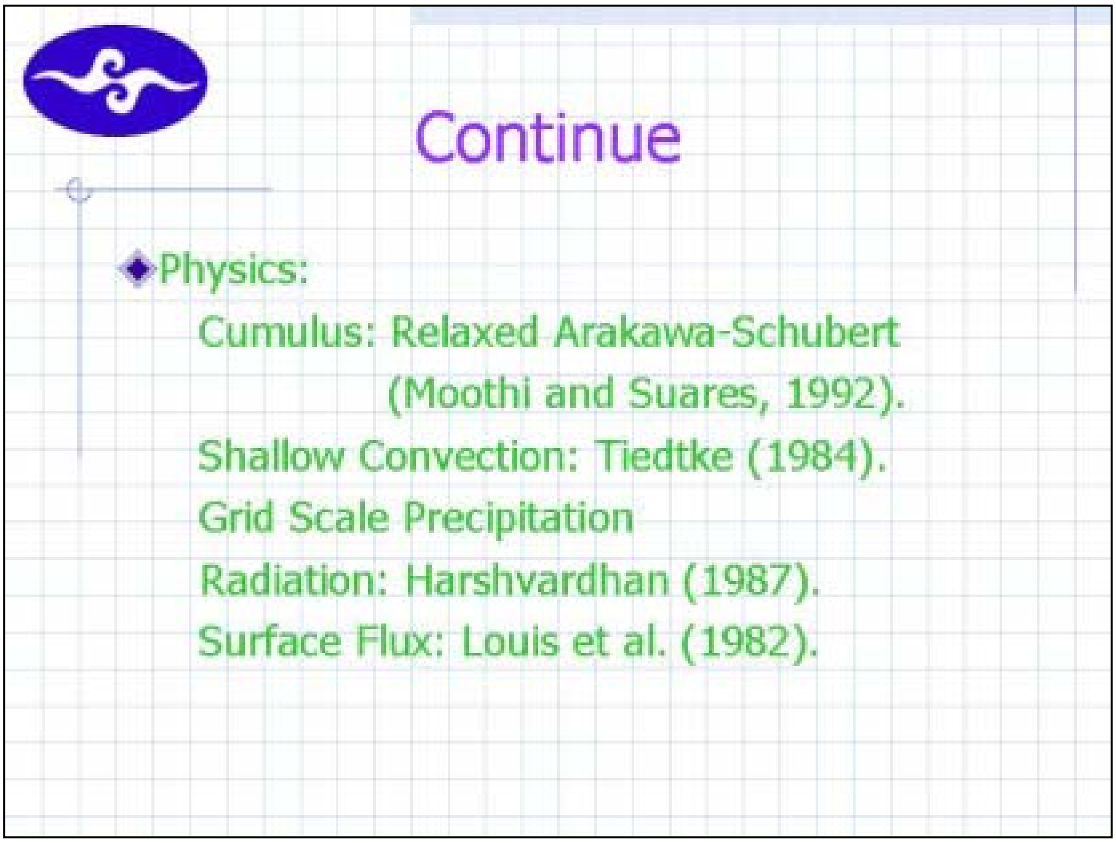
Other modules (ocean, land, sea ice, chemistry) of the Earth System Model under development at GFDL are described. Preliminary results from a coupled ocean-atmosphere model are shown. Plans are discussed for upgrading the atmospheric model component, with new parameterization schemes for convective and boundary layer processes, and improved representation of the stratosphere.

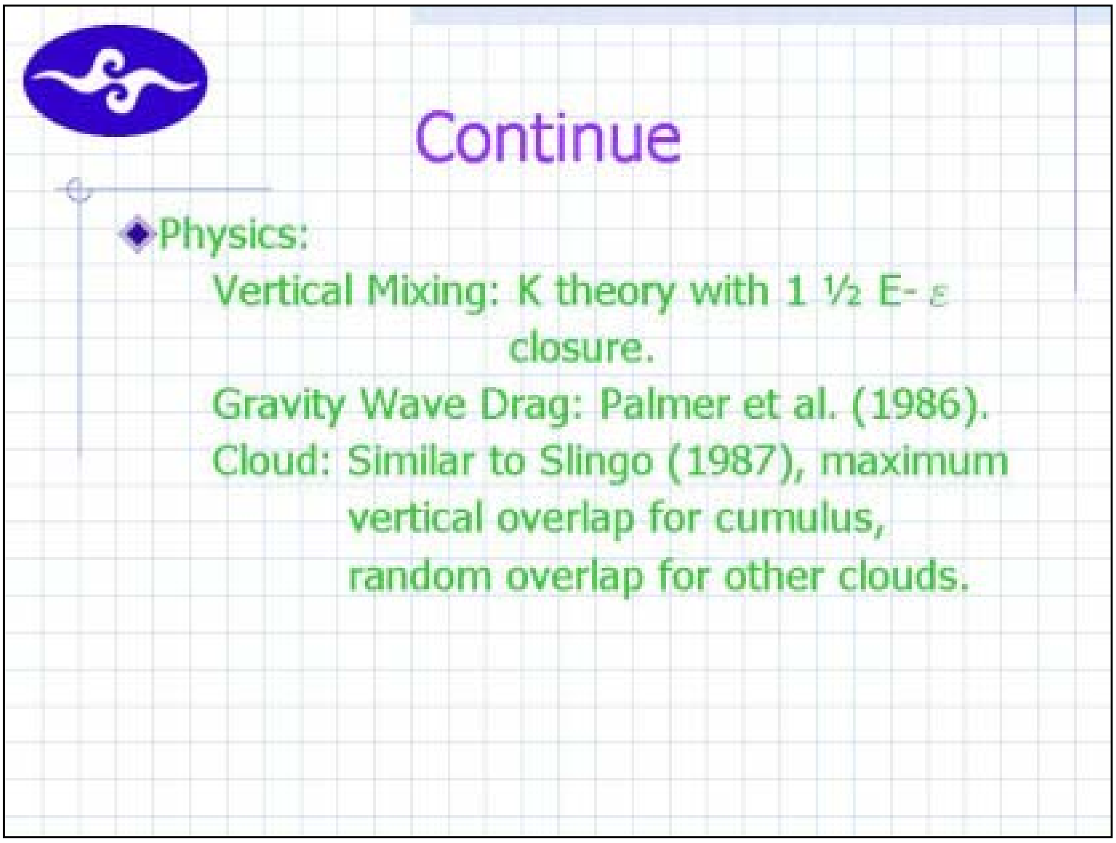
A Comparison of Model's Ensemble Simulation between CWB GFS and ECHAM4.5

Jyh-Wen Hwu and Chun-Rhu Jen

Research and Development Center
Central Weather Bureau




Continue
Physics:
Cumulus: Relaxed Arakawa-Schubert
(Moothi and Suares, 1992).
Shallow Convection: Tiedtke (1984).
Grid Scale Precipitation
Radiation: Harshvardhan (1987).
Surface Flux: Louis et al. (1982).

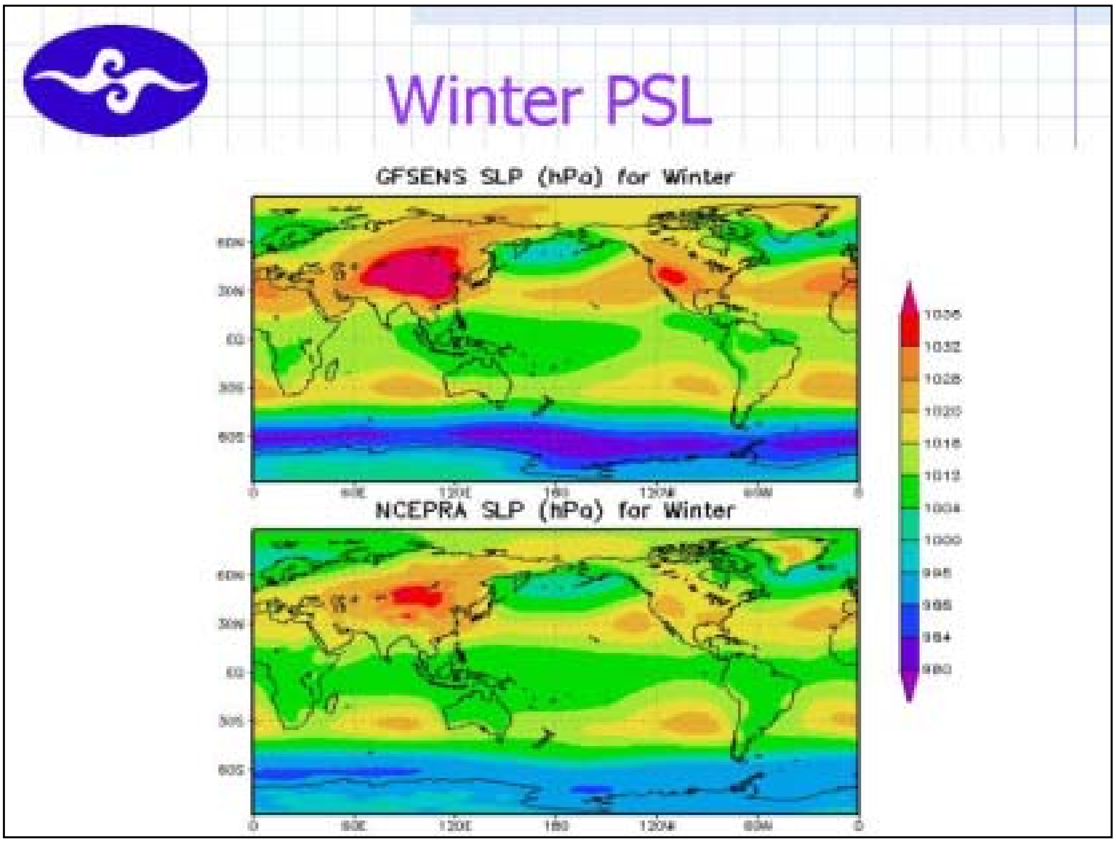

Continue
Physics:
Vertical Mixing: K theory with 1 ½ E-ε
closure.
Gravity Wave Drag: Palmer et al. (1986).
Cloud: Similar to Slingo (1987), maximum
vertical overlap for cumulus,
random overlap for other clouds.

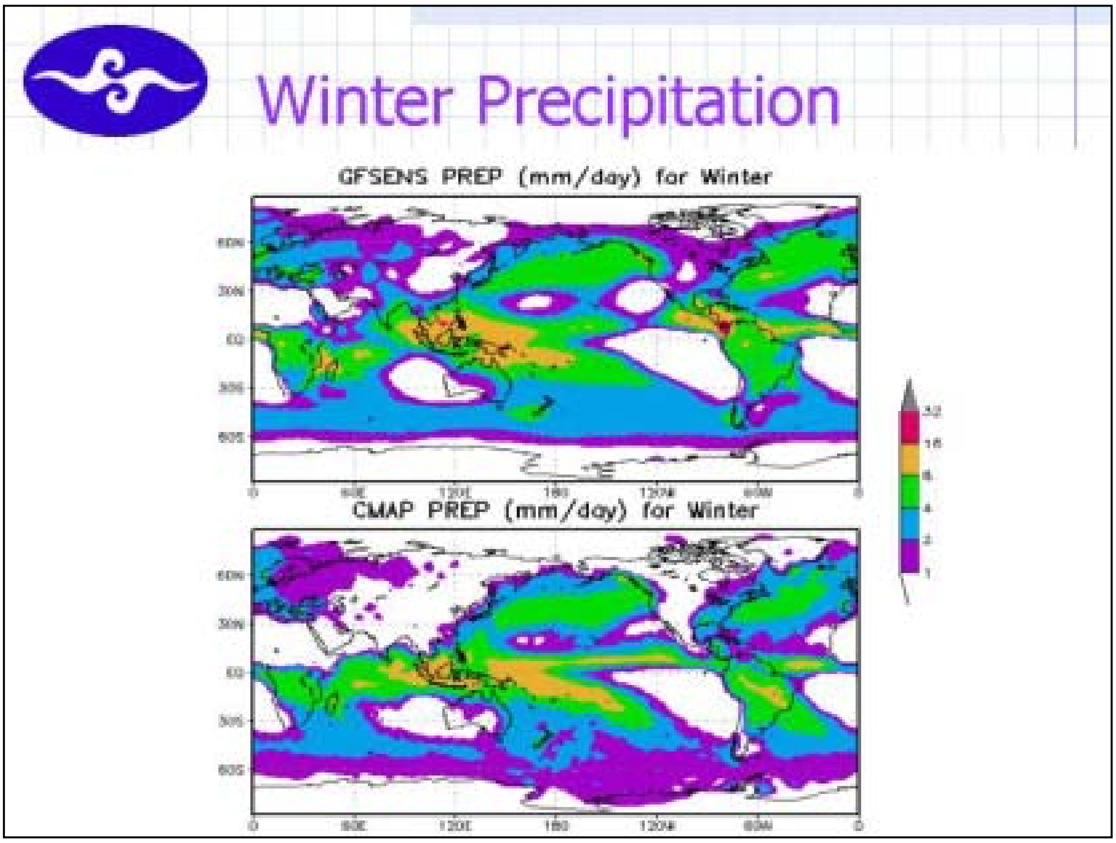
Experiment Design

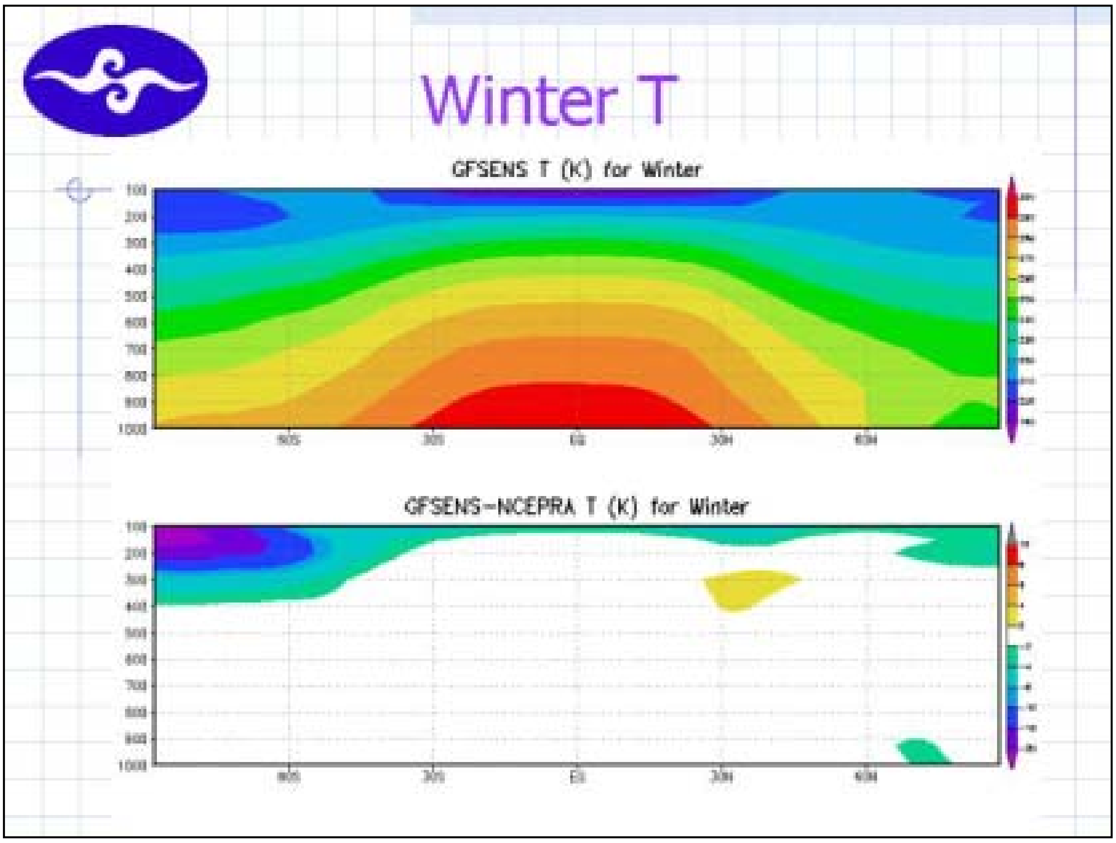
- SST: 1. 1950/01-1978/11→Reconstructed Reynolds
  2. 1978/12-1996/ 3→ PCMDI AMIP2
  3. 1996/4-1999/12→ NCEP OISST
- Others following the guideline of AMIP2.
- Ten members.
- Integrate from 1949 to 2001.
- 6 hours output, averaged into daily and monthly.

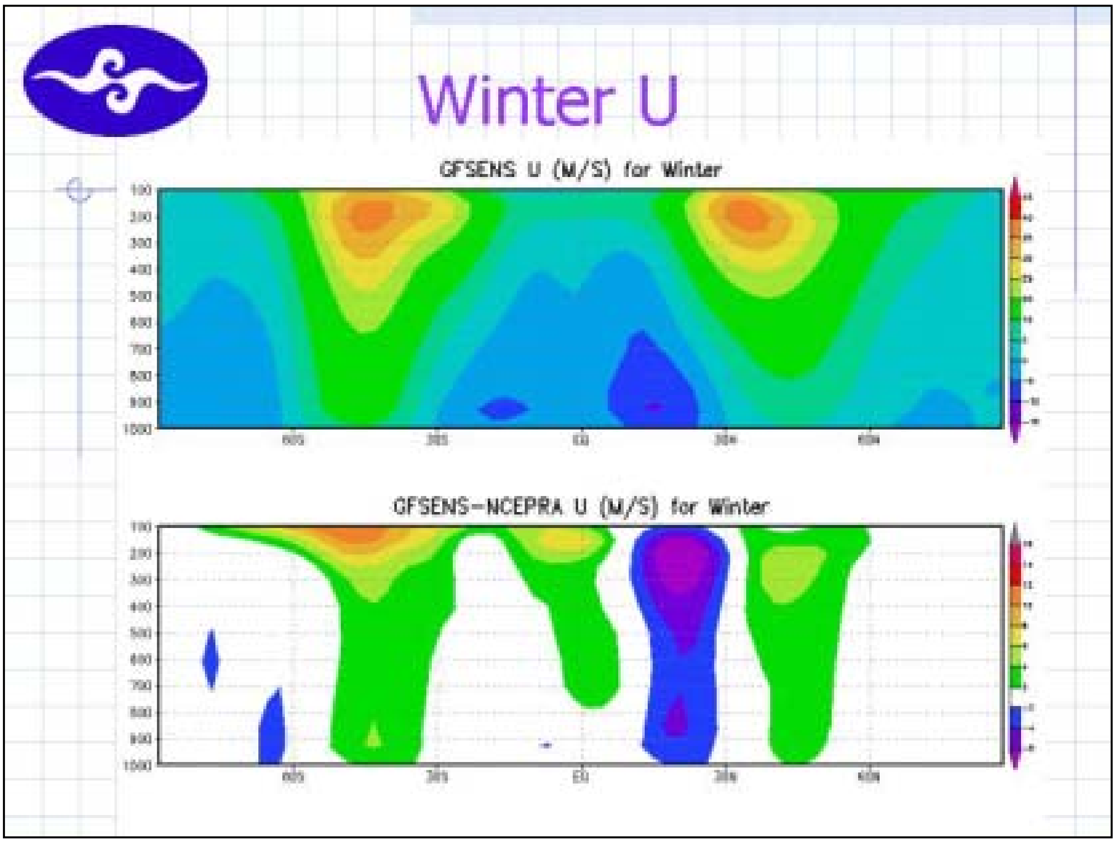
Data for Comparison

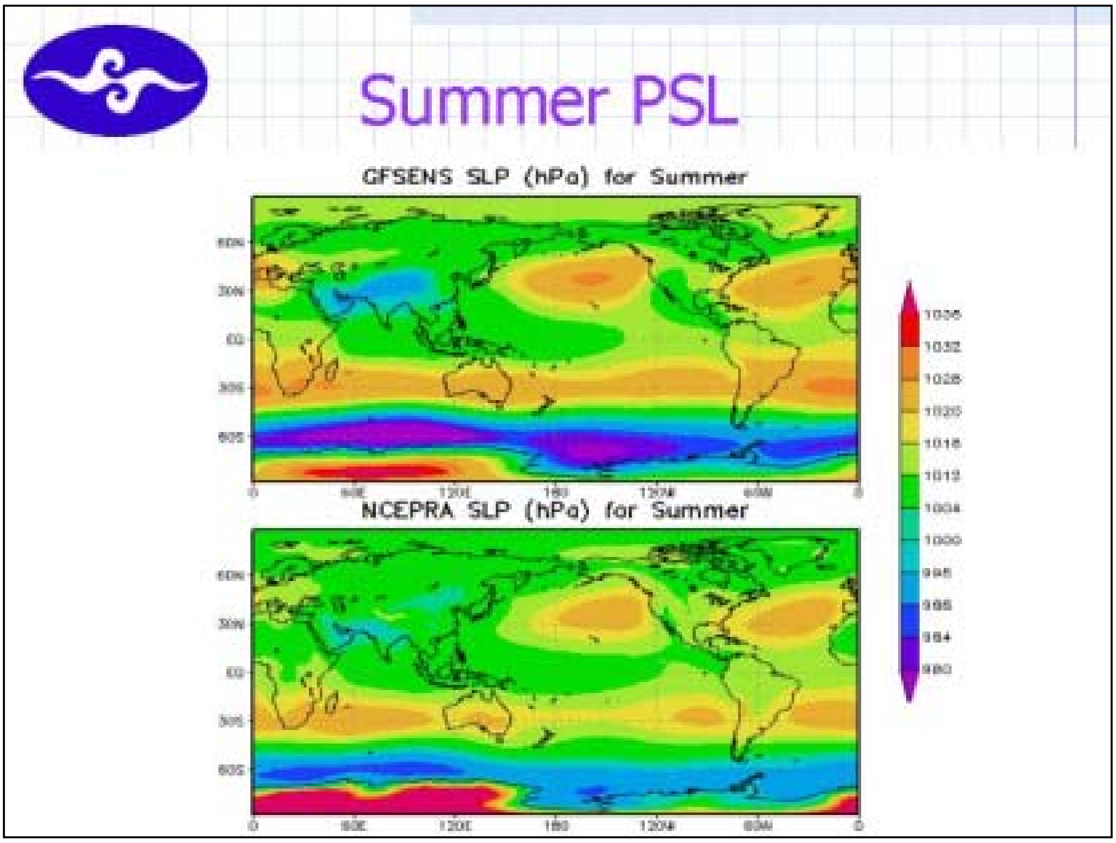
- NCEP/NCAR Reanalysis (1950-1999).
- CRU: Climate Research Unit, Univ. of East Anglia, UK.
- CMAP: CPC.
- ECHAM4.5 24 members, IRI.

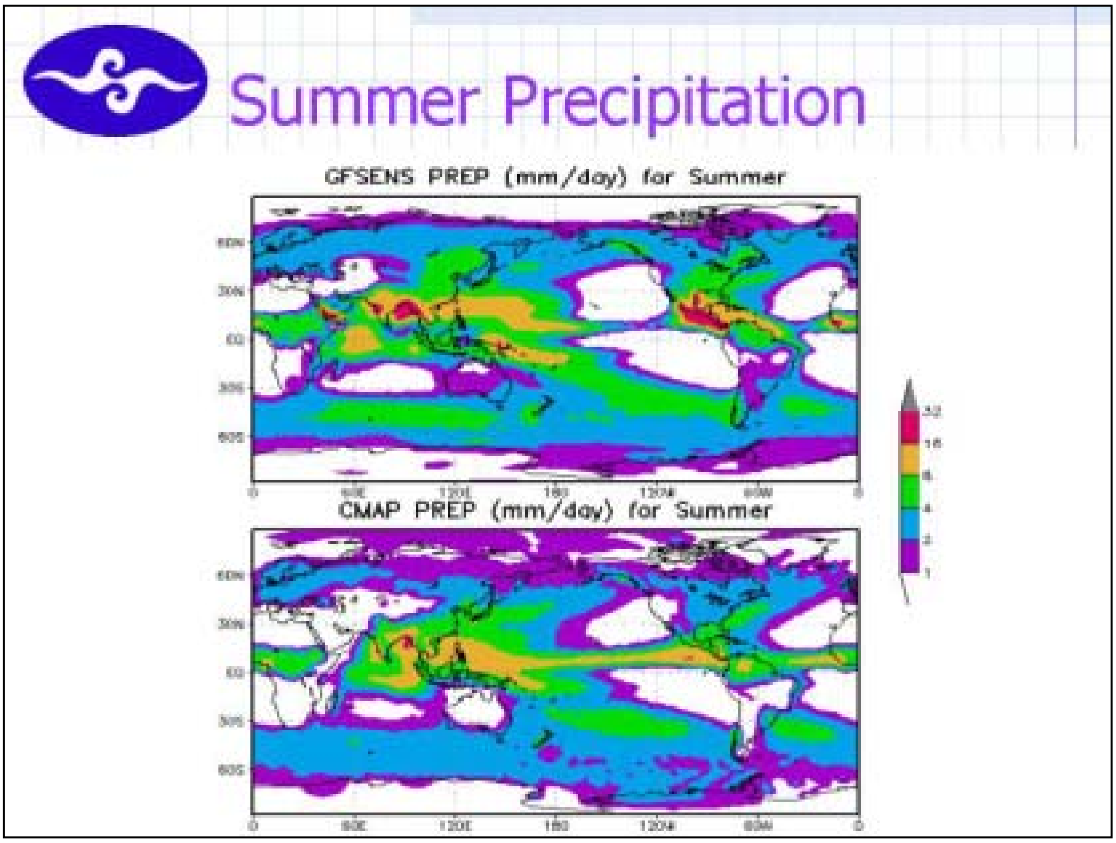

Winter PSL
GFSENS SLP (hPa) for Winter
NCEPRA SLP (hPa) for Winter

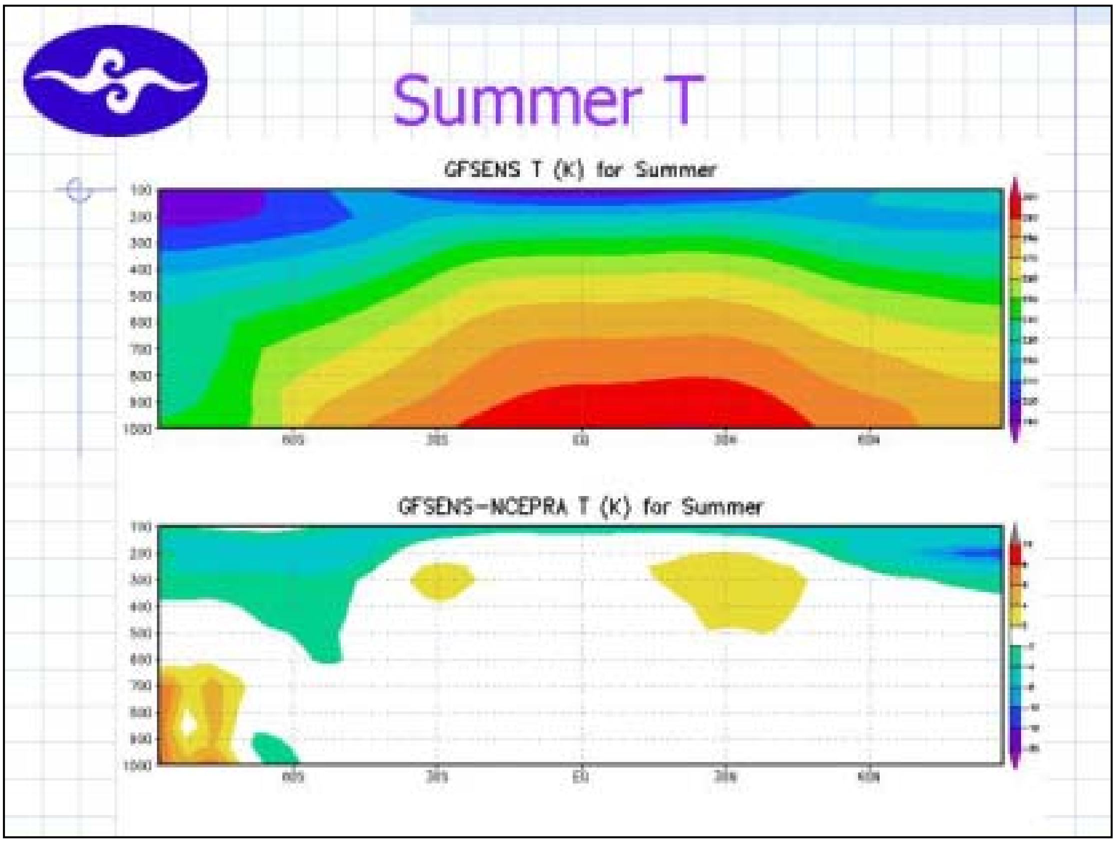

Winter Precipitation
GFSENS PREP (mm/day) for Winter
CMAP PREP (mm/day) for Winter

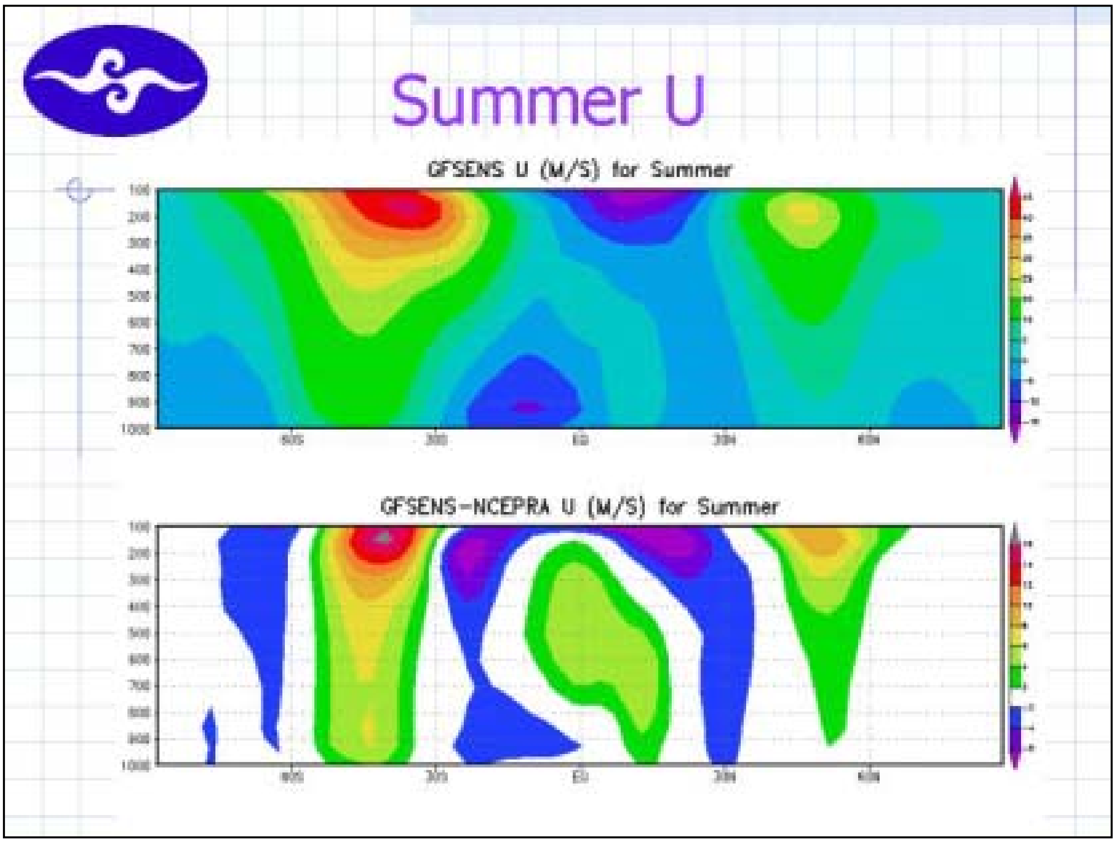

Winter T
GFSENS T (K) for Winter
GFSENS-NCEPRA T (K) for Winter

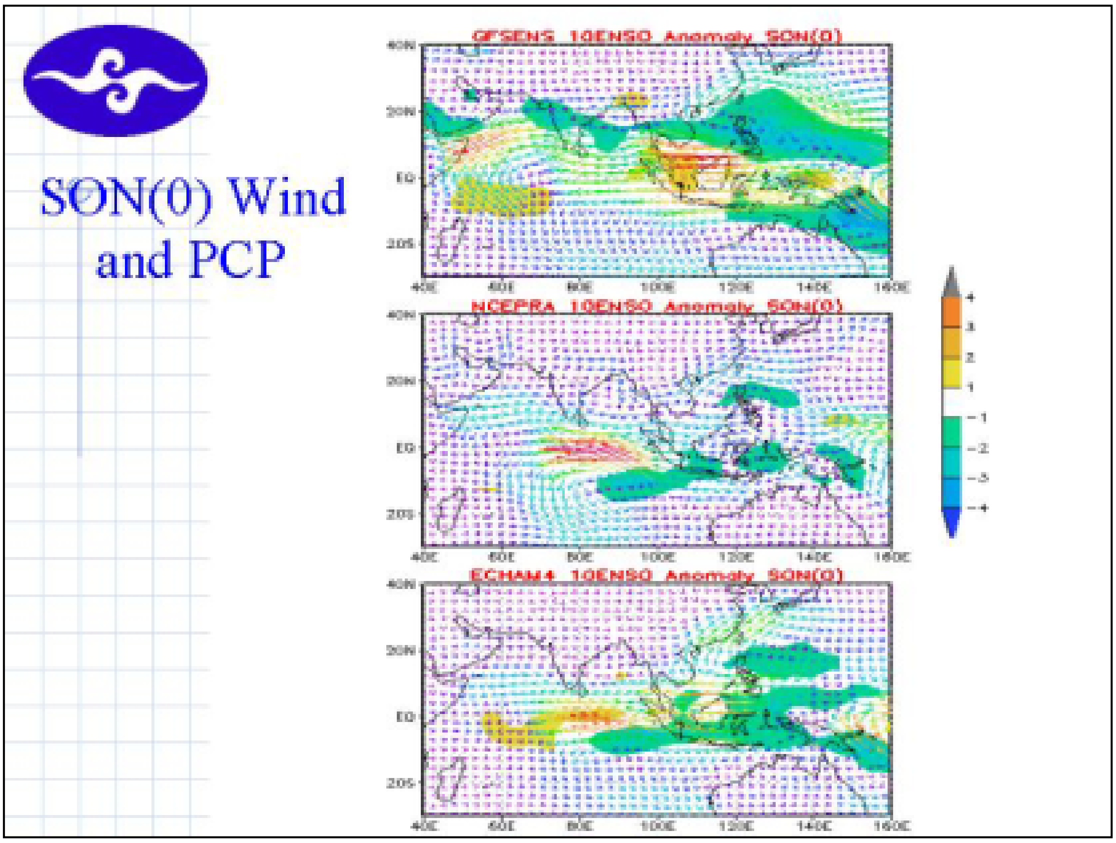

Winter U
GFSENS U (M/S) for Winter
GFSENS-NCEPRA U (M/S) for Winter

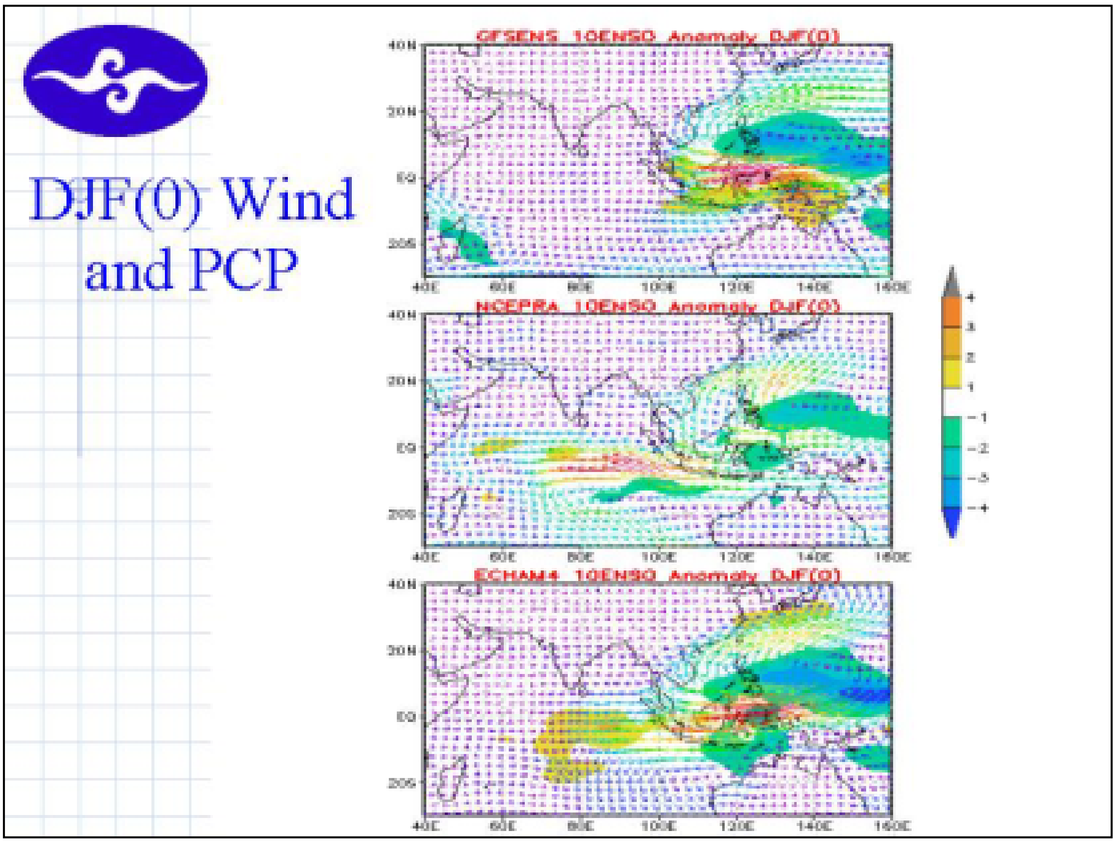

Summer PSL
GFSENS SLP (hPa) for Summer
NCEPRA SLP (hPa) for Summer

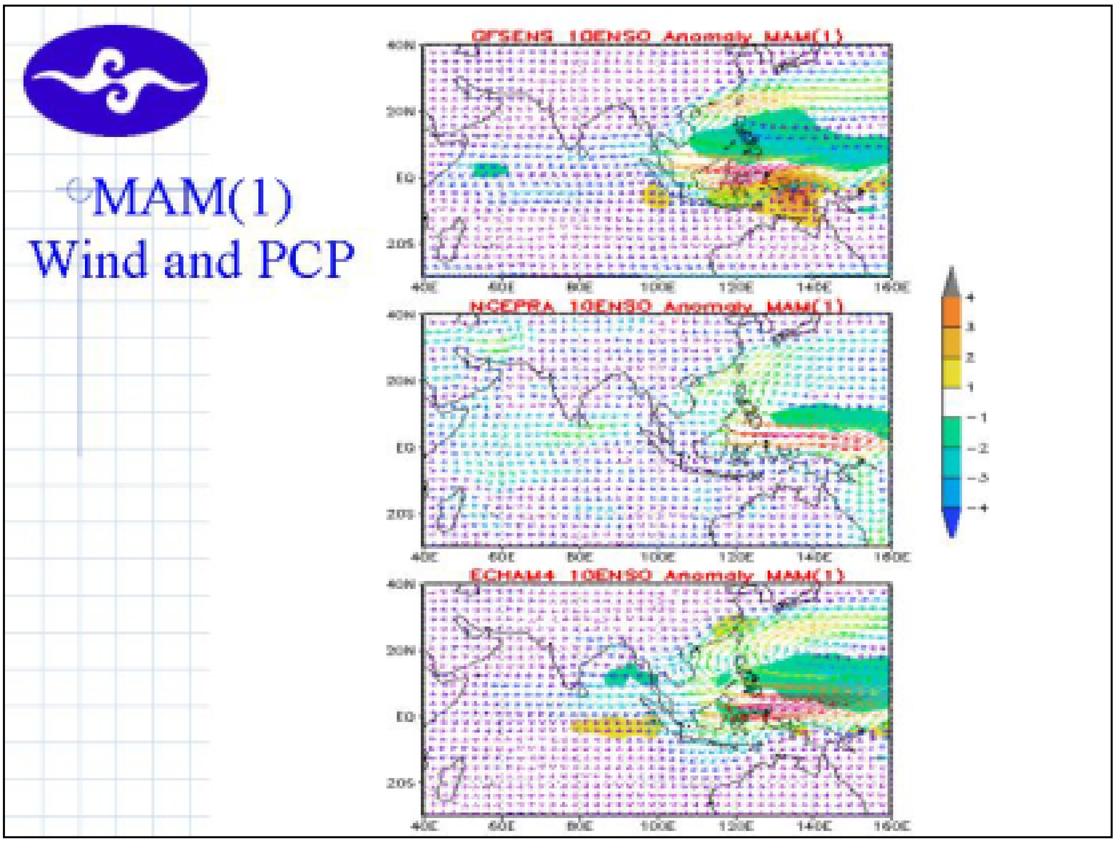

Summer Precipitation
GFSENS PREP (mm/day) for Summer
CMAP PREP (mm/day) for Summer

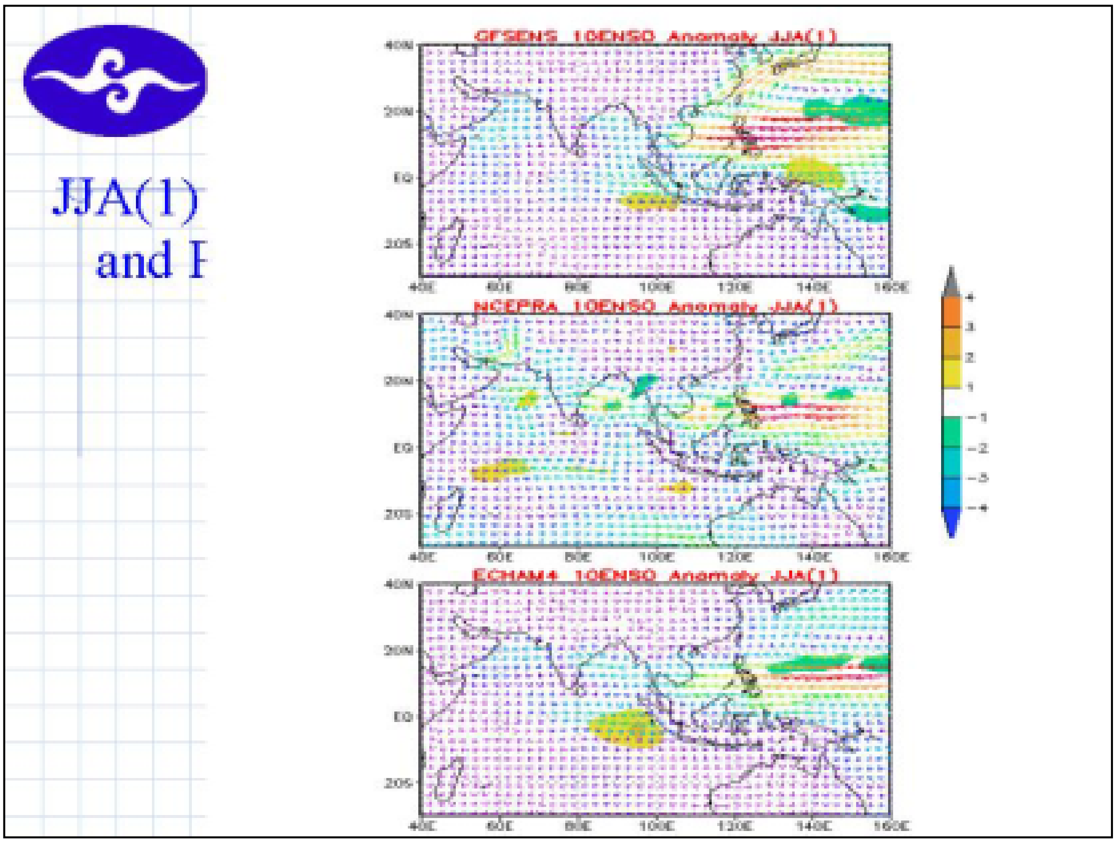

Summer T
GFSENS T (K) for Summer
GFSENS-NCEPRA T (K) for Summer

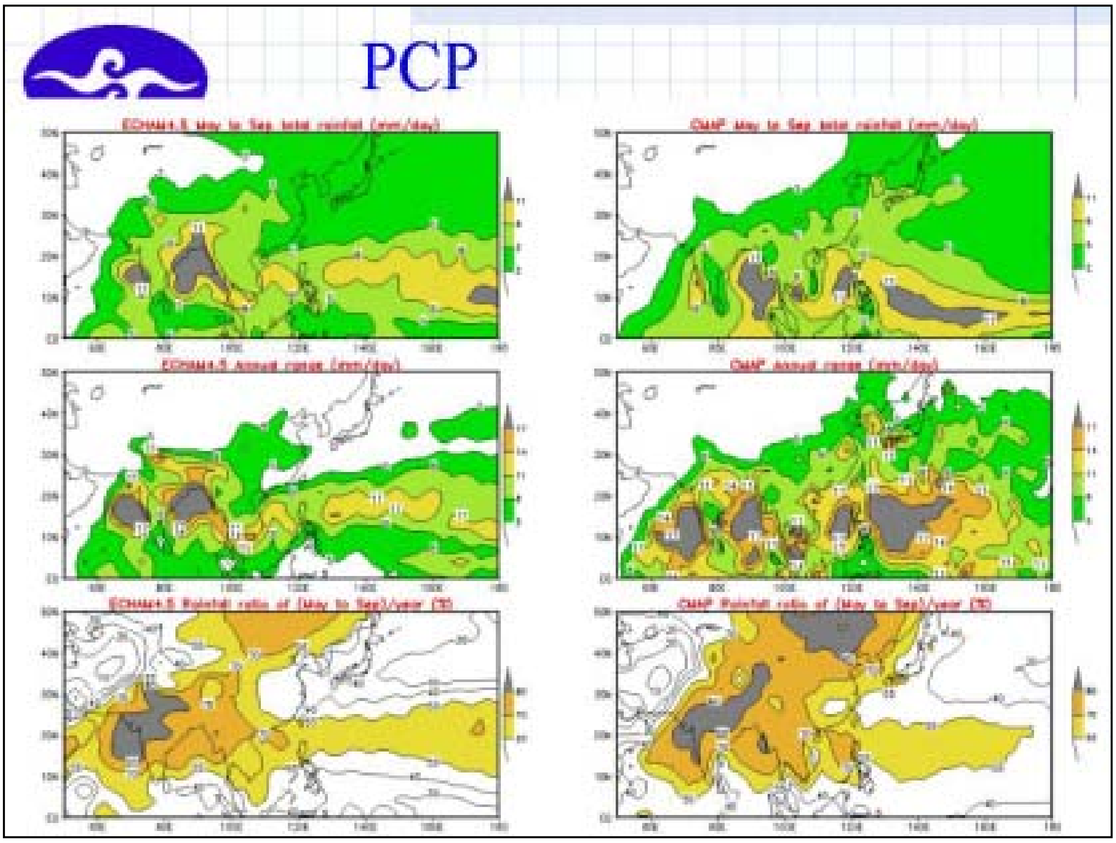

Summer U
GFSENS U (M/S) for Summer
GFSENS-NCEPRA U (M/S) for Summer

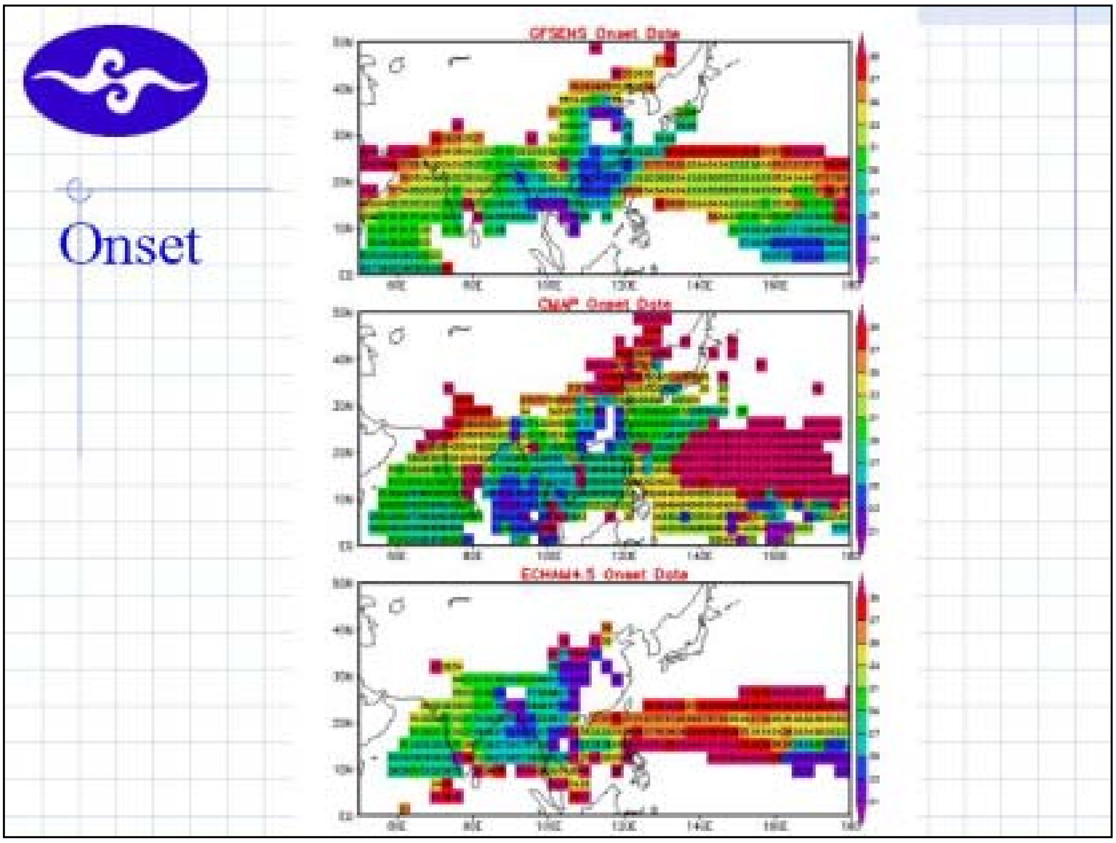

SON(0) Wind
and PCP
GFSENS 10ENSO Anomaly SON(0)
NCEPRA 10ENSO Anomaly SON(0)
ECHAM4 10ENSO Anomaly SON(0)

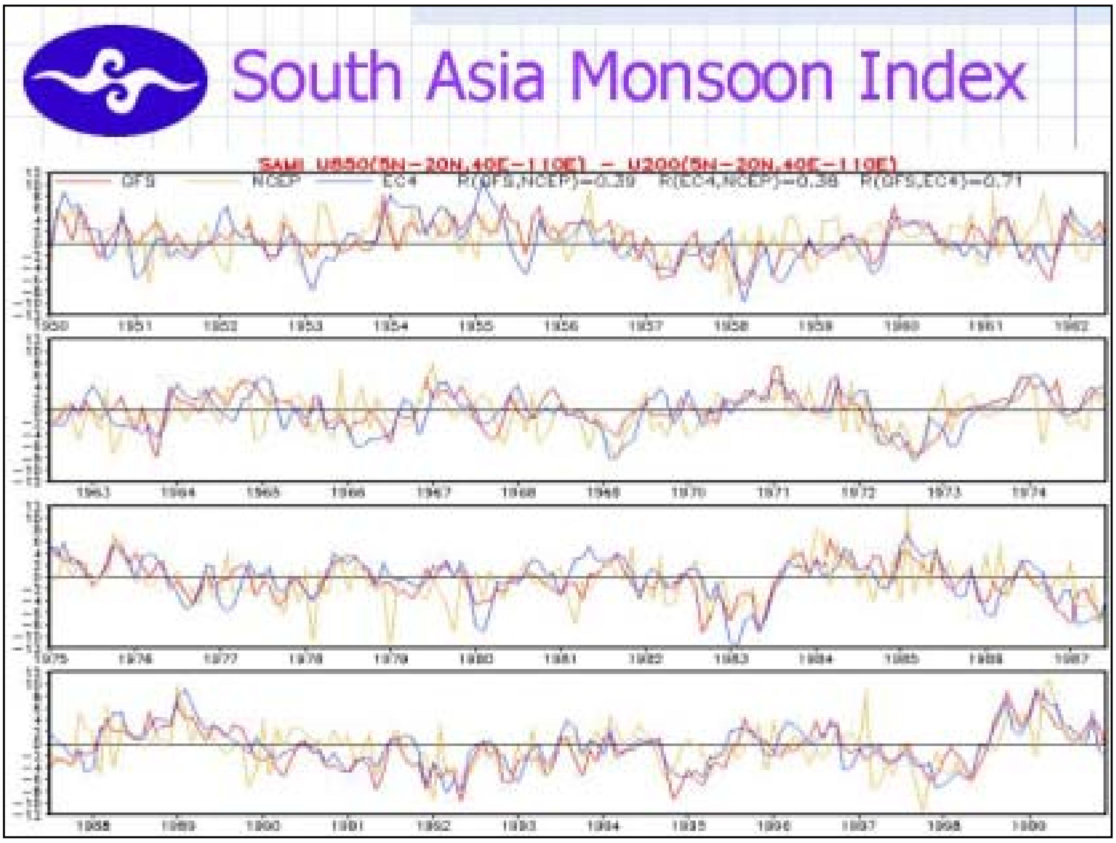

DJF(0) Wind
and PCP
GFSENS 10ENSO Anomaly DJF(0)
NCEPRA 10ENSO Anomaly DJF(0)
ECHAM4 10ENSO Anomaly DJF(0)

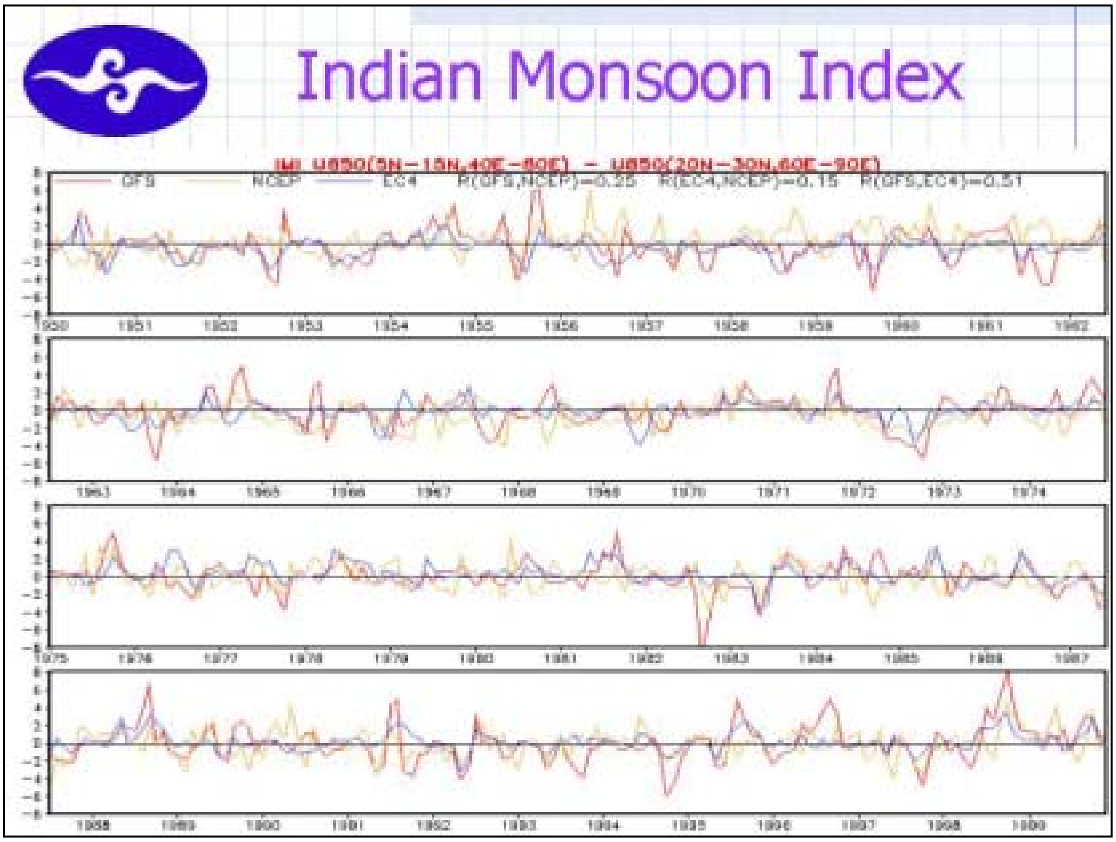

MAM(1)
Wind and PCP
GFSENS 10ENSO Anomaly MAM(1)
NCEPRA 10ENSO Anomaly MAM(1)
ECHAM4 10ENSO Anomaly MAM(1)

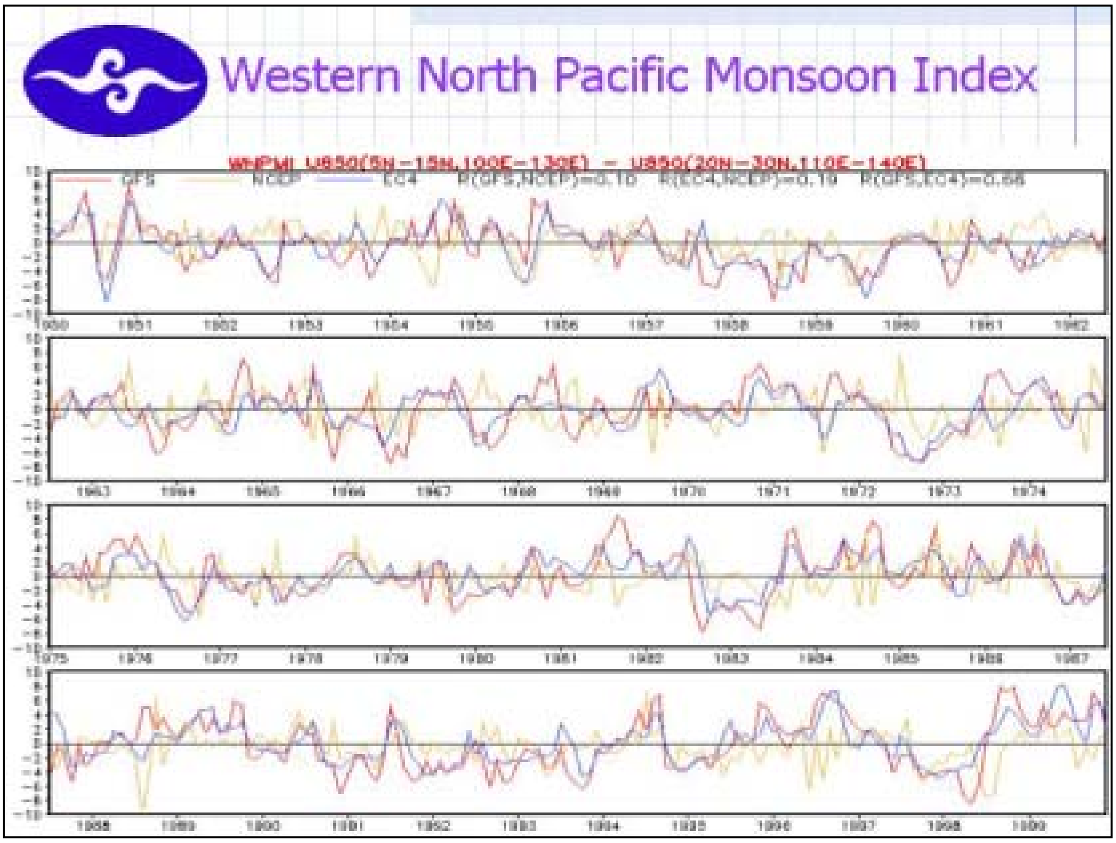

JJA(1)
and I
GFSENS 10ENSO Anomaly JJA(1)
NCEPRA 10ENSO Anomaly JJA(1)
ECHAM4 10ENSO Anomaly JJA(1)

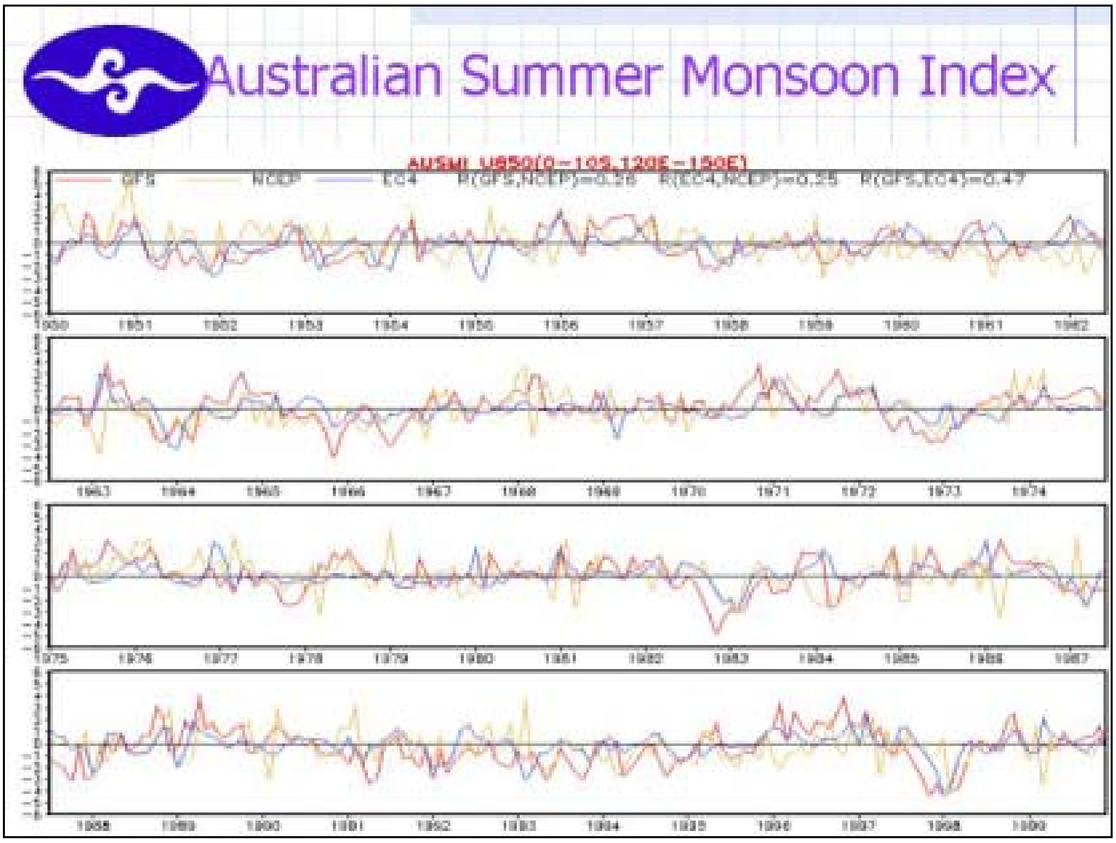

PCP
ECHAM4.5 May to Sep total rainfall (mm/day)
CMAP May to Sep total rainfall (mm/day)
ECHAM4.5 Annual range (mm/day)
CMAP Annual range (mm/day)
ECHAM4.5 Rainfall ratio of (May to Sep)/year (%)
CMAP Rainfall ratio of (May to Sep)/year (%)

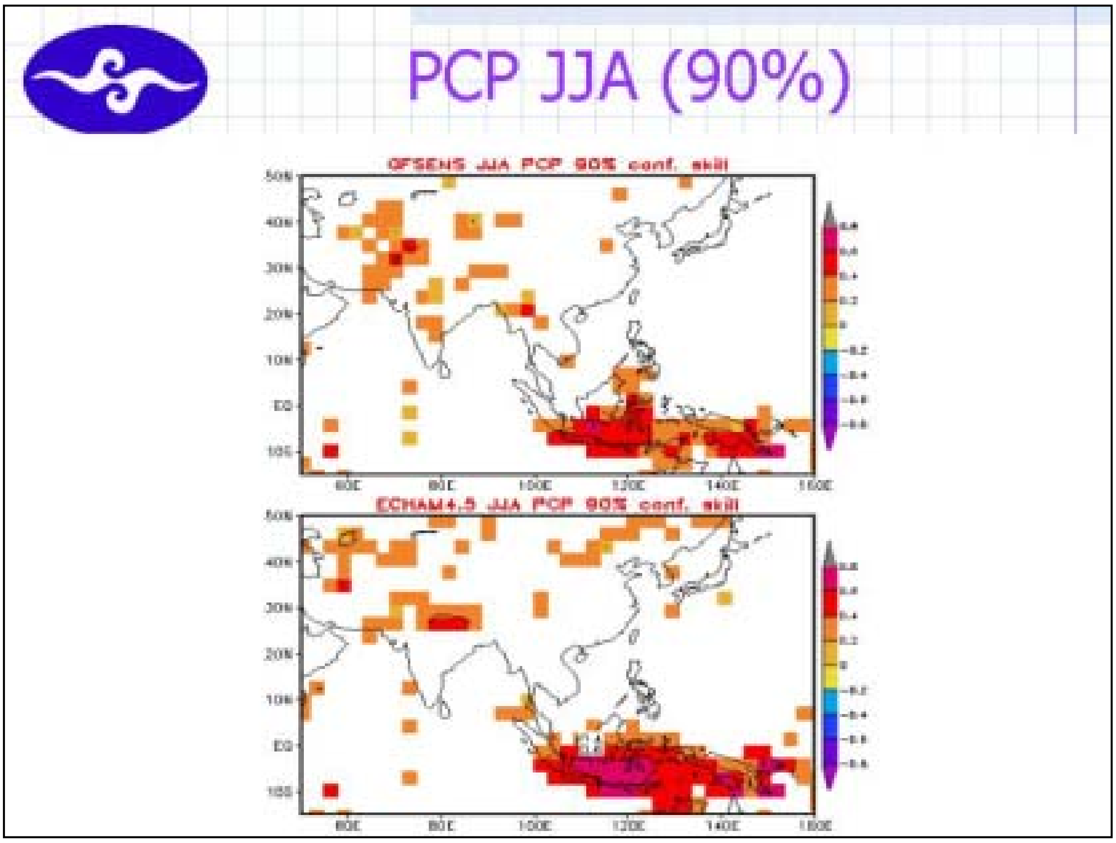

Onset
GFSEHS Onset Date
CMAP Onset Date
ECHAM4.5 Onset Date

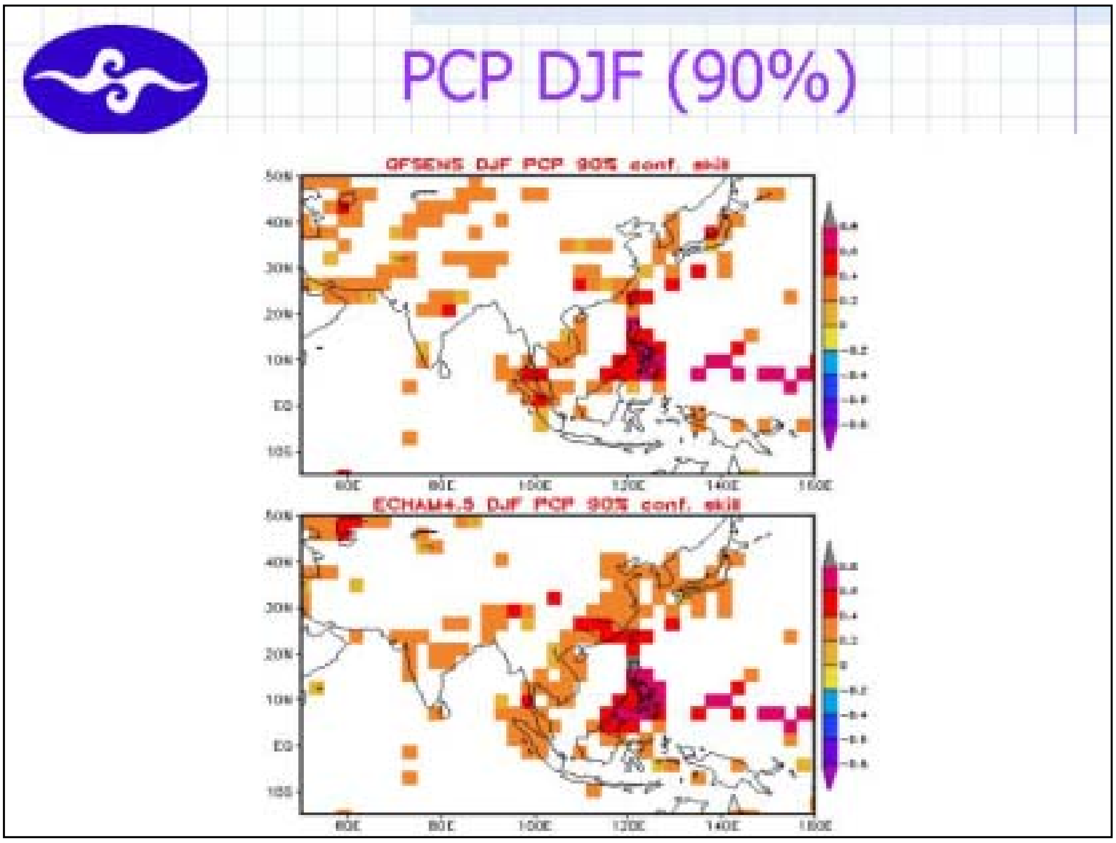

South Asia Monsoon Index
SAMI U850(5N−20N,40E−110E) − U200(5N−20N,40E−110E)
GFS NCEP EC4 R(GFS,NCEP)=0.39 R(EC4,NCEP)=0.38 R(GFS,EC4)=0.71

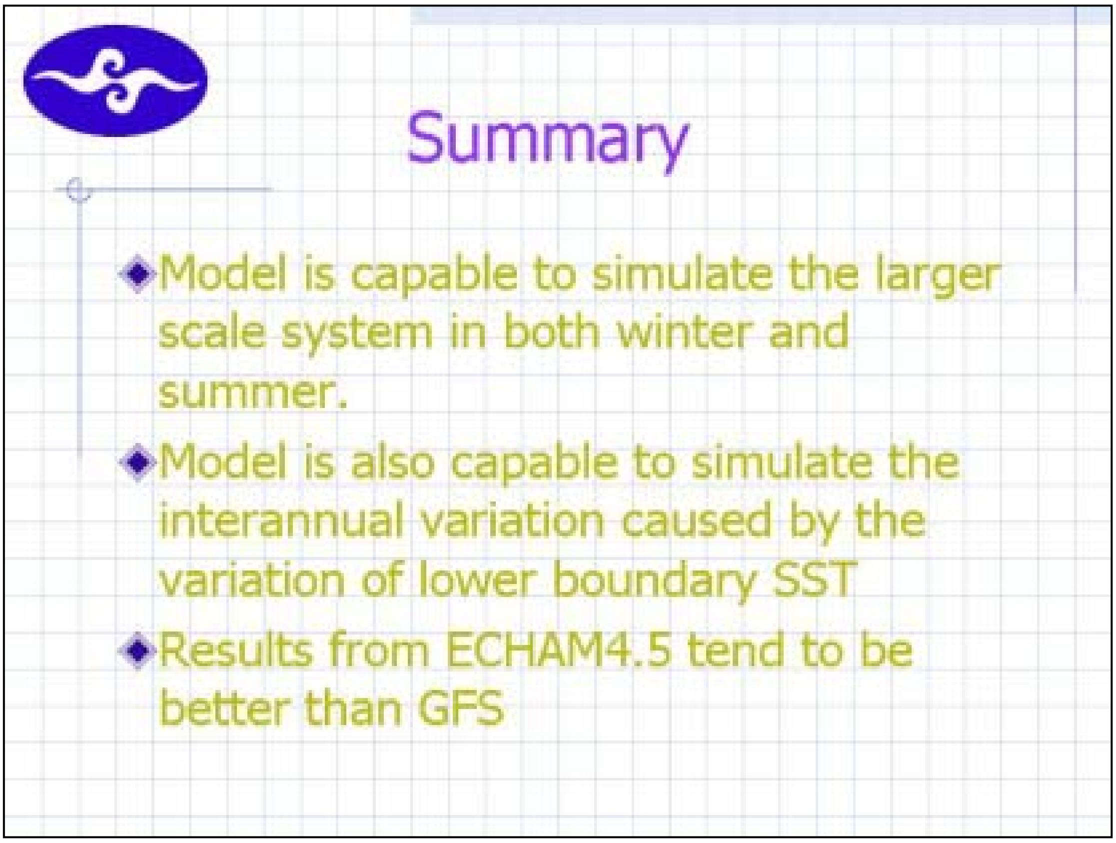

Indian Monsoon Index
IMI U850(5N−15N,40E−80E) − U850(20N−30N,60E−90E)
GFS NCEP EC4 R(GFS,NCEP)=0.25 R(EC4,NCEP)=0.15 R(GFS,EC4)=0.51


Western North Pacific Monsoon Index
WNPMI U850(5N-15N,100E-130E) - U850(20N-30N,110E-140E)
GFS
NCEP
EC4


Australian Summer Monsoon Index
AUSMI U850(0-10S,120E-150E)
GFS
NCEP
EC4


PCP JJA (90%)
GFSENS JJA PCP 90% conf. skill
ECHAM4.5 JJA PCP 90% conf. skill

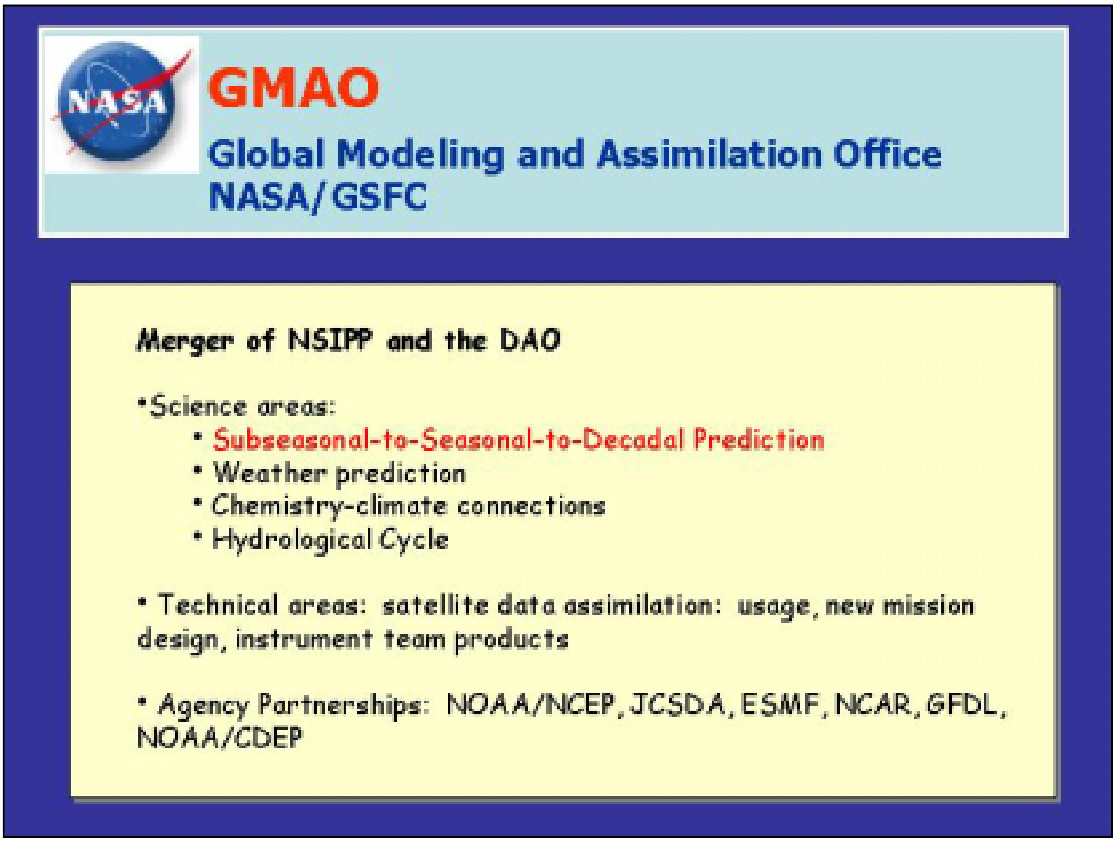

PCP DJF (90%)
GFSENS DJF PCP 90% conf. skill
ECHAM4.5 DJF PCP 90% conf. skill


Summary
◆Model is capable to simulate the larger scale system in both winter and summer.
◆Model is also capable to simulate the interannual variation caused by the variation of lower boundary SST
◆Results from ECHAM4.5 tend to be better than GFS

Subseasonal-to-Seasonal Prediction Efforts at NASA's Global Modeling and Assimilation Office

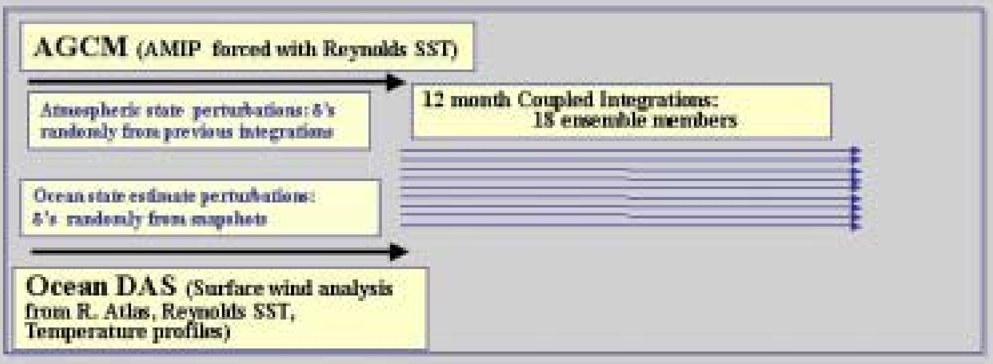
Siegfried Schubert

Global Modeling and Assimilation Office
NASA/Goddard Space Flight Center



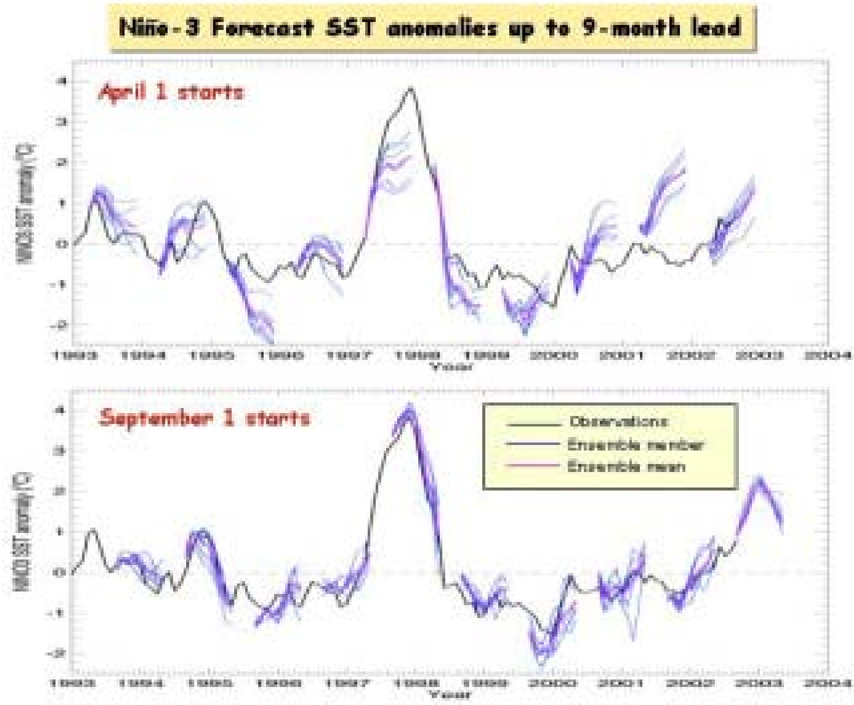
The GMAO/NSIPP Forecast/Analysis System

NSIPP CGCMv1 (Tier1) Forecast Ensembles



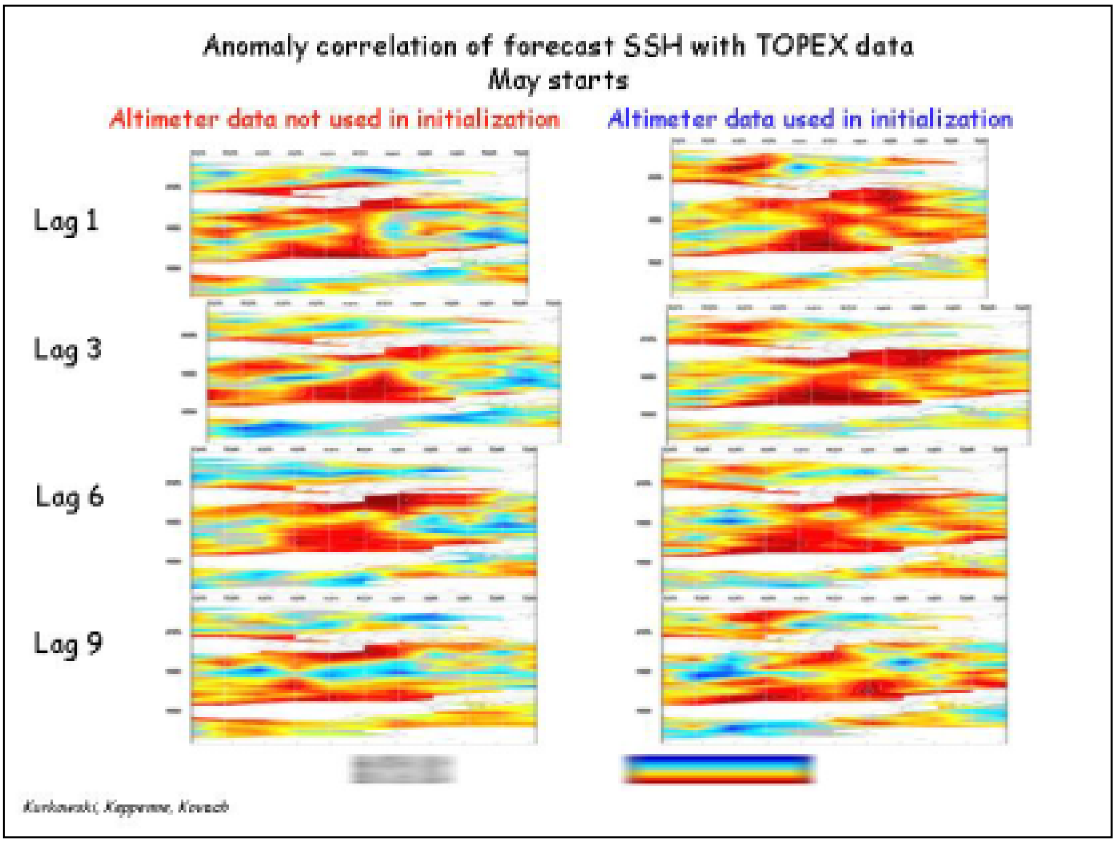
AGCM: NSIPP1 AGCM, 2 x 2.5 x L34
LSM: Mosaic (SVAT)
OGCM: Poseidon v4, 1/3 x 5/8 x L27, with embedded mixed layer physics
CGCM: Full coupling, once per day

ODAS: Optimal Interpolation of *in situ* temperature profiles - daily, salinity adjustment (Troccoli & Haines)

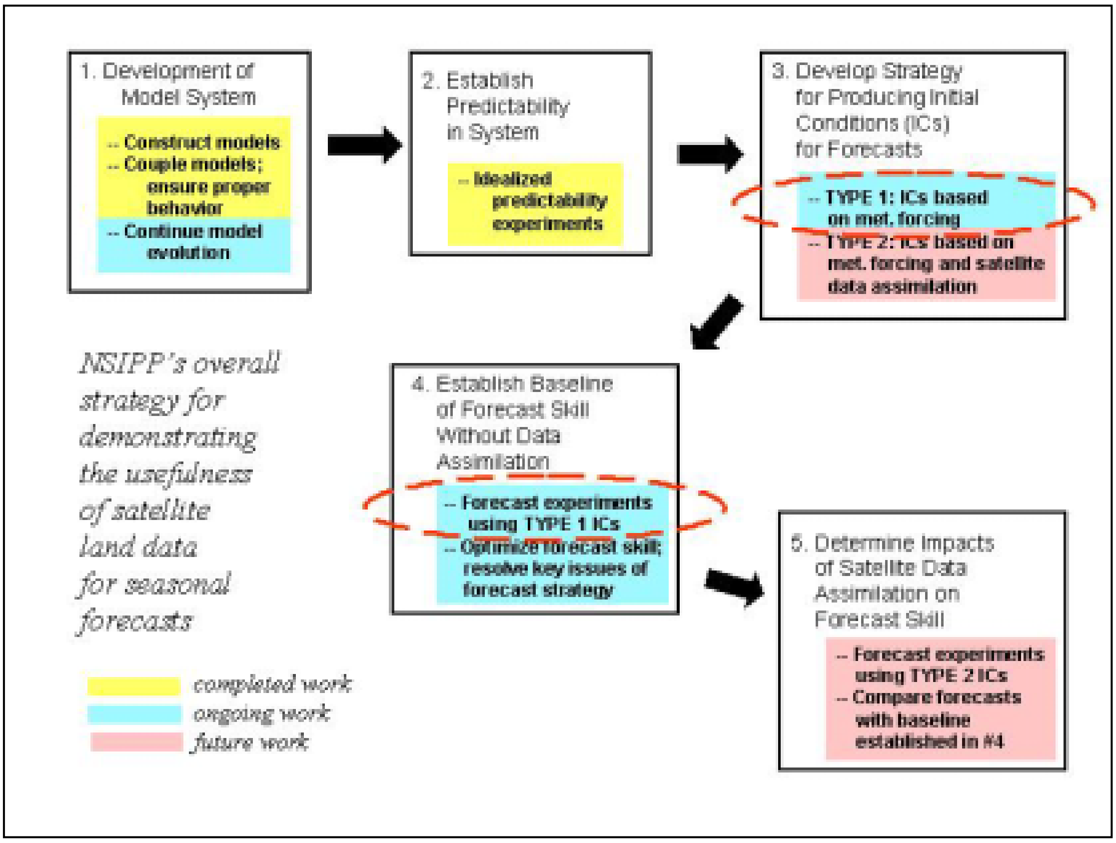


NSIPP Coupled Model Hindcasts

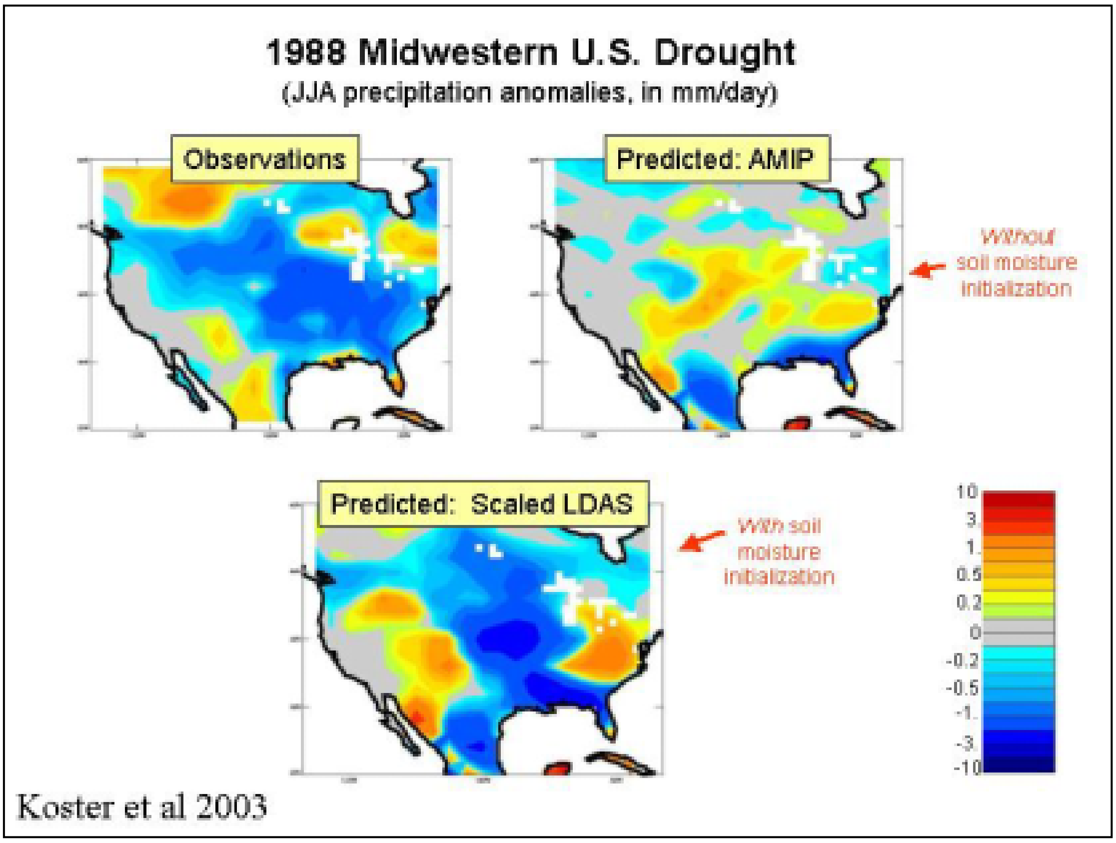
Impact of Assimilation- Ocean



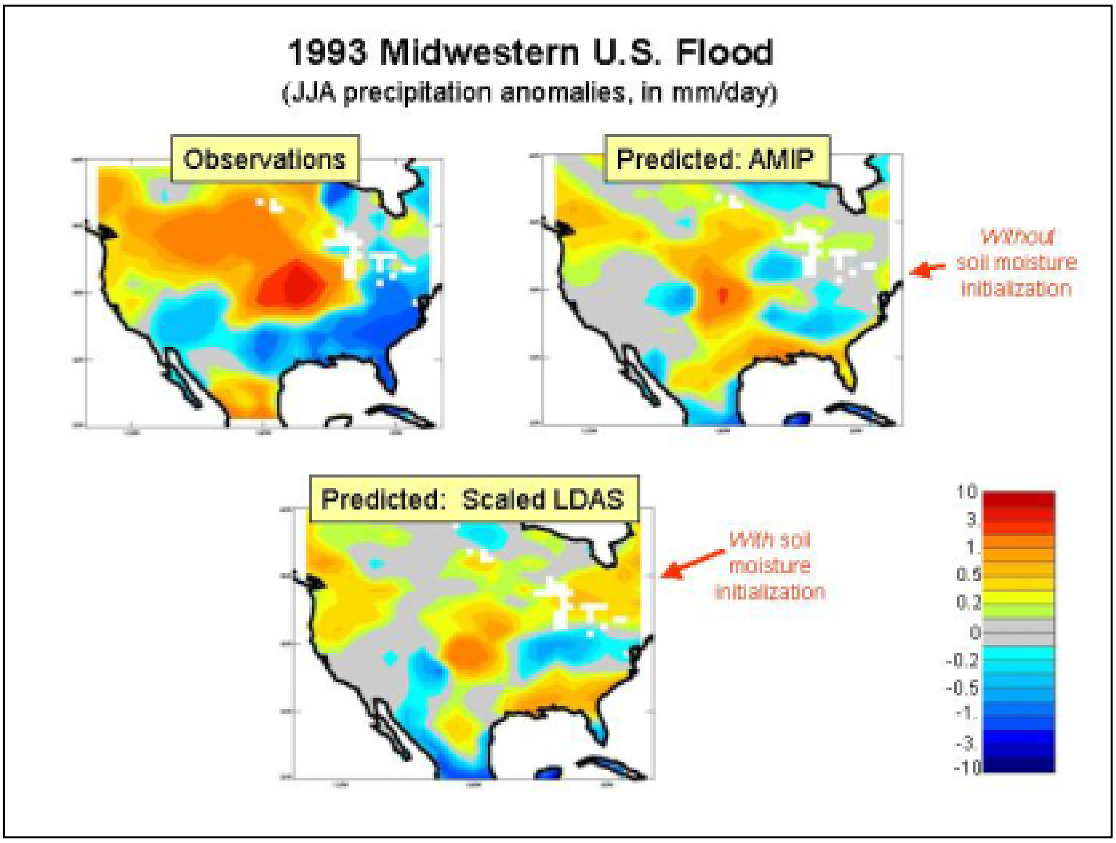
Impact of Soil Moisture Initialization



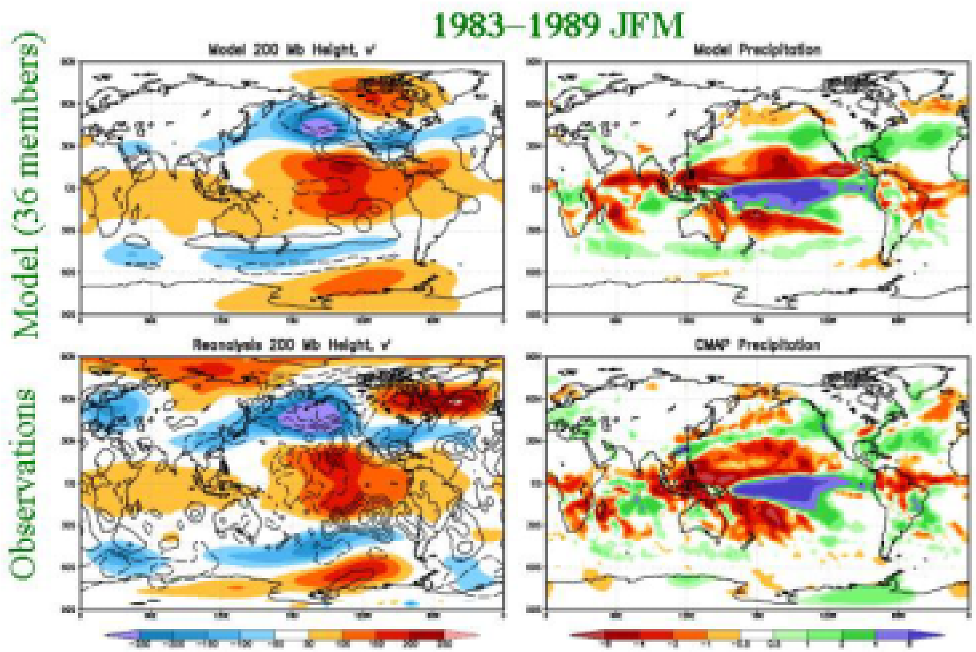
1. Development of Model System
-- Construct models
-- Couple models; ensure proper behavior
-- Continue model evolution
2. Establish Predictability in System
-- Idealized predictability experiments
3. Develop Strategy for Producing Initial Conditions (ICs) for Forecasts
-- TYPE 1: ICs based on met. forcing
-- TYPE 2: ICs based on met. forcing and satellite data assimilation
NSIPP's overall strategy for demonstrating the usefulness of satellite land data for seasonal forecasts
4. Establish Baseline of Forecast Skill Without Data Assimilation
-- Forecast experiments using TYPE 1 ICs
-- Optimize forecast skill; resolve key issues of forecast strategy
5. Determine Impacts of Satellite Data Assimilation on Forecast Skill
-- Forecast experiments using TYPE 2 ICs
-- Compare forecasts with baseline established in #4
completed work
ongoing work
future work



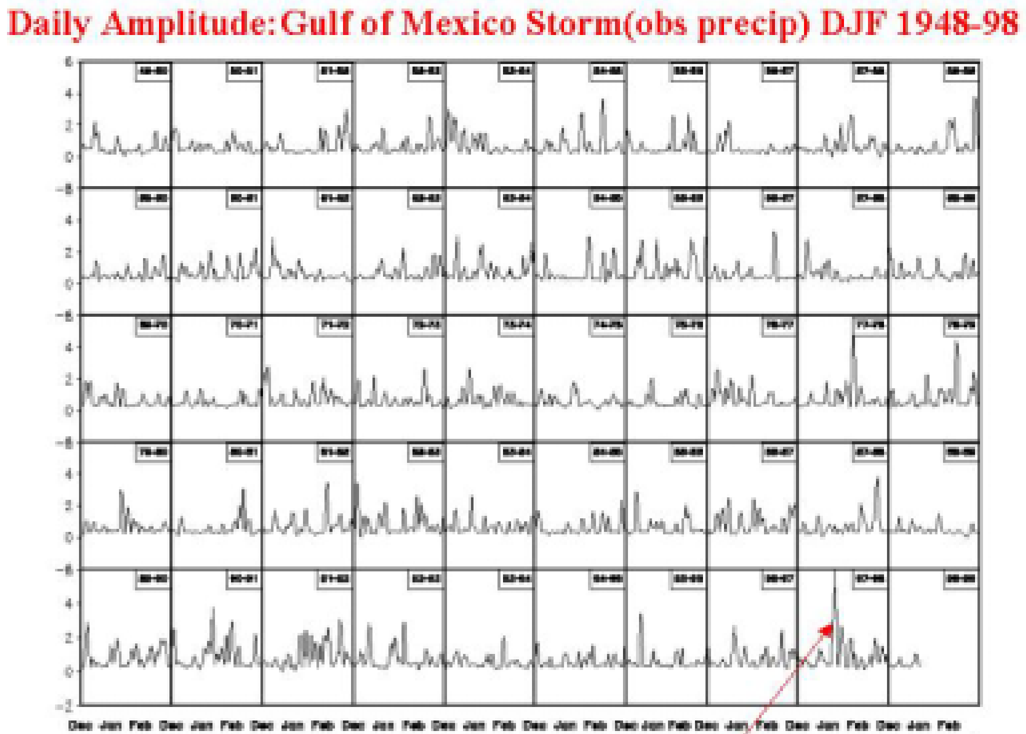
1988 Midwestern U.S. Drought
(JJA precipitation anomalies, in mm/day)
Observations
Predicted: AMIP
Without soil moisture initialization
Predicted: Scaled LDAS
With soil moisture initialization
10
3
1
0.5
0.2
0
-0.2
-0.5
-1
-3
-10
Koster et al 2003



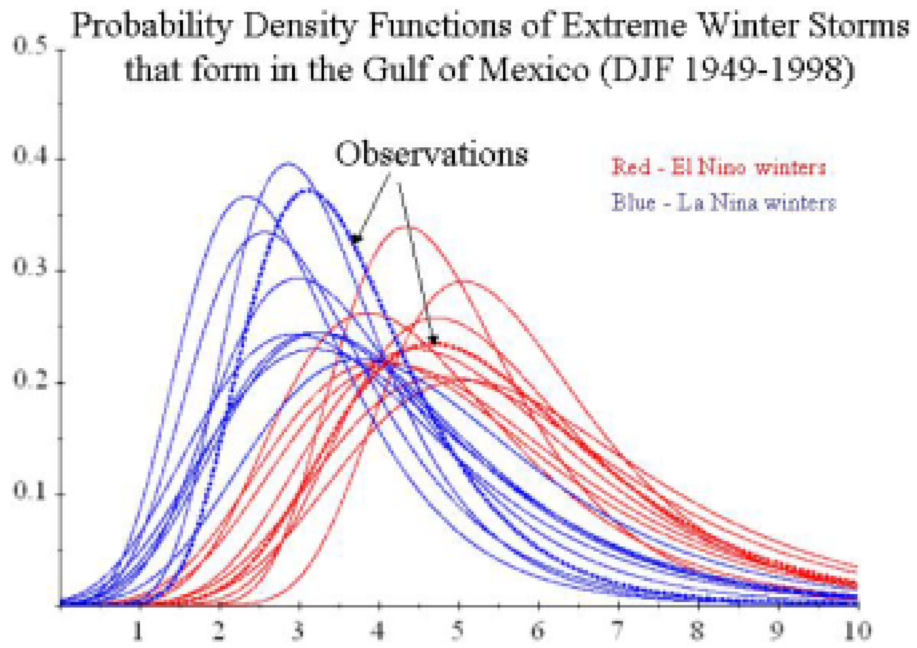
ENSO Response and Weather Extremes



The differences between the 1983 and 1989 January, February, March (JFM) mean fields (1983-1989) for the model simulations (top panels) and the observations (bottom panels). The left panels consist of the differences in the 200mb heights (color), and the differences in the 200mb variance in the daily meridional winds (contour intervals: 40 (m/s)^2). The right panels are the differences in the precipitation. The model values are the averages of 36 ensemble members for each year.



Floods throughout lower Mississippi Valley and SE - ice storms in NE and Canada: **$4.4B, 56 deaths**



Maximum value of the principal components associated with storms that form in the Gulf of Mexico. Thin curves are the NSIPP model results (9 ensemble members). Thick dashed curves are from the observations. Values are scaled so that the model and observed values have the same total variance. Units are arbitrary. The PDFs are the fits to a Gumbel Distribution. Schubert et al 2003: in

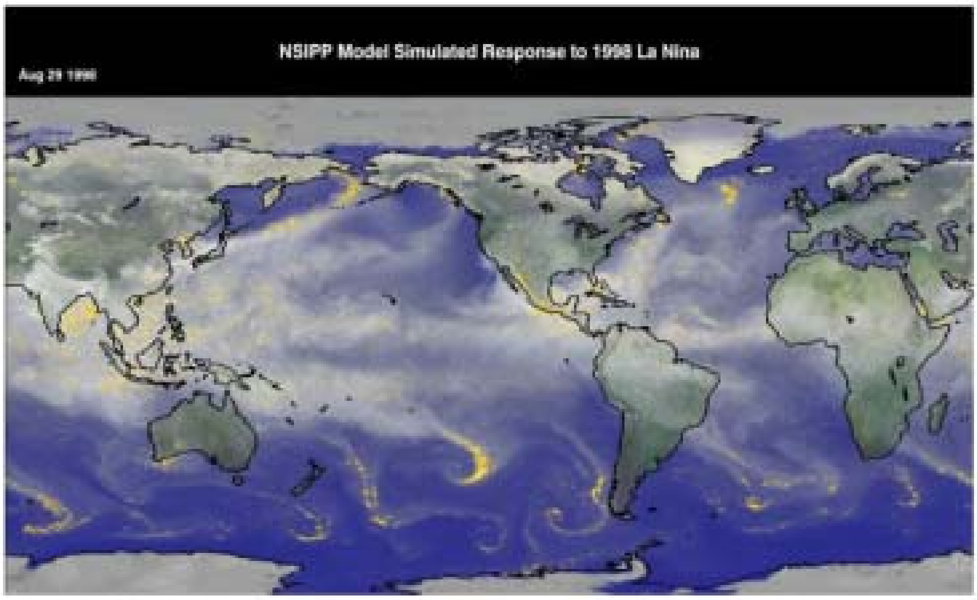
Plans

- **Forecast System Evolution**
  - Analysis system (EKF, multi-variate OI)
  - Unified model
  - Higher Resolution (. 1°, 1/2° regional issues -e.g. NAME)
  - Observations (altimetry, soil moisture, snow, …)
- **Science**
  - Link between weather and climate
  - Impact of other ocean basins
  - Subseasonal problem (MJO, soil moisture, etc.)
  - decadal focus on droughts and ENSO variability
  - evolution of full PDF

New approach: unified modeling capability - weather capable climate model and climate-reliable weather model

- Unified Goddard modeling system
  - **AGCM**: FVcore + evolving physics: combining GSFC developments with NCAR, GFDL collaborations
  - Working to include GISS under a common Goddard model "toolkit" (with Code 930)
  - **LSM:** Catchment LSM + features required for carbon, NWP, long-term climate
- Development and validation in collaboration with other centers and general community
  - CPTs (Centers and their collaborators)
  - GMAO Atmosphere Working Group (GISS, GSFC, NASA Centers)
  - GMAO Science Team (General Community)
- Next generation model:
  - Non-hydrostatic model
  - Non-CRM (i.e., parameterized physics)
  - Pushing the envelope on physics of cloud-resolving models
  - A nationally coordinated effort
- Modular, ESMF-based development of atmospheric model and subcomponents
  - Aerosol/chemistry from 916/Harvard/GMI

Higher Resolution



"Snapshot" of water vapor (white) and precipitation (orange) from a simulation with the NASA Seasonal-to-Interannual Prediction Project (NSIPP) AGCM run at 1/2 degree lat/lon resolution.

Sub-Seasonal Problem

Subseasonal (2 weeks to 2 months)

Held two community workshops (spring 2002/03)

1) Assessed promise and made recommendations for making progress on subseasonal prediction problem
   - Workshop report (Schubert et al. 2002)

2) Began carrying out recommendations of first workshop
   - Defined set of baseline experiments to help assess current capabilities, impact of observations, etc.
   - Developed plan for experimental prediction and model development focused on MJO
   - Workshop report (Waliser et al. 2003)

Recommendations of first workshop (Spring 2002):

a) That a coordinated and systematic analysis of current subseasonal forecast skill be conducted by generating ensembles of 30-day hindcasts for the past 30-50 years with several "frozen" AGCMs. Specific goals include, sampling all seasons, and generating sufficiently large ensembles to estimate the evolution of the probability density function.

b) That a series of workshops be convened focused on modeling the MJO, and that a coordinated multi-nation/multi-model experimental prediction program be developed focused on the MJO.

c) That new satellite observations and new long-term consistent reanalysis data sets be developed for initialization and verification, with high priority given to improvements in estimates of tropical diabatic heating and cloud processes, soil moisture, and surface fluxes (including evaporation over land).

d) That NASA and NOAA develop a collaborative program to coordinate, focus, and support research on predicting subseasonal variability.

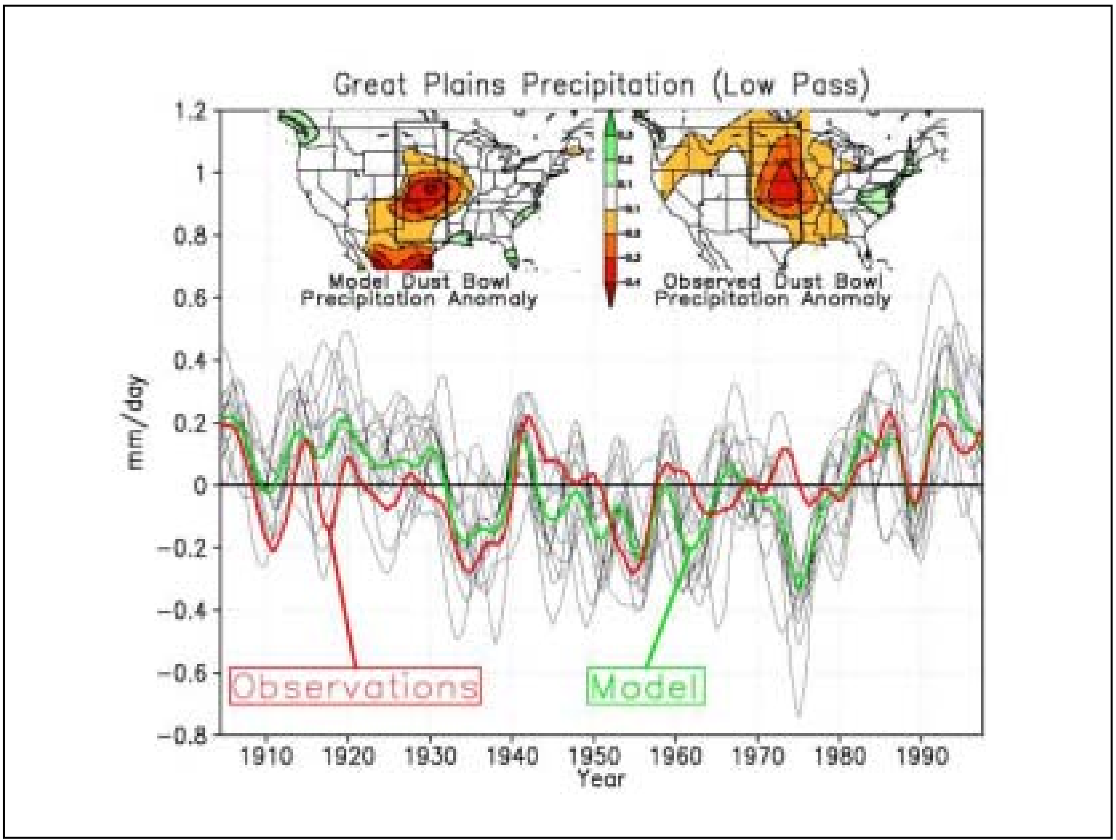
Outcomes of second workshop (Spring 2003):

1) the development of a recommended framework for a set of multi-decade ensembles of 45-day hindcasts to be carried out by a number of GCMs so that they can be analyzed in regards to their representations of subseasonal variability, predictability and forecast skill,
2) the development of an agenda and modeling/simulation work plan to address shortcomings associated with tropical variability, with a particular emphasis on remedying the shortcomings associated with GCM representations of the MJO/ISO, and
3) a final implementation plan for a multi-institute/multi-nation Experimental MJO/ISO Prediction Program.

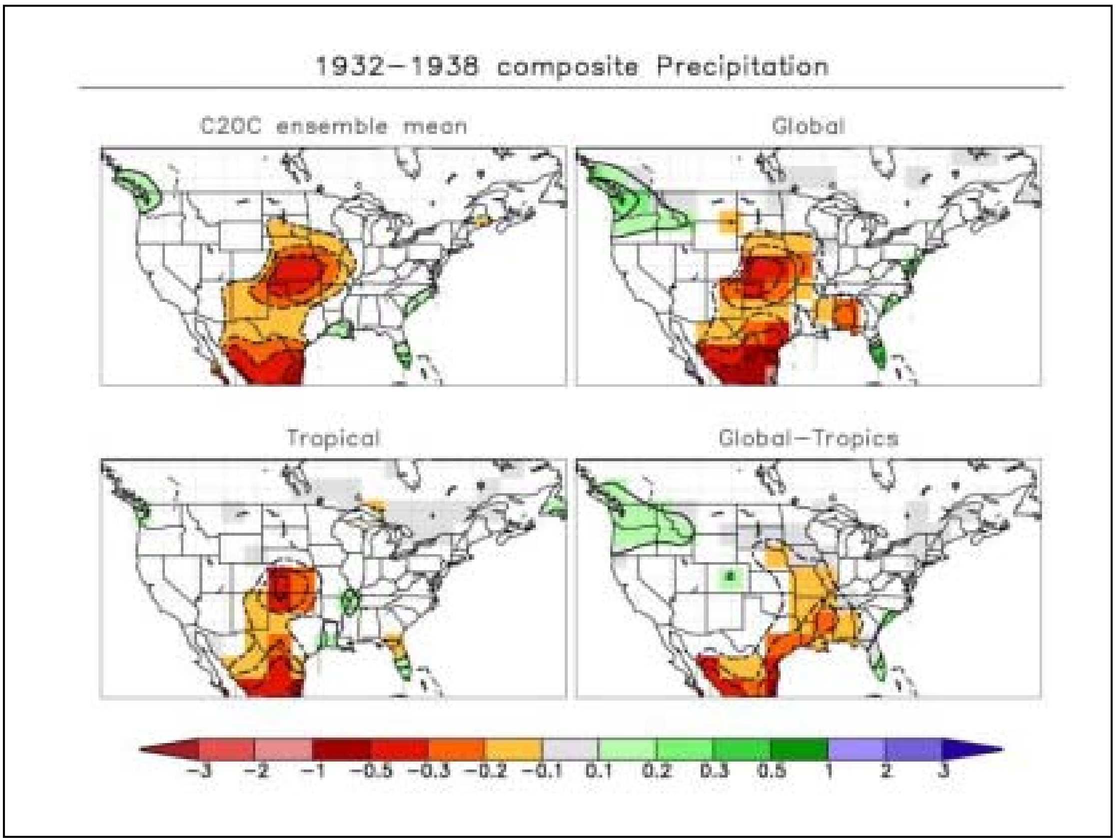
Outcomes of second workshop (Baseline Hindcasts):

Time period: most recent time period (1992 – present)
Forecast length: 45 days
Forecast frequency: every 5 days
SST: TBD – but most likely damped persistence (no "cheating")
Ensemble size: minimum of 10
Perturbations: TBD – but should include analyses from different centers if feasible
Resolution: high as possible
Land initial conditions: TBD – currently assessing different soil moisture products

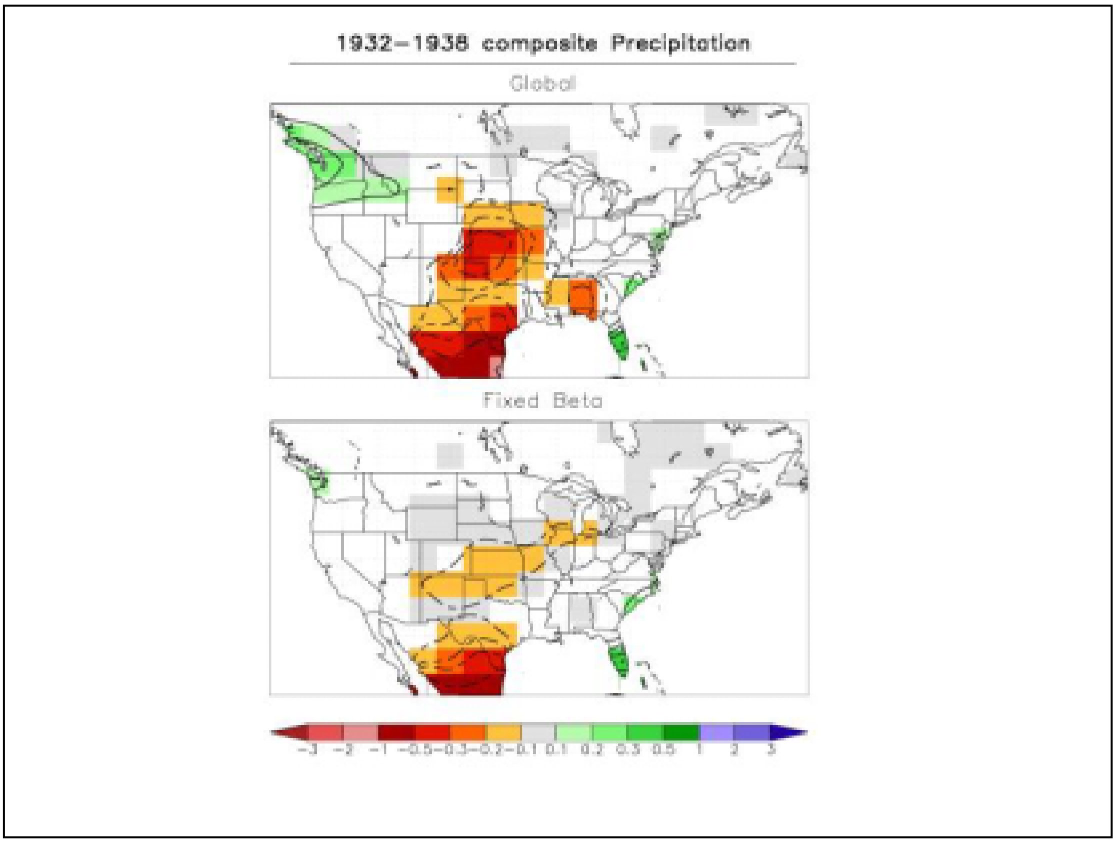
Decadal Problem

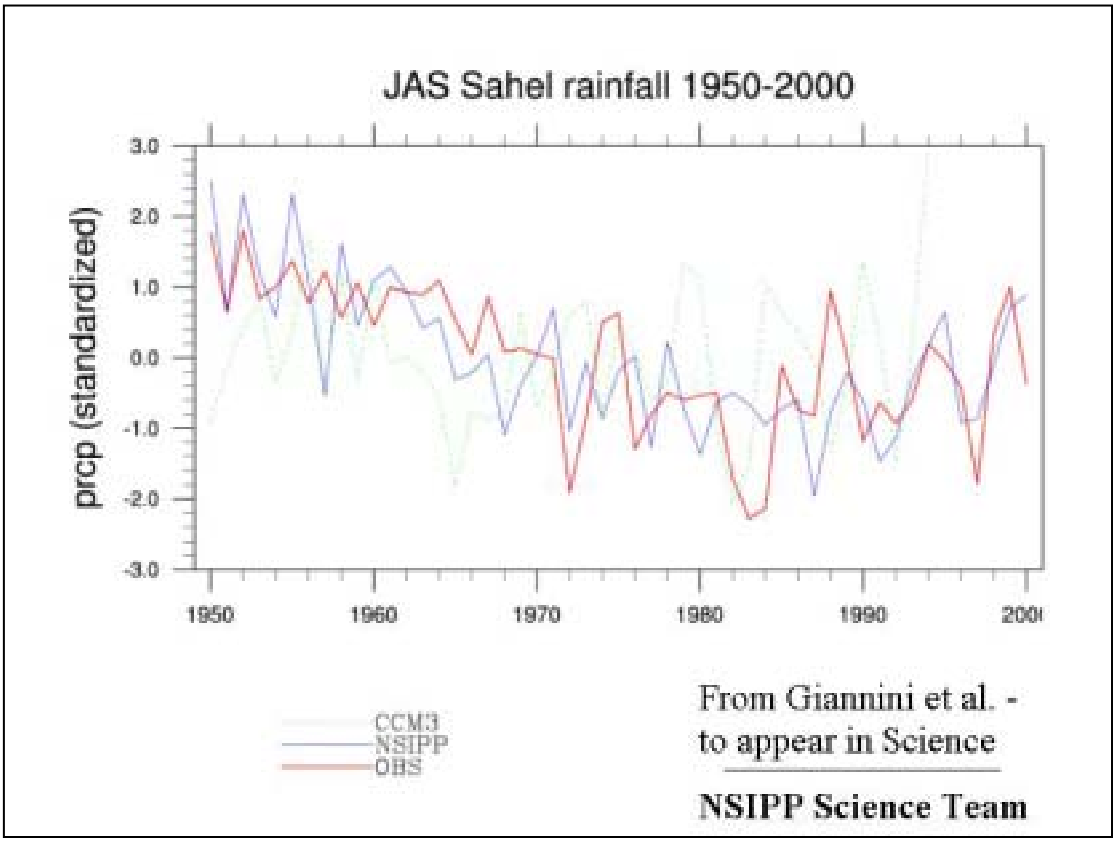


Great Plains Precipitation (Low Pass)
Model Dust Bowl Precipitation Anomaly
Observed Dust Bowl Precipitation Anomaly
mm/day
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
Observations
Model
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year



1932−1938 composite Precipitation
C20C ensemble mean
Global
Tropical
Global−Tropics
−3
−2
−1
−0.5
−0.3
−0.2
−0.1
0.1
0.2
0.3
0.5
1
2
3


1932–1938 composite Precipitation
Global
Fixed Beta
−3 −2 −1 −0.5 −0.3 −0.2 −0.1 0.1 0.2 0.3 0.5 1 2 3


JAS Sahel rainfall 1950-2000
prcp (standardized)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
1950
1960
1970
1980
1990
CCM3
NSIPP
OBS
From Giannini et al. -
to appear in Science
NSIPP Science Team

Seasonal Forecasting at the Met Office - a CGCM vs AGCM Comparison

S. Ineson, R.J. Graham and M.K. Davey

Meteorological Office

Abstract

Seasonal prediction skill available with Met Office coupled and uncoupled GCM systems (known as GloSea and HadAM3 respectively) has been evaluated and contrasted for various geographical regions using 9-member ensemble retrospective forecast datasets generated as part of the DEMETER project. The datasets used cover the 43-year period 1959-2001, a major increase in sample from previous studies that will give improved robustness of results. In most cases, evaluation is on probabilistic predictions of positive or negative anomalies (i.e. two-category events) in 3-month-average 2m temperature and rainfall. Results provide an appraisal of our current capabilities for seasonal prediction, with comparisons of coupled and uncoupled model performance adding quantification of the skill benefits obtained through full coupling of the ocean and atmosphere components. Additionally, skill enhancement in years with ENSO events is investigated.

1. Introduction

The Met Office coupled ocean-atmosphere global seasonal prediction model, GloSea, provides a 6-month outlook, 40-member ensemble forecast each month. Forecasts are available on our web-site http://www.metoffice.com/weather/seasonal

GloSea runs in parallel with System 2, the ECMWF coupled model, and will form a component of an operational European real-time multi-model prediction system. Earlier this year, GloSea replaced HadAM3, an uncoupled AGCM, as the current Met Office operational real-time system. The AGCM forecast model is a two-tier system, with the ocean boundary condition based on simple persistence of observed SST anomalies.

Atmospheric variability on seasonal timescales is closely related to oceanic variability on these timescales through ocean-atmosphere interactions that are particularly strong in the tropics. Hence it is expected that the use of coupled ocean atmosphere GCMs which allow for a full range of physical processes and dynamic interaction between the ocean and atmosphere will

result in seasonal forecasts with better skill and longer range than atmosphere-only systems. However, given the biases and drift that are present in coupled models it is useful to assess the benefits of the fully coupled system. Retrospective seasonal forecasts, for the 43-year period 1959-2001, have been performed with both the coupled GloSea and the uncoupled 2-tier systems, as part of the EU project DEMETER (Development of a European Multi-model Ensemble System for Seasonal to Interannual Prediction). More information on DEMETER and extensive verification diagnostics can be found at http://www.ecmwf.int/research/demeter.

In this paper we describe our models and experimental set-up as used in the DEMETER project and present a comparison of coupled and uncoupled model performance.

2. Model descriptions and experimental set-up

The GloSea model is based on the Met Office coupled climate model HadCM3 (Gordon et al., 2000). It uses a stretched north-south ocean grid, in which a resolution of 1.25° in both the meridional and zonal directions improves to 0.28° in the meridional direction in the tropics, and has 40 vertical levels. As in HadCM3 no flux correction is employed, and an interactive sea-ice model is incorporated. A coastal tiling scheme is used which allows the ocean model to have a coastline determined by the ocean grid, rather than by the lower resolution atmosphere grid – yielding improved representation of land/sea geography. The Ocean Data Assimilation scheme is based on the Met Office FOAM system (Bell et al., 2000) and uses a form of optimal interpolation. As with other DEMETER CGCMs, perturbations used in the initialisation of GloSea hindcasts were generated using a common (DEMETER) set of windstress and SST perturbations to generate eight perturbed initial ocean states and one unperturbed control state. No perturbations were applied to the atmosphere component which was initialised from ERA40.

The atmospheric component of GloSea is also used in the two-tier experiments and is known as HadAM3 (Pope et al., 2000). It has a horizontal resolution of 2.5° latitude and 3.75° longitude and 19 vertical levels. In the two-tier experiments HadAM3 is forced with a statistical prediction of SST and sea-ice based on persistence of the one-month SST anomalies (derived from HadISST1, Rayner et al., 2000) in the month preceding the integration start date. The SST anomalies (SSTA) are added to the monthly SST climatology covering the period of integration, interpolated in time and updated in the model at 24-hr intervals. In the open ocean SSTA is kept constant until month four and is then relaxed to zero by the end of month six. Ice is assumed to be present where predicted SST falls below −1.8°C; thus positive (negative) initial SSTA can delay (hasten) ice formation. In contrast to the GloSea experiments perturbations for the two-tier system are derived using atmospheric perturbations only, the SST forcing being identical for all ensemble members. A lagged approach is used in which the 6-hourly ERA40 analyses over the 24hrs prior to the start time form the initial conditions for the 9 members.

For both models hindcasts are run from four start dates in the year; specifically 00GMT on the first day of February, May, August and November, and are of 6-months range. For both models land surface conditions are initialised from ERA40.

In this report we summarise predictive skill for ensemble-mean SST anomalies and for probabilistic predictions of positive or negative anomalies in average 2m temperature and rainfall, i.e. two category events defined by average temperature and rainfall above or below the climate normal. Predicted anomalies are defined relative to the model climatology (as calculated over all ensemble members and all years used in the evaluation) in order to remove, a posteriori, the model bias. For 2m temperature and SST assessments ERA40 is used for verification and the full 43-year sample is verified. For rainfall assessments the GPCP dataset (Rudolf et al., 2000) is used for verification and, because of the shorter span of this dataset, only a 23-year subset of the hindcasts (1979-2001) is evaluated. For each geographical region considered skill evaluated over all available years is compared to that obtained when only years with ENSO events (as defined in the WMO Standard Verification System document) are included in the score calculation. The skill diagnostic employed for probabilistic predictions is the area under the Relative Operating Characteristic curve or ROC score (Stanski et al., 1989), while for SST predictions temporal correlation (corr) of the ensemble-mean and observed anomalies is used.

3. Results

3.1 SST prediction

Sea surface temperature is a key variable with regard to ocean-atmosphere interaction, and as such it is an important quantity to analyse in a coupled GCM. Due to its strong influence on the atmosphere virtually worldwide, for example through ENSO events, SST in the tropical Pacific is the region that attracts the most attention. The predictive performance of the GloSea system is best in the central tropical Pacific, in a region roughly corresponding to the Niño3.4 area. Correlation statistics for GloSea Niño3.4 predictions for MAM and JJA at 1-month lead (Table 1) substantially exceed those obtained for the statistical predictions used to force HadAM3. At 3-month lead GloSea correlations exceed those of the statistical scheme in all seasons, with notable improvements in the FMA, MJJ and ASO seasons.

	GloSea model		Statistical scheme	
Lead time Start/valid time	2-4	4-6	2-4	4-6
Feb 1: MAM, MJJ	0.89	0.77	0.81	0.28
May 1: JJA, ASO	0.76	0.76	0.47	0.33
Aug 1: SON, NDJ	0.90	0.90	0.91	0.88
Nov 1: DJF, FMA	0.95	0.92	0.94	0.83
All	0.89	0.85	0.78	0.54

Table 1: Correlation of GloSea ensemble-mean and statistically predicted Niño3.4 SST anomalies with observed (ERA40) anomalies for the period 1959-2001, at 1-month (2-4) and 3-month (4-6) leads (the corresponding 3-month valid periods are also provided).

3.2 Prediction of 3-month-average 2m temperature and precipitation anomalies

A comparison of ROC scores for GloSea and HadAM3 predictions of 3-month-mean temperature anomaly is provided in Fig. 1 for selected regions (see caption for details). Reference lines indicate the "no-skill" threshold for the ROC score (0.5), and the score estimated by Graham et al. (2000) to be the lower limit required for 90% significance (0.6). In general scores are similar for both models, though GloSea is better for most regions/leads in all seasons except summer. In spring and winter benefits from GloSea are most prominent at the longer (3-month) lead (Figs. 1a&d), indicating that the coupling of ocean and atmosphere is successful at extending the predictability range. Notable improvements with the GloSea model include 3-month lead scores for the tropics and North America in spring and winter. For the tropics, scores at both 1-month and 3-month leads are substantially in excess of 0.6

for both models with, as expected, best skill at the shorter lead. For the extratropics best skill is obtained at 1-month lead for the spring season (Fig.1a), for which all four regions considered (including Europe) exceed scores of 0.6. For these regions scores are somewhat lower, but still generally of order 0.6 for summer (Fig.1b) at 1-month lead, while in autumn and winter (Figs. 1c&d) scores for Europe and North America fall below 0.6. At 3-month lead scores for most extratropical regions are below 0.6; exceptions include the 3-month-lead scores for Europe in autumn and winter which are of order 0.6 and exceed those for 1-month lead, this may be an artefact of the different valid period used for the long and short leads (see caption). Scores obtained when evaluation is restricted to those seasons in which an El Niño or La Niña event was active are provided in Fig. 2, and may be compared with those for all years (Fig.1). The most prominent skill differences occur in the tropics where there is improved skill with both models in most seasons/leads, and for the spring and summer seasons in the extratropics. For seasons with ENSO events improved skill is expected with the GloSea model, because of its ability, unlike the persistence based SST predictions of the two-tier HadAM3 system, to predict the onset and decline of ENSO events. Improved skill with GloSea is clearly evident in the winter season when ENSO SST anomalies are typically at their peak, GloSea outperforming HadAM3 in 7 cases vs 3 (Fig. 2d). In spring (Fig.2a) GloSea performs better at 3-month lead while HadAM3 is better at 1-month lead. Skill for summer and autumn seasons with ENSO events appears, apart from in tropical regions, to be generally better with HadAM3, the reason for this is unclear and needs further investigation. Individual scores of note include the 3-month lead scores for North America in spring and summer which increase substantially relative to scores for all years, reaching 0.7 in spring with the GloSea model. Substantial increases are also seen with both models for Europe at 3-month lead in summer. In spring seasons with ENSO events (Fig. 2a) HadAM3 has a notable advantage relative to GloSea at 1-month lead, a result which deserves in depth investigation.

For precipitation (Fig.3) ROC scores exceed 0.6 in tropical regions at 1-month with both models and additionally at 3-month lead with GloSea (except in autumn). Scores are below 0.6 in all extratropical regions, with the European region having generally least skill with scores near or below the 0.5 threshold. GloSea provides the overall better performance in all seasons, with better performance at longer lead again notable, as for temperature, in winter and spring. In years with ENSO events (Fig. 4) skill in tropical regions is generally enhanced at both lead-times. In contrast skill in most extratropical regions remains similar to that obtained over all years. One notable exception is the winter season (Fig. 4d) at long-lead, for which the GloSea model (but not HadAM3) achieves substantially better skill relative to that for all years, bringing scores near or above the 0.6 threshold.

3.3 Prediction for the rainy seasons of specific regions

A comparison of GloSea and HadAM3 performance for the rainy seasons of a number of tropical regions is provided in Figs 5a&b. For each region skill for 1-month lead predictions of the conventional season (blue/dark grey) and 2-month lead predictions of the late season (green/light grey) are shown. Notable benefits from the GloSea model are evident for the 1-month and 2-month lead predictions for the Guinea and NE Brazil seasons for which GloSea scores exceed 0.7. GloSea benefits for the Guinea region are particularly useful as HadAM3 scores for Guinea are less than 0.6. Enhanced skill is present in ENSO years for both regions (Fig. 5b). Note that in ENSO years scores with both models for North East Brazil reach the best possible score of unity. Scores for the East Africa rainy season exceed 0.6 for the 1-month and 2-month leads with both models, again with enhanced skill in ENSO years. Scores for the Asian monsoon are generally low (at all leads) when evaluated over all years but improve to greater than 0.6 (with both models) when only ENSO years are considered, though the sample available is small (6 years). Scores for the Sahel season at 1-month and 2-month leads appear close to the no-skill threshold with both models.

4. Summary

Skill summary

The GloSea model has significant skill for 2m temperature in the tropics at both 1-month and 3-month lead, with marked skill enhancements in ENSO years. Skill for precipitation is lower than for temperature, but still generally significant at both 1-month and 3-month leads. A focus on specific regional rainy seasons found significant skill for the NE Brazil and Guinea seasons at both 1-month and 2-month leads, with predictions for the latter region showing substantial benefits over HadAM3. Skill is also available for East Africa and, in years with ENSO events, for the Asian monsoon region. In contrast little skill appears available for the Sahel region.

In extratropical regions skill is significant for temperature predictions at 1-month lead in spring and summer, but is generally marginal in other seasons and at 3-month lead - though scores for 3-month leads indicate encouraging potential for prediction at the longer range. Skill enhancements in ENSO years are most marked in spring and summer. Scores for precipitation do not reach significant levels in any of the extratropical regions considered - though encouraging skill enhancements in ENSO years are noted at 3-month lead in the winter season (with the GloSea model only).

Comparison of GloSea and HadAM3

The GloSea coupled system provides substantially improved predictions of tropical Pacific SST relative to statistical predictions used in the uncoupled HadAM3 system. Best improvements in all seasons are found at 3-month lead, indicating the success of the coupled model in extending the predictability range. GloSea skill is highest in the NDJF season, an important result since SST anomalies associated with ENSO events typically peak in the NDJF period.

For temperature and precipitation anomalies notable differences include better skill from the GloSea model for the northern spring and winter seasons in both the tropics and extratropics at 3-month lead, a result that is reinforced when only years with ENSO events are considered. The improvements are likely due to the ability of GloSea (in contrast to the persistence based statistical SST predictions) to capture the onset and decline of ENSO events in these seasons. Improvements with GloSea are not universal, however, and further study of cases where HadAM3 provides better skill should be useful in improving coupled model performance.

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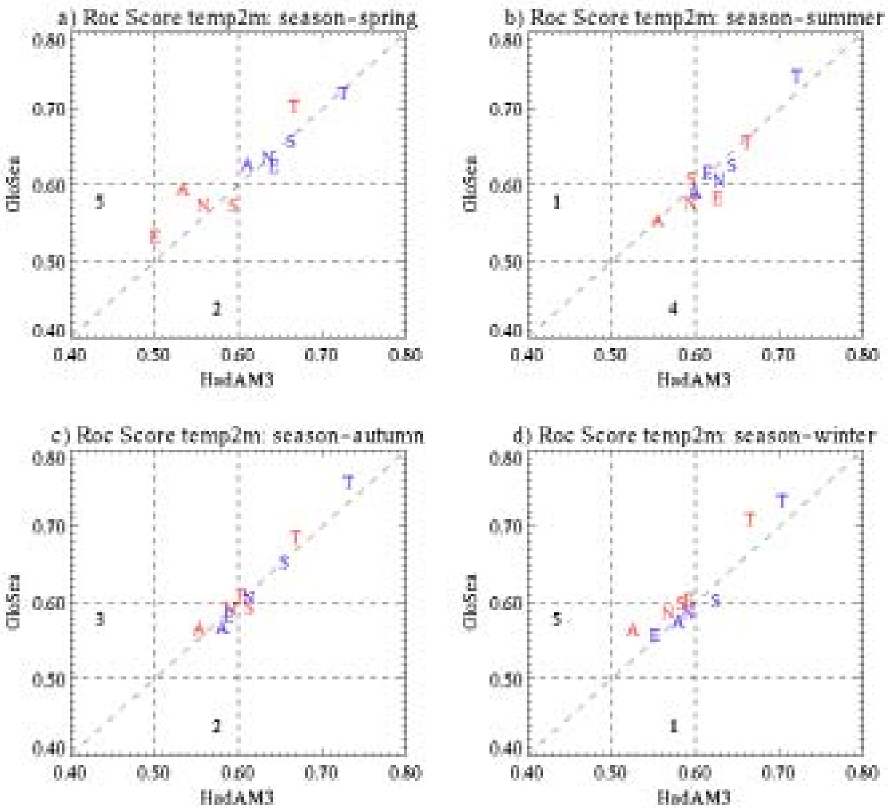

Fig. 1: Comparison of ROC scores for probabilistic forecasts of the event "2m temperature above the climate normal" obtained with the GloSea and HadAM3 models for five geographical regions: Northern Extratropics (30°N - 90°N), N; Tropics (30°S - 30°N), T; Southern Extratropics (30°S - 90°S), S; Europe (12.5°W - 42.5°E; 35°N - 75°N), E; and North America (60°W - 130°W; 30°N - 70°N), A. For each region and season forecast scores at two leads are shown, a 3-month-lead (long-lead) forecast for the "early" northern season (early spring/summer/autumn/winter = FMA/MJJ/ASO/NDJ) shown in red (light grey), and a 1-month-lead "update" forecast for the conventional season (MAM/JJA/SON/DJF) shown in blue (dark grey). The number of times the score obtained with each model exceeds that of the other model is provided next to the appropriate axis; only cases when the winning model achieves a ROC score that exceeds 0.5 (the "no skill" threshold), and exceeds that of the other model by 2% or more are counted. ROC scores are calculated over the 43-year period 1959-2001. Forecasts are verified against observed anomalies from the ERA40 reanalysis.

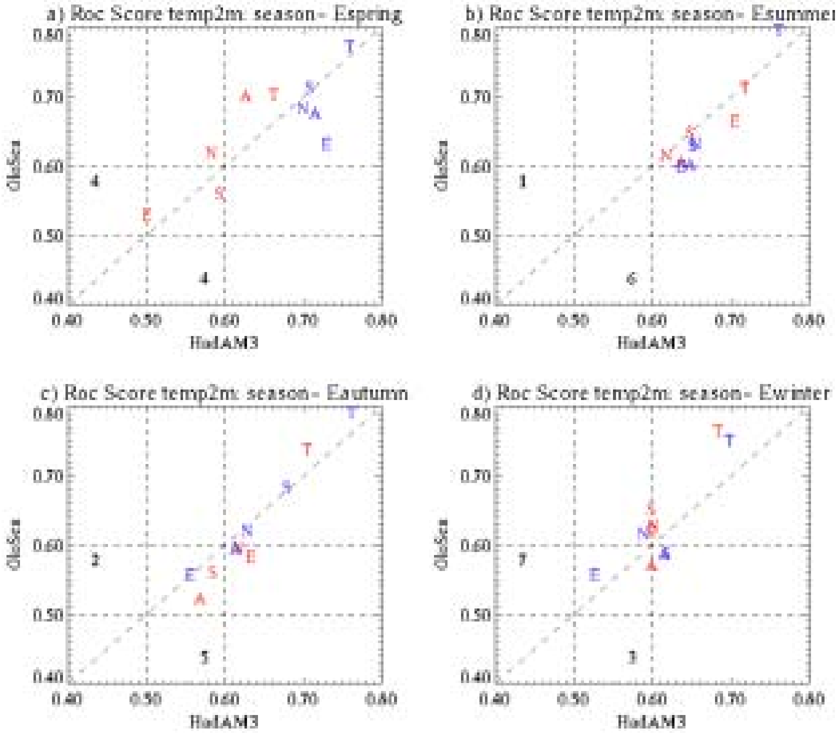

Fig.2: As Fig.1, but calculated over the sub-sample of years with active El Niño or La Niña events, as defined in the WMO SVS document. Sample sizes are: spring, 8 years; summer, 9 years; autumn, 16 years; winter, 14 years.

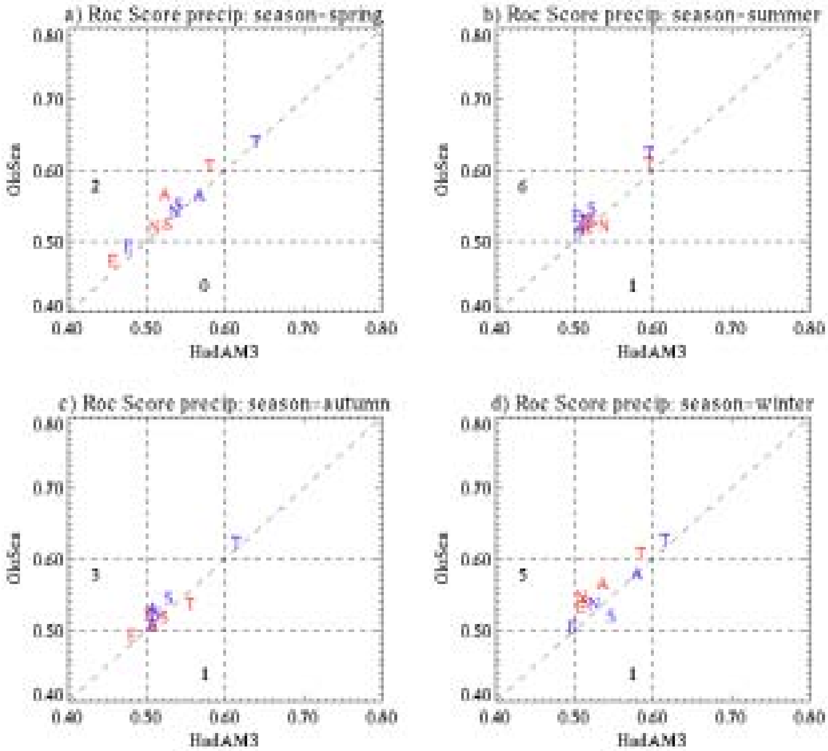

Fig. 3; as Fig. 1, but for precipitation and for the period 23-year period 1979-2001 using the GPCP dataset for verification.

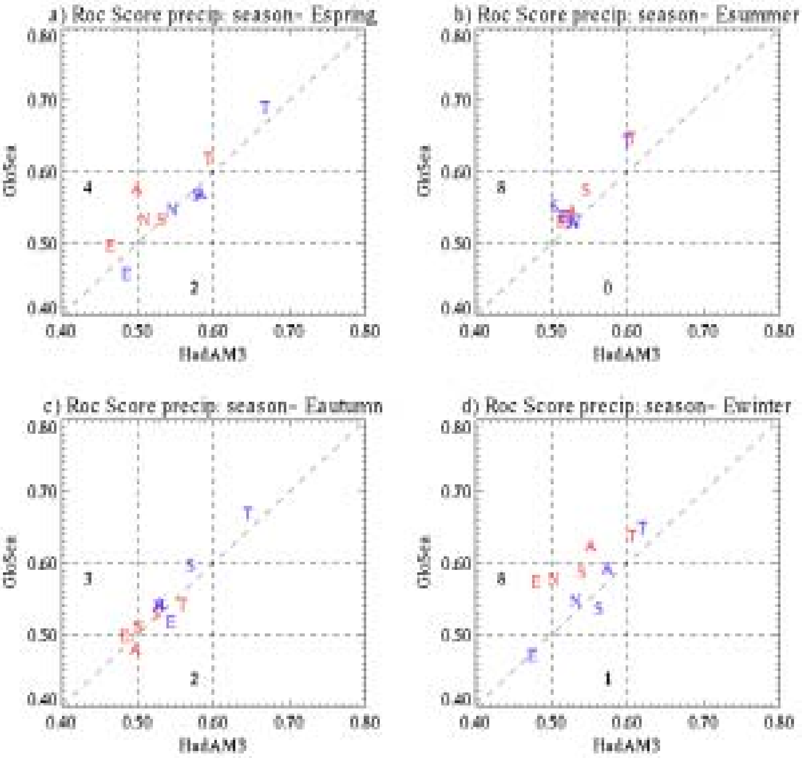

Fig.4: As Fig.3, but calculated over the sub-sample of years with active El Niño or La Niña events, as defined in the WMO SVS document. Sample sizes are: spring, 7 years; summer, 6 years; autumn, 9 years; winter, 8 years.

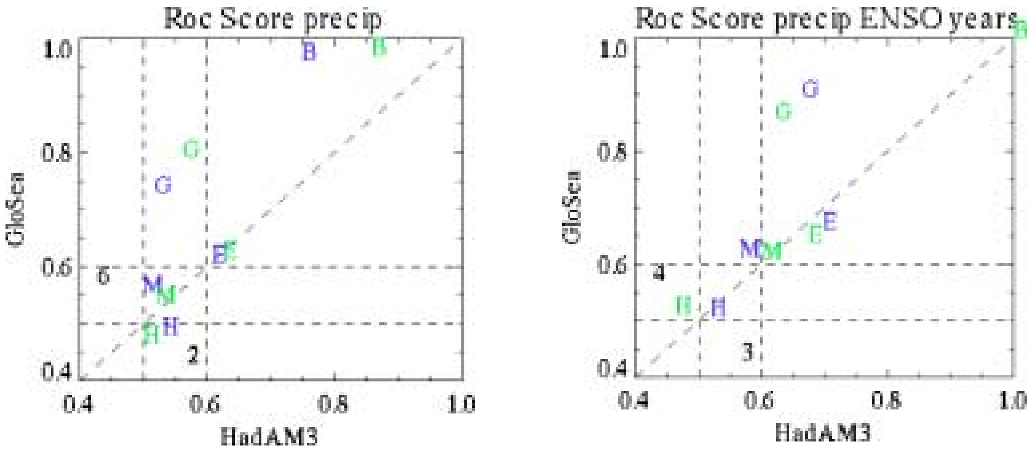

Fig.5: Comparison of ROC scores for probabilistic forecasts of the event “precipitation above the climate normal” obtained with the GloSea and HadAM3 models for the rainy seasons of various tropical regions. B = North East Brazil (37.5°W - 41.25°W, 5°S - 7.5°S); M = Asian monsoon (60°E - 120°E, 0°N - 30°N); H = Sahel (15°W - 37.5°E, 12.5°N - 17.5°N); G = Guinea (7.5°W - 7.5°E, 5°N - 10°N); E = East Africa (30°E - 45°E, 15°S - 5°N). For each region blue (dark grey) font indicates a 1-month lead prediction of the conventional season; green (light grey), a 2-month lead prediction of the late season. Conventional/late seasons are defined as follows; B = MAM/AMJ; M, H and G = JJA/JAS; E = SON/OND. a) scores evaluated over all years (1979-2001); b) scores evaluated over the sub-sample of years with active El Niño or La Niña events, as defined in the WMO SVS document. See Fig. 4 for sample sizes. Note scores for NE Brazil at 1- and 2-month leads are both equal to unity.

Precipitation Performance in the MRI/JMA AGCM

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1. INTRODUCTION

Inter-annual variability of precipitation in the tropical Western Pacific (WP) has been know as one of the key issues for the seasonal prediction over Japan during its winter (DJF) and summer (JJA). I report the predictability of the tropical precipitation, especially in the tropical WP. Then, I like to show the statistical study on how the successful/unsuccessful simulation of inter-annual precipitation variability is related to SST anomalies.

2. MODEL AND EXPERIMENTS

The MRI/JMA AGCM (Shibata et al., 1999) used here is based on the old-version of the JMA short-term prediction model with some schemes incorporated and some improvements made for a climatic model. Ensemble integrations with six members are made during January 1949 – December 1998 under the observed SST and sea ice (HadISST1). Analysis is focused on the 6-member ensemble average for December-January-February (DJF) and June-July-August (JJA) during 18 years from DJF 1980 (December 1979-February 1980) to DJF 1998 and from JJA 1980 to JJA 1998. The NCEP2 reanalysis data and Xie-Arkin precipitation data are used for the verification. Note that the WP domain is referred to as (130-150E, 5-15N) for DJF study and (130-150E, 10-20N) for JJA study.

3. RESULTS

3.1 GCM performance about tropical Western Pacific (WP) precipitation

The inter-annual variability of the tropical WP precipitation is shown in Fig.1a and Fig.2a for each member of the integrations, the ensemble average and the observation. The observed precipitation variability is within the uncertainty estimated from the diversity of six members, almost perfectly for DJF. The ensemble integration for a few of JJA cases misses to capture the observation within their diversity.

The observed tropical WP precipitation has different relationship with SST between DJF and JJA. The WP SST variability is plotted as well as the WP precipitation for DJF and JJA in Fig. 1b and Fig. 2b, respectively. The DJF WP precipitation is closely related to the WP SST variability. On the other hand, the JJA WP precipitation is not related to the WP SST.

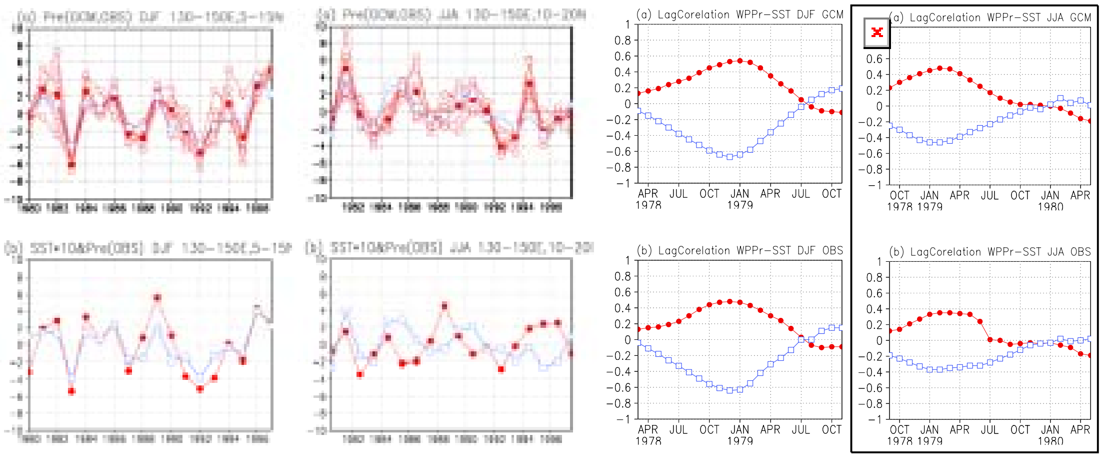

Fig.1-4 from left to right. In Fig.1 and Fig. 2 (a), empty circles for GCM members, filled circles for GCM average and squares for OBS. In Fig.1 and Fig.2 (b), squares for precipitation and circles for SST. In Fig.3 and Fig.4, circles for WP SST and squares for Nino3.4 SST. (a) GCM, (b) OBS. See the details in the text.

How about the relationship between the WP precipitation and the El-Nino SST? Fig. 3 shows the lagged correlation of WP precipitation for DJF with WP SST and Nino3.4 SST in the GCM simulation (a) and in the observation (b). Fig. 4 is the same but for JJA. First, I like to confirm that the GCM produces almost the same lagged correlation plots qualitatively and quantitatively. The DJF WP precipitation is well related not only to the WP SST positively but also the El-Nino SST negatively in DJF. These are the simultaneous relationship. For JJA, the WP precipitation is related to the WP SST and the El-Nino SST for the previous DJF, a half year ago. The GCM simulations get real history only from the observed SST and sea ice. The memory about the previous DJF must be left in other SSTs or sea ice coverage.

3.2 Why is the JJA WP precipitation related to the El-Nino SST in the previous DJF?

The simultaneous correlation of the WP precipitation with the global SST is shown in Fig. 5 for JJA. Significantly large correlated (> 0.8 or < -0.8) SST area is not found, including the WP SST. This fact indicates that any single SST area does not control the WP precipitation. Relatively large correlations (> 0.6 or < -0.6) are found in the Indian Ocean and the southern off-equatorial Pacific.

JMA's Dynamical Seasonal Prediction System and Prediction Skill of Seasonal Forecast Model

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1. Introduction

Several numerical weather prediction (NWP) centers are operating NWP model for seasonal forecast. (According to WMO definition, extended forecast is forecast beyond 10 days and up to 30 days, while long-range weather forecast is forecast

from 30 days up to two years. Recently, a term "seasonal to interannual (SI) forecast" is also used.) NWP model for seasonal forecast at JMA is essentially the same as that for short range forecast. However, lower boundary condition such as sea surface temperature (SST) and land surface parameters such as soil moisture, soil temperature and snow depth have large effect on interannual variation that we want to forecast. Moreover, ensemble prediction is necessary for seasonal forecast, since uncertainty of initial condition grows larger in the course of integration.

Introduction of NWP model into seasonal forecast has several merits. First, probability forecast is possible. Secondly, forecast is physically consistent. Thirdly, improvement based on advance of technology is expected. We recognize that dynamical seasonal forecast is now in a growing phase.

An ensemble prediction system (EPS) for Three-month Outlook has operationally conducted in March 2003; Forecast has been issued every month. The same system has been applied for Warm/Cold Season Outlook from September 2003; Outlook is issued on September and on February.

Table 1. Specifications of Global Spectral Model (GSM0103) for Long-Range Weather Forecasting (4/7-month EPS)

Basic equation	Primitive equations
Independent variables	Latitude, longitude and σ-p hybrid coordinate
Dependent variables	Vorticity, divergence, temperature, surface pressure, specific humidity, cloud water
Numerical technique	Euler semi-implicit time integration, spherical harmonics for horizontal representation and finite difference in the vertical
Integration domain	Global, surface to 0.4 hPa
Horizontal resolution	T63 (about 1.875degree Gaussian grid -180km)
Vertical levels	40
Time integration range	4 months or more, up to 7 months
Orography	Mean orography, GTOPO30 data set (30" x 30") spectrally truncated and smoothed
Horizontal diffusion	Linear, second-order Laplacian
Moist processes	Prognostic Arakawa-Schubert cumulus parameterization + middle level convection of mass flux type + large-scale condensation
Radiation	Shortwave (longwave) radiation computed every one hour (three hours), direct effects of aerosol taken into account
Cloud	Prognostic cloud water, cloud cover diagnosed from moisture and cloud water, vertical correlation of cloud overlap taken into account
Gravity wave drag	Longwave scheme for troposphere and lower stratosphere, shortwave scheme for lower troposphere
Planetary boundary layer	Mellor-Yamada level-2 closure scheme and similarity theory for surface boundary layer
Land Surface Parameters (soil temperature, soil moisture and snow depth)	Simple Biosphere Model (SiB). Initial conditions of land parameters are provided by a land data assimilation system, that has been operatioal since April 2002. Observation of snow depth reported in SYNOP is assimilated.
Executing frequency	Once a month (4-month prediction) Five times a year (Feb., Mar., Apr., Sep. and Oct.) (5- to 7- month predictions for JJA and DJF)
Ensemble size	31 members
Perturbation method	Singular Vector method
SST	Two-tiered method ; Combination of persisted anomaly , climate and prediction
note	7-month prediction is an extension of 4-month prediction

A specification of models for seasonal forecast are listed in Table 1.

We conducted a systematic seasonal forecast experiment for the past cases for 18 years with 5 members prior to the operation; This type of forecast experiment is called "hindcast". Hindcast is necessary to define model climatology and to estimate model forecast skill. We finished hindcast for Three-month Outlook and analyzed the results. We also finished hindcast for Worm/Cold Season Outlook. It has done almost same way except integration time (7-month) and sea surface temperature as a lower boundary condition.

2. Dynamical seasonal prediction system

2.1 Lower Boundary Condition

Lower boundary condition governs the interannual variability of atmosphere in seasonal forecast. SST is important for the seasonal forecast. We will use a combination of persisted anomaly, climate and prediction conducted by a ocean-atmosphere coupled model for Worm/Cold Season Outlook, while persisted anomaly is used for Three-month Outlook (Figure 1)

JMA started the operation of global land analysis system for NWP applying a land surface model in April 2002. Schematic diagram of the system is shown in Figure 2. The land surface parameters such as snow depth, soil moisture and soil temperature are calculated by the land surface model (Simple Biosphere model : SiB) with the radiative flux and precipitation amount provided by the operational four-dimensional data assimilation (4DDA) system of NWP. Only snow depth reported in SYNOP is assimilated into the land-surface analysis system as observational data. It is found that one month forecast is improved by using those land parameters compared to those without SYNOP snow depth data.

Since snow depth observation reported in SYNOP is insufficient in coverage, we have introduced a snow coverage retrieved from micro wave data observed with SSM/I .

2.2 Resent improvement of dynamical seasonal forecast and future plan.

Osean data assimilation system (ODAS) was upgraded in February 2003, and coupled ocean-atmosphere model (Kookai) was upgraded in July 2003, which brought better SST forecast provided as a boundary condition. Land data assimilation system was improved by making use of satellite data (SSM/I) in March 2003.

These development contributes the improvement of lower boundary condition. The seasonal prediction model, together with the model for short-range forecast, is continuously improved.

JMA will upgrade a computer in March 2006, and then, JMA will develop dynamical seasonal forecast using a coupled model towards operation.

3. Verification of 4-month EPS experiment (hindcast)

As mentioned above, dynamical seasonal prediction system was operationally conducted in March 2003. In preparedness for the operation, a systematic seasonal prediction experiment using JMA AGCM was conducted in order to define model climatology and to estimate model forecast skill. The specification of the experiment is as follows:

(1) Model : T63 version of JMA GSM0103
(2) Target years : 1984 to 2001, 18years
(3) Target months : All months (initial date is the end of every month)
(4) Integration time : four months
(5) Atmospheric initial condition : ECMWF 15-year Reanalysis (ERA-15) from 1984 to 1993, and JMA's operational global analyses from 1994 to 2001
(6) Land surface initial condition: Output from SiB forced by ERA-15 from 1984 to 1993, and 10-year average of them for 1994 to 2001 (Tokuhiro, 2002)
(7) Ensemble size: Five members
(8) SST: Optimum Interpolation (OI) analyses of NCEP by Reynolds and Smith(1994) for 1984 to 1993, and JMA's operational SST analyses (Nomura,1996) for 1994 to 2001. SST anomaly at initial date is persisted during the forecast period

The results of this 18 years "hindcast" type experiment are being evaluated. As an example of results from the experiment, ACCs of 90 day mean 500hPa geopotential height at 21–110 day forecast range are shown in Figure 3. Verification areas are defined as follows, NH:20N-90N,0E-360E EU:0E-180E,20N-90N PAC:90E-90W,20N-90N JAP:100E-170E,20N-60N. The systematic errors, that are estimated from the mean error of the 17 years other than the year we want, are corrected before computing ACCs. It can be seen that ACCs are tend to be higher in ENSO years than in non-ENSO years. The result is readily understood; it is expected that the second kind of predictability (Lorenz, 1974) is higher in ENSO years. Over the North Pacific region, averaged ACCs in cold season in ENSO years exceed 0.4 (Figure 4).

As a second example of results from the experiment, a skill of precipitation in summer (June, July, and August: JJA) is shown: initial date is 31 May. Figure 5 shows distribution of interannual temporal correlation coefficients between observed, CPC Merged Analysis of Precipitation (CMAP), and ensemble mean forecast precipitation in summer for 18 years (1984–2001). Although prediction skills are generally low in mid latitudes, the scores are high in the tropical Pacific and the western North Pacific to the east of Philippine Islands. Figure 6 shows interannual variations of observed and model precipitation anomaly in the western North Pacific east of Philippine Islands in JJA. The area averaged precipitation is well predicted; correlation coefficient between observed and ensemble mean forecast is 0.75. Since there are many studies that convective activities in the western North Pacific in summer, in other words activities of the western North Pacific summer monsoon (Murakami and Matsumoto, 1994) is closely related to interannual climate variation in East Asia (e.g. Nitta, 1987), the result greatly encourages us.

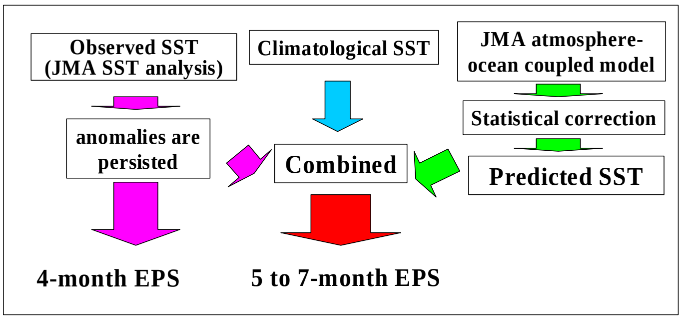

Figure 1 Schematic Diagram of Sea Surface Temperature for EPS

SST anomalies used as the lower boundary condition of the atmospheric model are persisted for the four-month integration. For five- to seven-month integration, a two-tiered method is employed for SST: combination of persisted anomalies, climatology and prediction with an atmosphere-ocean coupled model operated in JMA. The prediction of SST anomalies with the coupled model is used mainly in the equatorial Pacific region, while persisted anomalies or climatology are used dominantly in the middle and high latitudes.

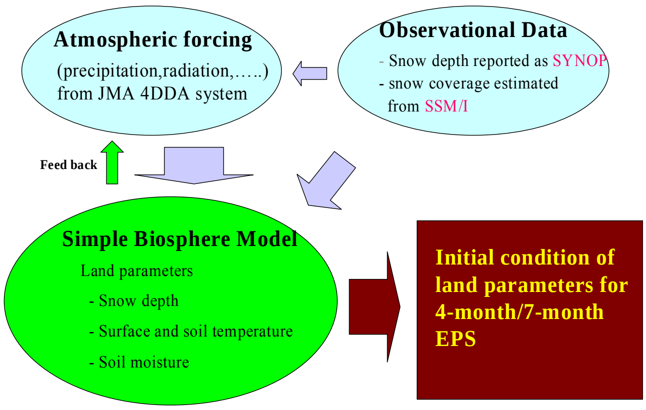

Figure 2 Schematic diagram of land data assimilation system

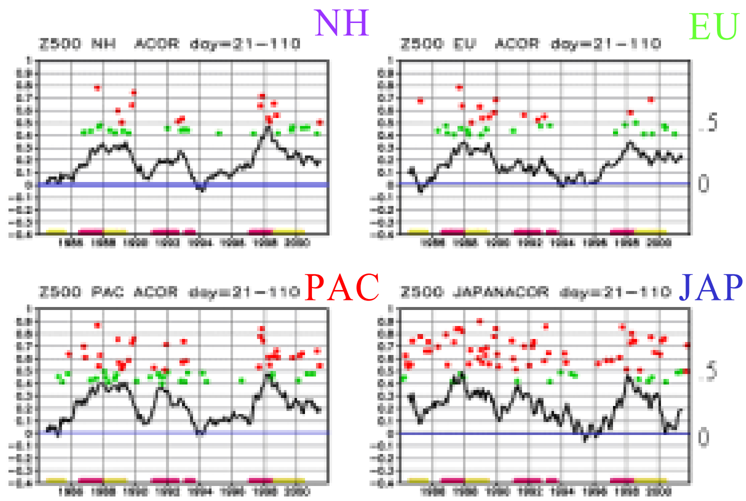

Figure 3 Forecast score of each year (500hPa geopotential height anomaly correlation)

13-month running mean
acor >= 0.5
0.5 > acor >= 0.4
Elñino period
Lañina period

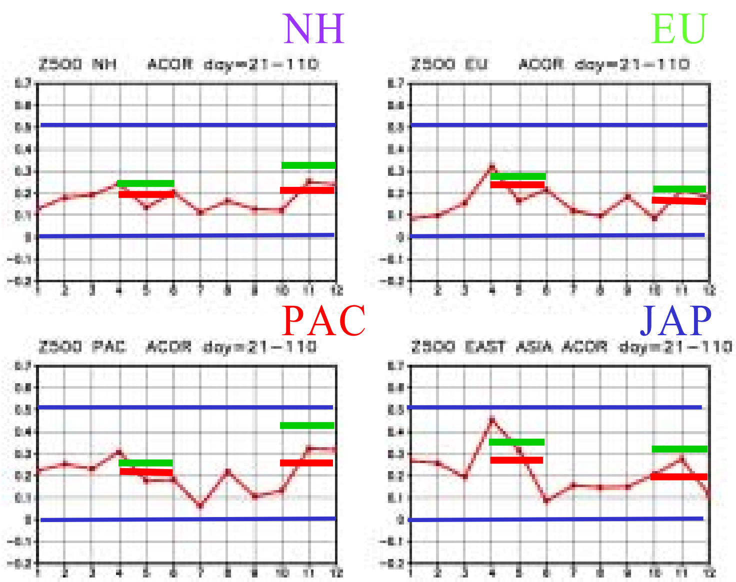

Figure 4 Forecast score of each month (500hPa geopohntial height anomaly correlation)

Horizontal axis :initial month of model integration
Vertical axis :anomaly correlation
18 years average of anomaly correlation ach 90day mean value
seasonaly mean
seasonaly mean (only ENSO years)

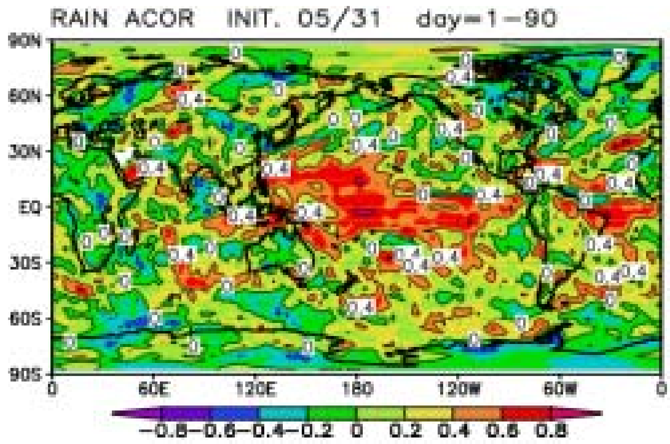

Figure 5 Distribution of interannual temporal correlation coefficients between observed(CMAP) and predicted precipitation in summer(JJA)

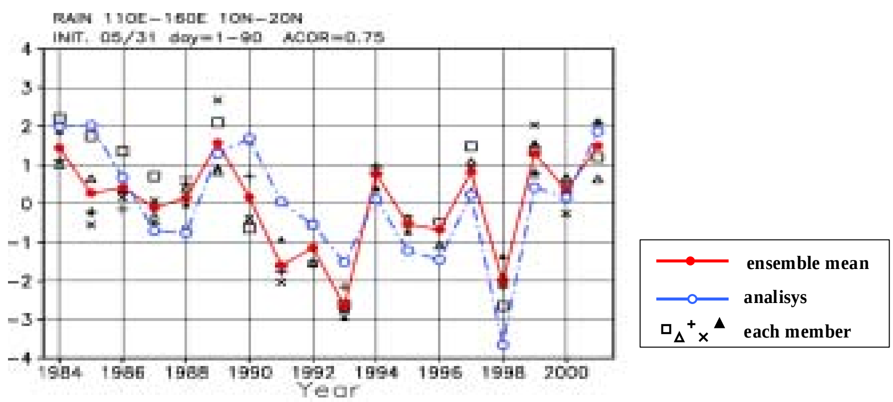

Figure 6 Interannual variations of observed and predicted precipitation anomaly(mm/day) in the western North Pacific east of Philippine Islands(110E-160E,10N-20N in summer(JJA)

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A Fully Coupled Architecture for Atmosphere-Vegetation-Hydrology Legacy Models Applied to the West African Monsoon

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I - Introduction

This is a global description of the project COUMEHY (COUplage MEteorologie HYdrologie - http://lthent1.hmg.inpg.fr/GRID) financed by the french ministry of research (via the ACI-GRID program; http://www-sop.inria.fr/aci/grid/public).

The aim of this project is to develop and use a modular structure of coupling, applied to climate topics, specially to the monsoon and to the water cycle over West Africa.

One of the main COUMEHY objectives is to develop an architecture of flexible coupling (modular) able to be integrated into GRID computing environments while using legacy models. This project will be completed at the end of the year 2004 and has already shown the possibilities of coupling legacies models of the atmospheric, hydrologic scientific communities and the biospheric one trough vegetation models (SVAT: Surface Vegetation Atmosphere Transfer models).

COUMEHY project includes two parts:

(i) **a scientific part** aims at the evaluation of the importance of the coupling between the water cycles from the atmosphere, the hydrological watersheds, the surface oceanic conditions (evolutive and prescribed from a weekly climatology within COUMEHY) and the vegetation, into a thin scale approach. It also aims at highlighting feedbacks that each system can result on the others, and to understand their reflected effects on the climate over West Africa.

(ii) **a technical part** designed to achieve the previous scientific objectives. To do that, it is necessary to develop a tool which permits **modularity** (independence of each legacies models), **inter-operability** (heterogeneous grid computing is thus possible) and **portability**.

The goal of this coupling is also to join many types of models resulting from several environmental scientific communities not being based on same methodologies and on different numerical and programming methods. The common point of these disciplines (and models) is the physical interface which represents boundary conditions that are usually treated either by forcing (boundary conditions are provided by climatologies) or by other no-inlined model outputs.Therefore, interfaces are the objects on which all the scientific and the technical works must be focused because technical interfaces are strongly linked with physical interfaces defined between each type of models. Usually, physical interfaces are coding inside technical interfaces or called independently by technical interfaces.

Four climatic environments – and type of models - must be thus represented: (i) atmosphere (ii) continental hydrologic systems (iii) temporal evolution and sub-surface impact of the vegetation (iv) ocean surface conditions. The concept of heterogeneity is thus here very strong. The coupling from a technical point of view is thus the communication of several models via a distributed architecture based on CORBA (Common Object Request Broker Architecture) objects which allows the integration of applications distributed on heterogeneous computers with heterogeneous models.

II - Scientific objectives

The objective of this project is to evaluate the importance of the coupling processes between atmospheric, continental hydrologic cycle, vegetation and ocean surface conditions and this, within the framework of the climatic changes.

The selected area is West Africa region whose climate is marked by strong feedback between the vegetation and the pluviometric mode on a broad range of time scales (from intra-seasonal to decadal at least). The supposed climatic role of the continental hydrological processes in these areas is to allow the vegetation to access to the soil and ground water ressources that involves the development and the persistence of the vegetation activity, in particular during the dry periods. It then results an impact on the surface-atmosphere water and energy budget via the reflectance capacity from (i) ground-vegetation system, (ii) radiative transfer through the vegetation (iii) transpiration. In addition, the vegetation is a significant component of the continental source of momentum sensible and latent heat fluxes and humidity for the atmosphere. This is why West Africa seems to be a geographical area well adapted for the evaluation of the relevance of a meteorological/surface conditions coupling.

For the entire study of the water cycle over West Africa, one must add oceanic surface conditions that many studies strongly link to the modes of precipitations. A study undertaken within the framework of COUMEHY was carried out to modelize and to check the influence of the SST (Sea Surface Temperature) on the African western pluviometric mode during dry years. The SST then seemed the main factor controlling the northward penetration of the monsoon over the continent and driving the intensity of rainfall over coastal regions (Messager et al, 2003; Vizy and Cook, 2002).

A method to estimate the water transfer in the soils must be implemented to be able to represent diversity of these transfers over area higher than the size of several watersheds. With this intention, hydrological models by type of basins will have to be considered if hydrology of the various basins is governed by varying processes from one site to another (so some models are dedicated for the Sahelian zone and other are dedicated for the wet zone).

Another task is the representation of the continental interaction atmosphère/surface, taking into account their respective treatments in the current numerical models. These problems are not new and were already considered within the framework of the climatic system modelling. More particularly, the atmosphere is divided into regular square meshs whereas the continental hydrological is divided into watershed and subdivided in non-homogeneous cells inside each watershed. One proposes to develop a coupling method to take into account the differences between the geometries.

The finest space resolution of the atmospheric models working on a climatic scale is about 100 to 20 kilometers with a regular organization of the computation nodes; whereas the hydrological models compute on scales much smaller (kilometer, even hundred of meters), with an irregular dispersion of the computation nodes often distributed according to the hydrographic network. So the problems consist in modelling the flows exchanged between the models by solving the geometry changes. With this intention, aggregation and downscalling methods of the flows exchanged through the interfaces will be tested by taking account of the geometry of the discretization grids, and of the dynamic flows influenced by a subgrid relief of the weather model (relief with a higher resolution than those inside the initial mesh of the climate model).

At continental/atmosphere interface, conservation of energy and water in the soil and the vegetation will be treated by SVAT model (e.g. SISVAT – De Ridder and Gallée, 1998; SISPAT – Braud et al, 1995). The characteristic of this SVAT is that it will be adapted and discretized on the watersheds and not on square meshes that it is usually done in weather models. Indeed, the calculation of the soil moisture distributions is dependent on hydrological parameters strongly linked with the localization of the watersheds and their geographic characteristics. The SVAT must thus be seen like an interface having the geometrical shape of the watershed cells and using the hydrological physics of those watersheds.

At ocean/atmosphere interface, the SST will be initially prescribed by the Reynolds climatology and computed by the SISVAT (Sea Ice SVAT – e.g. De Ridder and Gallée, 1998) which makes it possible to take into account both continental and oceanic surfaces for calculations of energy and moisture vertical fluxes. In a second step, it will be necessary to determine a better dataset for the SST. For example, it will be possible to use and validate new climatologies specifically adapted to the Guinea Gulf or model outputs from high resolution ocanographic models.

III - Technical problems

Several scientific branches have developed different models adapted to the diversity and the complexity of the associated scientific problems. In the same way, the calculators on which these models are exploited are very different: weather models use mainly high performance computers whereas hydrological models can be used - for the moment - on PC or workstations. Moreover, each scientific community has its characteristics in the numerical approach for modeling adapted phenomena and space resolution and temporal scales differing a lot. Consequently, the numerical resolutions must be synchronized, exchangeable and must physically consistent.

For the computing aspect, it is necessary to exchange and adapt informations through a computing interface to several models. So, several approaches exist (i) developing a specialized code, traditionally called “coupler”, which ensures the adaptation to the interfaces (ii) including all the interface functionalities, without coupler, as services integrated into the models themselves.

We choosed and developed the second way within the COUMEHY project, particulary because it offers more possibilities to integrate new models later (concept of extensibility) or to replace a model by an other one.

Overall, another aspect of the project is the portability of the developments while being based on the most widespread standards to guarantee an easy installation on other computers (this is due to the use of CORBA technology) and a most efficient perenity.

III-1 Software and data-processing

A significant part of the project will be devoted to implementation of exchange technology between the various models, using different physics or time and space scales.

The choice of CORBA (Common Object Request Broker Architecture) is essential because it offers today the best way of answerring to the exposed objectives. Standard CORBA offers a total infrastructure to bring the whole of the needs for interworking in the heart of all the data-processing applications. It is codified since ten years within a consortium gathering most of the major partners, as well as the users, who establishes the successive specifications of this standard.

The other solutions now available do not authorize easy reuse of existing codes known as " legacy codes" (with the example of JAVA), or remain partial while answering only part of the imposed constraints (portability, extensibility and inter-operability). Such various approaches were born in the scientific world, in particular around the concept of message exchanges.

This technology thus allows a modeling of multi-physics or multi-scales phenomena by the coupling of several applications, without upsetting those which continue to evolve independently in the hands of their respective developers.

III-2 Numerical models considered

Three classes of atmospheric tools may be considered as far as regional climate modelling is concerned: General Circulation Models (GCM) with a stretched horizontal grid, and two classes of Limited Area Models (LAM).

The first class of LAM uses parameterizations of the non resolved physical processes similar to those used in the host model – the GCM - while the second class uses parameterizations adapted to their grid size and to the region of interest.

Most of European LAMS used in the regionalization of climate belong to the first class. LAMS of the second class are developed by US and Canadian teams (e.g., RegCM, MCR, MM5).

One difficulty arising from grid stretching results from the fact that the same parameterization is used in the area near the pole of stretching and near the opposite pole while the grid sizes may differ by a factor 10. Nevertheless the simulations could give acceptable results when one considers the stretched region specifically.

Regional Climate Models (RCM) developed in Europe generally belong to the first class. The idea to use the same physics as that of the host model results from the need to get numerical solutions as similar as possible in the host model and the LAM, in order to avoid numerical discontinuities at their interfaces. Nevertheless it has been proven that LAMs of the second class do not generate worst solutions at the GCM/LAM interface than LAMs of the first class (Giorgi and Mearns, 1999). Moreover the performances of LAMs of the second class are generally better than those of LAMs of the first class, when they are nested in the meteorological analyses (Giorgi and Mearns, 1999).

The MAR (Modèle Atmosphérique Régional, e.g. Gallée and Schayes, 1994, Brasseur et al., 1998; De Ridder and Gallée, 1998; Brasseur, 2001) belongs to the second class of LAM and has been used mainly in extreme regions (tropical and polar regions) where the parameterizations need the more important adaptations. Moreover, MAR – nested in GCM reanalysis - has shown its scientific availability to simulate the different West African Monsoon periods (Gallée et al, 2003; Messager et al, 2003).

Hydrological processes could not be treated with a single generic hydrologic model, consequently within COUMEHY several same models (several because there are a lot of watersheds on the coupling application, and each watershed is simulated by a hydrologic model) were used. The model used was ABC, developed and validated only for the Sahelian area. However, in arid and semi-arid regions, water-table is not explicitly resolved by the ABC model and it is thus impossible to use it over wetlands where the water-table is one of the main inflow of the river discharges. One of the futur objectives aim will be the adding of hydrologic model (such as TOPMODEL, e.g. Beven et al, 1995; Campling et al, 2002) adapted on the humid regions.

The treatment of the vegetation and of its temporal evolution will be classicaly devoted to a SVAT model (e.g. SISVAT – De Ridder and Gallée, 1998; SISPAT – Braud et al, 1995).

In a first step, ocean surface conditions will be prescribed by a SST climatology. In a second one, and depending on the project achievment degree and the necessity, other oceanic surface conditions will be implemented in the coupling system.

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POAMA: Bureau of Meteorology Operational Coupled Model Seasonal Forecasting System

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ABSTRACT

POAMA (Predictive Ocean Atmosphere Model for Australia) is a state-of-the-art coupled ocean/atmosphere model seasonal forecast system developed jointly by the Bureau of Meteorology Research Centre (BMRC), Melbourne and CSIRO Marine Research (CMR), Hobart, in a project partly funded by the Climate Variability in Agriculture Program (CVAP). It is based on the latest version of BMRC's unified climate/Numerical Weather Prediction atmosphere model (BAM) and the Australian Community Ocean Model (ACOM2). The POAMA system uses a sophisticated ocean data assimilation scheme that incorporates the latest oceanic observations into the initialisation procedure for the model forecasts. It is also one of the few models that uses real atmospheric data, taken from the Bureau's operational weather forecast system. One of POAMA's unique features is that it always uses the very latest oceanic and atmospheric data.

The POAMA system has been run in real-time by the operational section of the Bureau of Meteorology since 1st October 2002. The initial focus of POAMA is the prediction of El Nino. Local variables such as precipitation have not yet been made available to users. POAMA forecasts of SST anomalies are presented every month at the National Climate Centre's seasonal climate outlook meetings. It was the first coupled model, back in November 2002, to forecast that the 2002 El Nino would rapidly decay at the beginning of 2003.

The operational system and latest results are described. Results show that the skill of POAMA forecasts is at least as good as the best international models. Also discussed is the model's unique ability to simulate and predict intra-seasonal variability, such as, the Madden-Julian Oscillation (MJO), which is normally not well simulated by coupled models. Such variability has been associated with the onset of some El Ninos.

POAMA web site: http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA

1. Introduction

POAMA (Predictive Ocean Atmosphere Model for Australia) is a seasonal to inter-annual climate prediction system based on coupled ocean and atmosphere general circulation models. It was developed in a joint project involving the Bureau of Meteorology Research Centre (BMRC) and CSIRO Marine Research (CMR), with some funding coming from the Climate Variability in Agriculture Program (CVAP) of Land and Water Australia.

The POAMA model is a significant improvement over earlier versions of coupled models for seasonal forecasting at BMRC (Wang et al 2001, Kleeman el al 1995). It uses the latest state of the art ocean and atmosphere general circulation models. In addition real time oceanic and atmospheric initial states are used to initialise the coupled model. These are provided by an ocean data assimilation system that is run in real time as part of the POAMA system and by the Bureau of Meteorology operational weather analysis system.

Another unique feature of the POAMA system is the ability of the atmosphere model to represent the Madden-Julian Oscillation(MJO), most atmosphere models are not capable of adequately representing the MJO. This ability, together with the use of real-time ocean and atmospheric data means that POAMA can also produce forecasts of intra-seasonal variability out to a few weeks lead-time. Internationally, POAMA is the only operational coupled model with this capability.

Many plots from both real-time forecasts and hind-casts are available on the POAMA web site (http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA). These include horizontal plots of SST anomalies for each lead time, as well as equatorial/time plots with daily resolution of SST, 20C isotherm depth and surface zonal wind anomalies. These are produced for means of monthly ensembles, mean of last 30 forecasts and also individual forecasts. These plots are updated each day as each model forecast is produced.

The structure of this paper is as follows. Section 2 describes the different components of the POAMA seasonal forecast system. Section 3 describes the operational set up and shows some sample results. Section 3 describes a set of hind-casts and presents some results from these hind-casts, in particular an assessment of model skill. Finally in section 5 is a summary and a list of priorities/issues for future research.

2. Components of the POAMA system

a. Amosphere Model

The atmospheric component of the coupled model used in POAMA is the Bureau of Meteorology unified atmospheric model (BAM). As well as climate prediction it is also used for decadal and climate change research and operationally for daily weather prediction. The latest version (BAM 3.0d) was used in the forecasts described in this report. A modified convection closure was used because it allowed the model to have a good representation of the MJO. It has a horizontal spectral resolution of T47 and has 17 vertical levels. The performance of this model forced with observed SST is described in Zhong et al (2001).

b. Ocean Model

The ocean model component is the Australian Community Ocean Model version 2 (ACOM2). It was developed by CMR, and was based on the Geophysical Fluid Dynamics Laboratory Modular Ocean Model (MOM version 2). Improvements produced by CMR include: a mixing scheme and penetration of solar radiation into the upper ocean appropriate for tropical oceans, tidal mixing in areas near Australia where this process influences SST, and representation of islands and straits in the Indonesian region to give realistic representation of the Pacific to Indian Ocean Indonesian through-flow. The grid spacing is 2 degrees in the zonal direction. The meridional spacing is 0.5° within 8° of the equator, increasing gradually to 1.5° near the poles. There are 25 levels in the vertical, with 12 in the top 185 metres. Technical details of ACOM2 are given in CMR Reports 227 and 240 (Schiller et al., 1997; Schiller et al. 2002).

c. Coupler

The ocean and atmosphere models were coupled using the Ocean Atmosphere Sea Ice Soil (OASIS) coupling software (developed by CERFACS, France; Valcke et al, 2000). This coupler gives high flexibility for changing model components in the future as models further improve.

d. Ocean data assimilation

The ocean data assimilation scheme is based on the optimum interpolation (OI) technique described by Smith et al (1991). Only temperature observations are assimilated and only measurements in the top 500m are used. There are several improvements over the scheme described by Smith et al (1991). The OI scheme is used to correct the model background field every 3 days using a 3 day observation window, one and a half days either side of the assimilation time. Current corrections are calculated by applying the geostrophic relation to the temperature corrections, similar to the method described by Burgers *et al.* (2002).

e. Atmospheric initial conditions

For the real time forecasts the atmospheric component is initialised with weather analysis from the Bureau of Meteorology's operational NWP system (GASP). This means that the seasonal forecast model knows about the latest intra-seasonal state of the tropical atmosphere.

For the hind-casts, GASP analyses were not available. An attempt was made to use NCEP re-analysis but these were found to lead to dynamic instabilities in the east Pacific. This is being investigated further. The hind-casts described in this report used the atmospheric state from an integration of the atmosphere model used in POAMA forced at the surface with weekly Reynolds SSTs.

3. The real-time system

The POAMA system has been run in real-time every day by the Bureau of Meteorology operations branch since 1st October 2002. This real-time system consists of two suites: main ocean analysis system and forecast cycles.

a. Main analysis cycle

The main analysis cycle aims to use as many observations as possible to provide an estimate of the ocean state in near-real time. To allow as many observations as possible to be used the system is run approximately 10 days behind real-time. Each day the ocean state is integrated forward one day using the ocean model. The ocean model is forced with six-hourly fields from the GASP NWP system.

Every three days observations are assimilated into the ocean model. All available sub-surface temperature observations from the Global Telecommunications System (GTS) are used. Sea surface temperature observations are not assimilated. Instead, the ocean model surface temperature is relaxed to the SST analysis field used in the GASP system with an e-folding time scale of 3 days.

b. Catch-up analysis and forecast cycles

A significant number of ocean observations are received over the GTS within a day of real-time, for example, observations from the TRITON/TAO array. This means that more is know about the latest state of the ocean than the information that went to produce the main analysis because this analysis is produced 10 days behind real-time. For this reason a catch up analysis is produced each day as part of the forecast cycle. The ocean model is integrated forward from the main analyses to the present and observations are assimilated every three days as in the main analyses. The catch-up analysis does not have any impact on the main analyses.

Every day a 9 month coupled model forecast is produced in real-time using the very latest ocean state from the catch-up analysis and the latest atmospheric state from the GASP analysis. This is unique to the POAMA system.

c. Post-processing of model output

The coupled model experiences some drift during the forecast, a feature characteristic of all climate models. This is taken into account in the products produced from the forecasts by referencing all anomalies relative to the model forecast climatology. A forecast anomaly is calculated as:

$$a_m(t) = f_m(t) - \sum_y f_{ym}(t)$$

where $a_m(t)$ is the anomaly corresponding to the forecast value $f_m(t)$ starting in month m and as a function of lead time t. y represents the hind-cast years used to calculate the climatology (1987-2001). Thus the climatology used to calculate each anomaly depends both on start time of the year of each forecast and also on forecast lead-time. This is similar to the method of Stockdale (1997).

4. Forecasts and hind-cast skill

a. Model skill based on hind-casts

The initial focus of the POAMA system is the prediction of the El Nino phenomenon. Initially products focus on the structure of the upper ocean in the tropics. The main product for ENSO prediction is the forecast plume of NINO3 (region 90-150W and 5S-5N) anomalies. Research is underway to investigate how best to produce forecasts of local variables, for example, precipitation. Such products will be made available from the next version of POAMA (POAMA-2).

Testing of the skill in the coupled model used the so-called “hind-cast test”. This method initializes a prediction on, for example, 1 March 1987 using only information available before that date. The test of the model is then based on comparing the prediction to information collected during the remainder of 1987. Hind-cast tests initialized at many past dates can be combined into statistics to evaluate the accuracy of the forecasts, and to provide a measure of “skill” of the model.

A set of 180 forecasts, one per month (started on the 1st of each month) for the years 1987 to 2001, have been used to assess the performance of the model. Ocean initial conditions were taken from an ocean assimilation which was carried out from 1982 to 2001 using the same assimilation system as used for the operational version. GASP atmospheric initial conditions were not available for all of this period. Instead the atmospheric state was taken from the appropriate date during an integration of the atmosphere model forced with observed weekly Reynolds SST. Land surface conditions where also taken from this forced run of the atmosphere model. Because in the hind-casts the model was not initialized with the true atmospheric state from GASP, we do not expect it to perform as well as in the real time forecasts.

Another reason why the real time forecasts should have greater skill than the hind-casts is because the ocean observing system is being continually improved. For example, it was only in the early 1990’s that the TOGA-TAO array was implemented in the tropical Pacific. This array consists of moored temperature sensors and is the main source of observations in the equatorial Pacific. Another major revolution in the ocean observing system is happening right now. Around 300 autonomous floats, which drift around in the ocean measuring temperature and for the first time salinity, are being deployed in a project called Argo (Argo 1998). These ocean observations contribute to the skill of coupled model seasonal forecasts. Even so, the POAMA forecasts over the period 1987-2001, as will be shown below, have skill comparable with the best international models.

One measure of forecast skill is the anomaly correlation coefficient for NINO 3 SST anomalies. This is shown in figure 1 for both model and persistence, as a function of lead-time. The plot shows that the model beats persistence at all lead times, even during the first month of the forecast. At eight months lead-time the skill is relatively high at 0.7 and significantly better than persistence at 0.2.

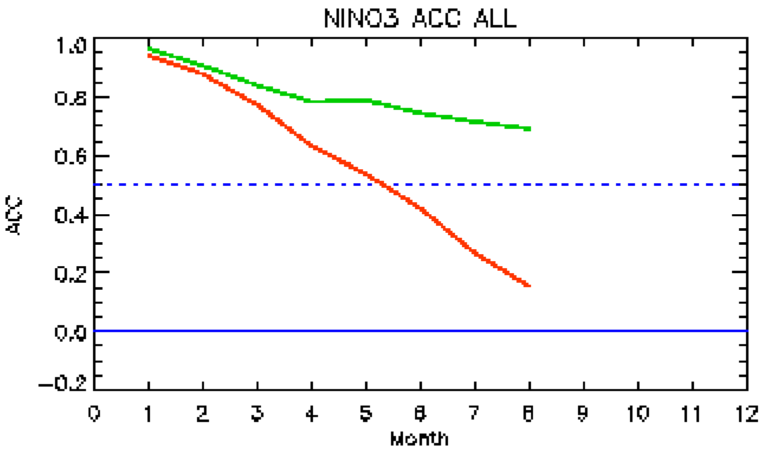

Figure 1. *Nino 3 anomaly correlation as a function of lead time for 60 forecasts starting one person during the period 1987-2001. Red – persistence of initial SST anomalies, Green – POAMA coupled model.*

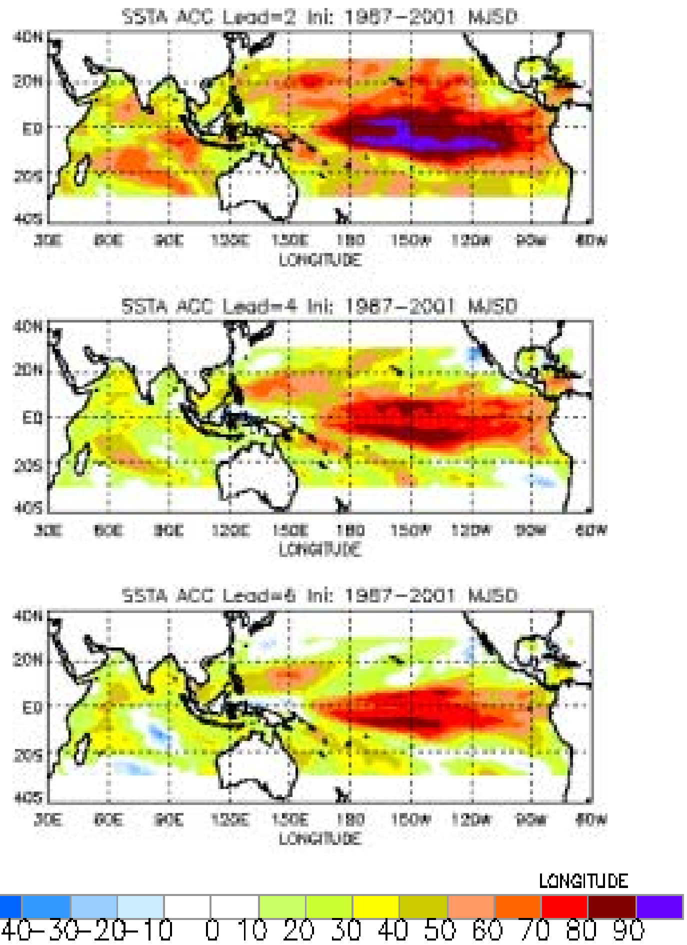

Figure 2. *Spacial distribution of anomaly correlation of SST anomaly (x100). Top- 4 month lead time, middle – 4 month lead time and bottom – 6 month lead time.*

Horizontal patterns of anomaly correlation skill are shown in figure 2 for lead times of two, four and six months. At all lead times the peak in skill is concentrated in the central and eastern Pacific, associated with the El Nino/La Nina phenomena. At two months lead time the anomaly correlation reaches over 0.9 in the central Pacific. At six months lead-time it reaches up to 0.8 in the central Pacific south of the equator. These skill measures are competitive with the best international models, especially when taking into account that only one hind-cast per month was used.

Results from the European Union DEMETER project (Doblas-Reyes pers. Comm.) show that forecast skill depends critically on ensemble size, mainly due to averaging out of noise when using an ensemble mean with a greater number of members. The POAMA real-time system produces an ensemble of 30 per month. For the hind-casts there is only one forecast per month. Therefore, the skill based on the hind-casts is likely to significantly underestimate the skill of the real-time system.

b. Sample real-time forecast of the 2002 El Nino

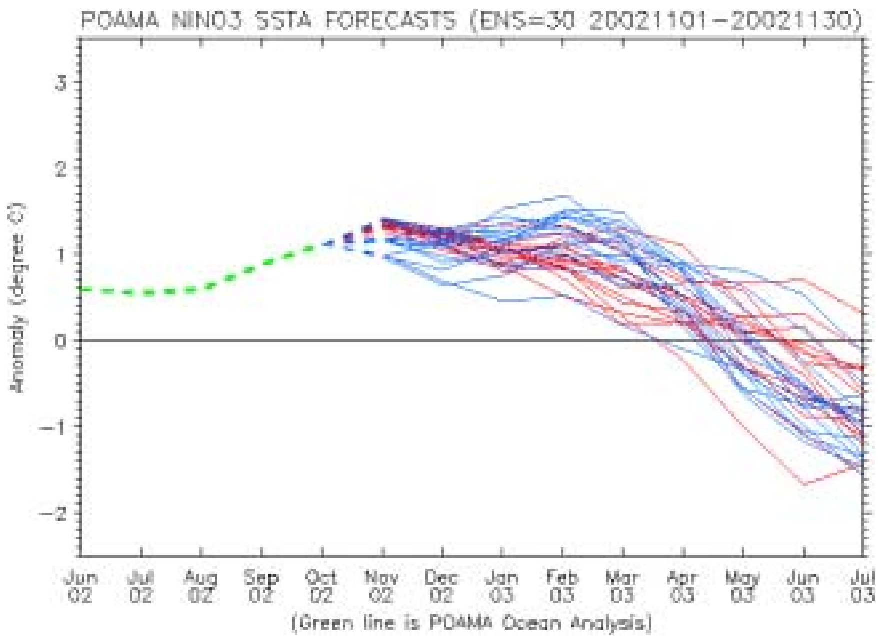

***Figure 3**. Nino 3 anomaly forecasts from operational POAMA. Ensemble of 30 forecasts, one starting each day throughout November 2002. Red curves show forecasts started in the latter half of November and Blue curves show forecasts started in the first half of November.*

An ensemble of 30 forecasts starting during November 2002 is shown in figure 1. The model shows the maintenance of weak El Nino conditions from October 2002 into early 2003. During March/April 2003 all members show cooling and the decay of the El Nino conditions. The POAMA model was the first operational coupled model to forecast that the 2002 El Nino would decay rapidly in the first few months of 2003.

Towards the end of the forecast period there is increase in ensemble spread with some members going to La Nina conditions while others going into neutral conditions. The increased ensemble spread is providing information about forecast uncertainty, showing that there is considerable uncertainty as to what will happen once the El Nino decays. The ability of coupled models to produce ensembles is one of their main benefits because the spread in these ensembles tell us something about the amount of uncertainty in the future.

Monthly ensemble mean forecasts from the real-time POAMA system, initialized around the peak of the 2002 El Nino, are shown in figure 4. As early as October 2002, when POAMA first went operational, the forecasts indicated that the 2002 El Nino would decay in the first half of 2003. Forecasts from subsequent months were even better, with remarkably accurate forecasts produced in January and February 2003.

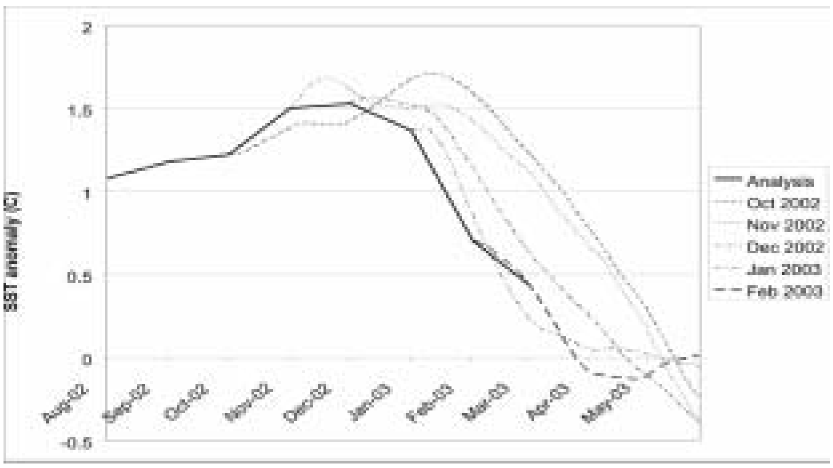

Figure 4*. Nino 3 SST anomaly monthly ensemble mean forecasts from operational POAMA. Each forecast curve shows ensemble mean for each month for forecasts during the period October 2002 to February 2004. The solid curve shows observed NINO3, taken from the POAMA analysis.*

Many other plots are freely available on the POAMA web site (http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA). These include horizontal plots of SST anomalies for each lead time, as well as equatorial/time plots with daily resolution of SST, 20C isotherm depth, outgoing long-wave radiation (OLR) and surface zonal wind anomalies. These are produced for means of monthly ensembles, mean of last 30 forecasts and also individual forecasts. These plots are updated each day as each model forecast is produced. Equatorial/time plots of OLR and surface wind provide information about intra-seasonal variability, such as the Madden-Julian oscillation and westerly wind bursts.

c. Forecasts of the 1997/8 El Nino

Forecast ensembles (20 members) were also produced for the onset and decay of the 1997/8 El Nino. These are shown in figure 5 for the Nino 3.4 region (120-170W, 5S-5N) in the central equatorial Pacific. The first plot shows an ensemble of forecasts starting on the 1st December 1996. Some of the forecasts in the ensemble follow the observations reasonably well. The second plot shows forecasts starting on 1st March 1997. All forecasts in the ensemble show warming and two of the forecasts are close to observations. The fact that most forecasts under-predict the event may indicate that the 1997/8 El Nino was a very extreme event, the extent of which may not have been predictable from 1st March 1997.

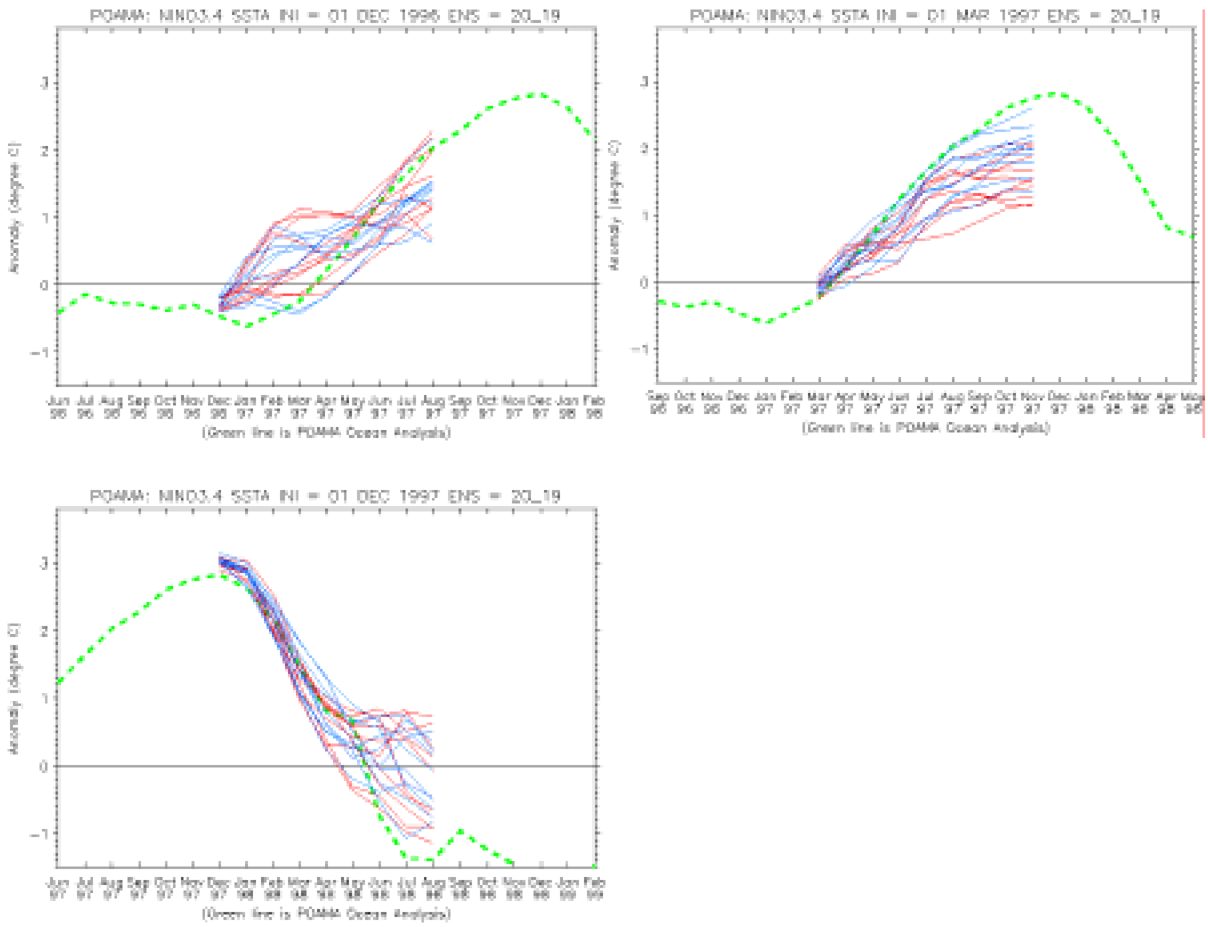

Figure 5. *Nino 3.4 SST anomaly curves. Green – observed, red/blue – model forecasts starting on the 1st December 1996 (top left), 1st March 1997 (top right) and 1st December 1997 (bottom).*

The final plot in figure 5 shows forecasts starting on 1st December 1997, near the peak of the El Nino. The model correctly predicts the rapid decay. The ensemble spread remains tight during the decay of the El Nino but increases once the El Nino has finished, indicating that somewhere between neutral to La Nina conditions would follow. These plots show that the POAMA model predicted the onset and decay of the SST anomalies in the Nino 3.4 region associated with the 1997/8 El Nino. The quality of these forecasts is comparable with those from the ECMWF model published in Stockdale et al (1998).

d. Forecasts of Intra-seasonal variability (MJO)

Coupled models are designed to represent the physics of the real ocean and atmosphere. These models must have a good representation of the physical processes during El Nino. Intra-seasonal variability, for example, the Madden-Julian Oscillation (MJO) and associated westerly wind bursts, are believed to play a significant role during some El Ninos. Therefore, one measure of the quality of a coupled model is how well it can simulate the MJO. However, most models generally have a poor simulation of the MJO, see Hendon (2000).

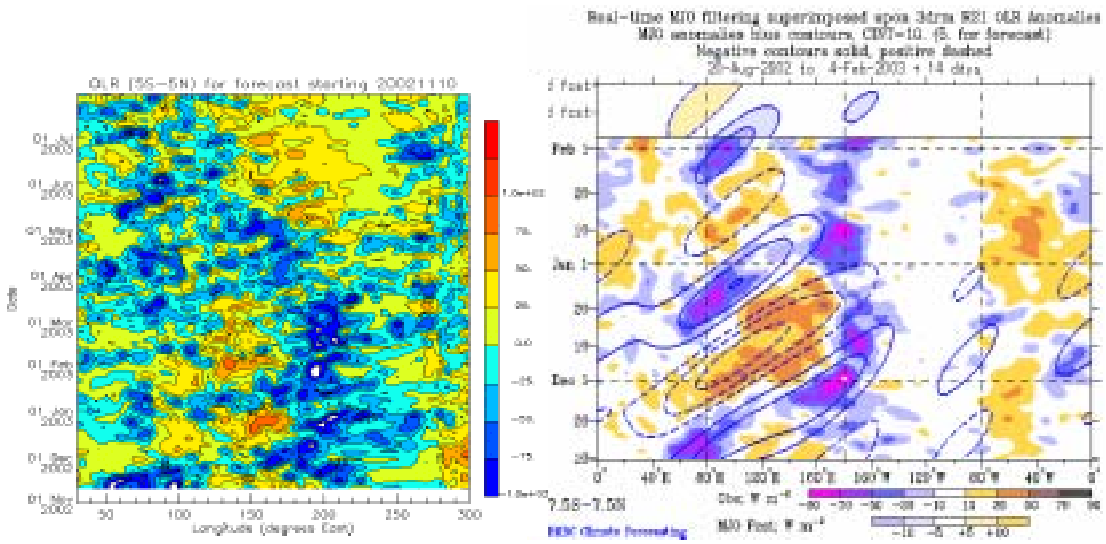

Figure 6. *OLR (Outgoing long-wave radiation) anomalies averaged about the equator (7.5N to 7.5S) show as a longitude/time plot. Left – first 80 days of a POAMA real-time forecast starting on 1st November 2002. Right – observed OLR obtained from the web pages of Matthew Wheeler (http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/OLR_modes/index.htm).*

One of the main strengths of the POAMA model is its ability to simulate the MJO. Furthermore, because operational POAMA is initialised with real atmospheric states from the Bureau's weather forecast analysis system it can be used to predict the MJO. Initial investigations show that POAMA has some skill out to a few weeks lead-time. An example forecasts is presented in figure 6, showing the real-time forecast starting on 10th November 2002. At this point in time there was enhanced convection in the Indian Ocean which subsequently propagated eastwards as an MJO event, reaching the central Pacific around 1st December (right hand plot of figure 6 shows observed evolution of OLR in the equatorial region). Observations also show a phase of suppressed convection propagating from west to east during the first half of December and then another enhanced phase starting in the second half of December, representing a second MJO event.

The POAMA forecast is also shown in figure 5 (left plot). In a similar manner to observations the forecast shows the enhanced convection in the west Pacific in the middle of November propagating eastwards as an MJO event. Remarkably, the forecast also shows the suppressed phase that follows and then a second MJO event which starts in the Indian ocean at the end of December, a little later than observed. These plots show two things. Firstly, that POAMA is able to simulate variability associated with MJO events, and it can do this throughout the entire forecast. This means that POAMA forecasts are able to generated westerly wind bursts associated with MJO during model forecasts. Secondly, that the model may have significant skill in forecasting the observed intra-seasonal variability (not just generating random MJOs) out to a few weeks lead-time. This is presently being investigated further.

5. Summary

The new Bureau of Meteorology seasonal forecast system called POAMA has been run in real-time since 1st October 2002. It is based on the Bureau's latest unified climate/weather prediction atmosphere model and a state-of-the-art ocean model developed by CSIRO Marine Research in Hobart. It produces an eight month forecast every day using the very latest ocean and atmosphere initial conditions. The ocean state is taken from an ocean analyses system also run in real time, based on optimum interpolation and using all sub-surface ocean observations received over the GTS. Atmospheric initial conditions are taken from the Bureau of Meteorology operational weather prediction system (GASP).

POAMA real time forecasts have so far been very successful. POAMA was the first operational coupled model to predict that the 2002 El Nino would rapidly decay at the beginning of 2003.

The skill assessment in terms of Nino 3 anomaly correlation based on 15 years of hind-casts is competitive with the best international models. The model beats persistence at all lead-times. In the central Pacific, skill measured using anomaly correlation of SST anomalies, reaches over 0.9 in the first one and two months and still reaches over 0.8 in parts after six months.

Ensemble forecasts during the 1997/8 El Nino show that the model was able to predict SST anomalies in the central Pacific associated with both the onset and decay of the event. Forecasts starting as early as 1st December 1996 were able to predict the rapid warming that followed in the central Pacific. The quality of these forecasts were comparable with those from the ECMWF model published in Stockdale et al (1998).

One of the notable features of the model is its ability to represent intra-seasonal variability characteristic of the MJO. This is one of the measures of the ability of the model to represent the physical mechanisms relevant to seasonal prediction; most operational seasonal forecast models have difficulty simulating realistic intra-seasonal variability. This feature of POAMA, as well as its use of real-time ocean and atmosphere information for its initial conditions, make it able to also produce intra-seasonal forecasts of MJO variability. Initial investigations suggest that POAMA may have some skill in forecasting observed MJOs out to a few weeks lead-time. This potential skill is being investigated further at BMRC. POAMA is the only operational international seasonal forecast model with this capability.

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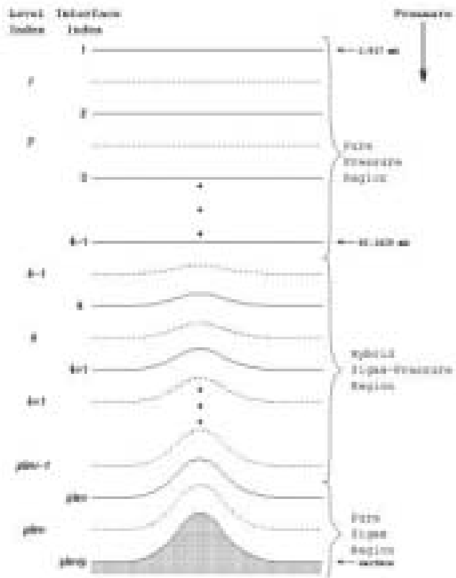
Hindcast of Tropical Pacific Ocean Temperature using a Coupled GCM

Joong-Bae Ahn[1] and Hyei-Sun Park[2]

[1]*Pusan National University*
[2]*Korea Institute of Sciences and Technology Information*

- **AGCM(NCAR/CCM3)**
  - Horizontal Resolution :
    T42 Spectral model (~2.8125°)
  - Vertical Resolution :
    From surface to 2.9hPa,
    Hybrid sigma-pressure coordinate,
    18-layer
  - 6-layer LSM(Land Surface Model)
  - CH_4, N_2O, CFC11, CFC12, CO_2 and back ground aerosol concentration effect



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OGCM(GFDL/MOM3)

- Horizontal Resolution (Arakawa B-grid) :
  - a. zonal direction : ~2.8125°
  - b. meridional direction :
    ~ 0.7° (low latitude), ~ 1.4° (middle latitude), ~ 2.8° (high latitude)
- Vertical Resolution :
  29-layer (10, 40, 60, 80, 100, 120, 140, 161, 186, 218, 257, 300, 346, 404, 480, 580, 704, 846, 1000, 1163, 1356, 1600, 1927, 2340, 2847, 3443, 4115, 4843, 5600 m)
- Vertical mixing scheme :
  Richardson number-dependent mixing(Philander & Pacanowski 1980)
- Upper boundary conditions :
  bulk aerodynamic formula from atmospheric variables

PNU/CPML

Sea Ice Model(LANL/CICE)

- Thermodynamic/Dynamic Sea-Ice Model
- Thermodynamic part : Semtner's 3-layers model
  → Amount of sea-ice is determined by thermal heat balance.
- Dynamic part : Elastic-Viscous-Plastic(EVP) model
  → Sea-ice velocity is determined by deformation rate and viscosity due to internal stress and momentum fluxes from atmosphere and ocean.
- Fractions of thick ice, thin ice and open water within a grid
- Solar radiation absorption by brine pocket
- Horizontal Resolution : Same as OGCM resolution
- Vertical structure : 2-layer of sea-ice, 1-layer of snow
  : Variable vertical layer according to the sea-ice thickness, presence of snow and stability

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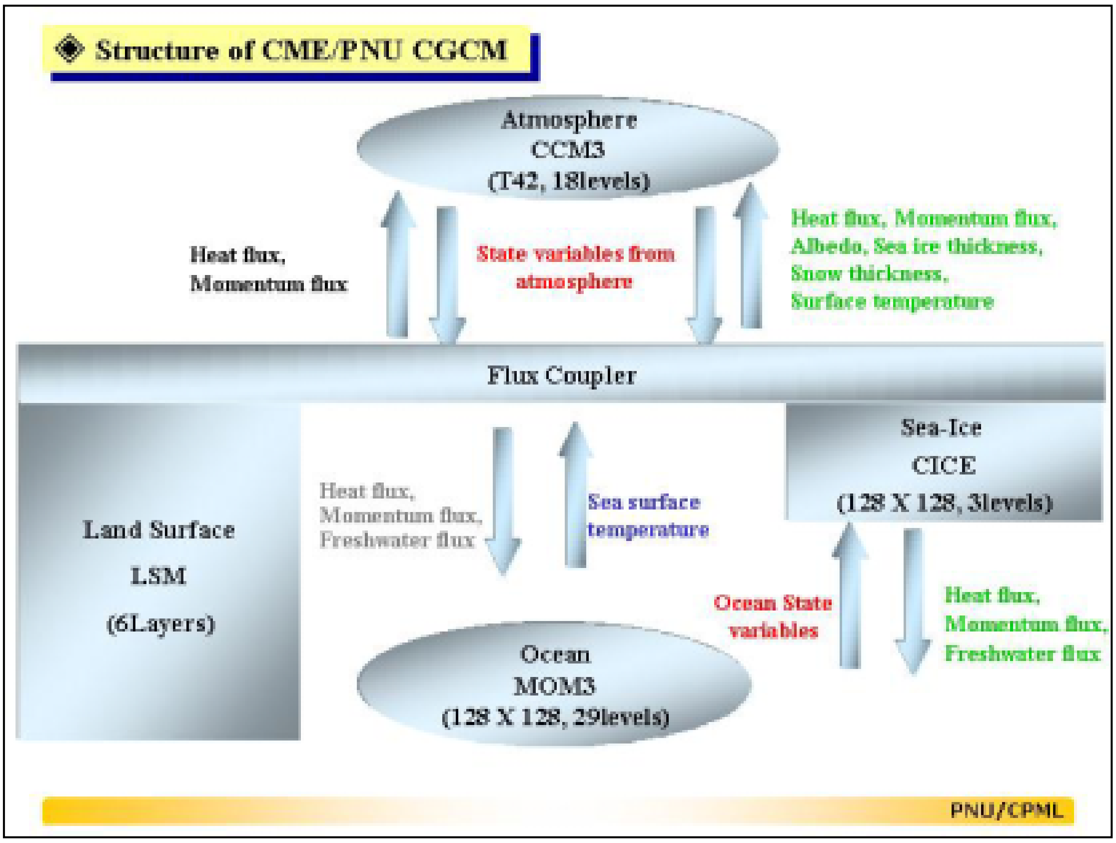
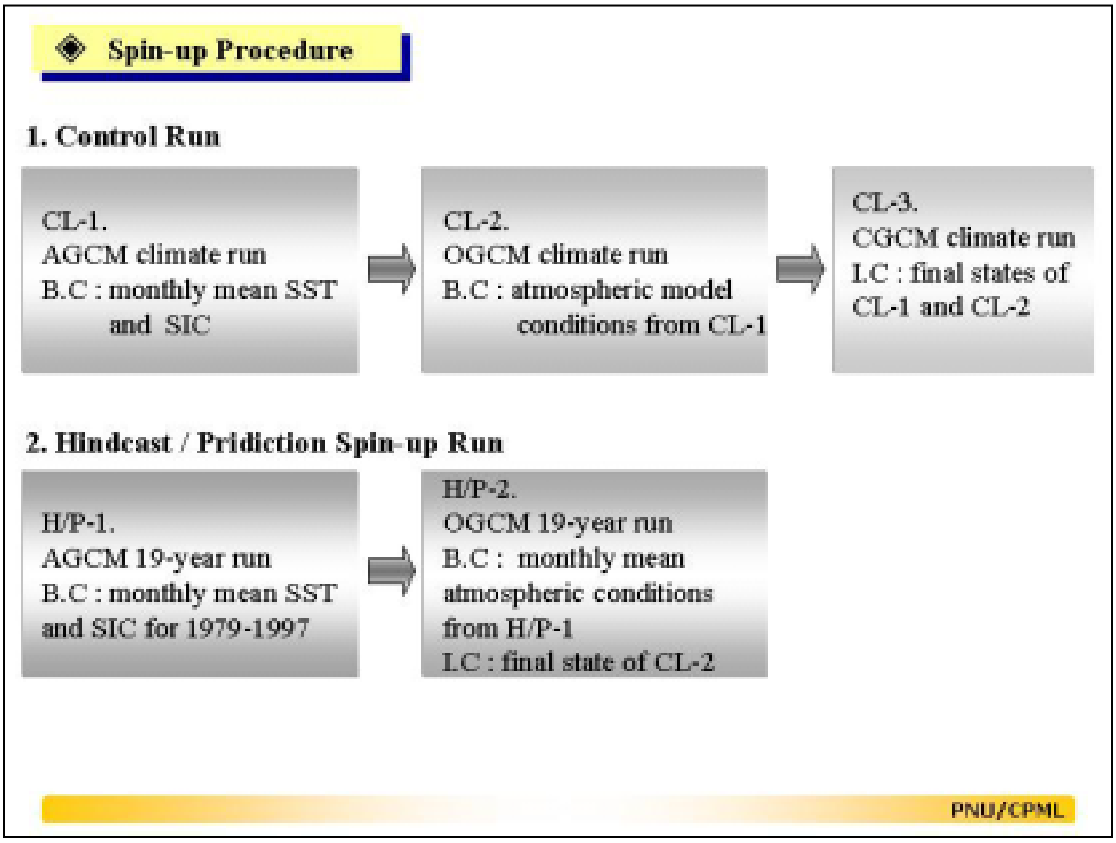

Structure of CME/PNU CGCM
Atmosphere
CCM3
(T42, 18levels)
Heat flux,
Momentum flux
State variables from
atmosphere
Heat flux, Momentum flux,
Albedo, Sea ice thickness,
Snow thickness,
Surface temperature
Flux Coupler
Land Surface
LSM
(6Layers)
Heat flux,
Momentum flux,
Freshwater flux
Sea surface
temperature
Sea-Ice
CICE
(128 X 128, 3levels)
Ocean State
variables
Heat flux,
Momentum flux,
Freshwater flux
Ocean
MOM3
(128 X 128, 29levels)
PNU/CPML


Spin-up Procedure
1. Control Run
CL-1.
AGCM climate run
B.C : monthly mean SST
and SIC
CL-2.
OGCM climate run
B.C : atmospheric model
conditions from CL-1
CL-3.
CGCM climate run
I.C : final states of
CL-1 and CL-2
2. Hindcast / Pridiction Spin-up Run
H/P-1.
AGCM 19-year run
B.C : monthly mean SST
and SIC for 1979-1997
H/P-2.
OGCM 19-year run
B.C : monthly mean
atmospheric conditions
from H/P-1
I.C : final state of CL-2
PNU/CPML

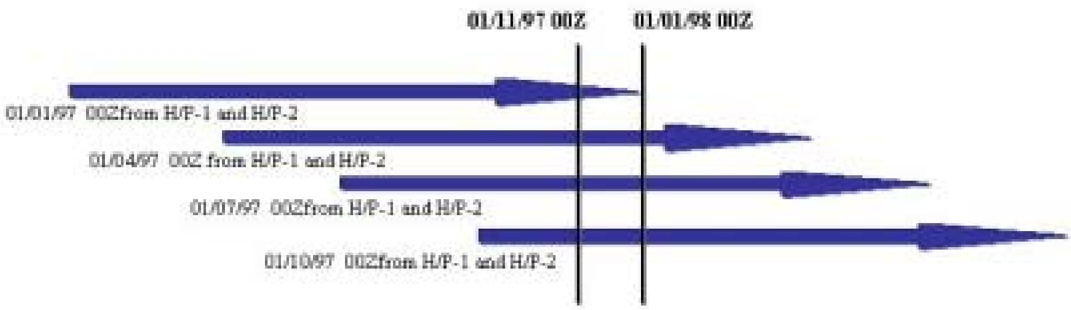
◆ Hindcast / Prediction Procedure

❑ CGCM Run

IC : Atmosphere and Oceanic Model States from H/P-1 and H/P-2

❑ Procedure (Examples)

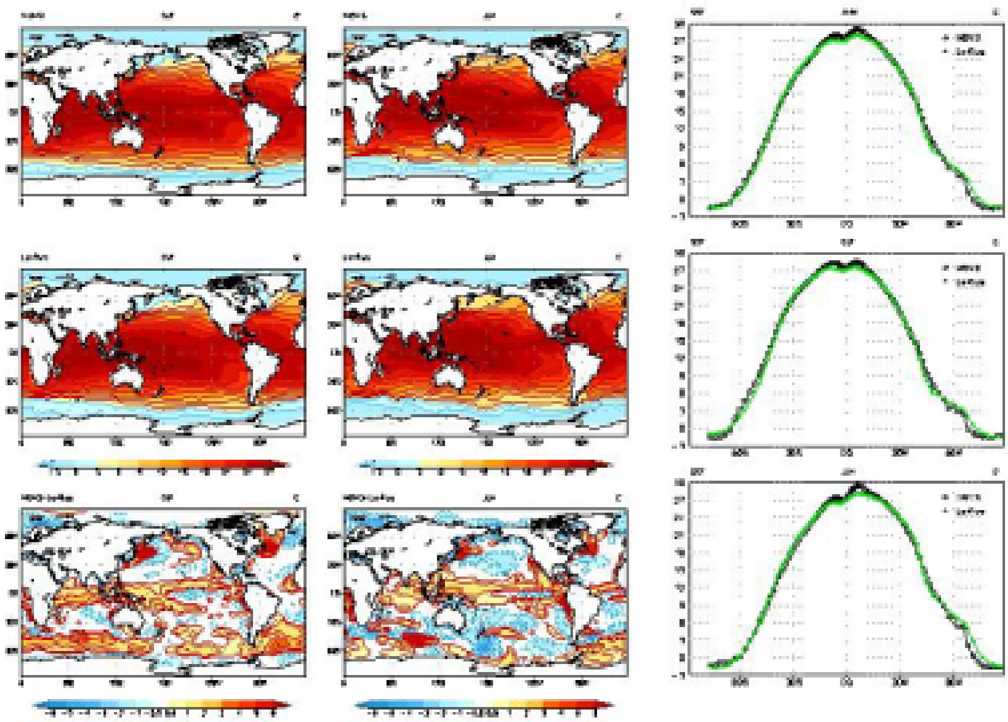
- 12-month lead hindcast experiment(7 El Ninos and La Ninas)

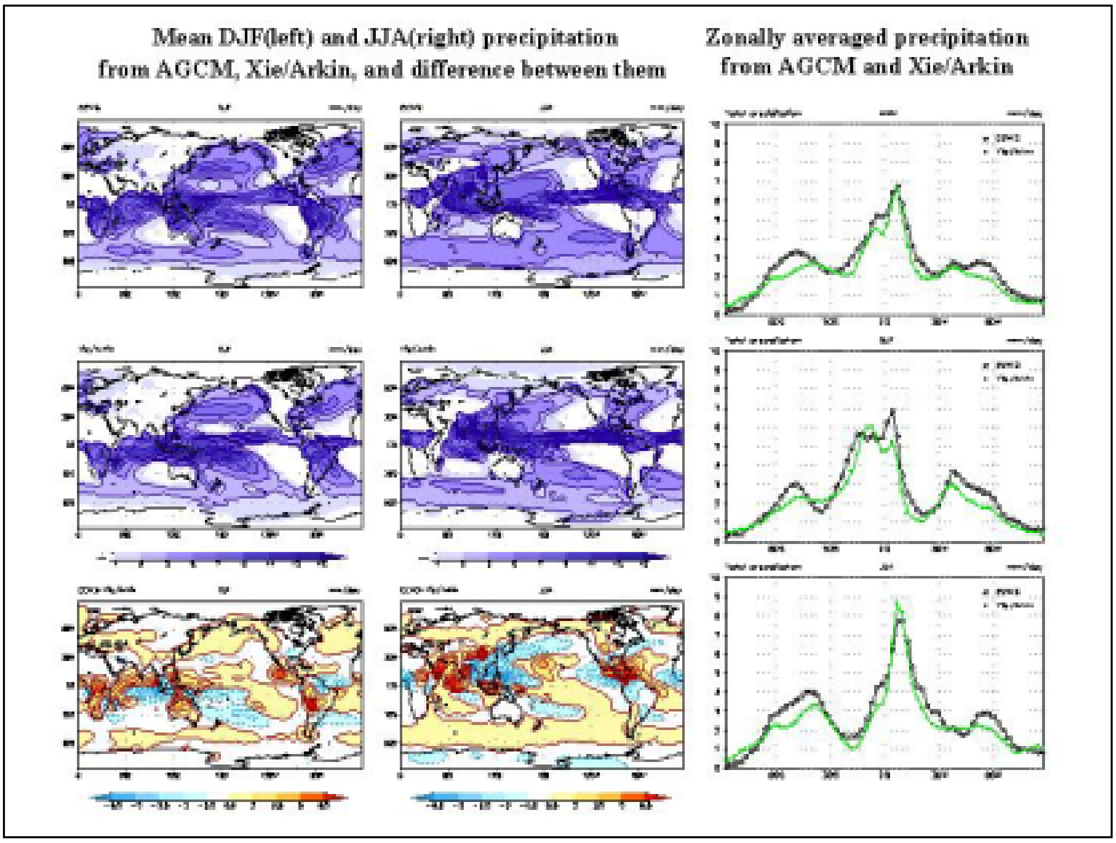


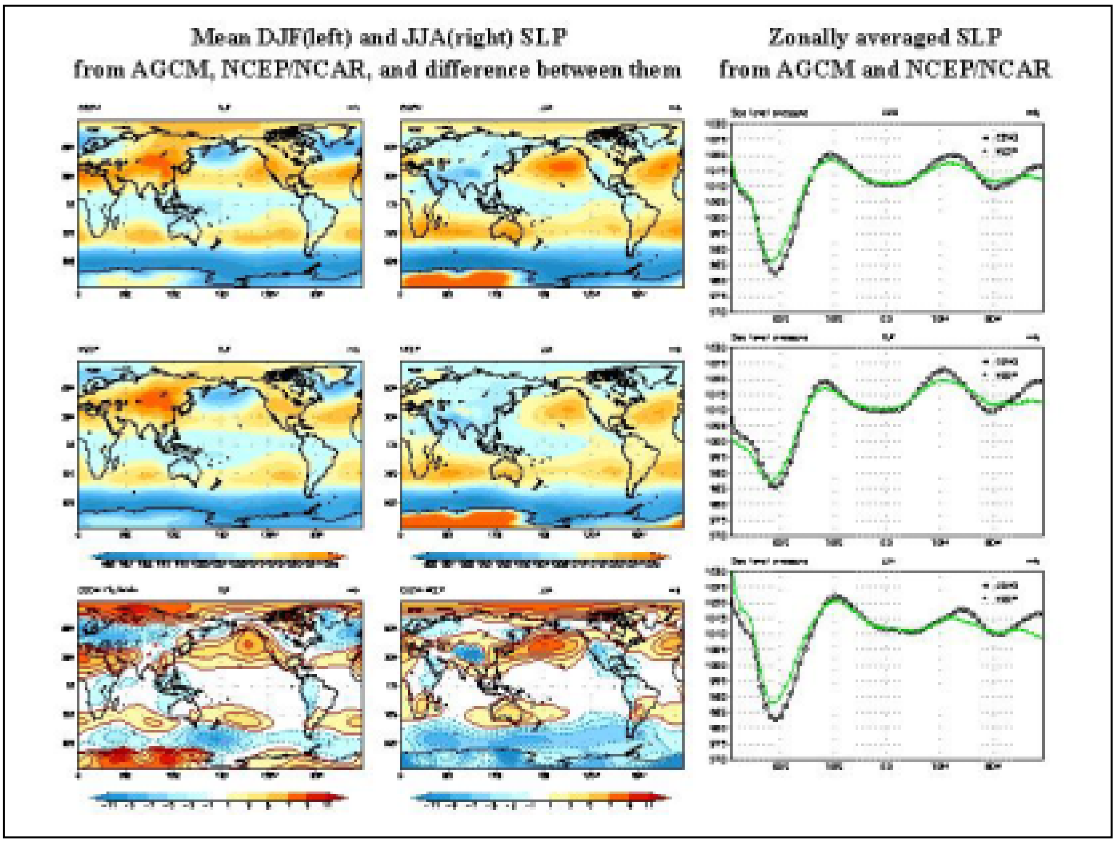
PNU/CPML

Mean DJF(left) and JJA(right) SST from OGCM, Levitus, and difference between them

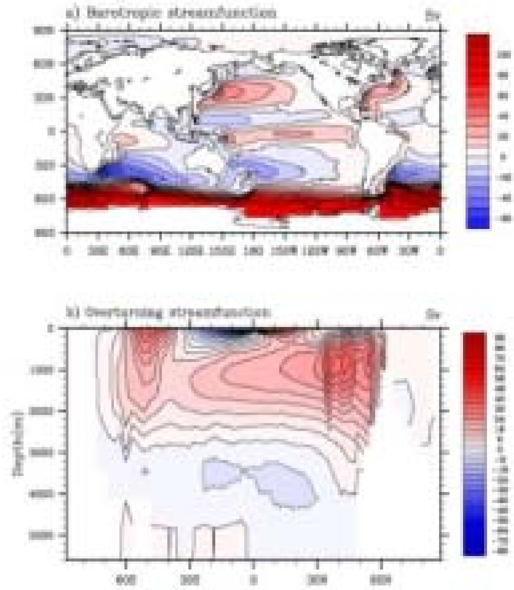
Zonally averaged SST from OGCM and Levitus




Mean DJF(left) and JJA(right) precipitation
from AGCM, Xie/Arkin, and difference between them
Zonally averaged precipitation
from AGCM and Xie/Arkin


Mean DJF(left) and JJA(right) SLP
from AGCM, NCEP/NCAR, and difference between them
Zonally averaged SLP
from AGCM and NCEP/NCAR

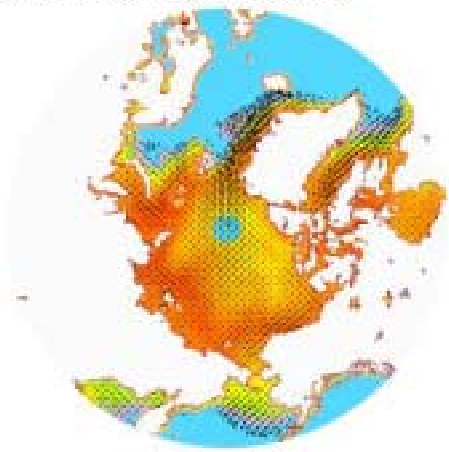
◈ **Global distribution of annual mean stream function(a) and vertical cross section of zonally averaged annual mean overturning from OGCM**



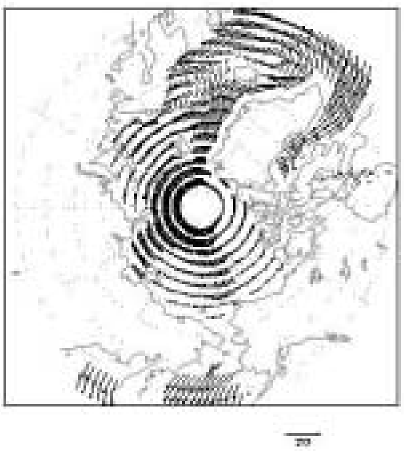
PNU/CPML

◈ **Sea-Ice motion in the Arctic for winter (Feb.-Mar.)**

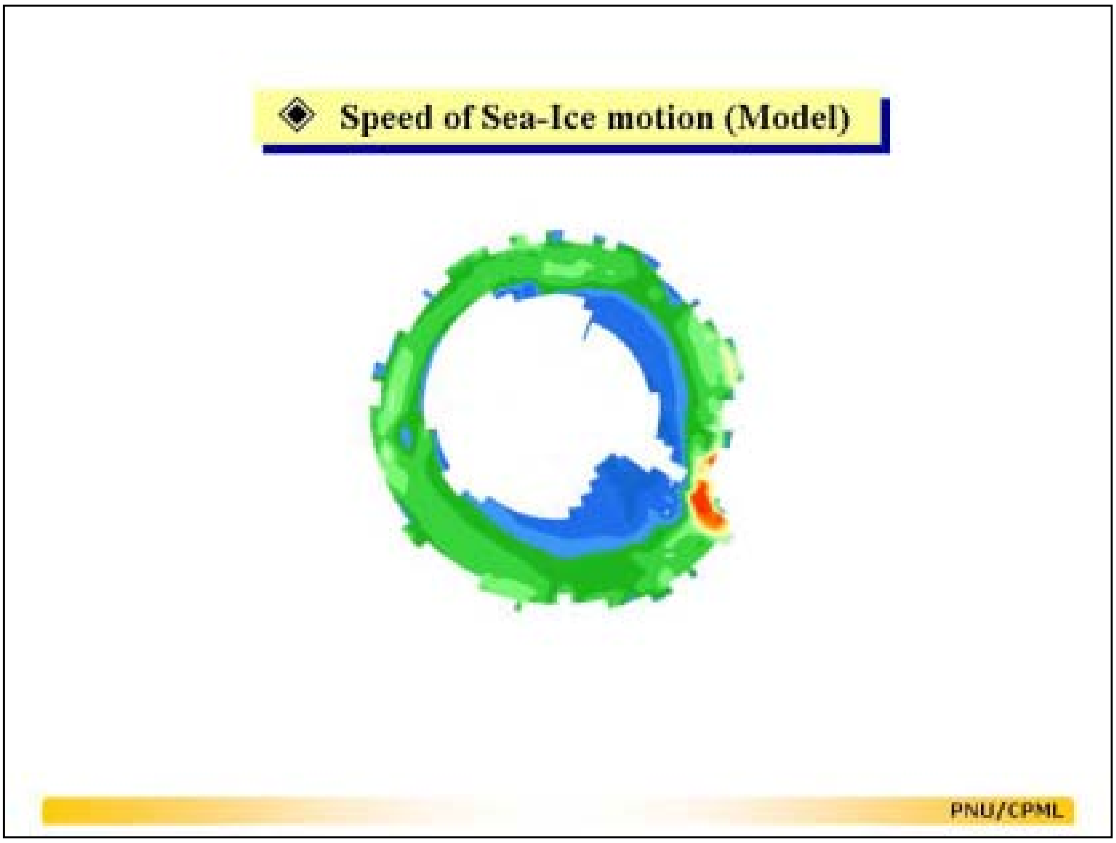
a. Observations
(derived from 85 GHz passive microwave)

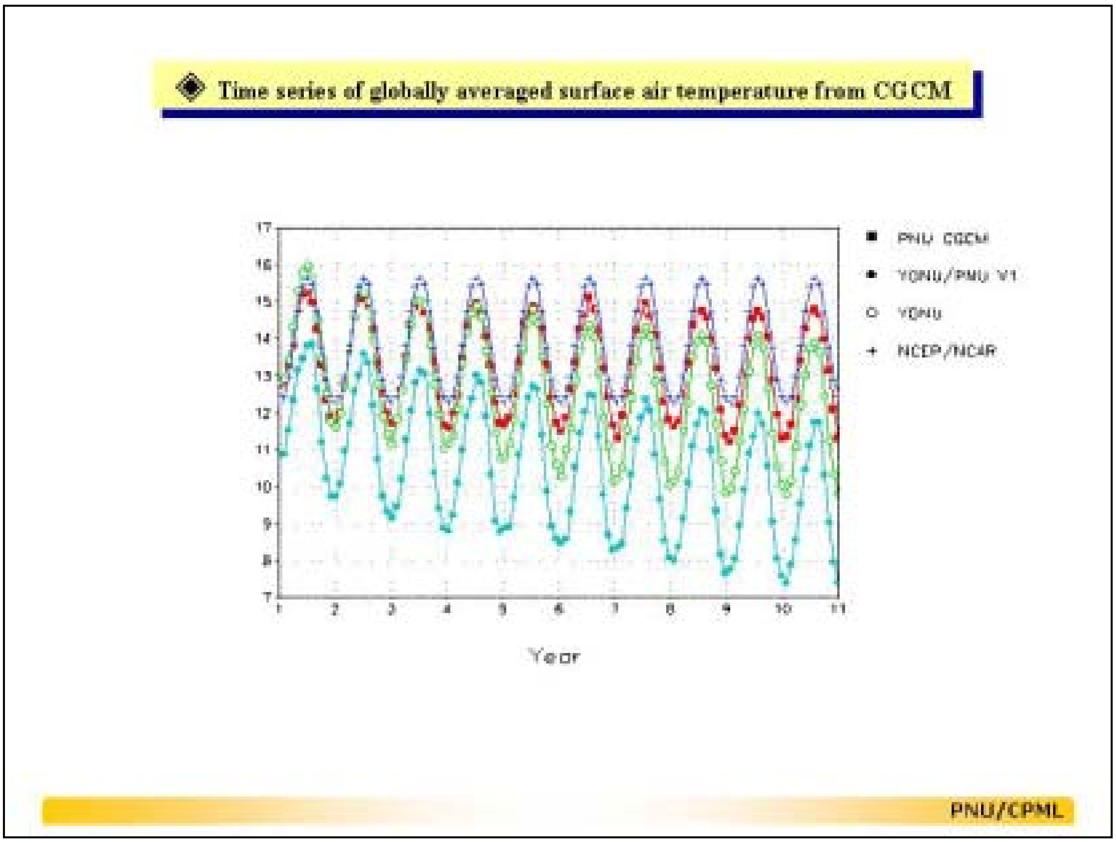


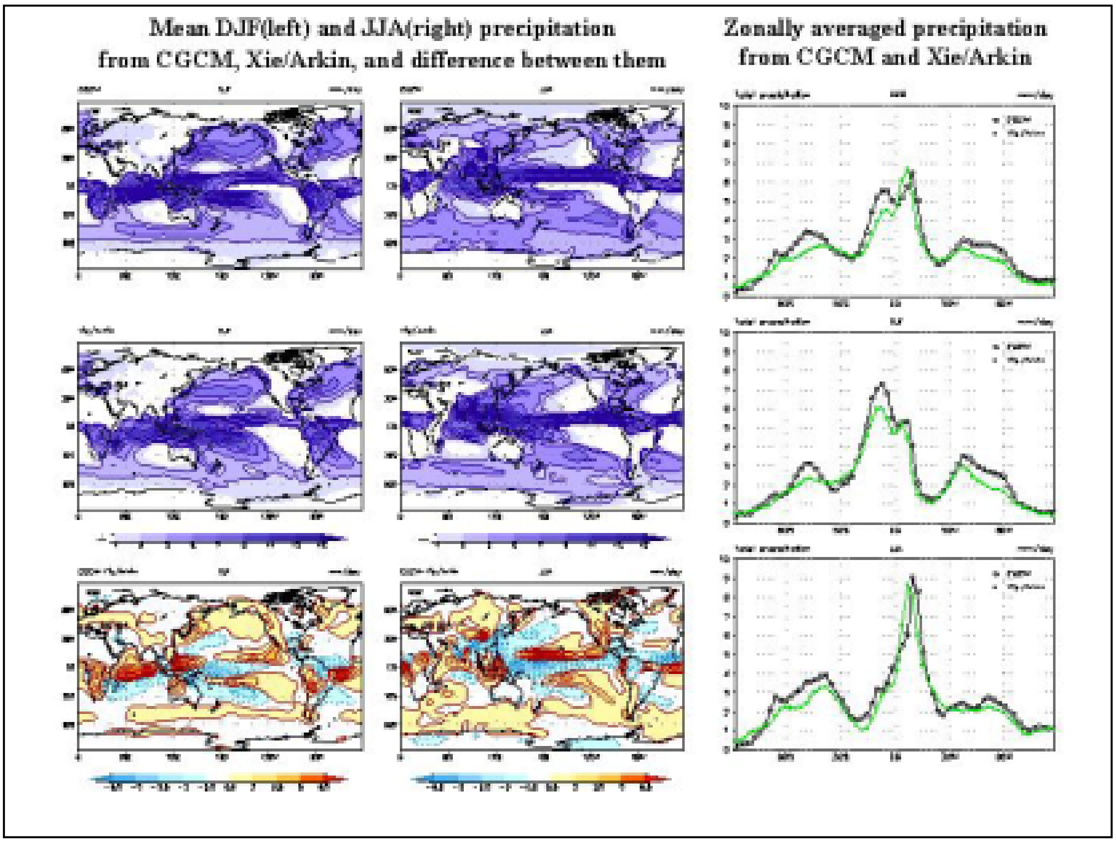
b. Model

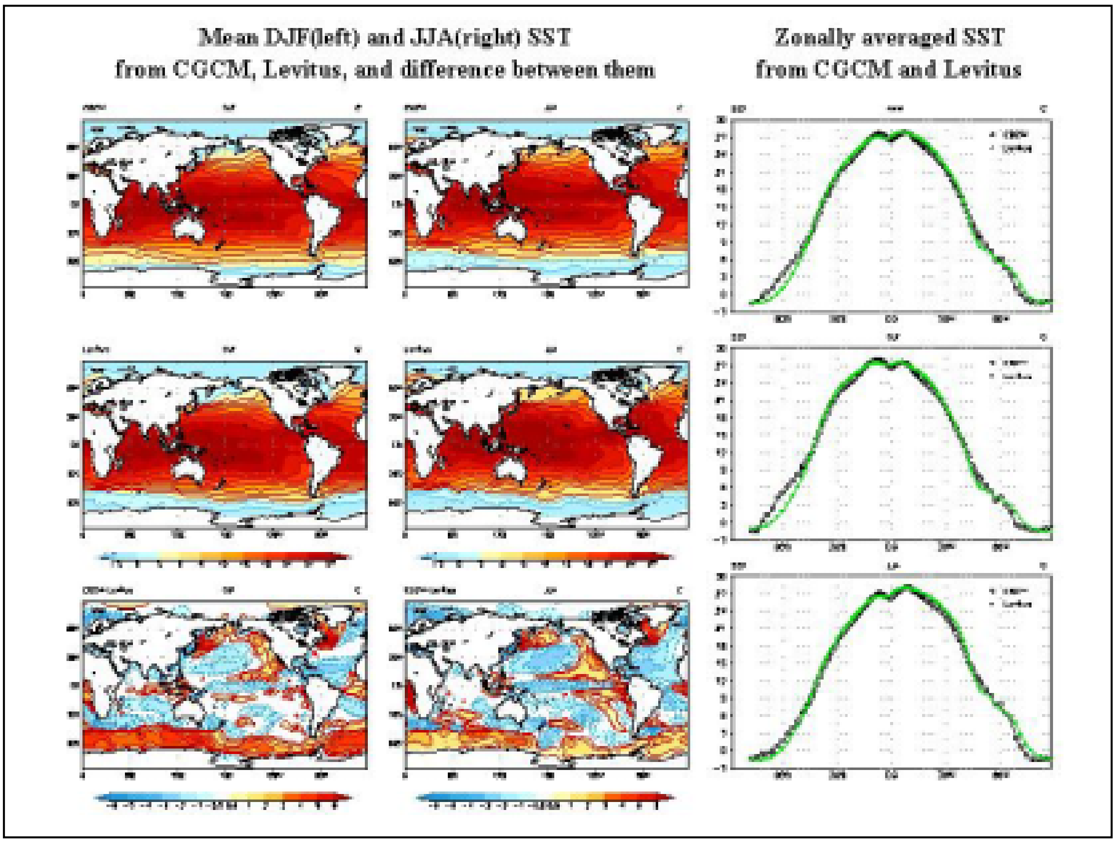


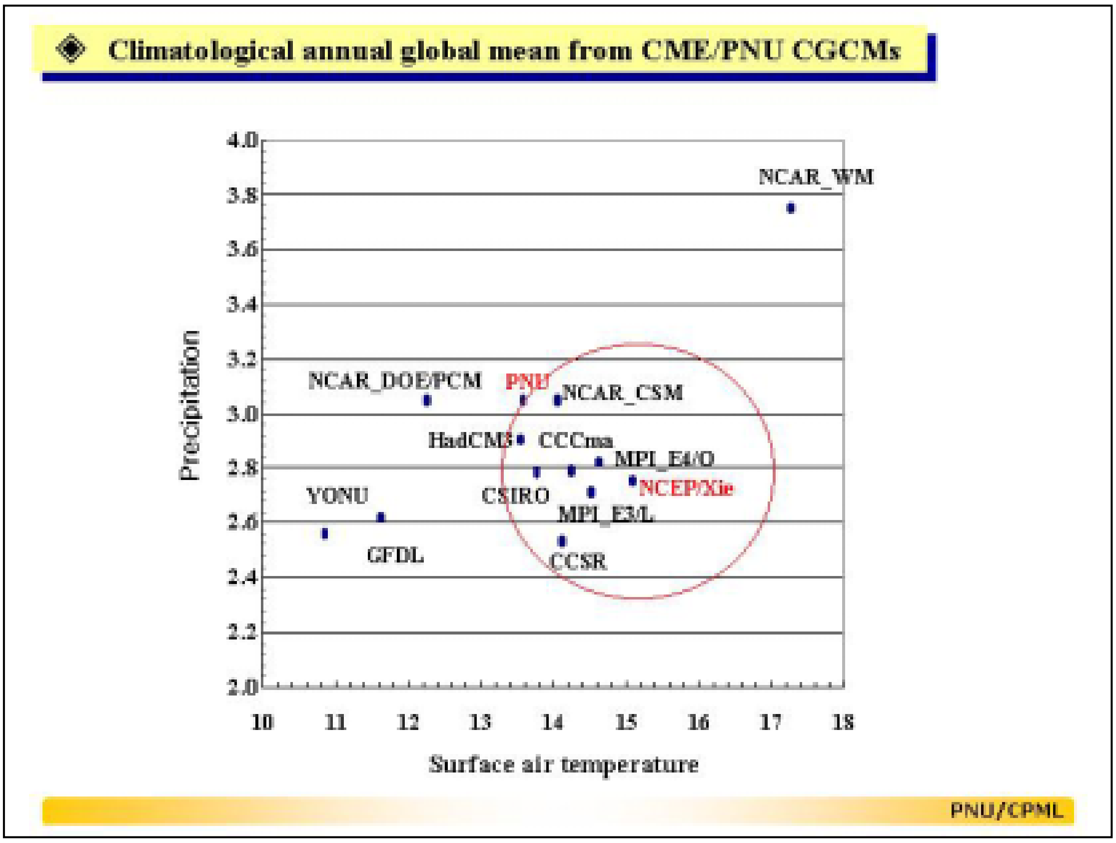
PNU/CPML

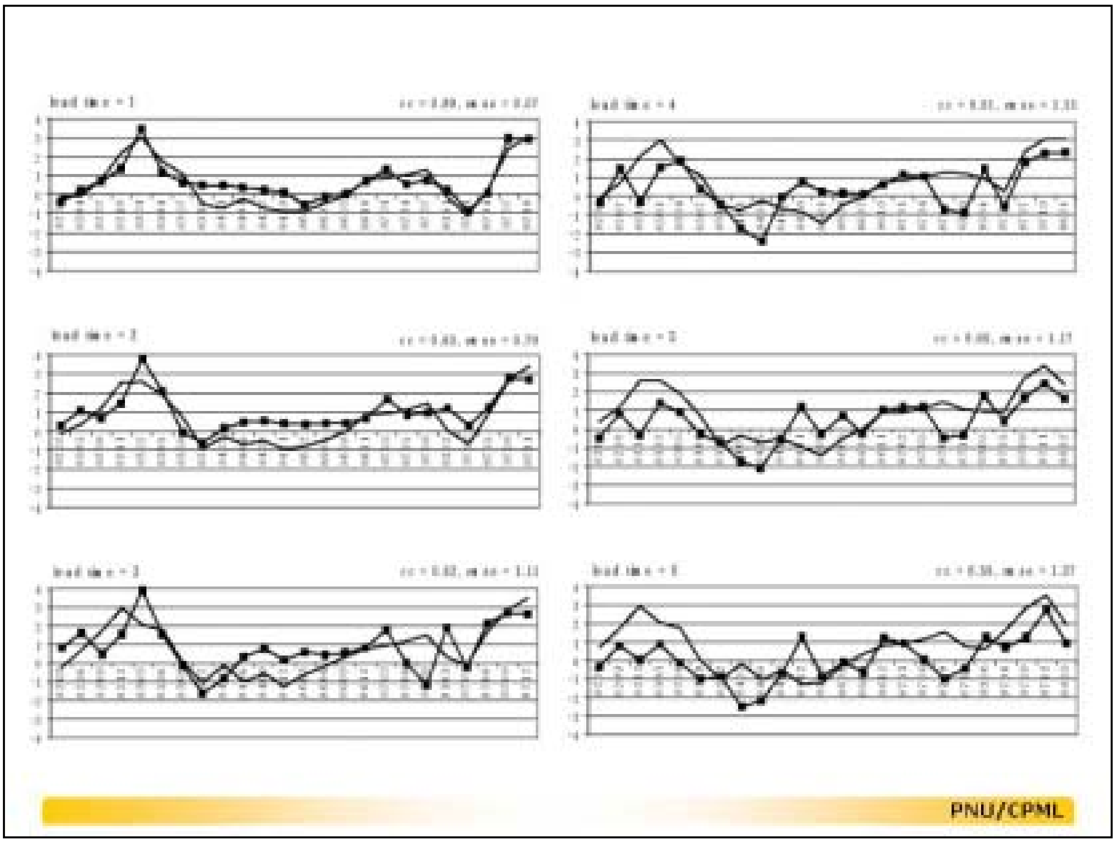

Speed of Sea-Ice motion (Model)
PNU/CPML

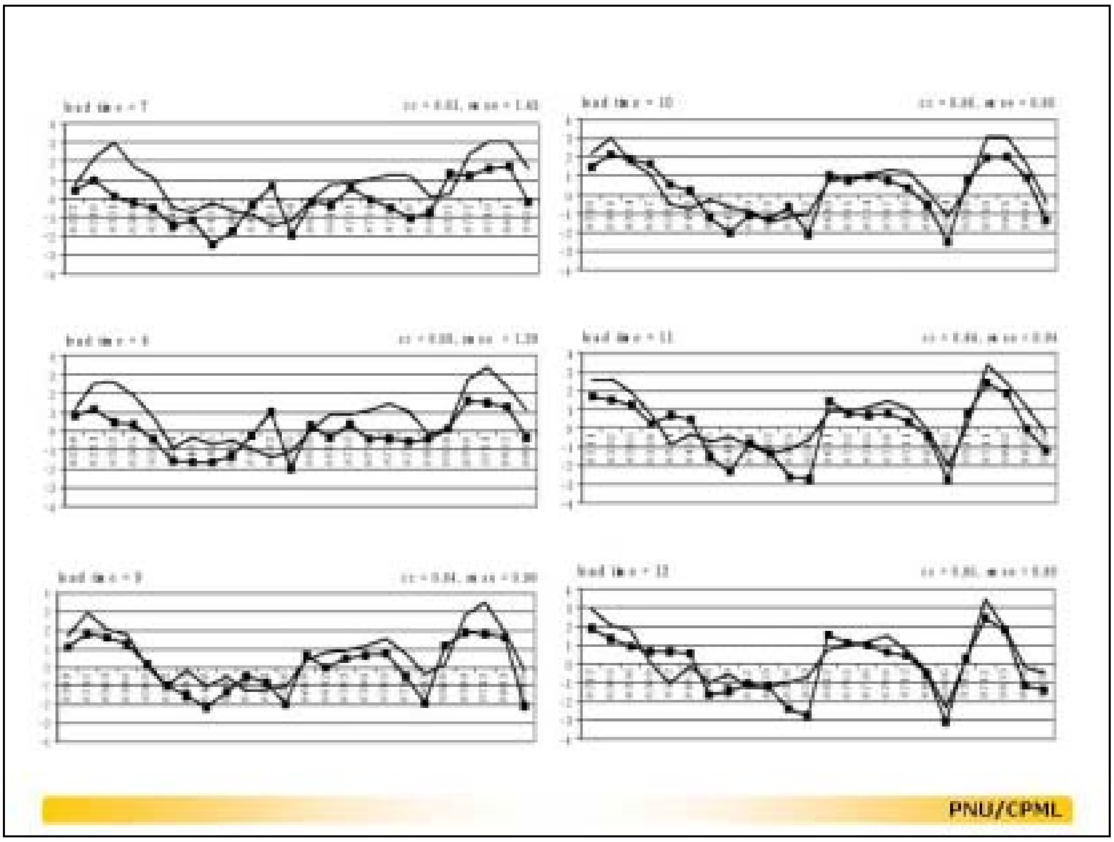

Time series of globally averaged surface air temperature from CGCM
PNU CGCM
YONU/PNU V1
YONU
NCEP/NCAR
Year
PNU/CPML

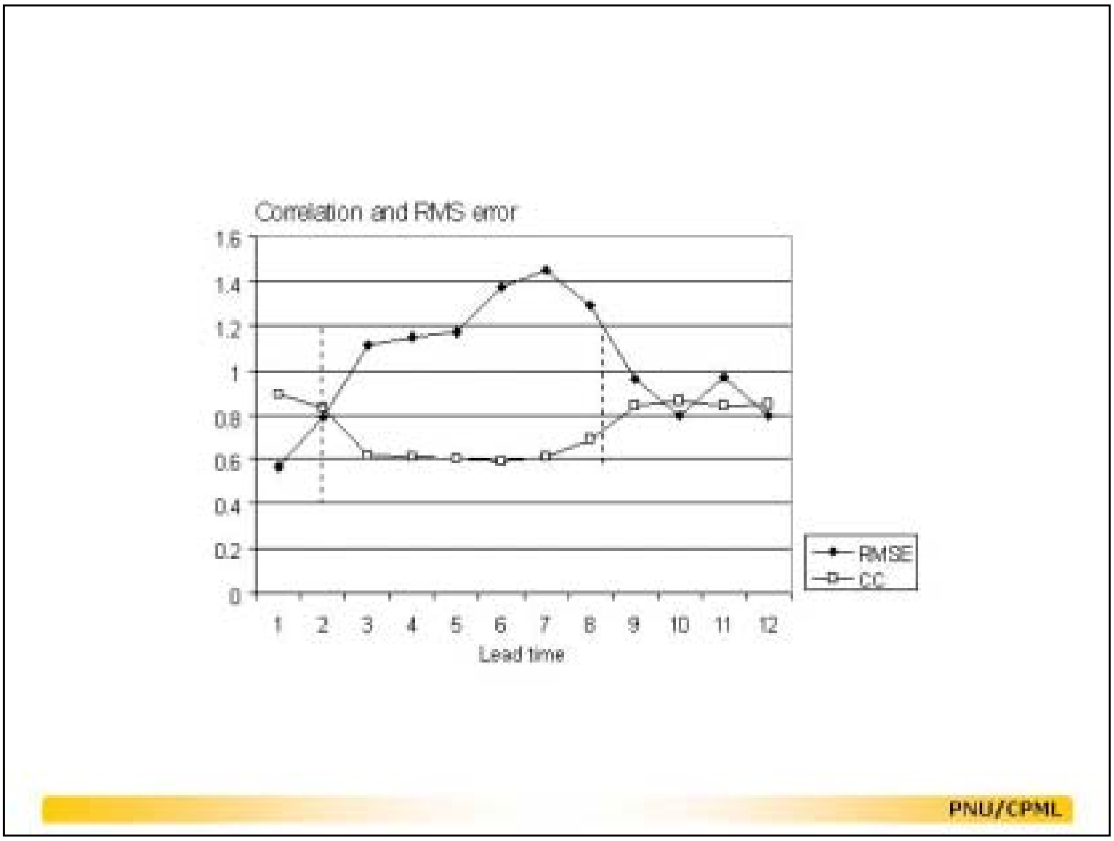

Mean DJF(left) and JJA(right) precipitation
from CGCM, Xie/Arkin, and difference between them
Zonally averaged precipitation
from CGCM and Xie/Arkin


Mean DJF(left) and JJA(right) SST
from CGCM, Levitus, and difference between them
Zonally averaged SST
from CGCM and Levitus

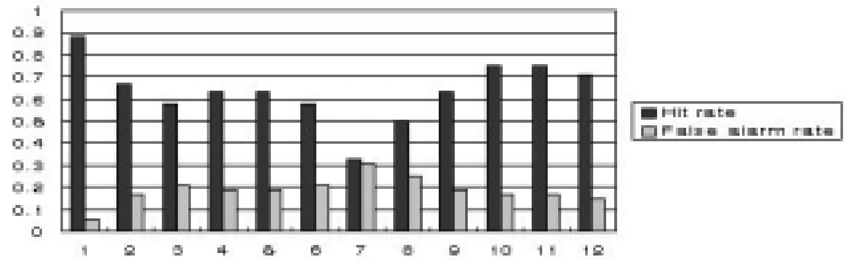

Climatological annual global mean from CME/PNU CGCMs
Precipitation
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
10
11
12
13
14
15
16
17
18
Surface air temperature
NCAR_WM
NCAR_DOE/PCM
PNU
NCAR_CSM
HadCM3
CCCma
MPI_E4/O
NCEP/Xie
YONU
CSIRO
MPI_E3/L
GFDL
CCSR
PNU/CPML


PNU/CPML

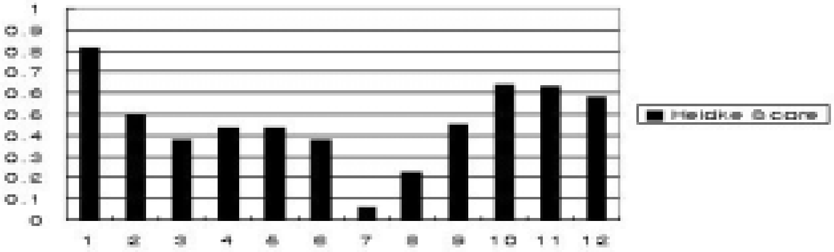

PNU/CPML


Correlation and RMS error
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 12
Lead time
RMSE
CC
PNU/CPML

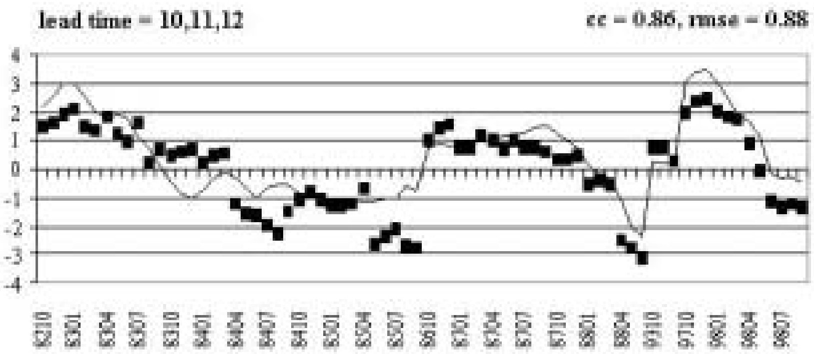
◈ Hit rate and False alarm rate



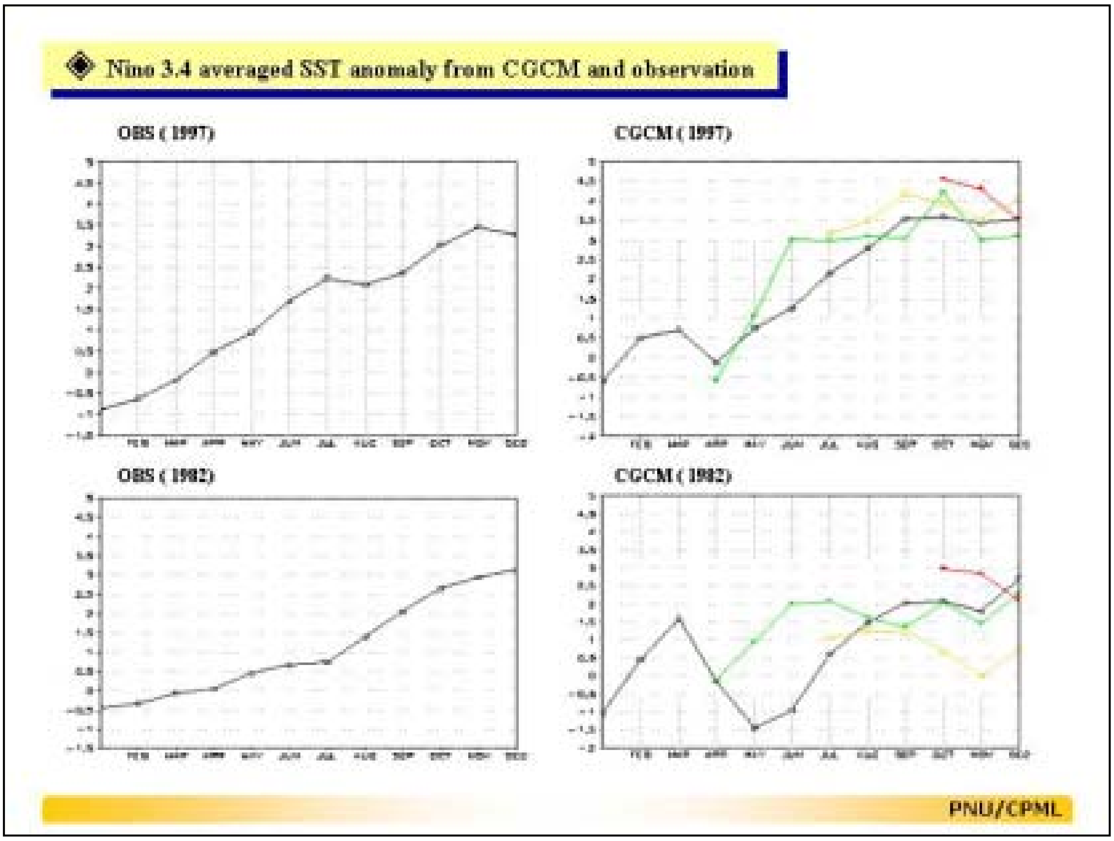
◈ Heidke Score

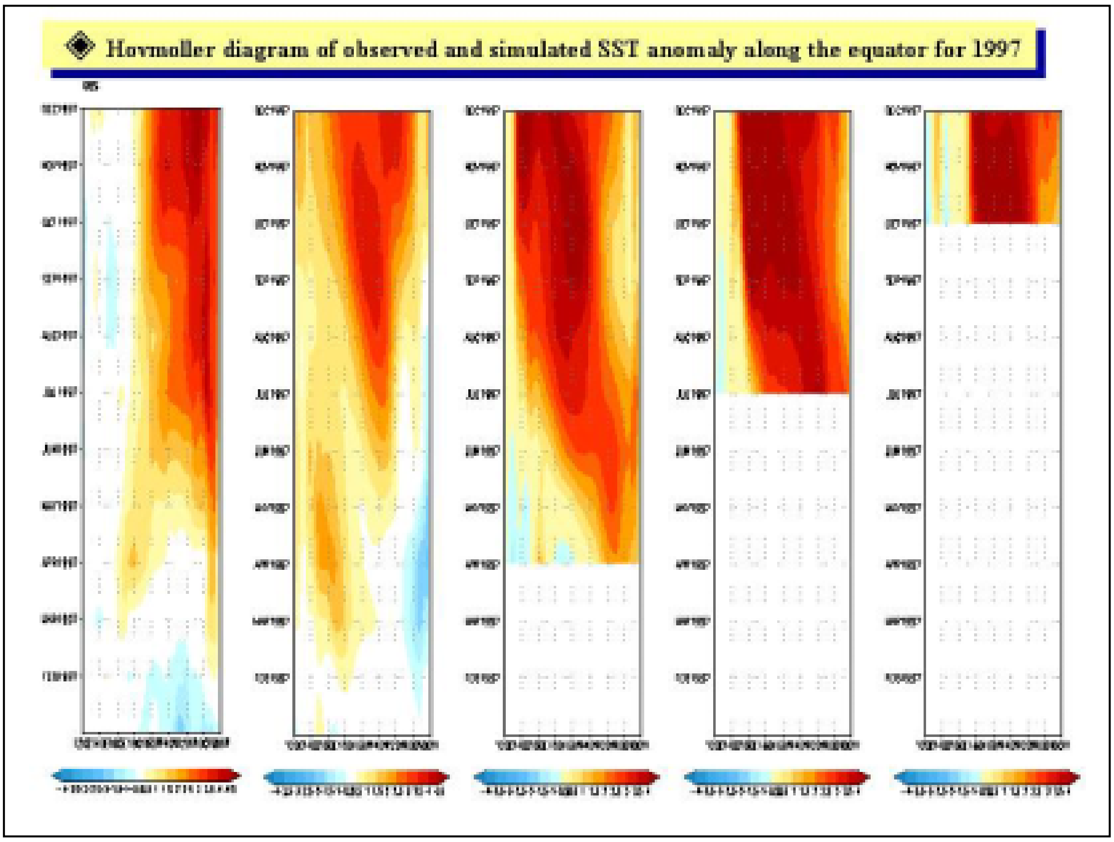


PNU/CPML

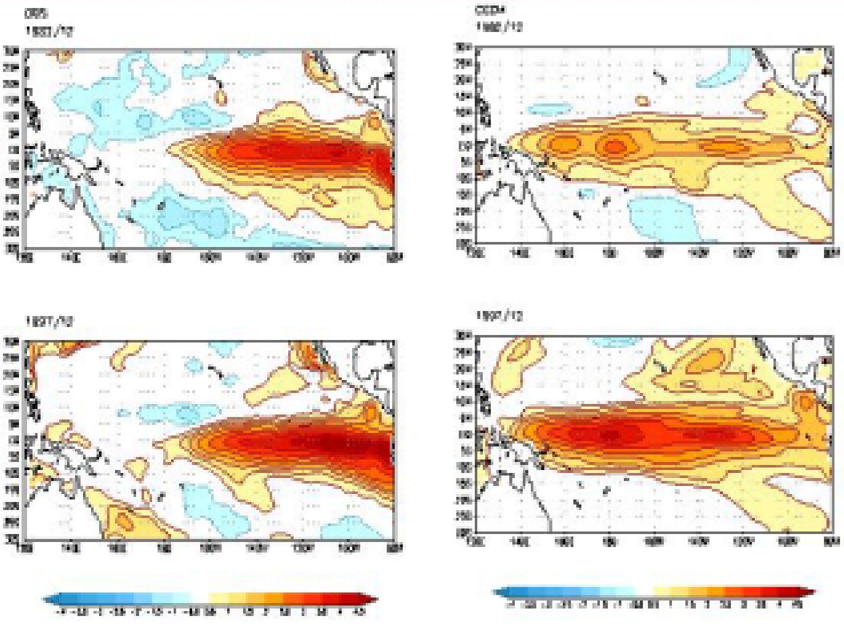


PNU/CPML

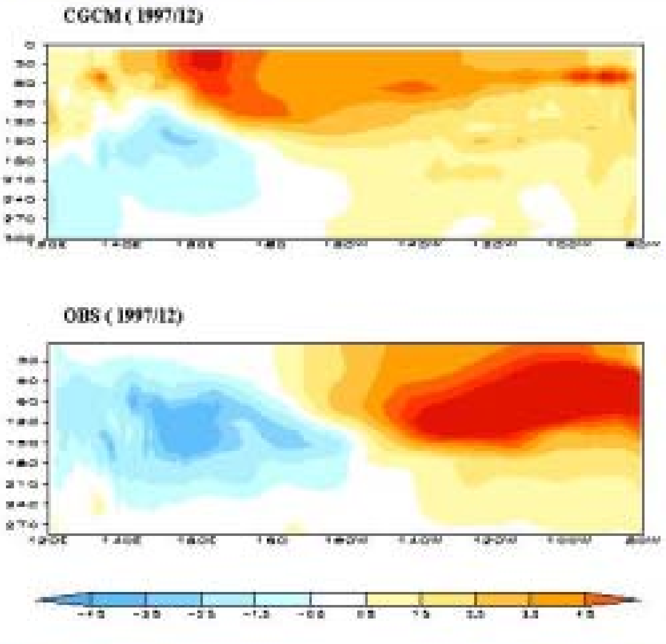

Nino 3.4 averaged SST anomaly from CGCM and observation
OBS (1997)
CGCM (1997)
OBS (1982)
CGCM (1982)
PNU/CPML


Hovmoller diagram of observed and simulated SST anomaly along the equator for 1997

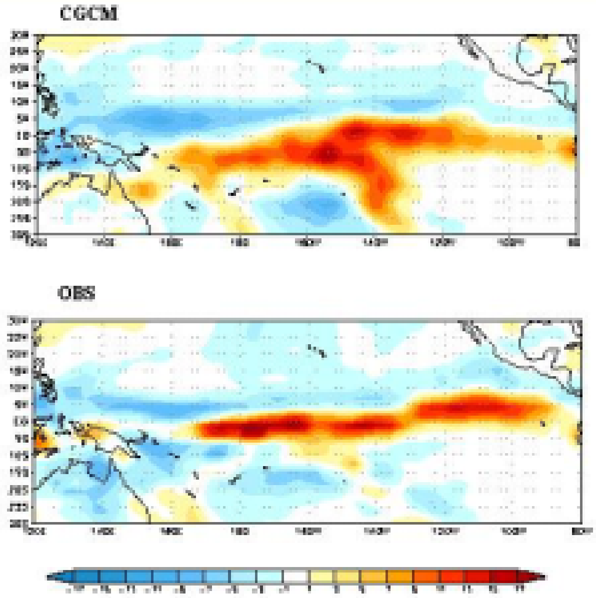
◆ SST anomalies of 12-month lead simulation and observation for December 1982 and 1997



◆ Vertical sea temperature anomalies of 12-month lead simulation and observation for December 1997

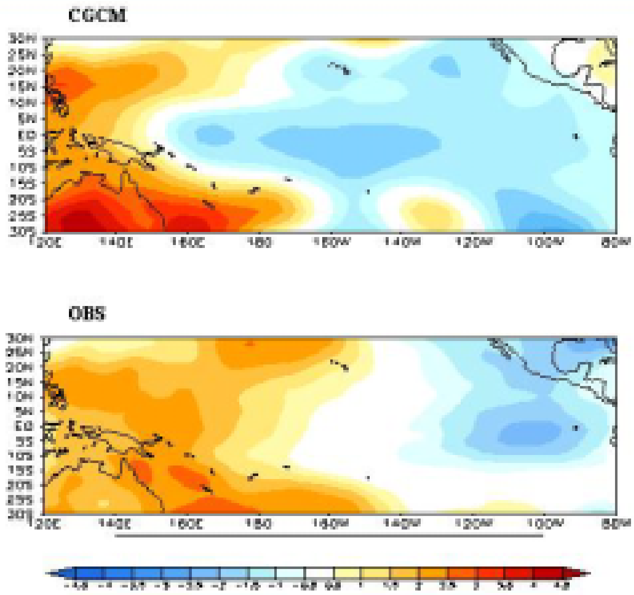


◈ Precipitation anomalies of 12-month lead simulation and observation for December 1997



PNU/CPML

◈ Sea Level Pressure anomalies of 12-month lead simulation and observation for December 1997



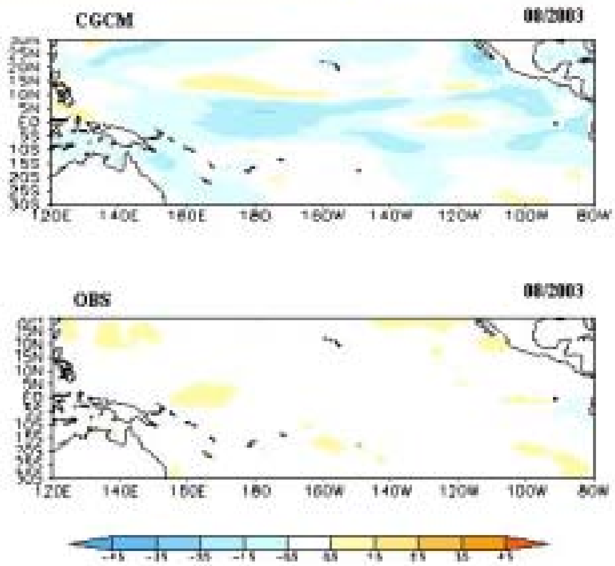
PNU/CPML

Conclusion

- The CGCM shows a good skill in predicting ENSO events with 10 to 12-month leads, in particular.

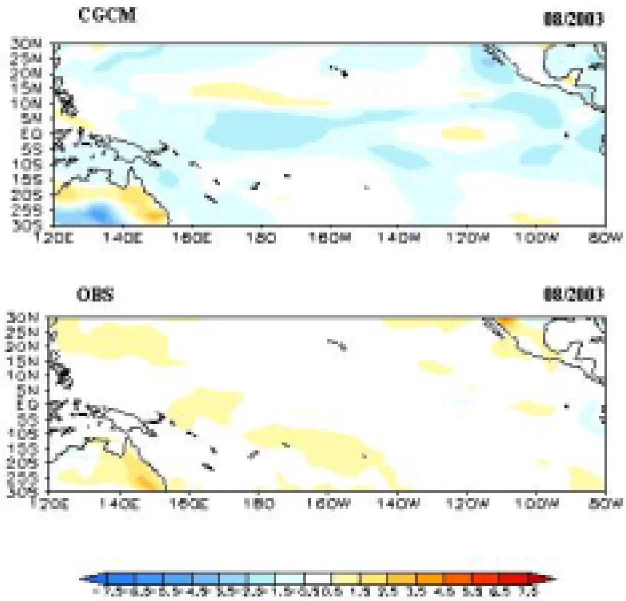
PNU/CPML

12-Month Lead SST Forecast



PNU/CPML

◈ 12-Month Lead Surface Air Temperature Forecast



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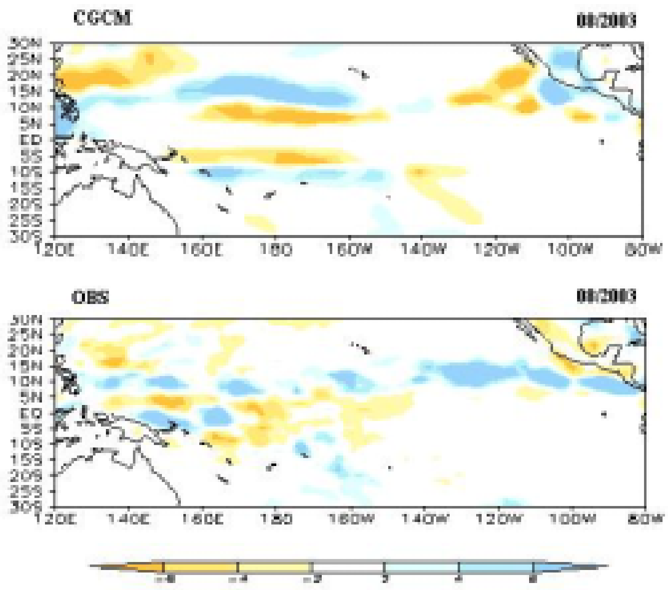
◈ 12-Month Lead Precipitation Forecast



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The Enhancement of the SST Predictability by Improving the Ocean Mixed Layer in the OGCM

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Abstract

The enhancement of the predictability of the sea surface temperature (SST), which is one of the most important elements in climate prediction, is attempted by improving the vertical mixing process in the OGCM. For this purpose we performed the comparison between three vertical mixing schemes, those by Pacanowski and Philander (1981) and Mellor and Yamada (1982) and a new mixed layer model by Noh et al. (2002), using the high resolution Pacific ocean model. Furthermore, the sensitivity of various parameters in the vertical mixing schemes in the OGCM, such as the effects of stratification, the Prandtl number, and surface wave breaking were examined.

1. Introduction

The most important element in the OGCM, which constitutes the climate model by coupling to the AGCM, is the predictability of the accurate SST. Moreover, the inadequate treatment of the vertical mixing process in the OGCM causes many persistent problems; for example, too strong southern equatorial current (SEC) and the consequent underestimation of the SST along it, too diffused thermocline with a warm bias at depths, too weak and deep equatorial undercurrent (EUC), and too weak seasonal and interannual temperature variability in the equatorial region. In particular, the development of large-scale climatic events like ENSO depends on the structure of the upper layer of the equatorial ocean affected by the vertical mixing process.

With an intention to improve the vertical mixing process in the OGCM, numerous works have been carried out (Rosati and Miyakoda 1988, Large and Gent 1999, Large et al. 1997, Blanke and Delecluse 1993, Chen et al. 1994, Pacanowski and Philander 1981, Halpern et al. 1995, Sterl and Kattenberg 1994). In particular, Noh et al. (2002) recently showed that the predictability of the upper ocean structure of the ocean, such as the SST and the mixed layer depth (MLD), can be substantially improved in the OGCM with a new ocean mixed layer model. The new model takes into account the recent observation of the near surface turbulence structure influenced by wave breaking and is able to maintain a well mixed layer, similarly to the case of bulk models (Noh and Kim 1999).

Meanwhile, most investigations were concerned with the intercomparison between two different vertical mixing schemes. In this way, it is not always clear whether the improved performance of one scheme is due to the better structure of the model or it is simply due to better coefficients used in the model. Especially, proper information is not yet available how the simulated ocean structure is affected by parameterizations of wave breaking, stratification, and the Prandtl number. Considering the serious difficulty in evaluating them accurately in the real ocean, we had better understand the sensitivity on their values.

In this paper, we will reexamine the performance of the new mixed layer model (N scheme) using the higher resolution Pacific Ocean model in comparison with other widely used schemes such as that by Pacanowski and Philander (1981) (hereafter PP scheme) and by Mellor and Yamada (1982) (MY scheme). Besides, we also attempted to evaluate the sensitivities of three parameterizations in the vertical mixing scheme mentioned above.

2. A new mixed layer model (N scheme)

In the new mixed layer model the eddy viscosity and diffusivities for tracers and TKE are calculated by

$$K_m = S_m q l \,, \tag{1}$$

$$K_h = S_h q l \,, \tag{2}$$

$$K_q = S_q q l \tag{3}$$

where $q^2/2$ (= E) is TKE, l is the length scale of turbulence, and S_m, S_h, and S_q are empirical constants. Here q is calculated from the TKE equation in which the dissipation rate ε is calculated by

$$\varepsilon = Cq^3 / l \tag{4}$$

Equations (1) - (4) are typical for the second-order turbulence closure model (Mellor and Yamada 1982). The coefficients are taken as the same as in Mellor and Yamada (1982) in homogeneous fluid: $S_m = 0.39\,(\equiv S_{m0})$, S_m/S_h= 0.8, and S_m/S_q = 1.95, and

$C = 0.06\ (\equiv C_0)$.

However, the model is quite different from the Mellor-Yamada model in the parameterizations of the surface forcing and of the effects of stratification. The boundary condition for TKE is given by

$$K_q \frac{\partial E}{\partial z} = m u_*^3 \tag{5}$$

where u_* is the frictional velocity due to wind stress. Meanwhile, the length scale l is given by

$$l = \frac{\kappa(z + z_0)}{1 + \kappa(z + z_0)/h} \quad , \tag{6}$$

where h is the depth of a mixed layer, κ is the von Karman constant (= 0.4), and z_0 the roughness length scale at the surface.

Based on Craig and Banner's analysis (1994), Noh and Kim (1999) assumed the values of m = 100 and z_0 = 1 m for (5) and (6). These values characterize the intensive mixing near the sea surface owing to wave breaking. In this case, the relevant Richardson number should be determined in terms of TKE itself rather than the mean velocity shear, because the TKE flux plays an important role in TKE production. Therefore, the TKE Richardson number defined by

$$Rt = (Nl/q)^2 \tag{7}$$

must be used instead of Ri.

In this case, we can parameterize the effects of stratification as

$$S_m / S_{m0} = (1 + \alpha \mathrm{Rt})^{-1/2} \tag{8}$$

$$C / C_0 = (1 + \alpha \mathrm{Rt})^{1/2} \tag{9}$$

where an empirical constant α is chosen as $\alpha = 20$. Meanwhile, the proportionalities of S_h and S_q to S_m are maintained. These parameterizations have an analogy to those by Gaspar et al. (1980), when Rt >> 1.

Nonlocal mixing during convection is implemented by forcing a very large value of K_h, while maintaining the values of K_m and K_q as in a homogeneous fluid. This large eddy diffusivity helps to maintain the homogeneous temperature within the mixed layer, but it does not affect the entrainment process directly since it cannot extend to the stably stratified region near the bottom of the mixed layer.

The dependence of Pr on stratification is usually neglected in the ocean mixed layer models, including the N scheme. Meanwhile, the PP scheme and the TKE model by Gaspar et al. (1980) assumed that Pr increases linearly with Ri, based on the observation data by Peters et al. (1988). It is also expected that the larger values of Pr under the strong stratification may help to improve the simulation of the equatorial ocean by weakening the upwelling and thus alleviating the cold bias along the SEC while preventing too diffused thermocline. Therefore, in the resent paper we examined the effects of the dependence of Pr on stratification as

$$\mathrm{Pr} = (S_m / S_h)(1+\beta Rt)^{1/2} . \tag{10}$$

3. OGCM

The OGCM used in this study is the GFDL MOM 2.2. Horizontal resolution is 1.125^{o} in longitude and 0.5625^{o} in latitude. There are 37 levels in the vertical, with 25 of these levels in the upper 400 m. Both vertical and horizontal resolutions are higher than the OGCM of the previous study (Noh et al. 2002). Horizontal eddy viscosity and diffusivity are 1 x 10^4 m^2s^{-1} and 1 x 10^4 m^2s^{-1}, respectively.

The model is the same as used in Matsuura and Iizuka (2000) and Kawamura et al. (2001), but the domain of the model is restricted to the Pacific Ocean, which covers between 35.5 ^{o}S and 65 ^{o}N. A damping toward the climatological monthly mean temperature and salinity is used near the southern boundary.

The model was started from a state of rest, with annual mean temperature and salinity distributions by Levitus (1982), and forced by Hellerman and Rosenstein (1983) wind stress climatology. To prescribe the heat flux at the surface the reanalysis data from NCEP were used. To enforce the heat flux at the sea surface the combined boundary condition was used. The coefficient of the restoring term 11.2 $Wm^{-1}K^{-1}$, corresponding to τ = 30 days, was smaller than other experiments, which helps us to investigate the performance of the vertical mixing schemes more effectively. For the penetration of short wave radiation, we used the Jerlov type Ib. The smaller restoring term helps us to investigate the performance of the vertical mixing schemes in predicting the SST more effectively. The restoring boundary condition was used for salinity. The model was integrated for 10 years until it reached the quasi-steady state.

4. Results

a. Characteristics of the SST prediction with the new mixed layer model

Fig.1 shows the distribution of SST anomaly from the observed values, for the cases of the annual mean, January, and July. The significant underestimation of the SST along the SEC and the overestimation in the eastern equatorial region are found, which is common in most OGCMs. The strong overestimation of the SST in the northwestern Pacific is mainly due to the overshooting of the Kuroshio. Meanwhile, it also shows a seasonal bias in which SST is too high during summer and too low during winter, which suggests the insufficient vertical mixing in both seasons.

Fig. 2 and 3 show the zonal distribution of temperature and zonal velocity along the equator. We can find the substantially improved reproduction of the equatorial ocean compared to the previous simulations (Chen et al. 1994), although the diffused thermocline and the weaker EUC are still observed. We can reduce the seasonal bias of the SST anomaly by increasing the vertical mixing with smaller values of α, but it makes worse the diffused thermocline and the weak EUC.

b. Intercomparison of the vertical mixing schemes.

The effects of the vertical mixing schemes on the predictability of SST can be observed from the annual variation of SST, as shown in Fig. 4. It clearly evidences the significantly improved performance of the SST prediction from the N scheme in both high latitude and equatorial regions. It is well known that the insufficient mixing near the surface in the MY scheme causes serious overestimation of SST during summer (Rosati and Miyakoda 1988, Halperin et al. 1996, Chen et al. 1994). It is interesting to note that the PP scheme causes the overestimation of SST during summer in the high latitude, but the underestimation of SST at the equator. In this set of experiments, the penetration of short wave radiation was neglected.

c. The effects of parameterization in the vertical mixing schemes

In order to understand the roles of each parameterization, wave breaking, stratification, and the Prandtl number in the mixed layer modeling, we examined the response of the one-dimensional model results. The comparison between four different parameterizations (EXP O, A, B, C) in the N-scheme reveals a very interesting pattern in the response to the surface heating depending on the latitude (f = 0.0, 1.0 x 10^{-4} s^{-1}) (Fig. 5). Here EXP A represents the case with no wave breaking effects (m = 0), EXP B represents the stronger dependence on stratification ($\alpha = 200$), and EXP C considers the effects of the Prandtl number ($\beta = 0.1$). The MLD increases with the increasing effects of stratification, i.e., the value of α, in both the equator and the high latitude. On the other hand, the MLD is sensitive to the variation of the Prandtl number in the equatorial region but it is sensitive to the intensity of the near surface mixing due to wave breaking in the high latitude.

In the presence of the Coriolis force, the penetration of momentum and heat is restricted by the Ekman boundary layer, and the MLD is determined by the intensity of the turbulence in the upper ocean. On the other hand, in the absence of the Coriolis force, the penetrations of heat and momentum continue indefinitely. In this case, the shear production dominates in the turbulence budget below the near surface zone. The larger Prandtl number means that the eddy viscosity is larger than the eddy diffusivity, and the smaller vertical shear of the velocity appears for a given density stratification. It makes the shear production smaller, and thus results in the weaker vertical mixing.

d. Sensitivity of wave breaking, stratification and the Prandtl number

As shown in Fig. 6, the SST anomaly is found to become larger in all three cases (EXP A, B, and C), as a result of the reduced vertical mixing. However, the respective discrepancy between EXP O, A, B, and C are not as clear as in the one-dimensional experiments, which requires further analysis. The profiles of annual mean temperature and zonal velocity show the corresponding effects (Fig. 7 and 8).

5. Conclusion

In the present paper, we have shown the enhanced predictability of the SST from the OGCM with a new mixed layer model in comparison with the existing models. Furthermore, we investigated the sensitivity of various parameters in the vertical mixing scheme in the OGCM, such as sensitivities to stratification, the Prandtl number, and surface wave breaking.

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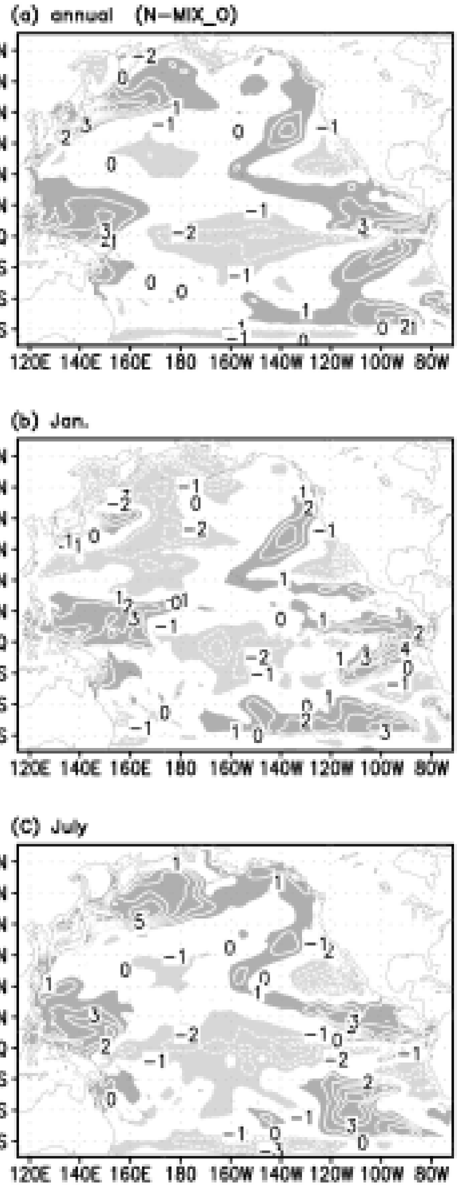

Fig 1　Distribution of the SST anomaly:
(a) annual mean, (b) January, (c) July.

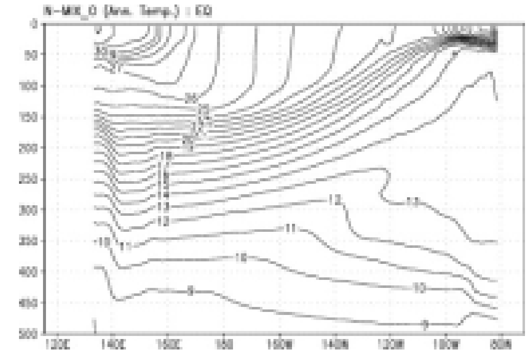

Fig. 2 Zonal distribution of temperature along the equator.

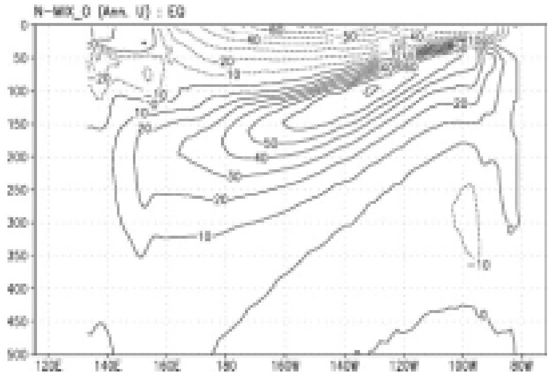

Fig. 3 Zonal distribution of zonal velocity along the equator.

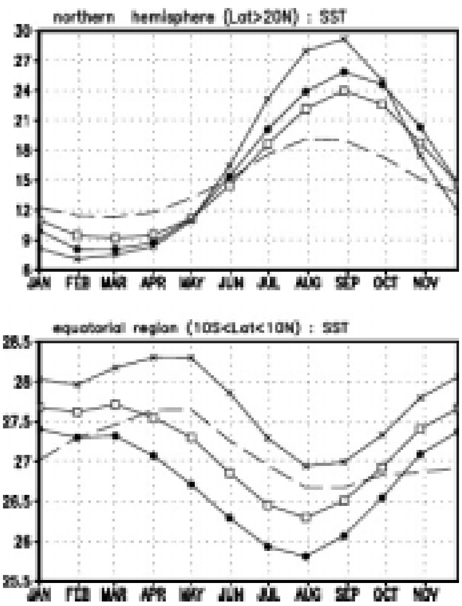

Fig. 4 Seasonal variation of the mean SST. Dashed line indicate Levitus, and ●, □, and × indicate PP,N, and MY, respectively.

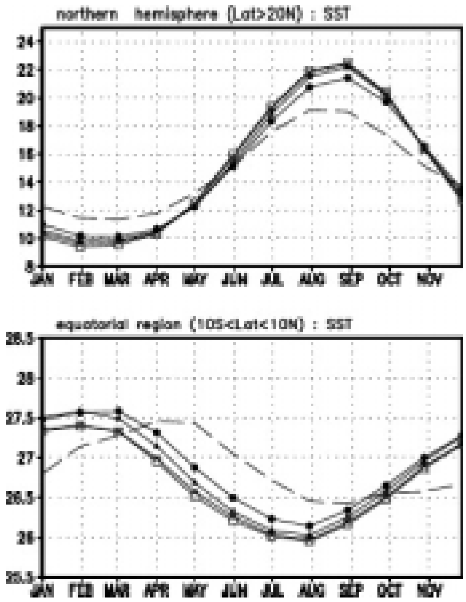

Fig. 6 Seasonal variation of the mean SST. Dashed line indicate Levitus, and ●, □, × and ▲ indicate EXP O, A, B, and C, respectively.

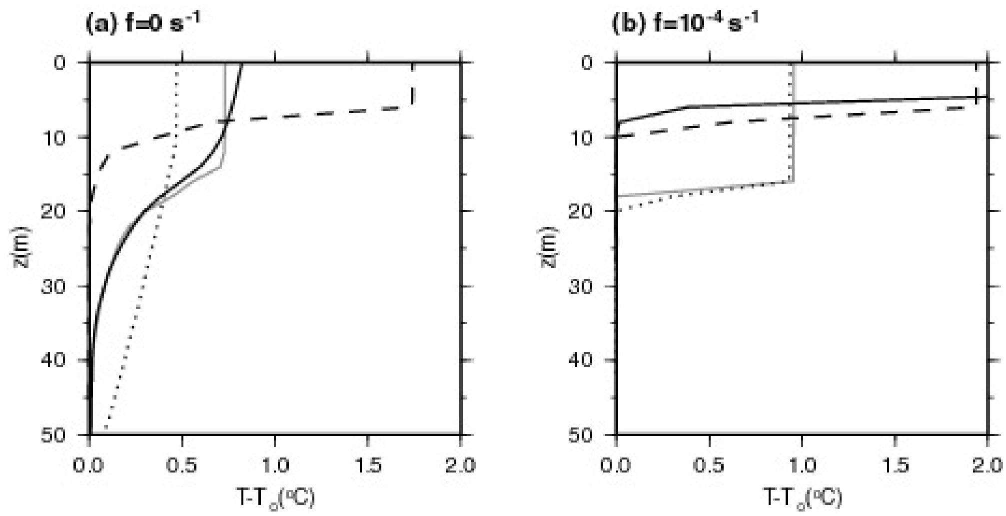

Fig. 5 Profiles of temperature after 10 days of surface heat flux ($Q_0 = 10^{-6}m^2s^{-3}$): (a) $f=0s^{-1}$, (b) $f=10^{-4}s^{-1}$. Gray, solid, dashed, and dotted line indicate EXP O, A, B, and C, respectively,.

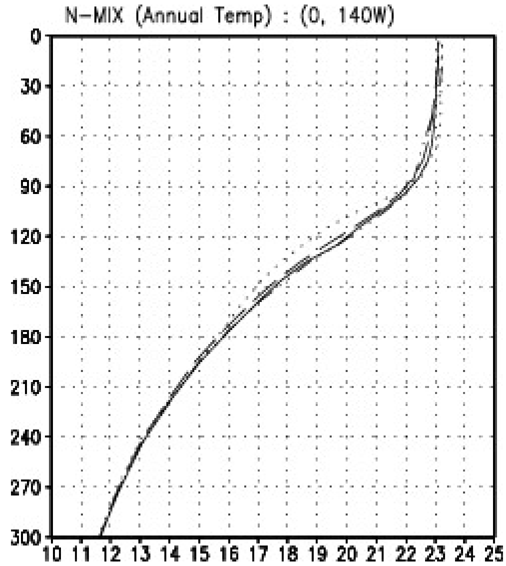

Fig. 7 Profiles of annual mean temperature at the equator and 140W. Solid, dashed, , dotted, and dot dot dashed line indicate EXP O, A, B, and C, respectively.

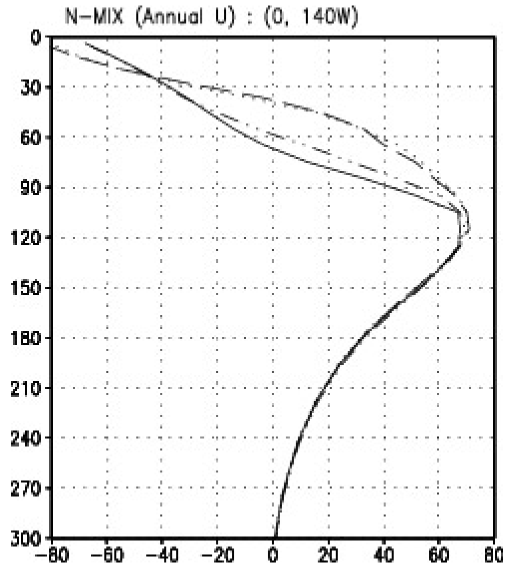

Fig. 8 Profiles of annual mean zonal velocity at the equator and 140W. Solid, dashed, , dotted, and dot dot dashed line indicate EXP O, A, B, and C, respectively.

Global SST Prediction System at Climate Environment System Research Center

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1. Introduction

As understanding of ENSO oscillating dynamics has accumulated for the last two decades, a number of studies have been devoted to a better prediction of the tropical Pacific SST. The tropical Pacific SST has been operationally forecasted by several dynamical and statistical models which have a predictive skill up to 12-months lead time for the equatorial eastern Pacific SST as correlation is more than 0.5 (Latif et al. 1998). However, little research has been devoted to predicting ocean areas other than the tropical Pacific.

Recently, there has begun to emerge a need for global sea surface temperature forecasts for initialing boundary conditions of atmospheric GCMs in long-range forecasting. In addition, climate variabilities of many local areas are significantly affected by the regional ocean SST rather than the tropical Pacific SST.

Therefore, Global SST prediction system was developed at Climate Environment System Research Center (CES). And the global SST prediction is operationally performed by the global SST prediction system. In this study, CES global SST prediction system is described and its predictive skill is discussed.

2. CES global SST prediction system

The CES global SST prediction system consists of dynamical El Nino prediction model and statistical global SST prediction model. In order to obtain final global SST prediction, each model separately performs SST prediction, then two prediction is combined.

- Dynamical El Nino prediction model

The dynamical El Nino prediction model used in this study is based on the intermediate ocean and statistical atmosphere model developed by Kang and Kug (2000). The ocean model is a modified version of the Lamont Model (Zebiak and Cane, 1987). The primary change is subsurface temperature, heat flux, and vertical mixing parameterization. The parameterization of subsurface temperature is replaced by a statistical relationship constructed based on the Singular Value Decomposition (SVD) of the 20^{o}C isotherm depth and the water temperature at 45m depth from the NCEP ocean assimilation data. The parameterization is closed related to the improvement of the forecast skill for central and eastern Pacific SST. In addition, heat flux and vertical mixing is developed to the ocean model in order to improve the western Pacific prediction (Kug et al. 2003). Since the domain of the ocean model is limited to the tropical Pacific, the El Nino prediction model only supplies SST prediction of that domain interior. The atmospheric model is a statistical model which is based on the SVD of the observed wind stress and SST. The initial condition of the ocean model is obtained by spinning up the wind stress, which is made by combining the NCEP wind stress and the wind stress derived from the observed SST anomalies (Kug et al., 2001). For details of the model the reader is referred to Kang and Kug (2000). The model has a predictive skill up to 12-month lead time judged to have a correlation of more than 0.6 [Kug et al. 2001]. The detail forecast skill for the NINO3 SST is referred to in Fig. 3 of Kug et al. [2001].

- Statistical Prediction Model

The statistical model utilized in this study is a Coupled Pattern Projection Model (CPPM), which was developed by Lee (2003). In this section, brief description of the model is supplied. The CPPM is one kind of pointwise regression model. The main idea of the model is to generate realizations of the predictand from projection of covariance pattern between the large-scale predictor field and the one-point predictand onto a large-scale predictor field for the target year.

To obtain one forecast value, a statistical relationship is constructed between the predictand and the predictor field. There are three steps to construct the statistical relationship. In the first step, the coupled pattern between the one-point predictand and the predictor field is calculated in terms of the covariance between them using the fitting period data. In the second step, realized time series of predictands are obtained from projection of the coupled pattern onto the predictor field for the training period. Finally, a transfer function between two time series of the predictand and the realization is constructed using a linear regression method. The forecast of the predictand is obtained from applying the predictor field for the target year to the coupled pattern and transfer function constructed for the training period.

In order to obtain optimized forecast skill, the best predictor field is searched by the model procedure. In statistical prediction, selection of the location, and domain size of the predictor field play a crucial role. To choose the best location and domain size for the predictor field, hindcast experiments are repeated using a huge number of cases of predictor field with flexible size and location in the training period. The minimum domain size was 80-longitude x 10-latitude and the maximum was the entire domain of the model. This flexible domain is moving from east to west and south to north. Among the huge number of hindcast cases, the predictor field having the best hindcast skill is selected.

For a 1-month lag to an 18-month lag, each preliminary multi-lag forecast is performed. From the 18 preliminary prediction sets, the final forecast is determined by an ensemble process of the preliminary forecasts.

- Ensemble of statistical and dynamical prediction

Over the tropical Pacific basin, the El Nino prediction model and statistical model are competed for final prediction. The final prediction between both model predictions is adopted by comparing hindcast skill during training period. In the eastern and central Pacific, the predictions of the dynamical model were mainly chosen. However, the predictions of the statistical model were mostly adopted in the western Pacific.

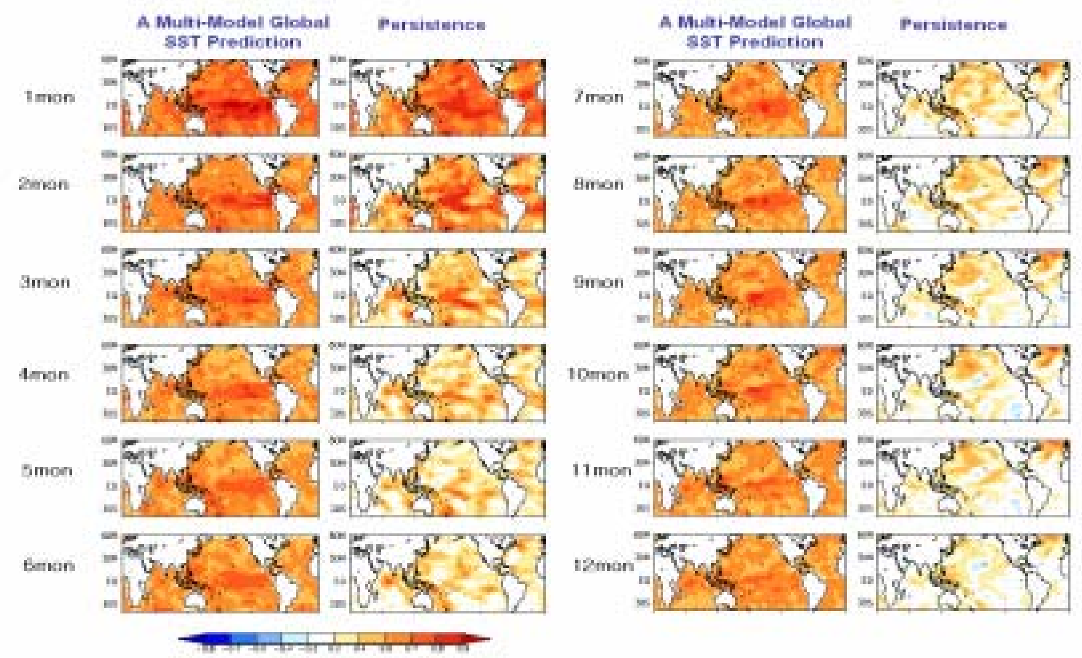

Figure 1. Correlation coefficients between observed SST and multi model prediction (Left panel) and persistence prediction (right panel) as a function of forecast lead time.

3. Prediction

Using the dynamical model and statistical model, forecast experiments were performed for the period 1981-2000 and the results were compared to those of persistence prediction. The forecast skill is evaluated by the cross validation.

Figure 1 shows forecast skills of the ensemble prediction of the statistical and dynamical model, and persistence prediction as a function of forecast lead time. For 1-month lead forecast, the present model has a similar forecast skills to those of the persistence prediction. As forecast lead time is long, the present model has significantly better forecast skills than those of persistence prediction. In addition, the present model has predictive skill up to 12-month lead time for most global ocean as judged by a correlation exceeding 0.5. Its skill is better than that of most dynamical models such as coupled GCMs.

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Understanding and Predicting the Asian Monsoon Onset – Impacts of the Tibetan Plateau

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1. Monsoon Onset (MO) Studies

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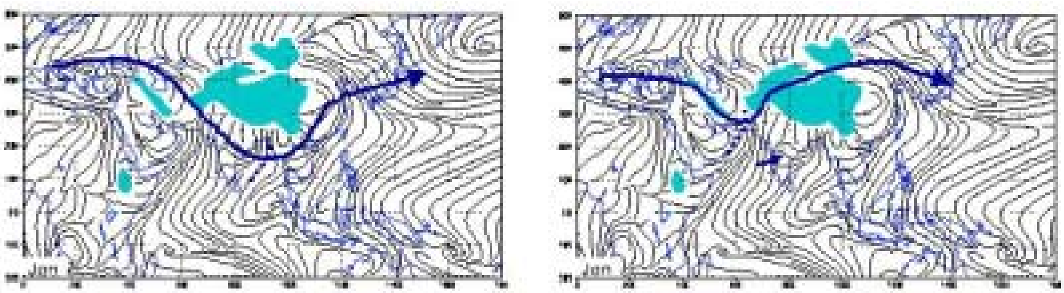
- **The Earliest Start of the Rainy Season** (T. Y. Mao, 1949)
- **The Earliest MO: South China Sea (SCS) MO** (Tao and Chen, 1987; Yanai et al., 1988, 1992, …)
- **MO Sequence: Three Stage Structure** (Wu and Zhang, 1998:MWR; Liu et al., 2002: MWR; Wu and Liu, 1999:Acta Meteor. Sinica; Liu, et al., 2001:Climate Dyn.)

- **The Earliest Start of the Rainy Season** (T. Y. Mao, 1949)



The Earliest MO: South China Sea (SCS) MO
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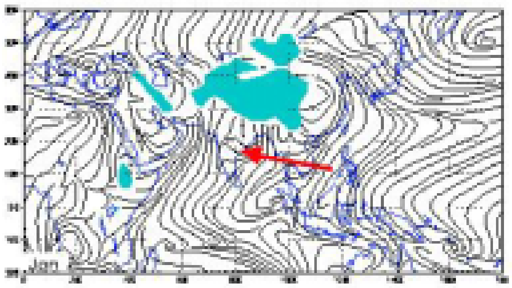

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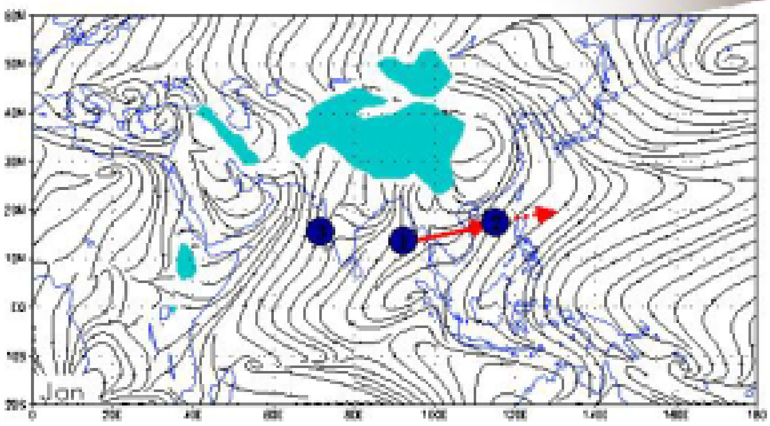


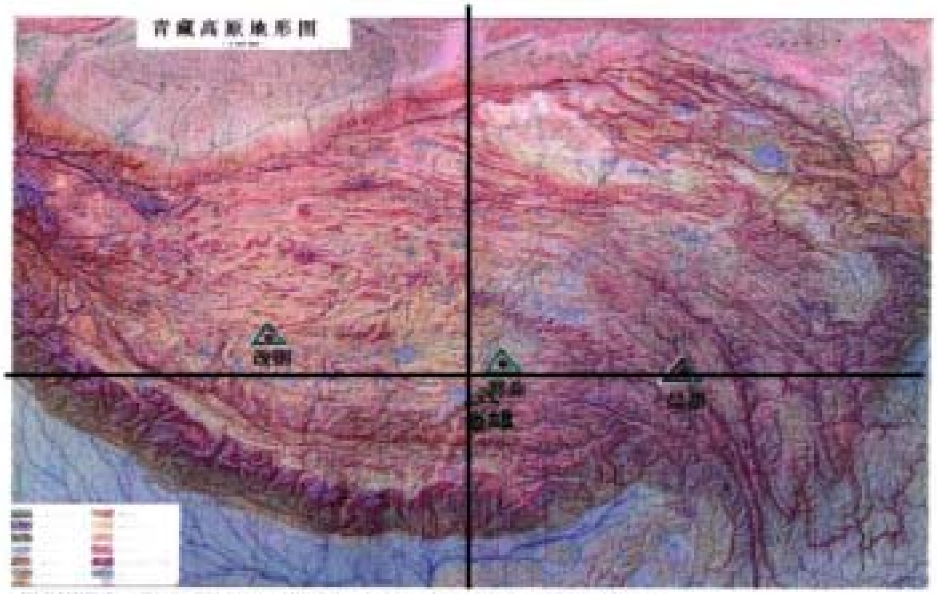
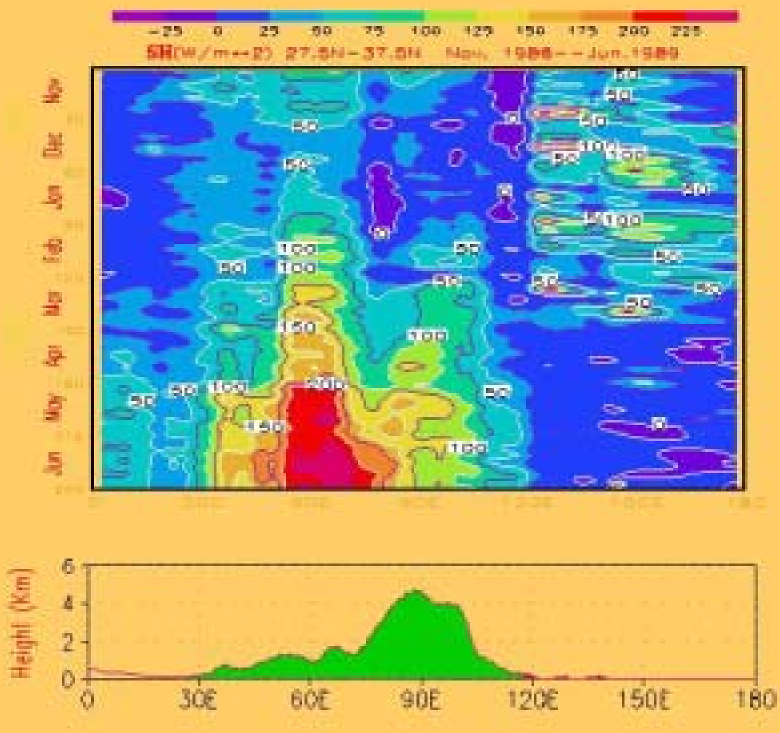


FIGURE 2. The Tibetan Plateau with the Three IOP Bases
(From West to East) : Gaize (改则) (32.2N, 84.4E; 4416M): Tundra desert
Naqu (那曲) (31.5N, 92.1E; 4508M): frozen soil
Changdu (昌都) (31.2N, 97.2E; 3307M): Prairie / Coniferous forest



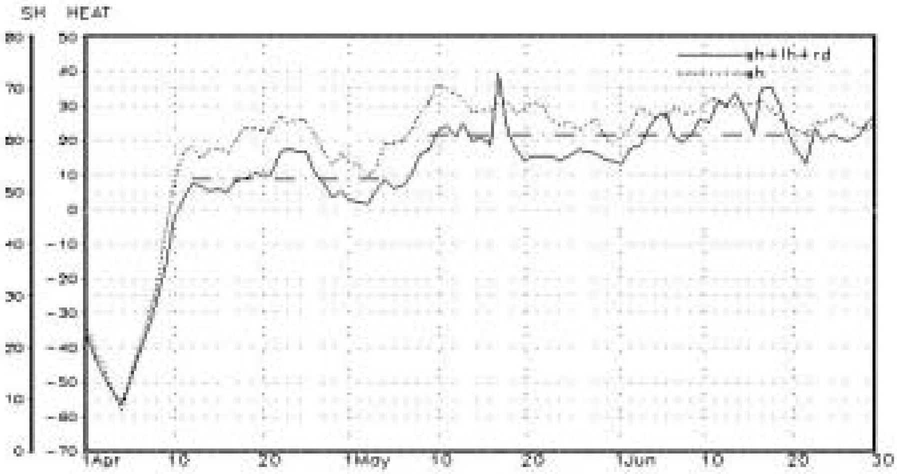
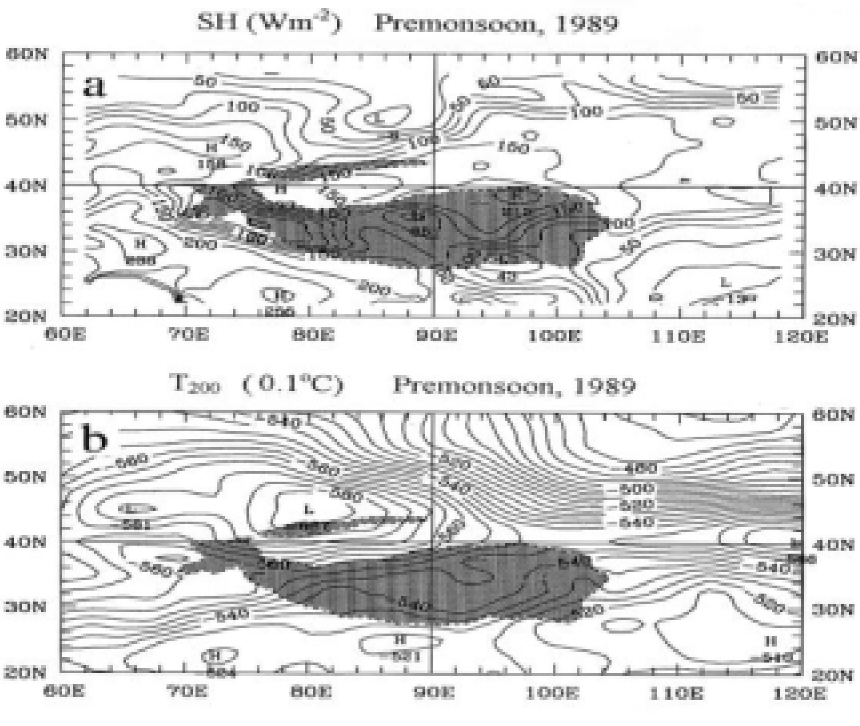
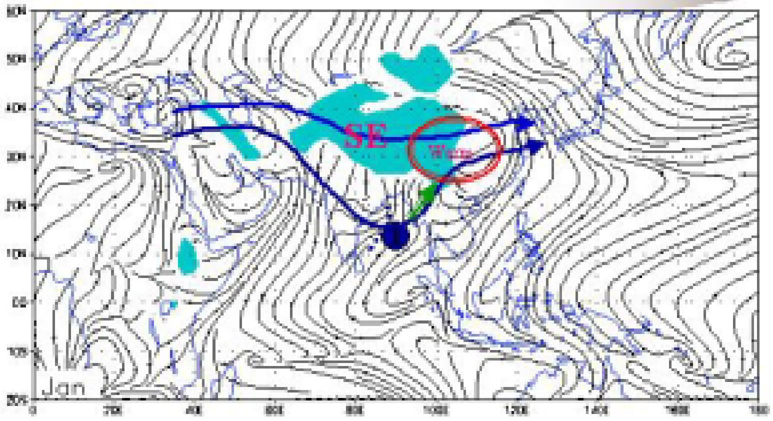


Fig 19 86~95 mean Apr. 1 to Jun. 30 daily mean diabatic heating and sensible heating over Tibetan Plateau



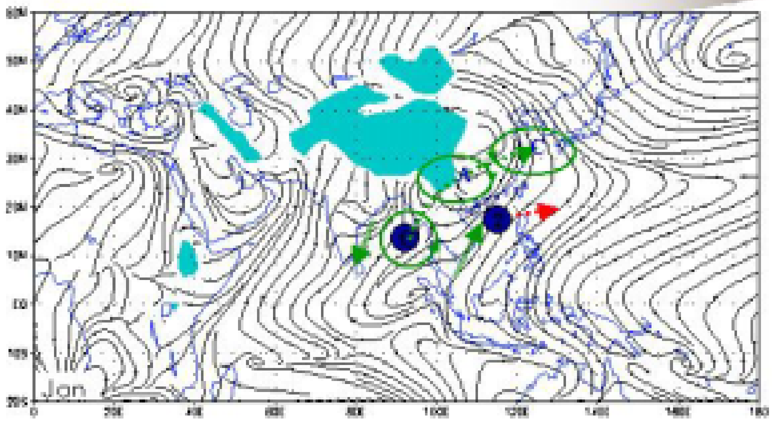
MO Sequence: Three Stage Structure

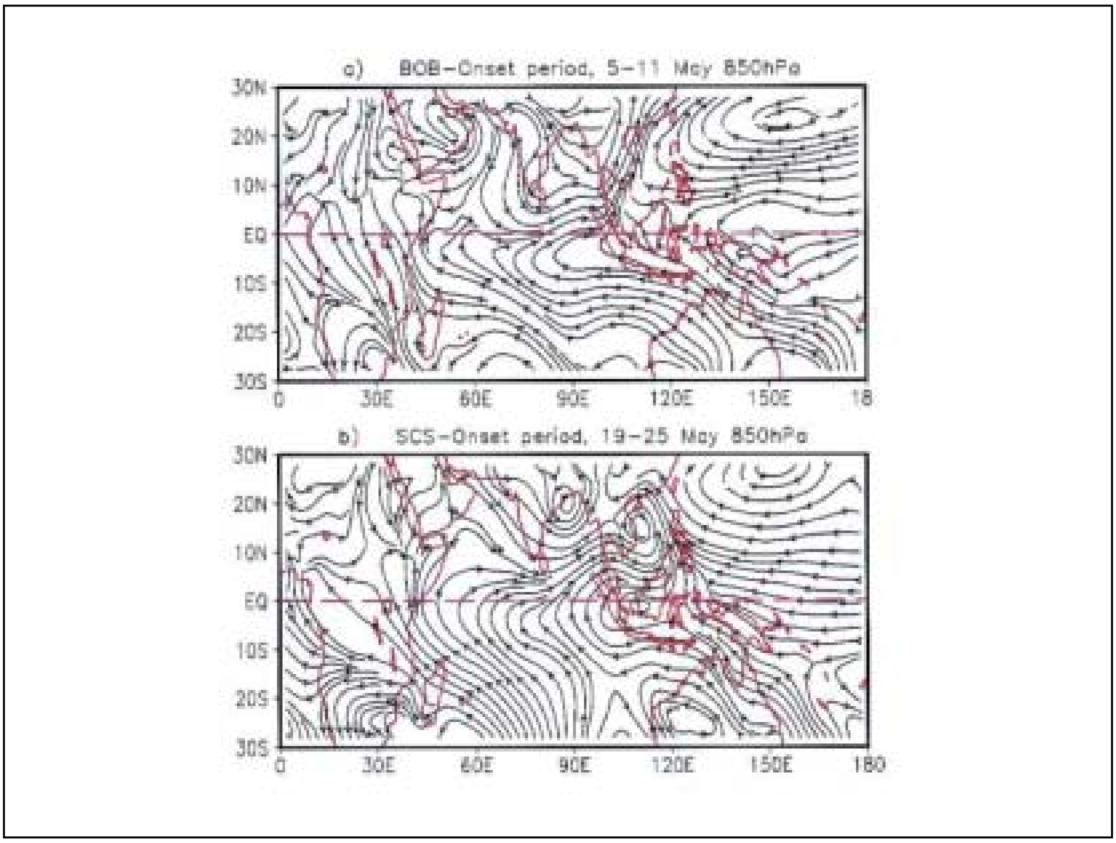
Stage 1: BOB Monsoon Onset

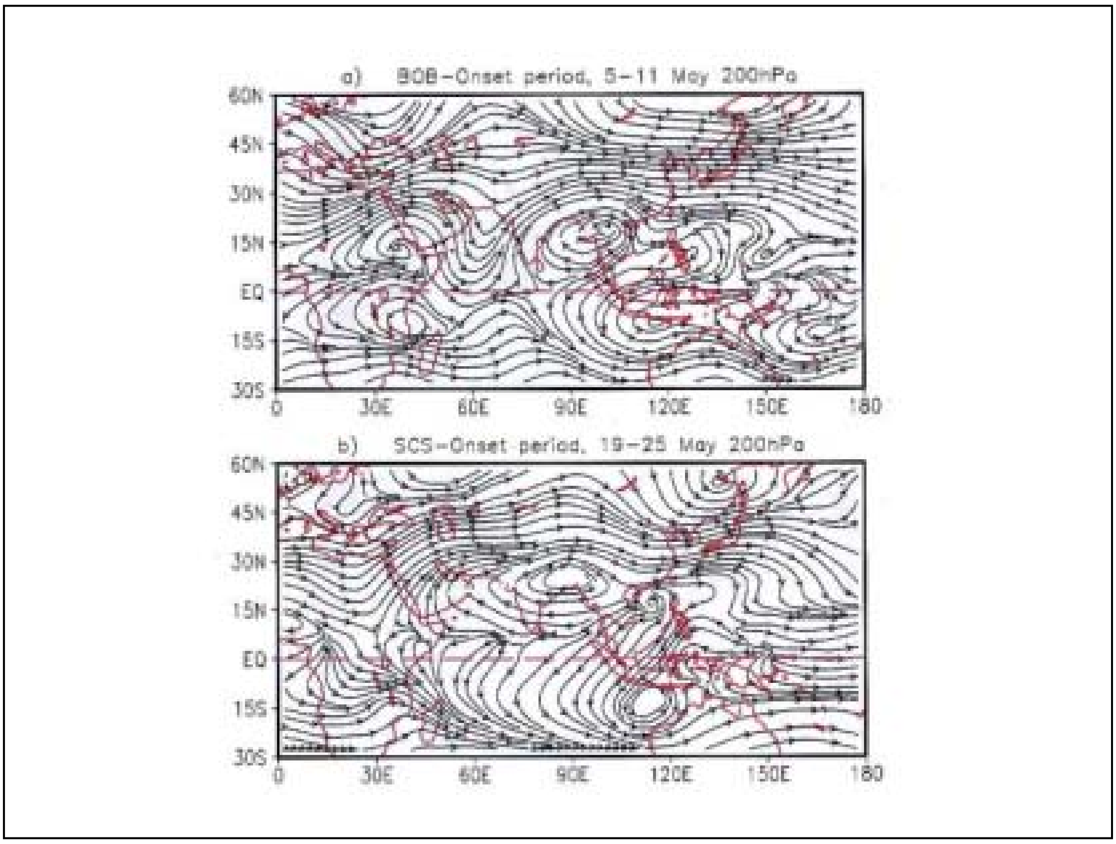


MO Sequence: Three Stage Structure

Stage 2: SCS Monsoon Onset

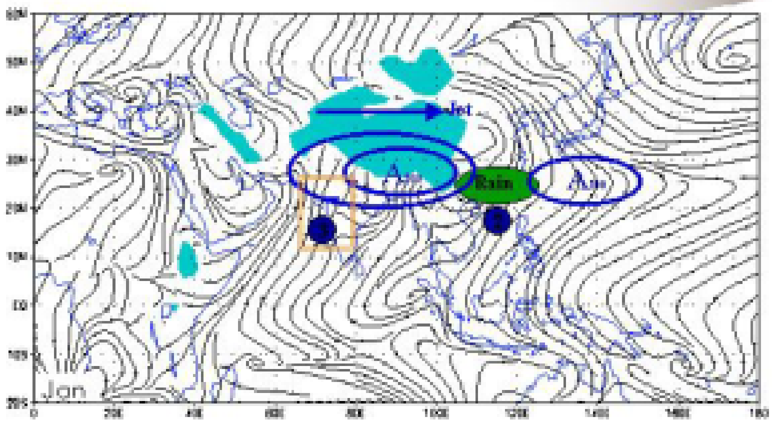



a) BOB-Onset period, 5-11 May 850hPa
b) SCS-Onset period, 19-25 May 850hPa
30N
20N
10N
EQ
10S
20S
30S
0
30E
60E
90E
120E
150E
180

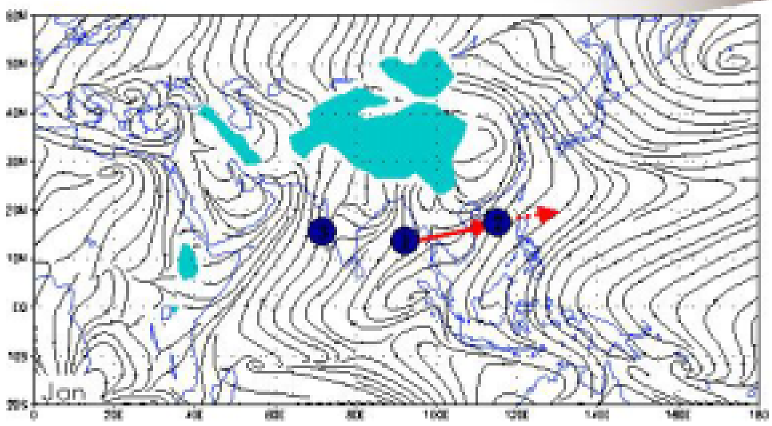

a) BOB-Onset period, 5-11 May 200hPa
b) SCS-Onset period, 19-25 May 200hPa
60N
45N
30N
15N
EQ
15S
30S
0
30E
60E
90E
120E
150E
180

MO Sequence: Three Stage Structure

Stage 3: Indian Monsoon Onset



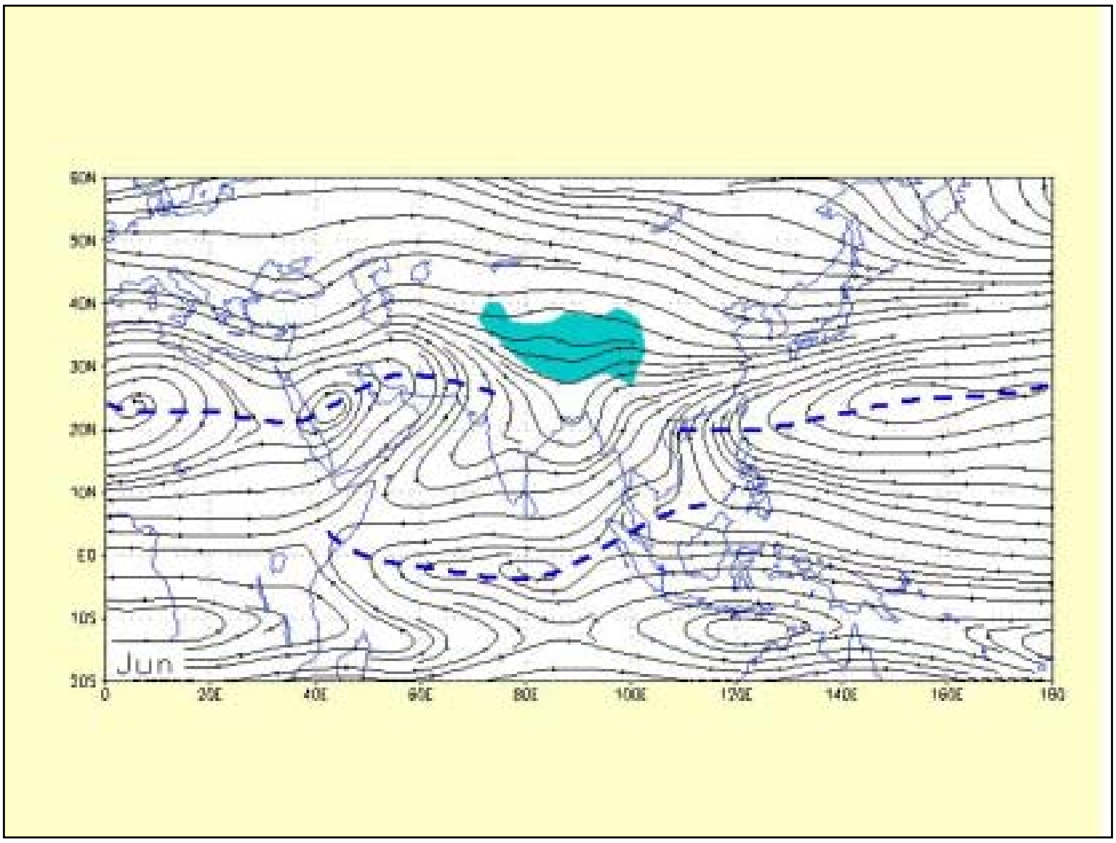
MO Sequence: Three Stage Structure (Wu and Zhang, 1998:MWR; Liu et al., 2002: MWR; Wu and Liu, 1999:Acta Meteor. Sinica; Liu, et al., 2001:Climate Dyn.)

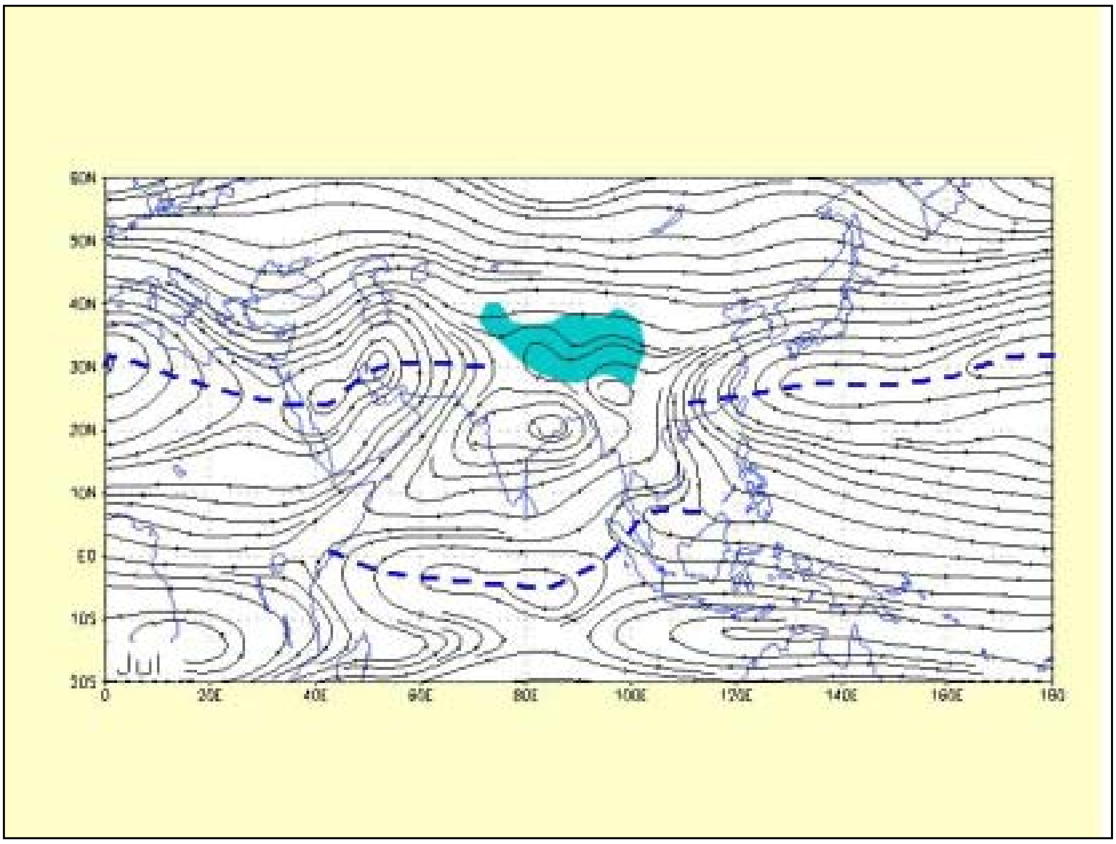


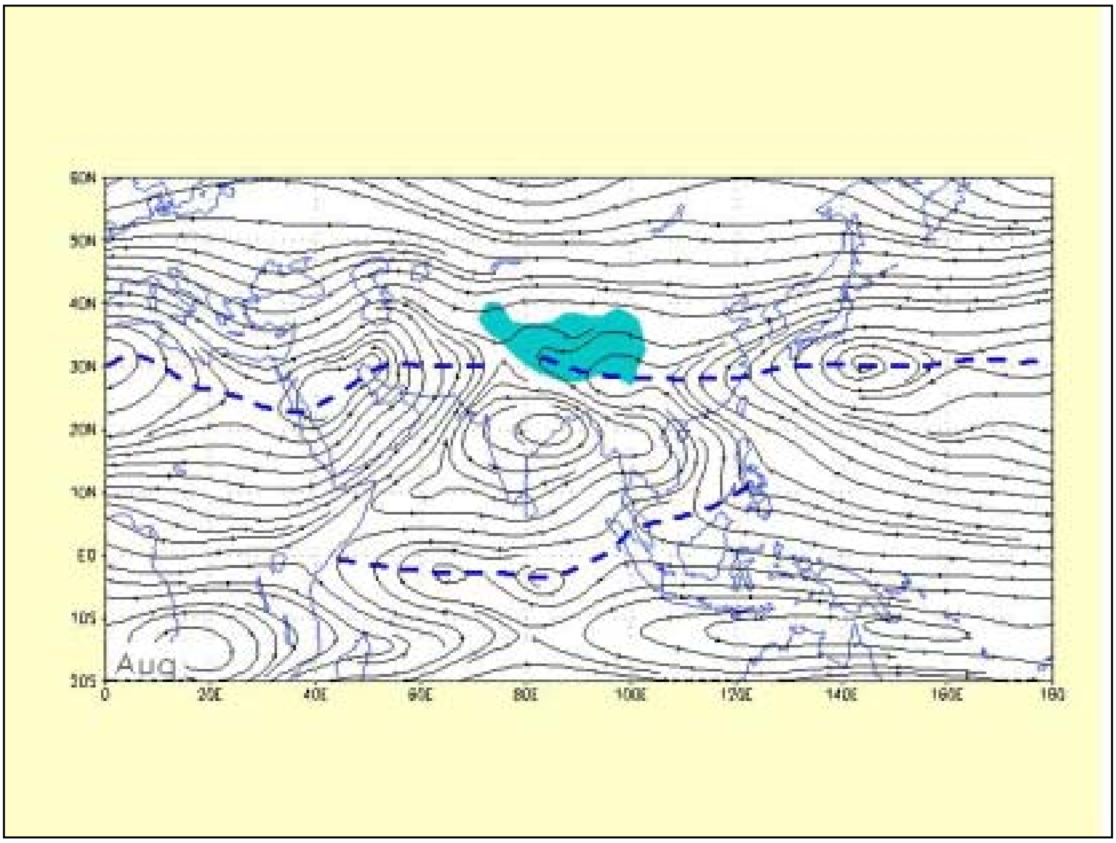
2. Tilting of the Subtropical Anticyclone Surface (WEB) and Monsoon Onset

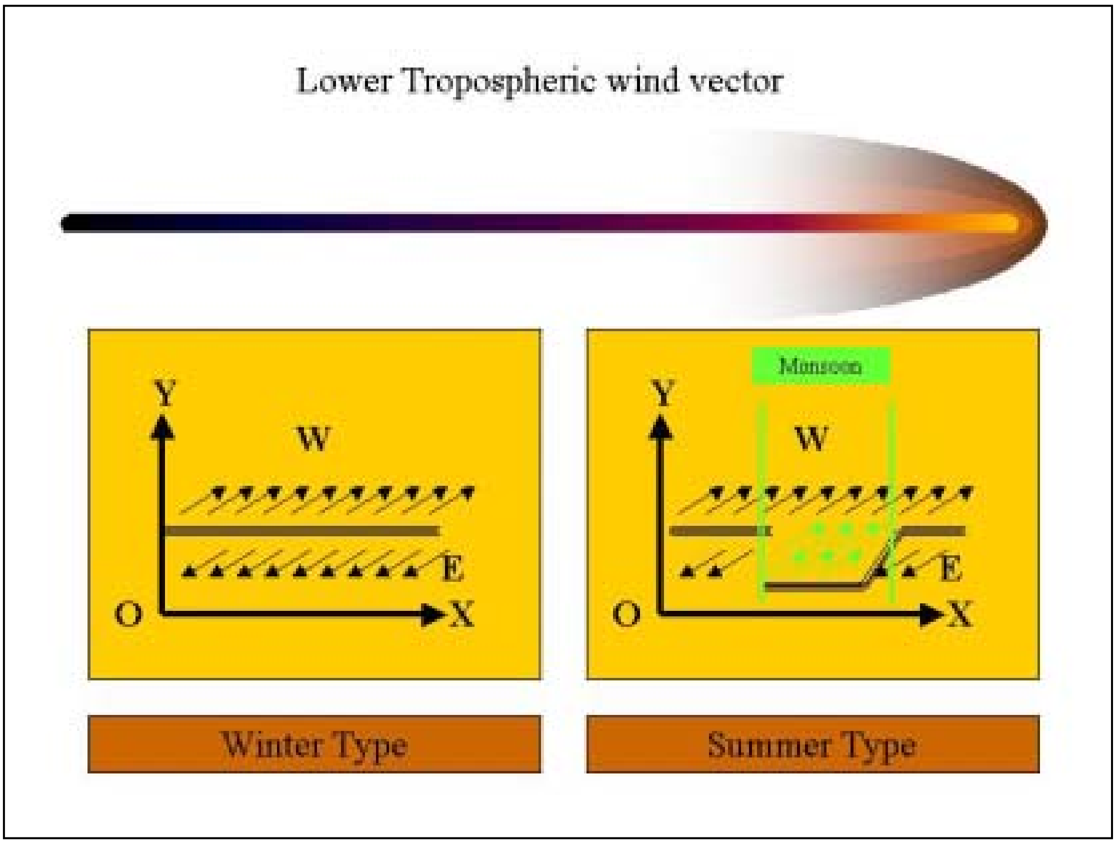
500hPa Wind Field Climatology

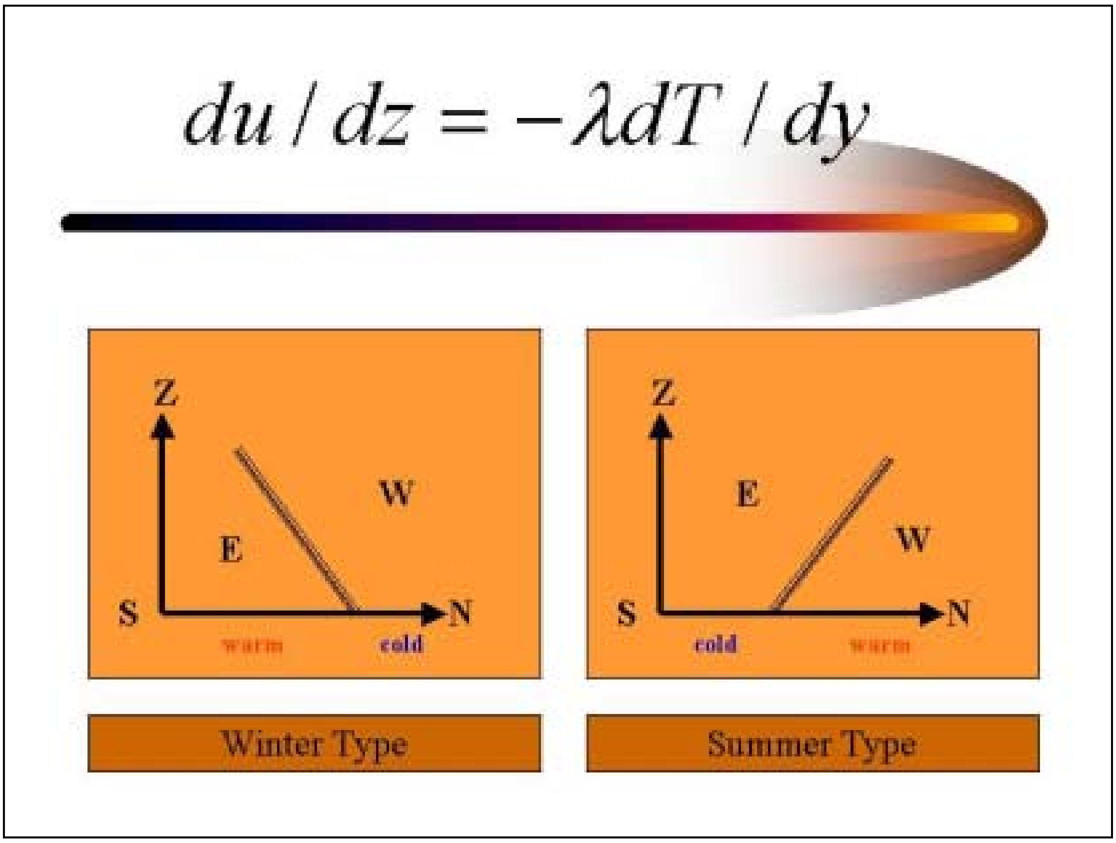
Based on NCEP/NCAR Data for the Period 1958-1997


60N
50N
40N
30N
20N
10N
EQ
10S
20S
Jun
0
20E
40E
60E
80E
100E
120E
140E
160E
180


60N
50N
40N
30N
20N
10N
EQ
10S
20S
Jul
0
20E
40E
60E
80E
100E
120E
140E
160E
180


Aug


Lower Tropospheric wind vector
Y
W
E
O
X
Winter Type
Monsoon
Y
W
E
O
X
Summer Type



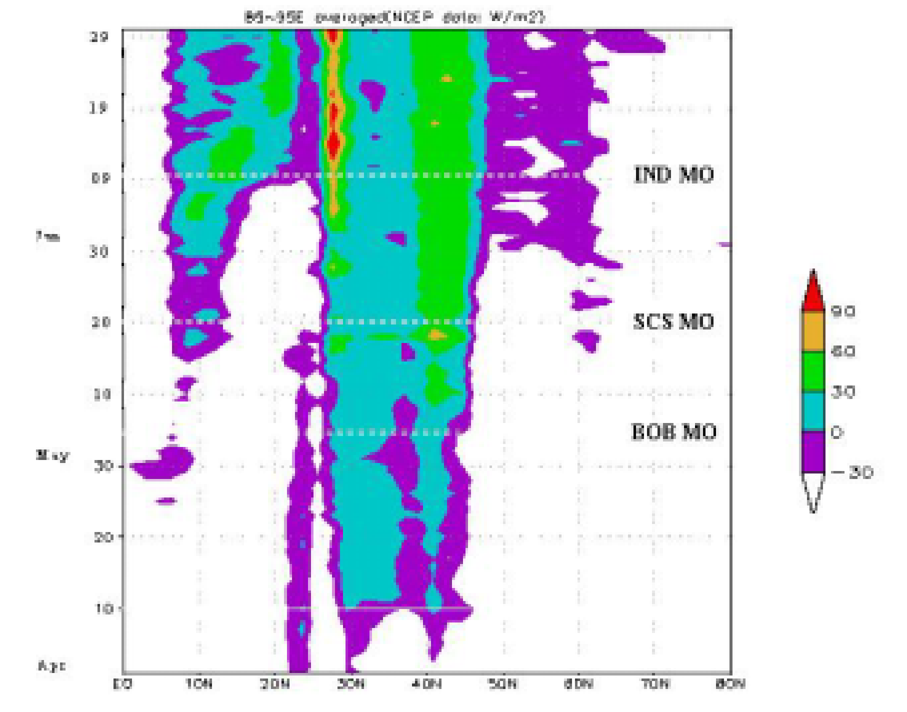
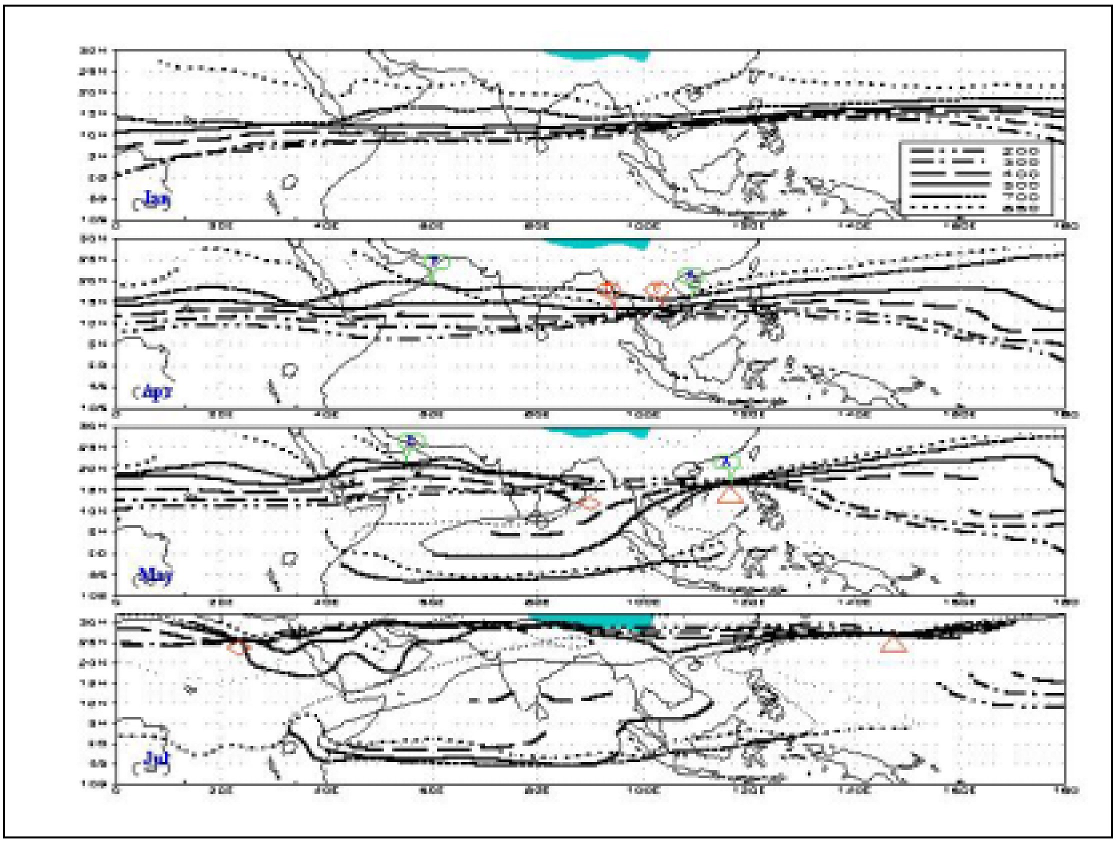
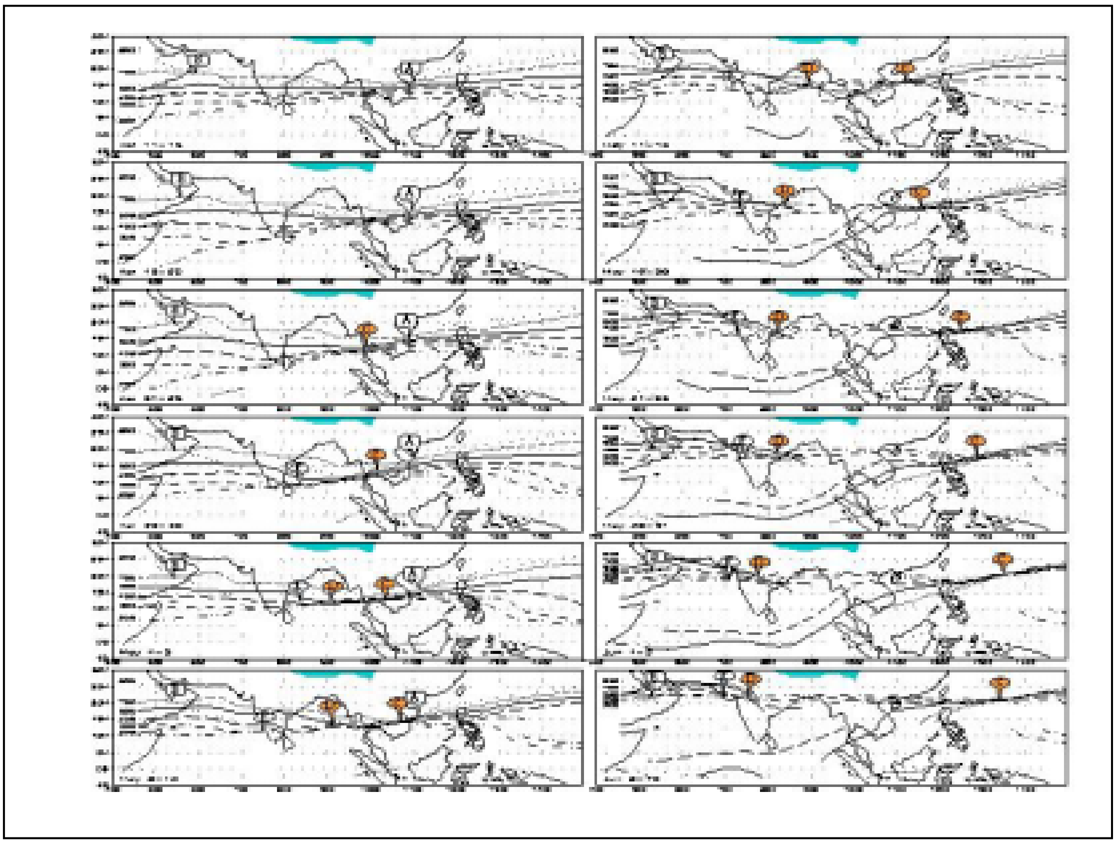
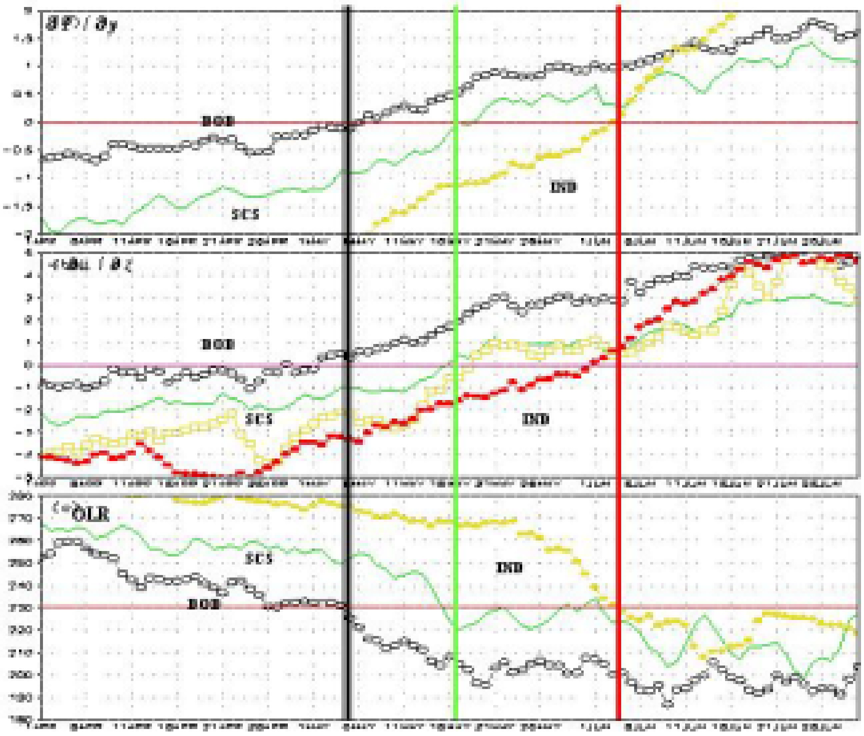


Fig. 20 86~95 10 years mean Apr. to Jun. daily diabatic heating rate


Jan
Apr
May
Jul





Climatological Evolution of (a) area-averaged Meridional Mean Temperature Gradient (1e-5 K/km) and (b) area-averaged Vertical Wind Shear (1e-2 m/s/hPa) between 200 and 850hPa (c) area-averaged OLR (W/m-2)from 1 Apr to 30 Jun for Eastern Bay of Bengal (5-15N,85-100E,open circles),South China Sea (5-20N,110-120E, solid line), and India (10-20N,60-85N,solid circles).Open squares in (b) indicate area-averaged 850hPa Zonal wind over South China Sea

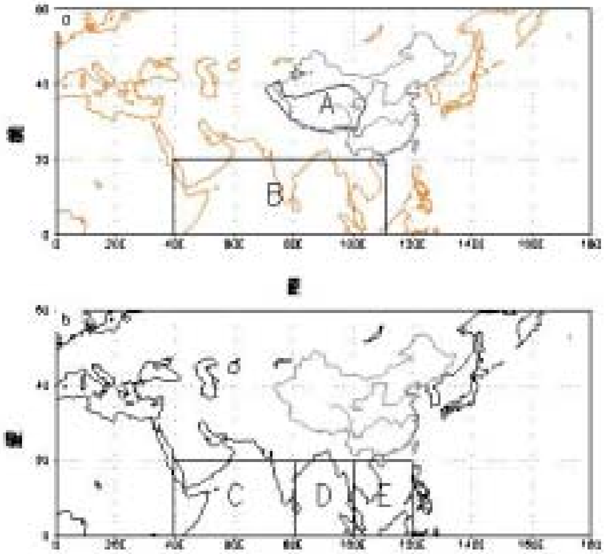


Fig. 1. a) Tibetan Plateau heating index averaged region(A), Webster-Yang Monsoon area(B); b) Indian monsoon area (C), Bay of Bengal monsoon region(D), and South China Sea monsoon region(E)

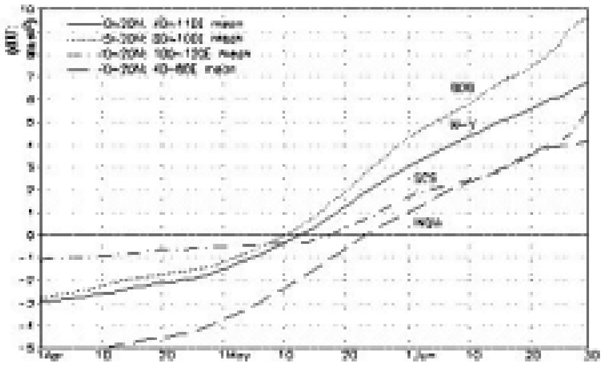
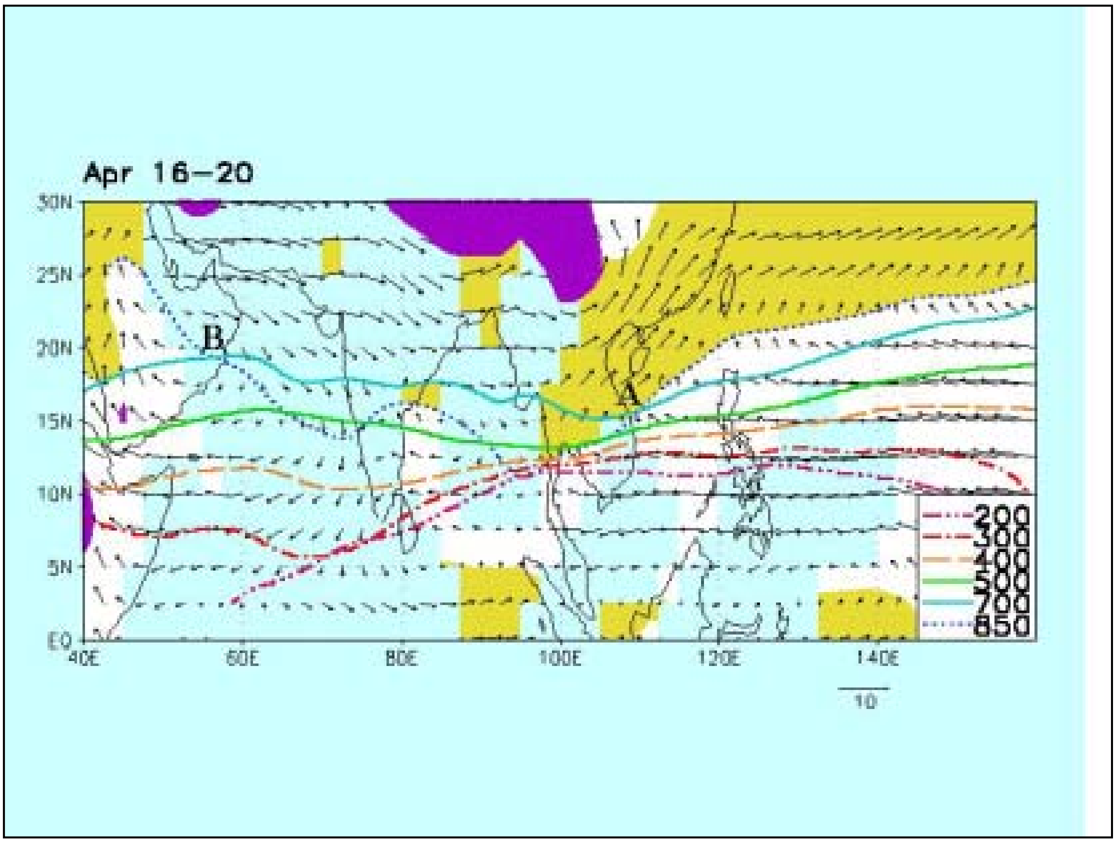


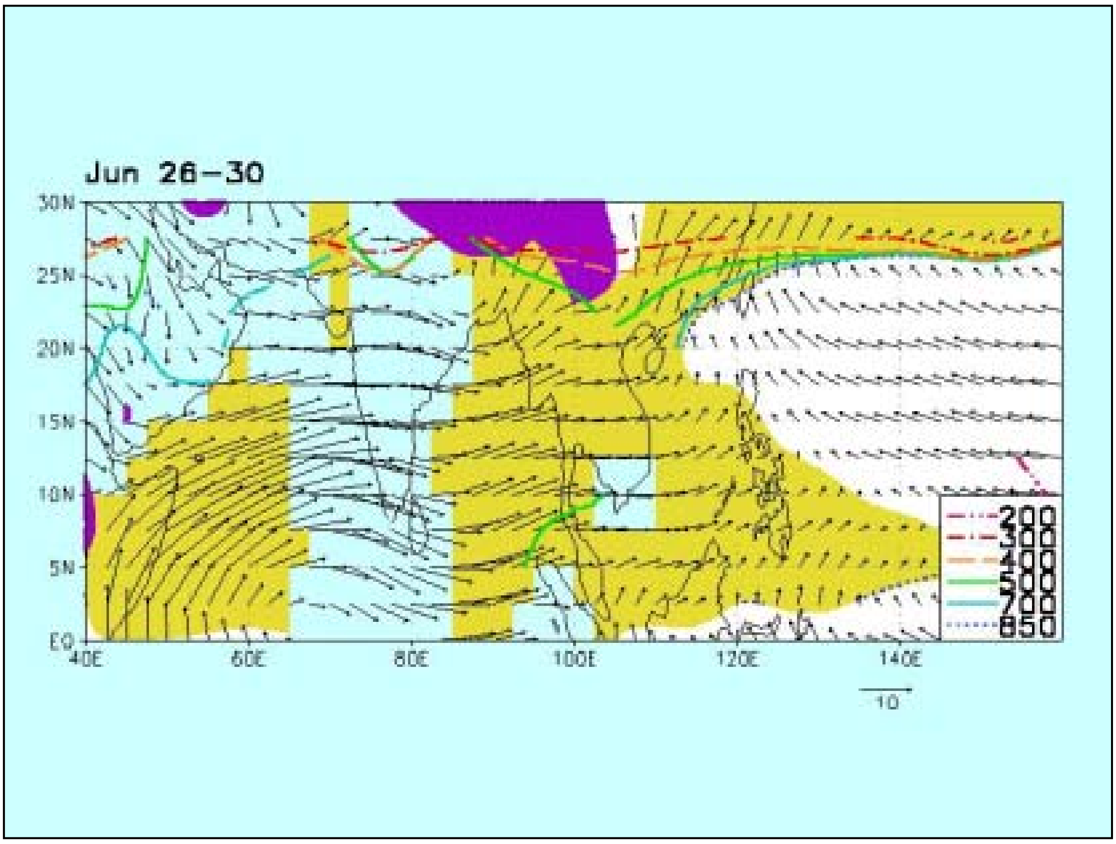
fig. 7 South Asian Monsoon and South China Sea Monsoon Index

Subtropical Anticyclone and Asian Summer Monsoon Onset

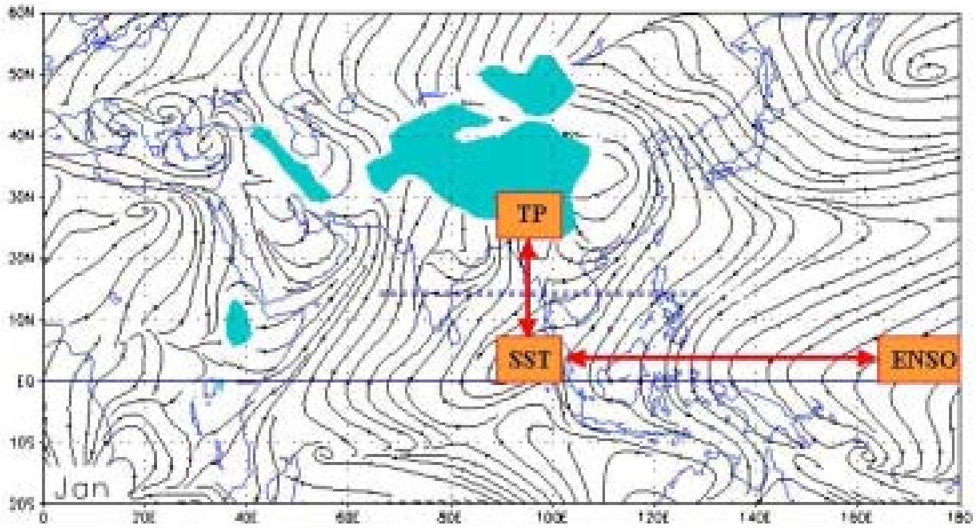
" Seasonal Transition Axis" and 850 hPa Wind

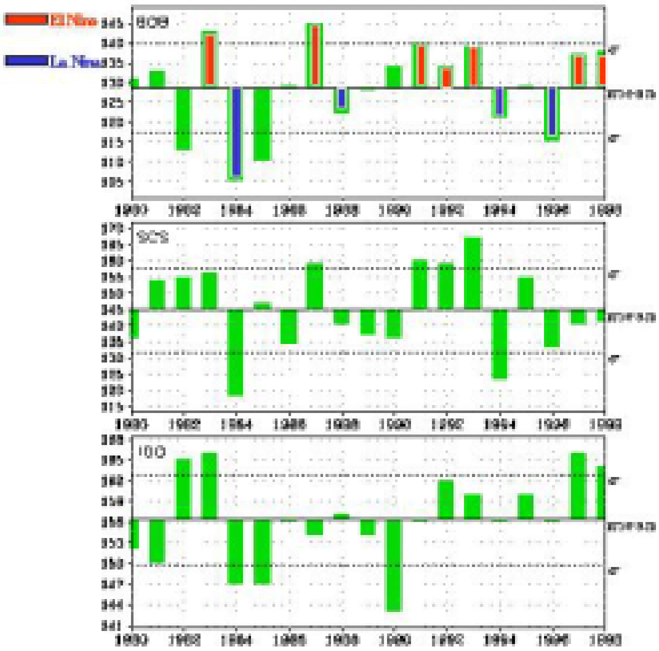
Caption: 20-year pentad mean 850 hPa wind field (vector) and subtropical high ridgelines (thick line) indicated by u=0. The yellow shading denote the region where southwesterlies prevail, the purple areas represent the terrain above 1500m.


Apr 16-20
30N
25N
20N
15N
10N
5N
EQ
40E
60E
80E
100E
120E
140E
B
A
200
300
400
500
700
850
10

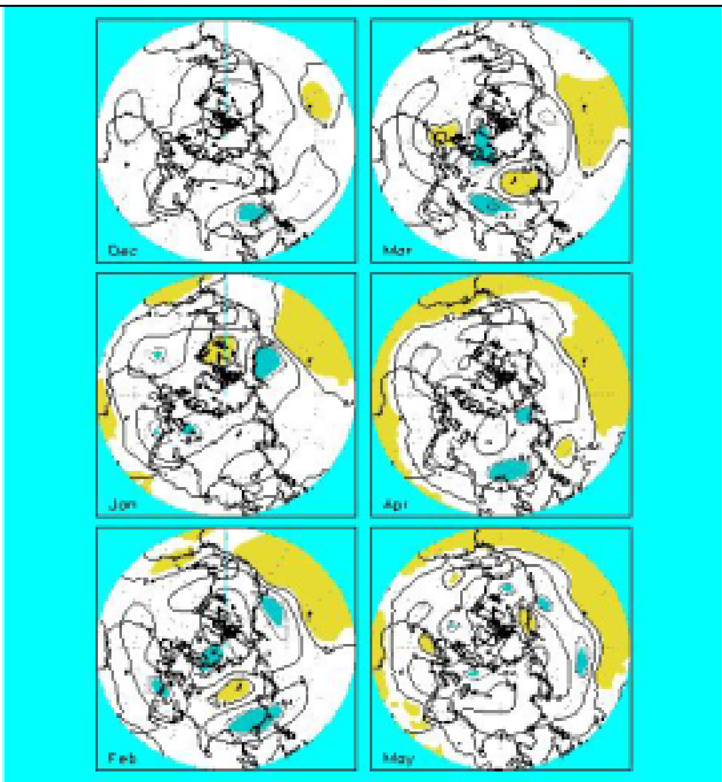

Jun 26-30
30N
25N
20N
15N
10N
5N
EQ
40E
60E
80E
100E
120E
140E
200
300
400
500
700
850
10

3. Prediction of the Monsoon onset over the Bay of Bengal





Time series of Monsoon Onset Date (Calendar day) for BOB (5-15N,90-100E) (upper) ,SCS(5-20N,110-120E) (middle) and IDO (10-20N,60-85E) (lower) Determined by area-averaged dT/dy (200-500hPa), OLR and/or 850hPa Zonal Wind. Dashed lines denote standard deviation.



Lagged correlations between time series of BOB onset and 200 hPa Height field from December to May. Critical positive (negative) values of the correlation at the 95% confidence level are shaded.

Predictability of Asian Monsoon Onset

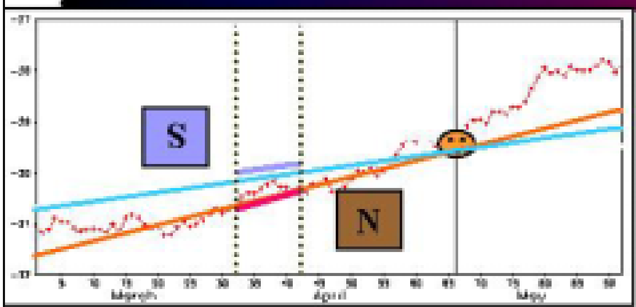
$$\frac{\partial}{\partial y}\left(\frac{\partial T}{\partial t}\right) \propto \frac{\partial Q}{\partial y} \qquad \boxed{\frac{\partial}{\partial t}\left(\frac{\partial T}{\partial y}\right) \propto \frac{\partial Q}{\partial y}}$$

Time needed for overturning meridional temperature gradient, or monsoon onset, is

$$\Delta t = (t_1 - t_0) = -\frac{\partial T(t_0)}{\partial y} \bigg/ \frac{\partial \overline{Q}}{\partial y}$$

Theory

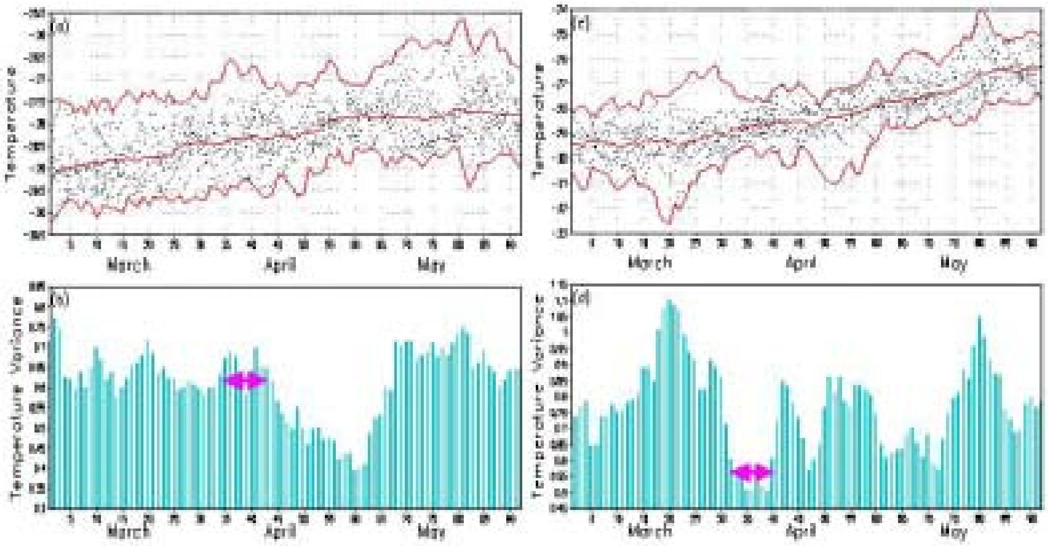
Climate mean NCEP/NCAR daily temperature evolution in north and south side of the ridge of subtropical high at 300hPa over the BOB monsoon region during the period of seasonal transition(MAM).



$$T(t) = a + bt + \sum_k C_k \sin \omega_k t + R(t)$$

$$\approx a + bt$$

$$\Delta t = -\frac{T_{S0} - T_{N0}}{\frac{\partial T_N}{\partial t} - \frac{\partial T_S}{\partial t}}$$

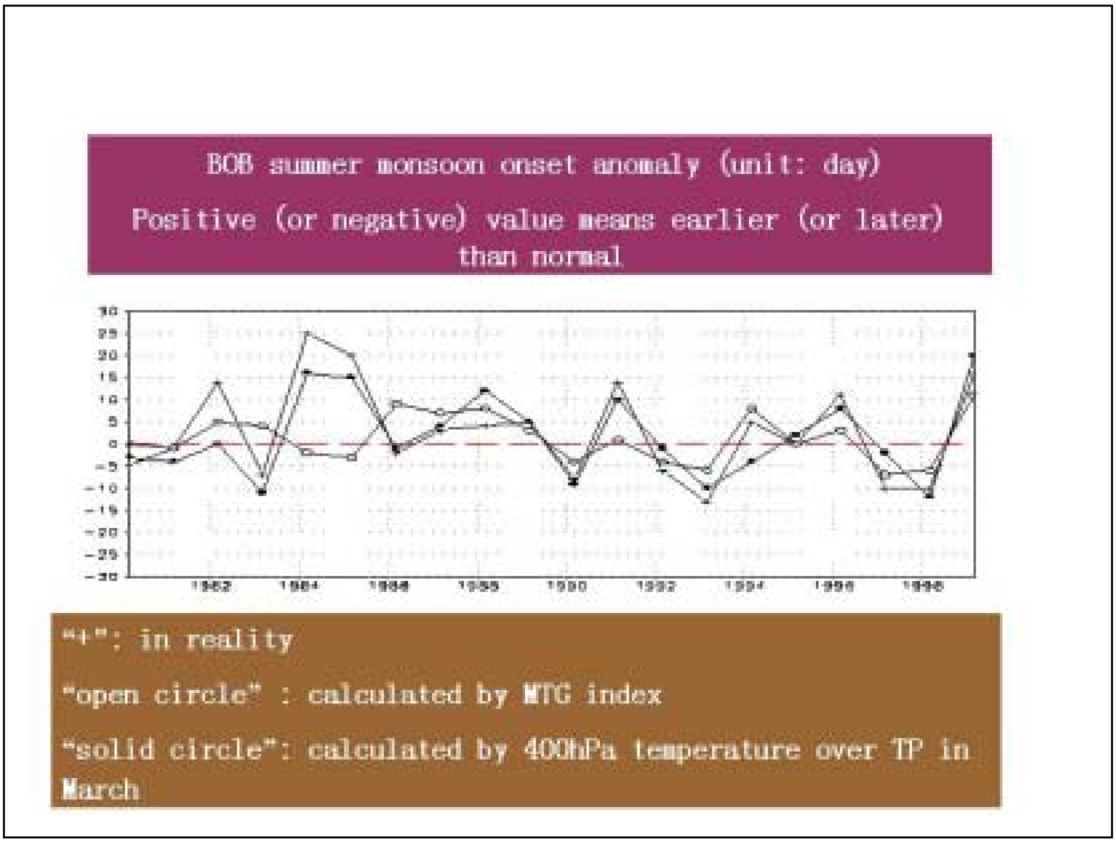


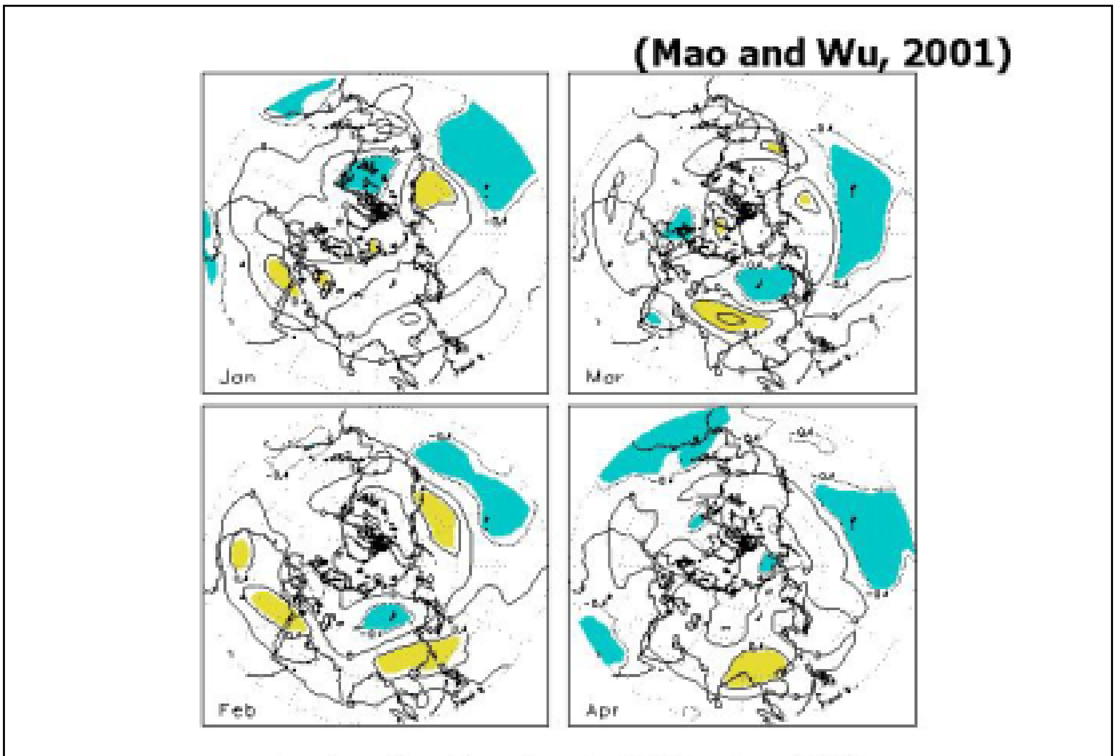
Temperature of south and north part of BOB monsoon region on 200-500hPa and variance. (a) and (b) for south and (c) and (d) for north.

Definition of BOB summer onset: from April 1, the day when the averaged upper-level (500-200hPa) MTG over BOB monsoon region changes from negative to positive and keeps 10 days at least.

Regression equation between the real BOB summer monsoon onset date anomaly series and that calculated by initial time MTG and averaged meridional gradient of local temperature variation

$$D_1(i) = 39.82 + 0.113 \times D_0(i)$$





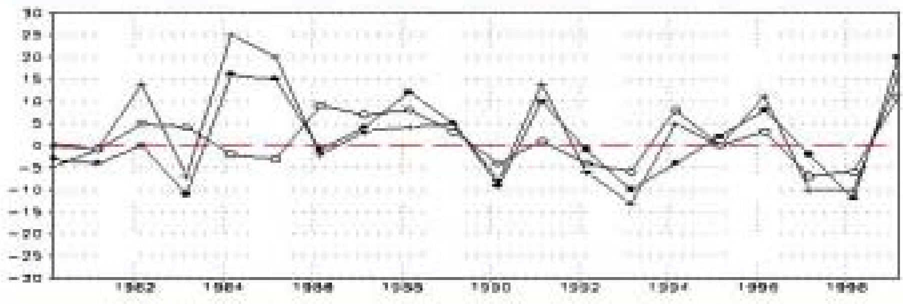
Lagged correlations between time series of BOB transition and 400 hPa temperature from January to April. Critical positive (negative) values of the correlation at the 95% confidence level are shaded.

Regression equation between the BOB summer monsoon onset date anomaly and the averaged temperature at 400hPa over the Tibetan Plateau was constructed

$$D_2(i) = 331.688 + 11.7257 \times H(i)$$

BOB summer monsoon onset anomaly (unit: day)

Positive (or negative) value means earlier (or later) than normal



"+": in reality

"open circle" : calculated by MTG index

"solid circle": calculated by 400hPa temperature over TP in March

Qualitative prediction test (1980-1999)

Qualitative prediction results of the BOB summer monsoon onset in 2000 and 2001 based on these two equations

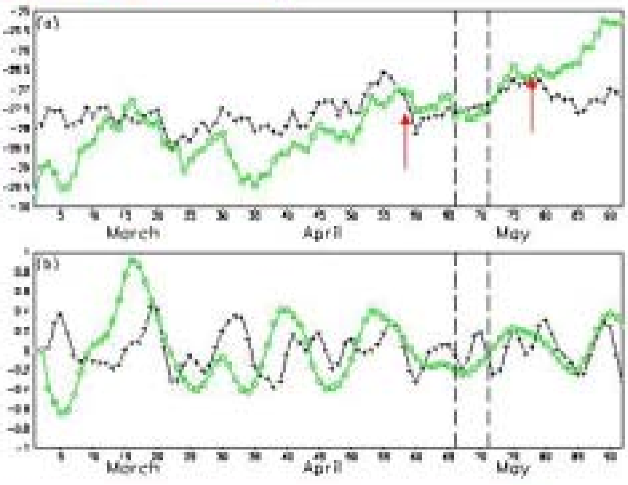
	Prediction by MTG index	Prediction by 400hPa T over TP in March	observation
2000	19 April (earlier)	9 April (earlier)	11 April (earlier)
2001	26 April (earlier)	10 April (earlier)	17 April (earlier)

A case of atmospheric low-frequency variation impacts on the prediction in 1983

4d earlier than normal by prediction but 7d later than normal in observation

$$T(t)=a+bt+\sum_k C_k \sin\omega_k t+R(t)$$

$$\approx a+bt$$



500~200hPa temperature variation of north (circled line)and south (cross line) BOB monsoon region during March to May in 1983.

(a): original temperature (C°); (b) 5~15d band-passed (south) and 10~25d band-passed respectively

4. Concluding Remarks

1. The seasonal evolution of the ridge-surface of the subtropical anticyclone provides another perspective for understanding the Asian Monsoon Onset;
2. Asian MO is composed of three sequential stages, with the earliest occurring over BOB;
3. BOB MO is linked to the thermal status over the TP to the north and SST in the eastern BOB to the south, and thereby to the ENSO events;
4. Qualitative prediction of the BOB MO may be achieved by estimating the *in situ* meridional temperature gradient in the early spring.
5. LFO should be included for quantitative prediction.

Why Atmospheric Models Fail to Simulate Seasonal Rainfall Anomalies in Monsoon Convergence Zones

Bin Wang

University of Hawaii

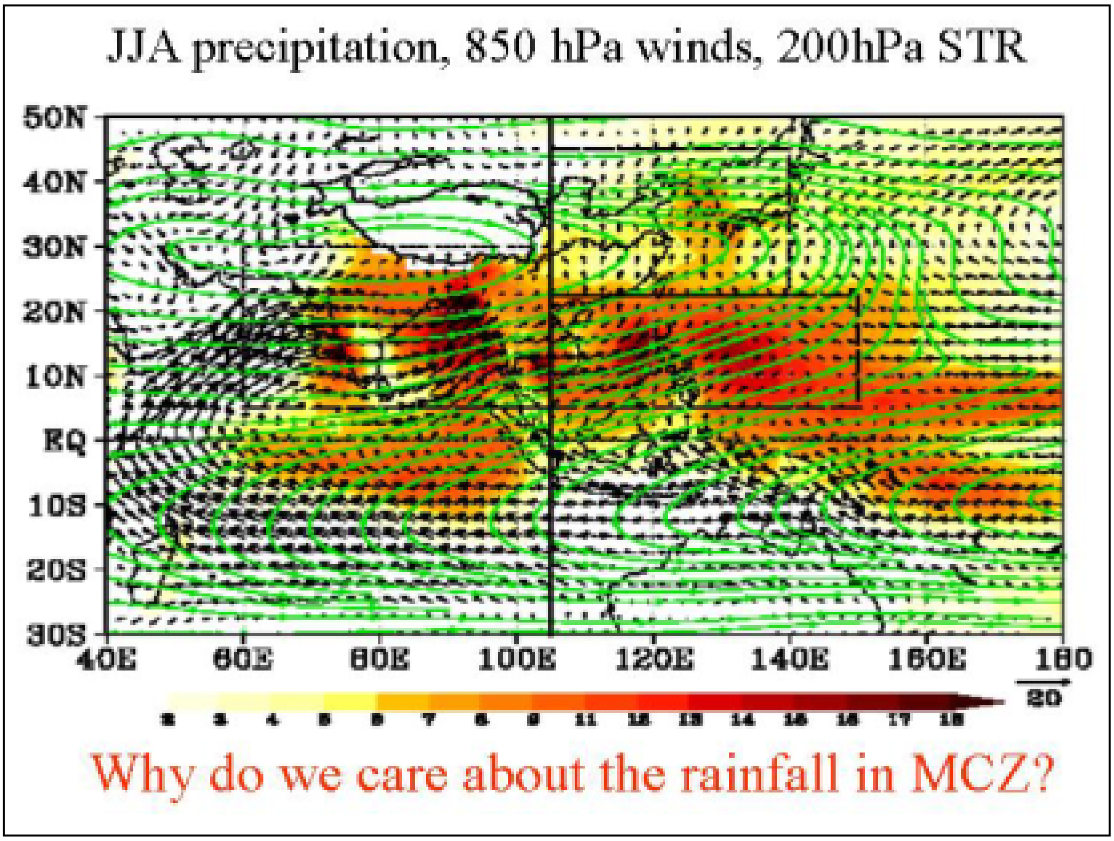
Main Points

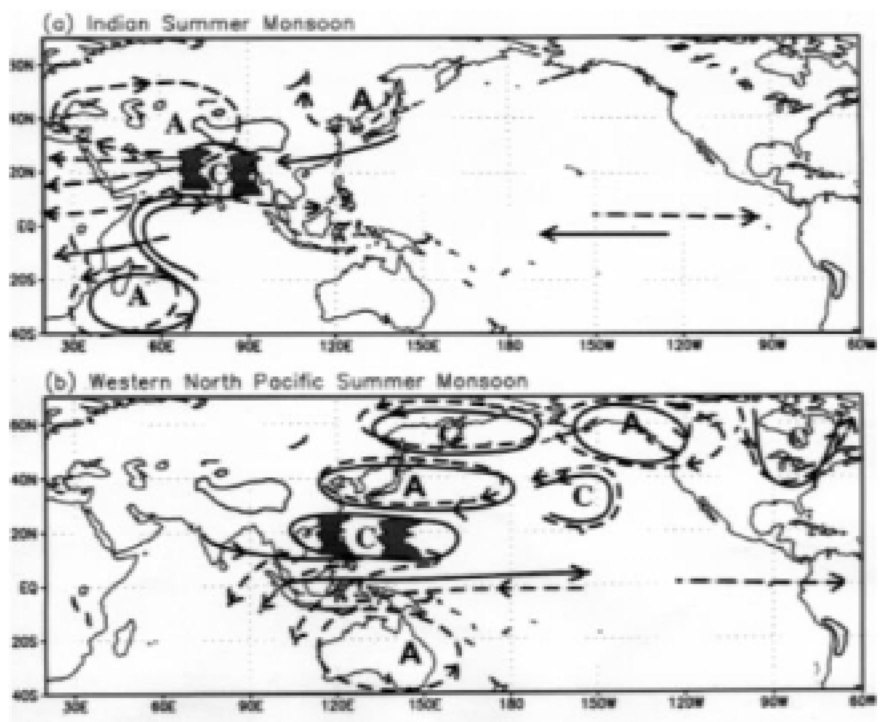
AGCM alone can not reproduce realistic seasonal rainfall anomalies in summer Monsoon Convergence Zone (MCZ).

Caution should be taken when validating model or determining upper limit of predictability using AMIP approach.

Two-tier approach may be inherently inadequate for monsoon rainfall anomalies.

Atmospheric only model may loss significant amount of predictability on MJO.



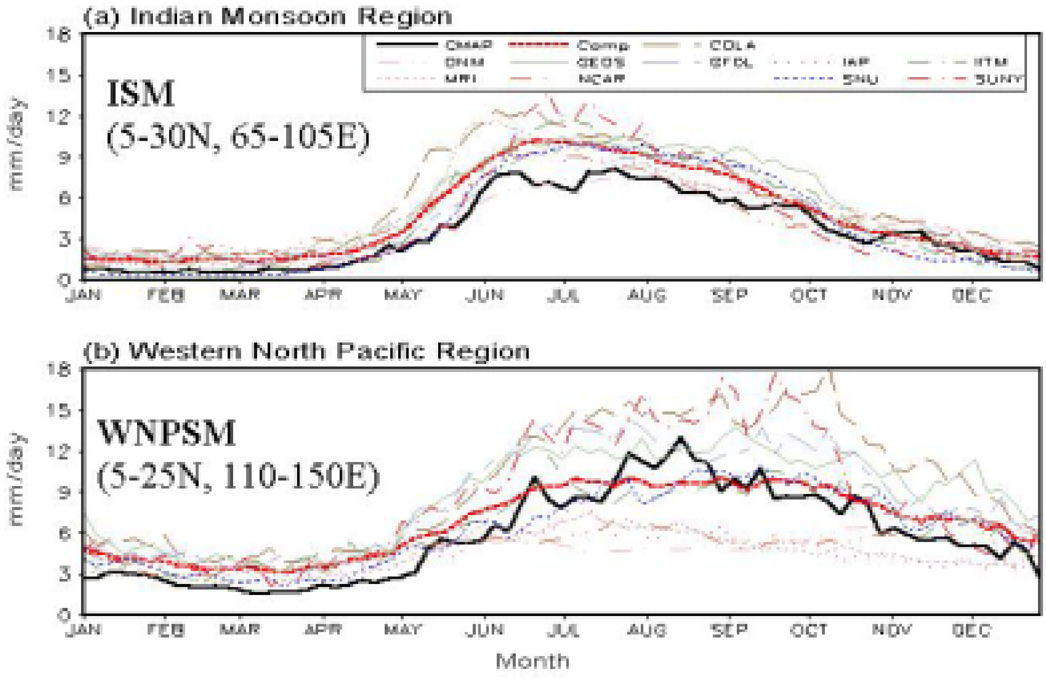


Source of predictability for EASM

How well are the Asian summer monsoon rainfall simulated in 11 AGCMs that participate the CLIVAR/ Monsoon panel Intercomparison project (Kang et al. 2002)?

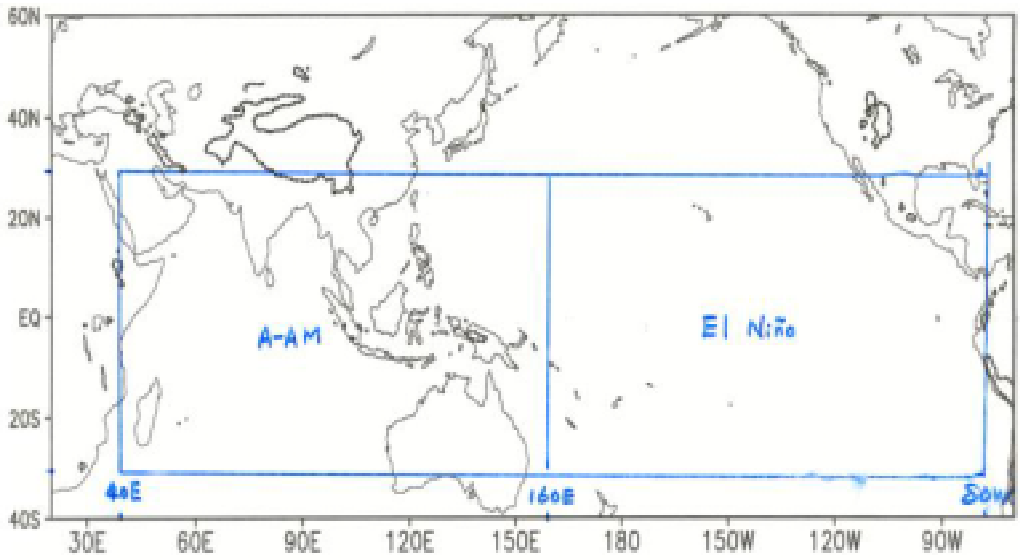
AMIP design
10-member ensemble
2-year (Sept 1 1996-August 31 1998)

Climatological Pentad Mean Precipitation

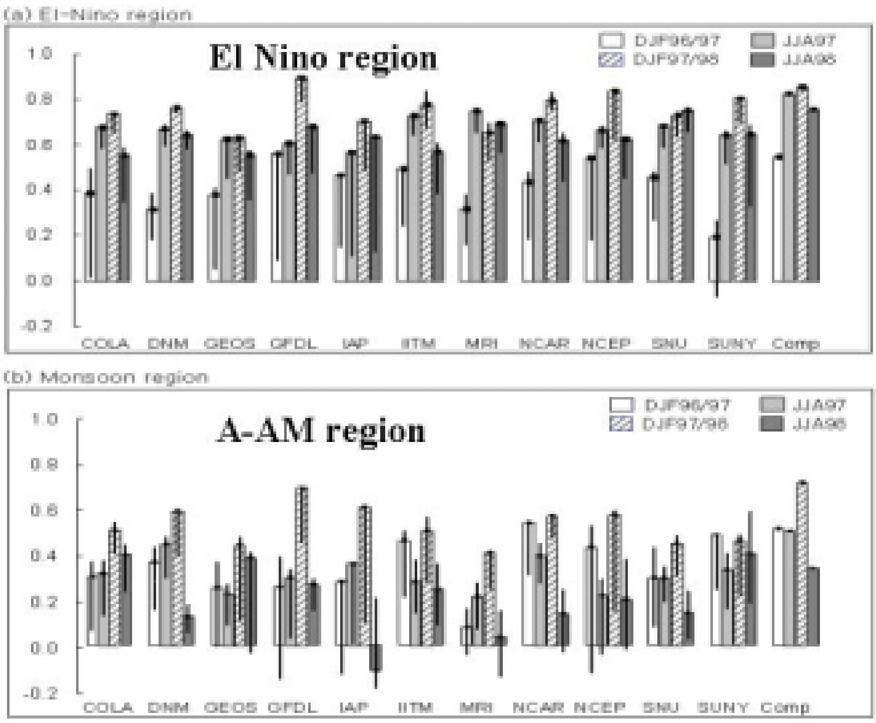


AGCMs simulate climatology poorly over the WNP heat source region

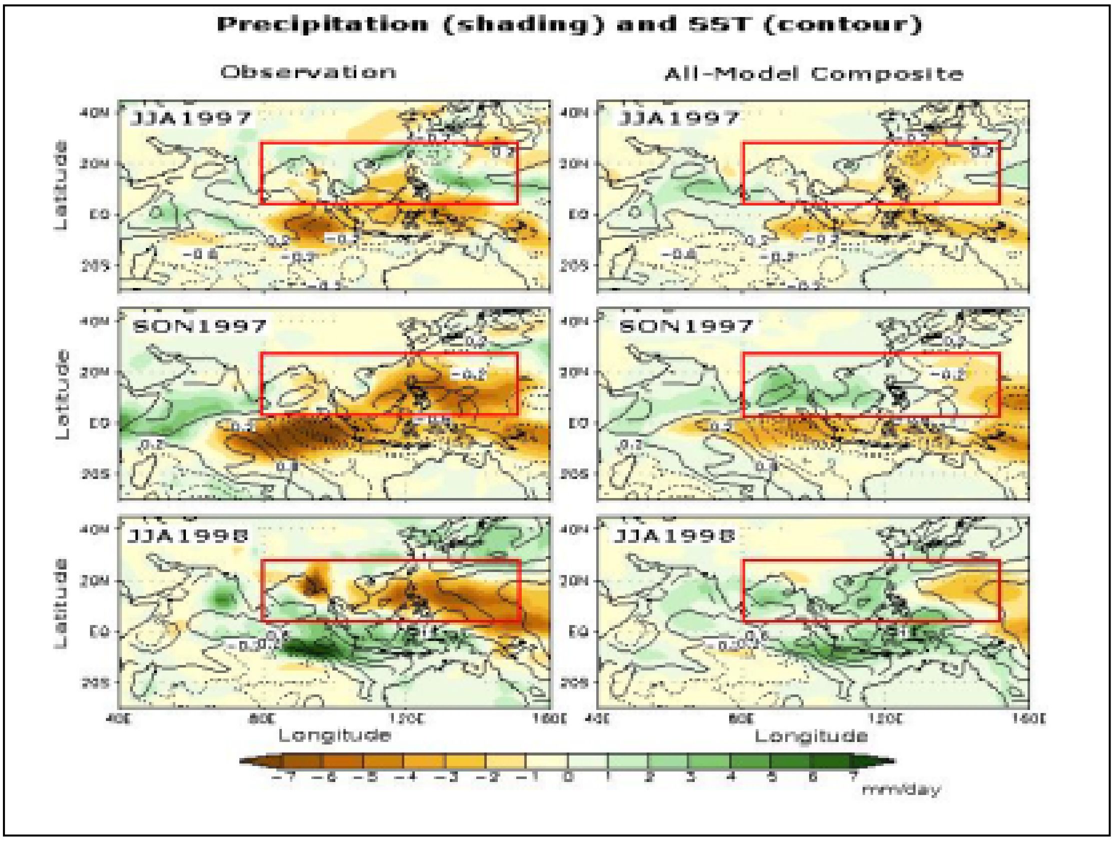
What about interannual variability of A-AM rainfall?



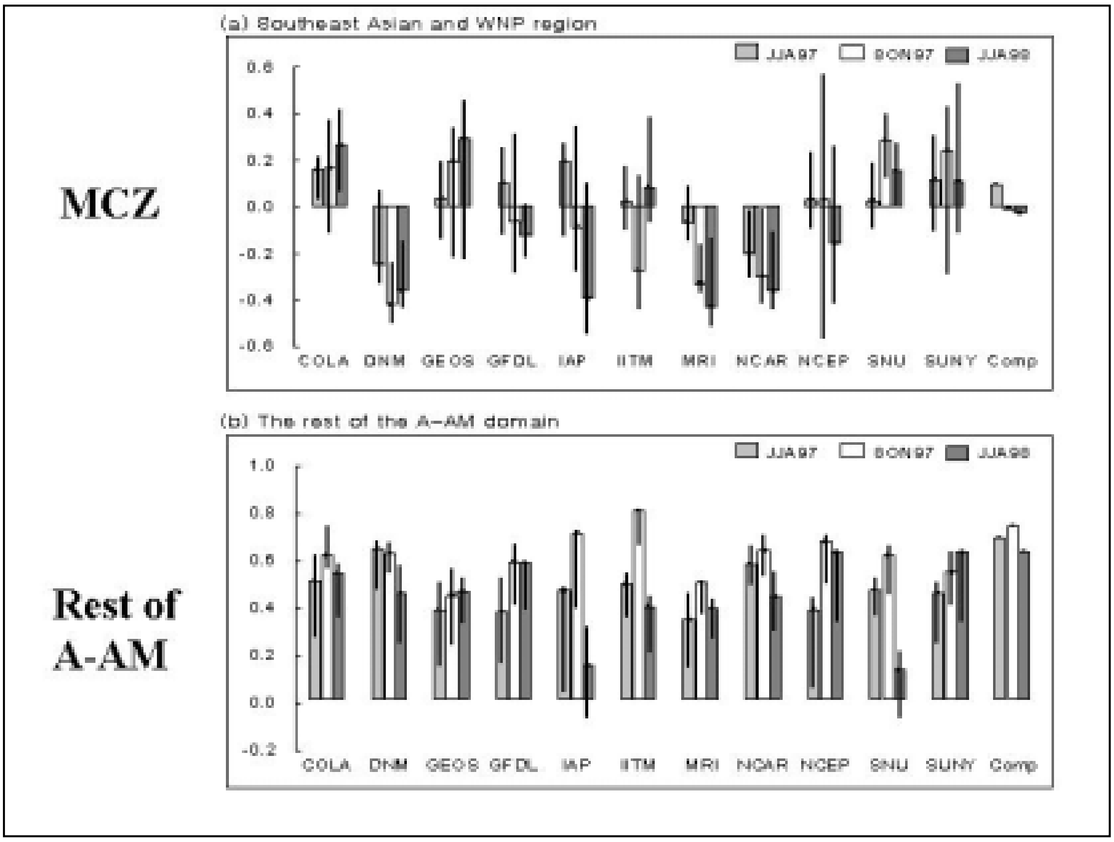
Pattern Correlation Coefficients



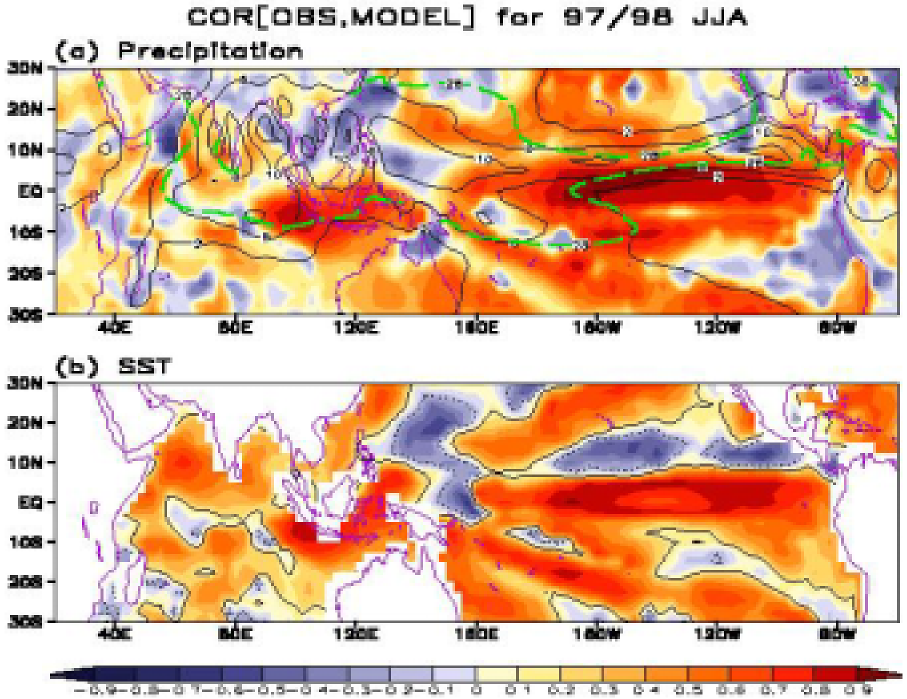
Wang, Kang, Lee 2003, JC



Precipitation (shading) and SST (contour)
Observation
All-Model Composite
JJA1997
SON1997
JJA1998
Latitude
Longitude
mm/day



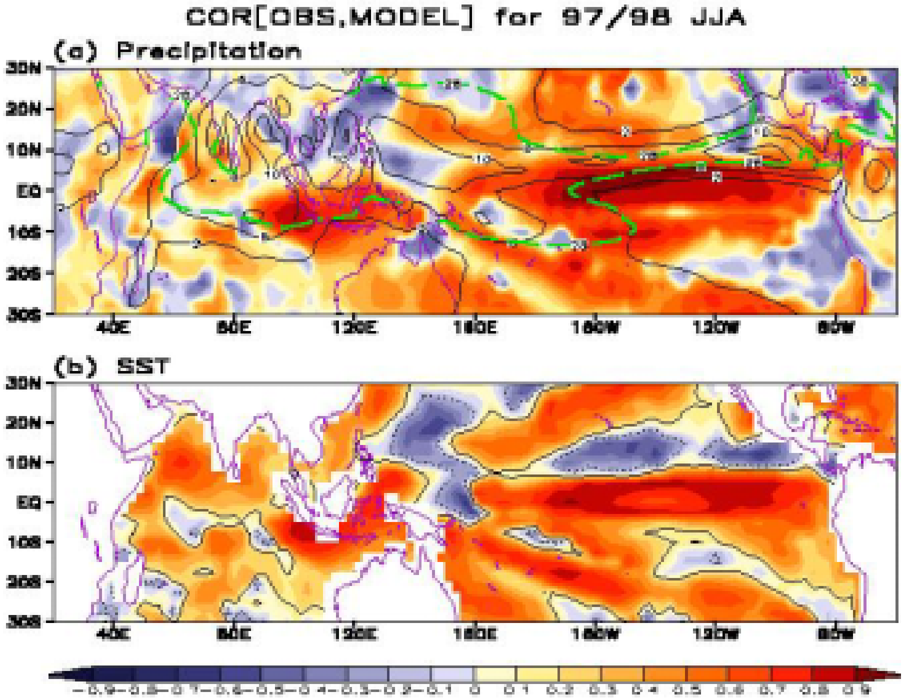
MCZ
(a) Southeast Asian and WNP region
JJA97
SON97
JJA98
COLA DNM GEOS GFDL IAP IITM MRI NCAR NCEP SNU SUNY Comp
Rest of A-AM
(b) The rest of the A-AM domain
JJA97
SON97
JJA98
COLA DNM GEOS GFDL IAP IITM MRI NCAR NCEP SNU SUNY Comp



(a) Correlation coefficients between the observed and simulated summer mean (JJA) precipitation anomalies during 1997 and 1998. The color shading denotes the correlation coefficients and the contours denote climatological seasonal mean rainfall rate (1979-98 CMAP climatology), and the green dashed line denotes the contour of seasonal mean 28°C SST (1971-2000 OISST climatology).
(b) The same as in (a) except for the correlation coefficients between observed SST and simulated precipitation anomalies during JJA 1997 and 1998. The contour denotes the significance level with 99% confidence level (0.17).

Why do nearly all Atmospheric Models Fail to Simulate Seasonal Rainfall Anomalies in Monsoon Convergence Zones?

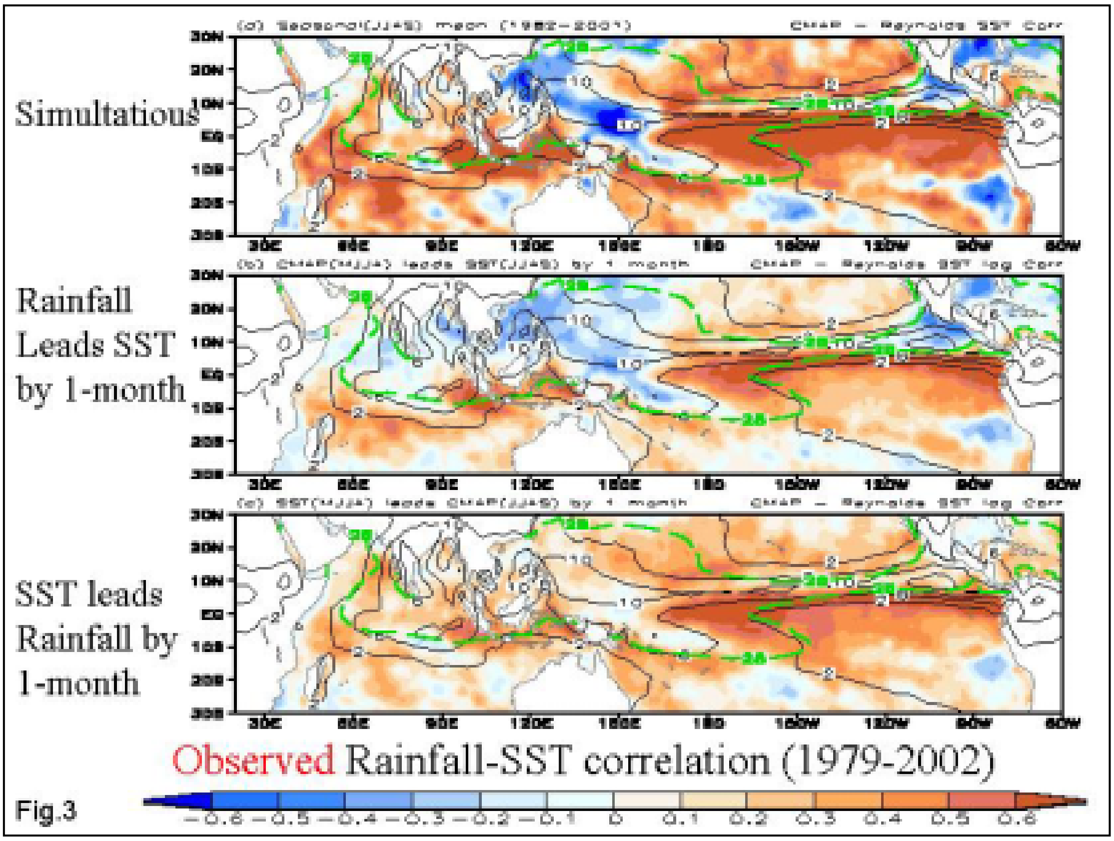
Bad model?
Inadequate strategy?

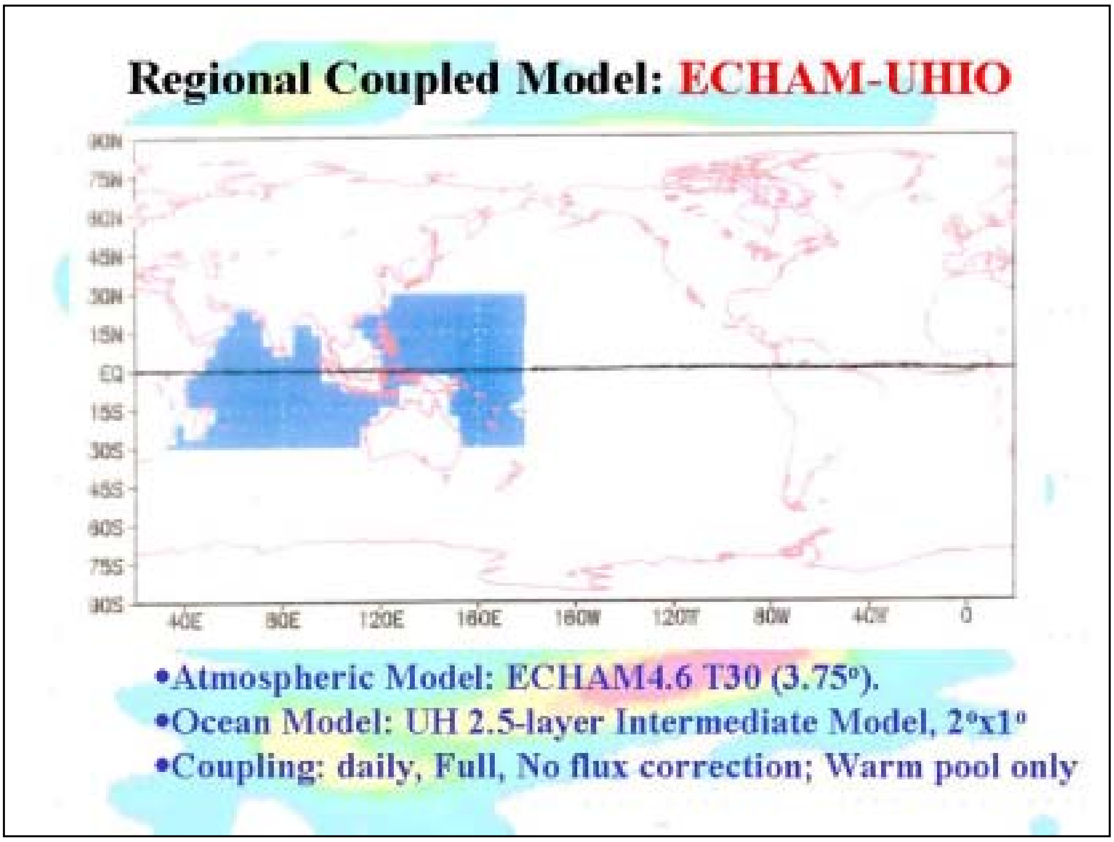


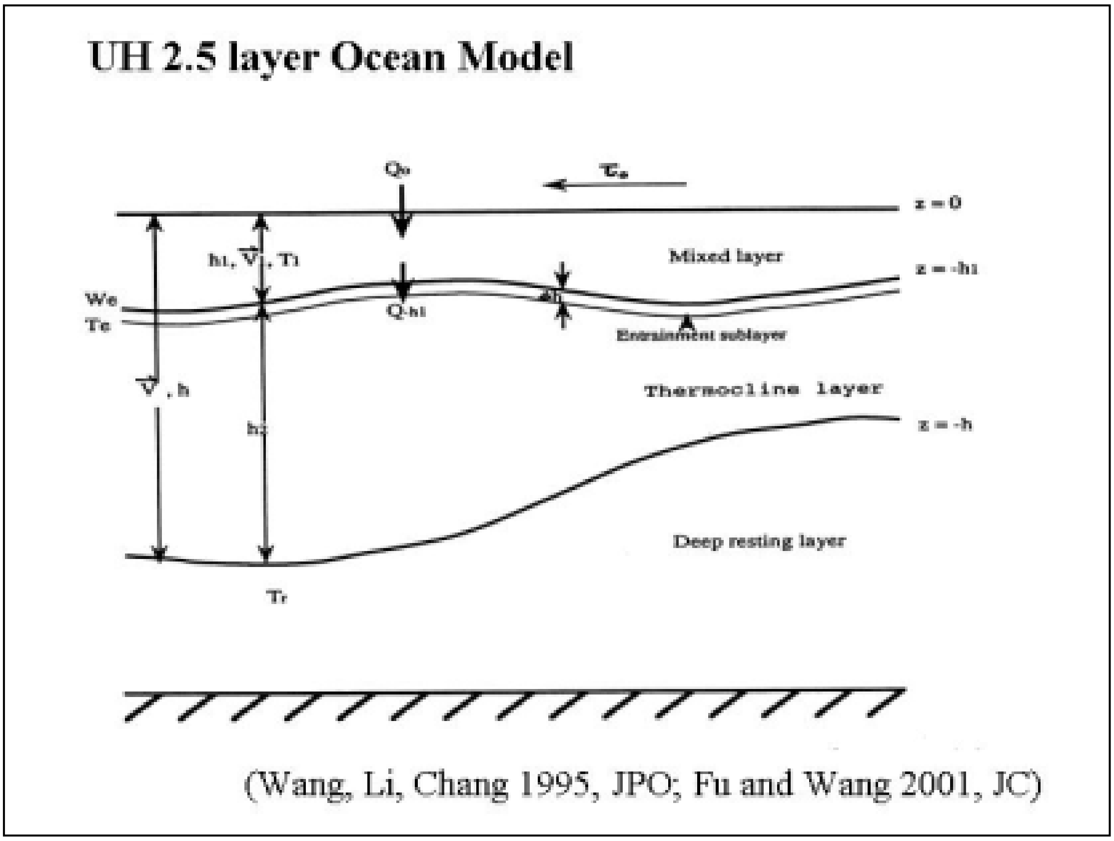
(a) Correlation coefficients between the observed and simulated summer mean (JJA) precipitation anomalies during 1997 and 1998. The color shading denotes the correlation coefficients and the contours denote climatological seasonal mean rainfall rate (1979-98 CMAP climatology), and the green dashed line denotes the contour of seasonal mean 28°C SST (1971-2000 OISST climatology).
(b) The same as in (a) except for the correlation coefficients between observed SST and simulated precipitation anomalies during JJA 1997 and 1998. The contour denotes the significance level with 99% confidence level (0.17).

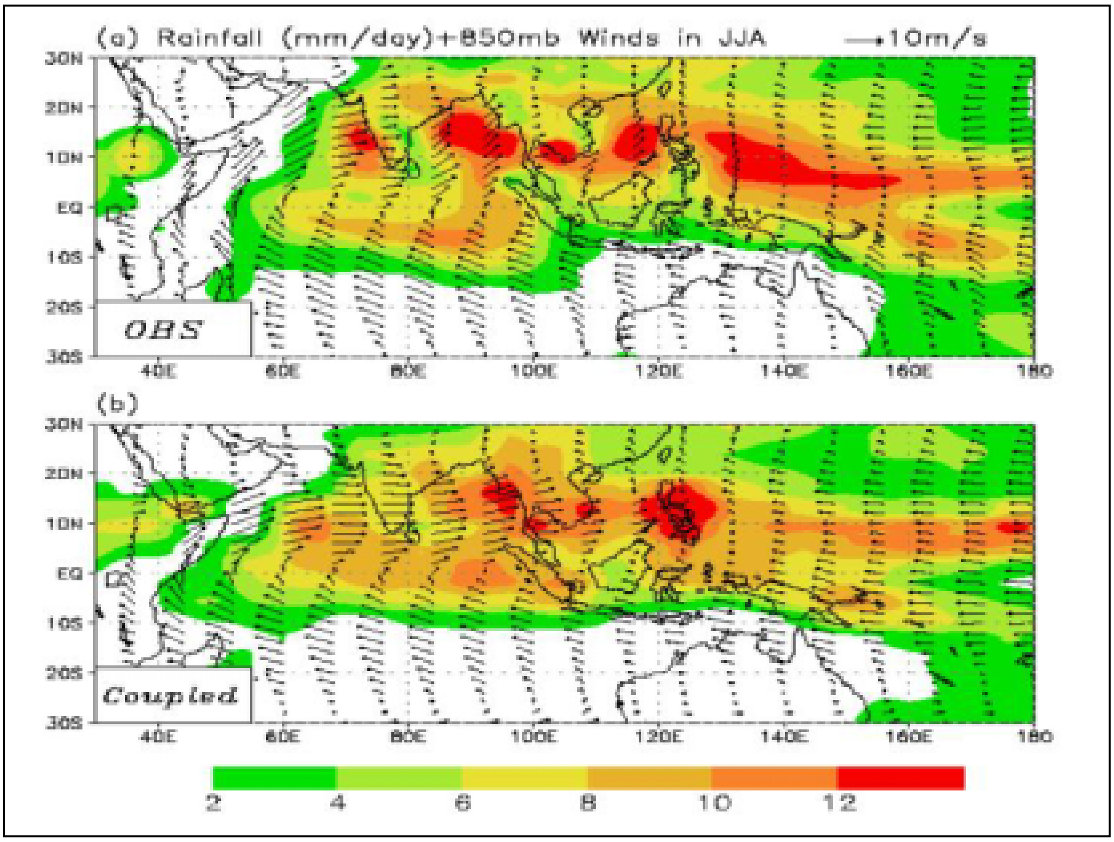
Correlation coefficients: Local SST-Precipitation Anomalies

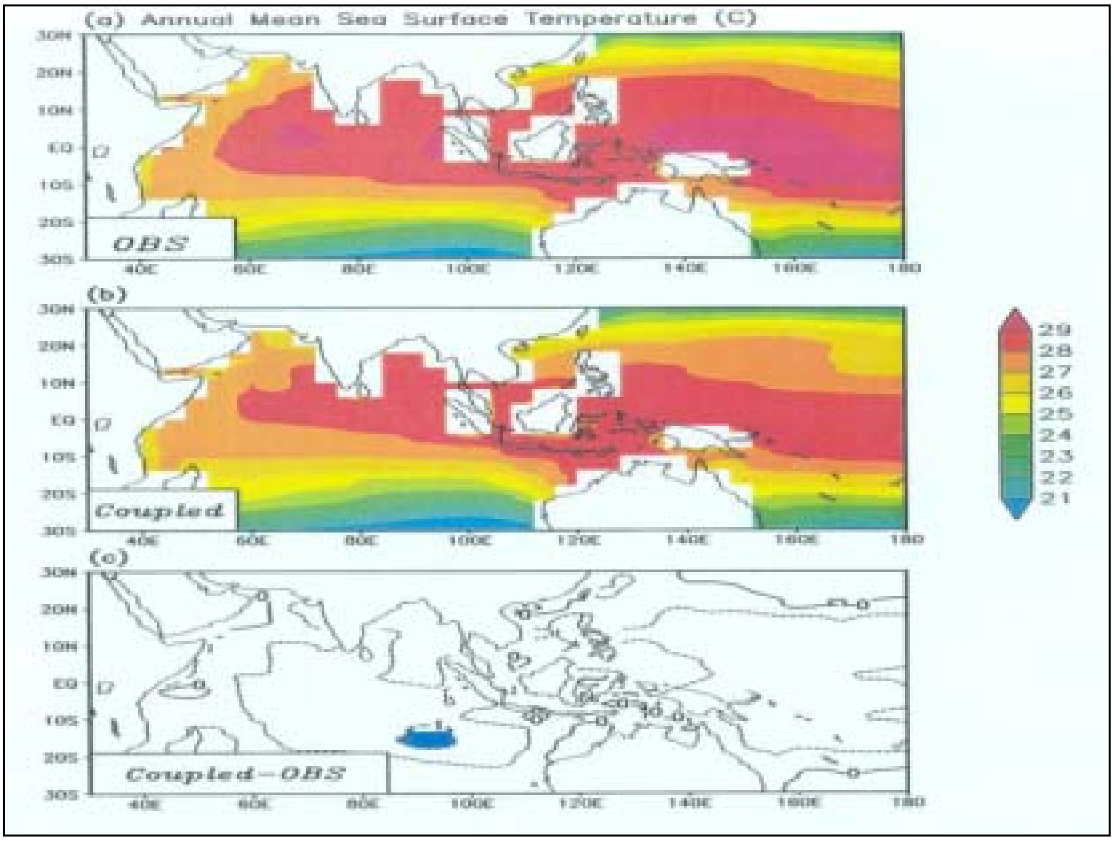
	OBS	11-COMPOS.	COLA	DNM	GEOS	GFDL	IAP	IITM	MRI	NCAR	NCEP	SNU	SUNY
JJA 97	-0.15	0.59	0.42	0.49	0.38	0.19	0.02	0.15	0.49	0.43	0.39	0.36	0.33
SON 97	-0.33	0.71	0.59	0.7	0.5	0.35	0.45	0.49	0.44	0.66	0.37	0.34	0.37
JJA 98	-0.45	0.56	0.19	0.77	0.24	0.52	0.59	0.44	0.5	0.51	0.57	-0.12	0.38
TO-TAL	-0.35	0.58	0.33	0.65	0.32	0.42	0.42	0.37	0.47	0.51	0.47	0.04	0.35


Simultatious
Rainfall
Leads SST
by 1-month
SST leads
Rainfall by
1-month
Observed Rainfall-SST correlation (1979-2002)
Fig.3


Regional Coupled Model: ECHAM-UHIO
•Atmospheric Model: ECHAM4.6 T30 (3.75°).
•Ocean Model: UH 2.5-layer Intermediate Model, 2°x1°
•Coupling: daily, Full, No flux correction; Warm pool only


UH 2.5 layer Ocean Model
Mixed layer
Entrainment sublayer
Thermocline layer
Deep resting layer
(Wang, Li, Chang 1995, JPO; Fu and Wang 2001, JC)


(a) Rainfall (mm/day)+850mb Winds in JJA
10m/s
OBS
(b)
Coupled


(a) Annual Mean Sea Surface Temperature (C)
OBS
(b)
Coupled
(c)
Coupled-OBS

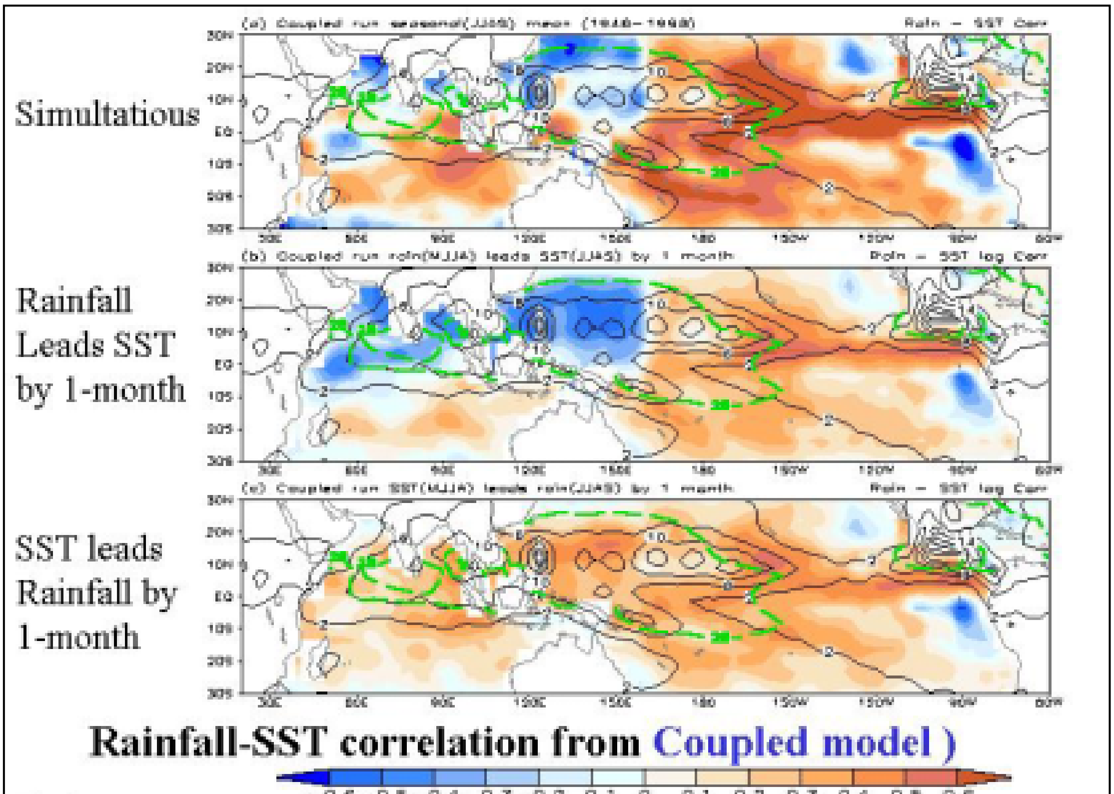

Simultatious
Rainfall Leads SST by 1-month
SST leads Rainfall by 1-month
Rainfall-SST correlation from Coupled model)

Fig.4

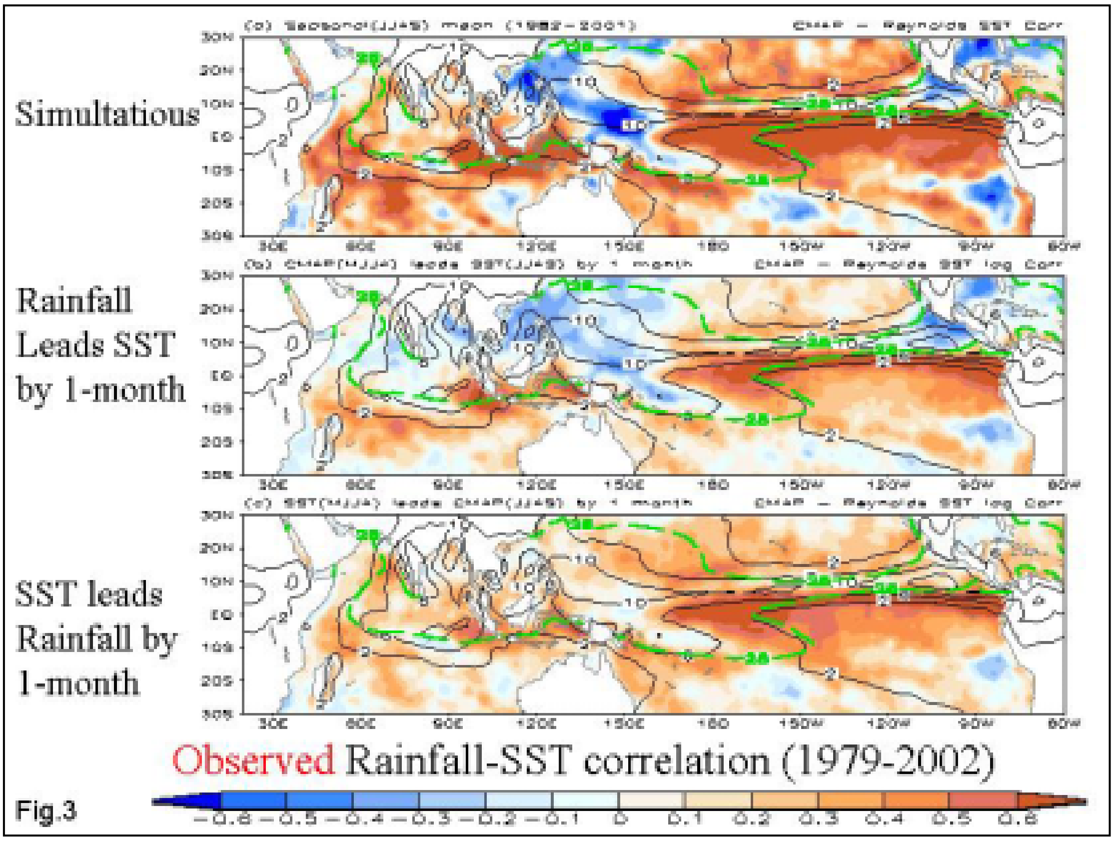

Simultatious
Rainfall
Leads SST
by 1-month
SST leads
Rainfall by
1-month
Observed Rainfall-SST correlation (1979-2002)

Fig.3

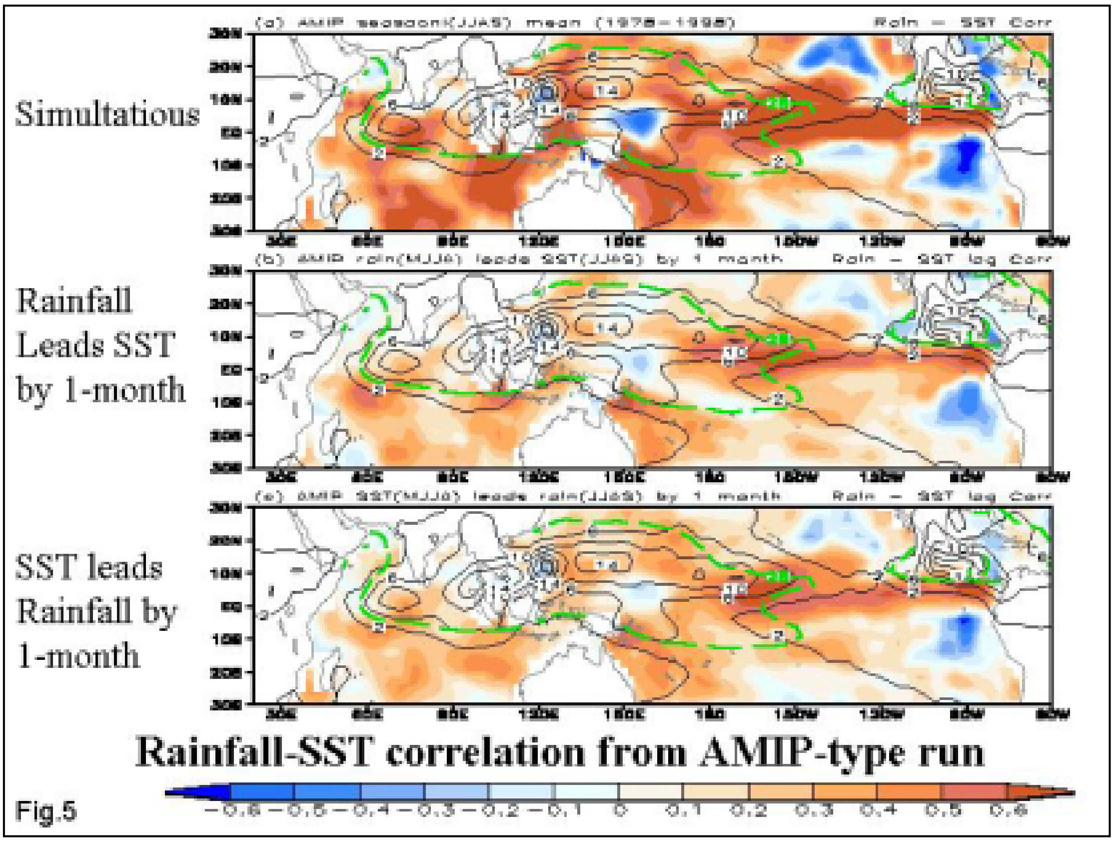
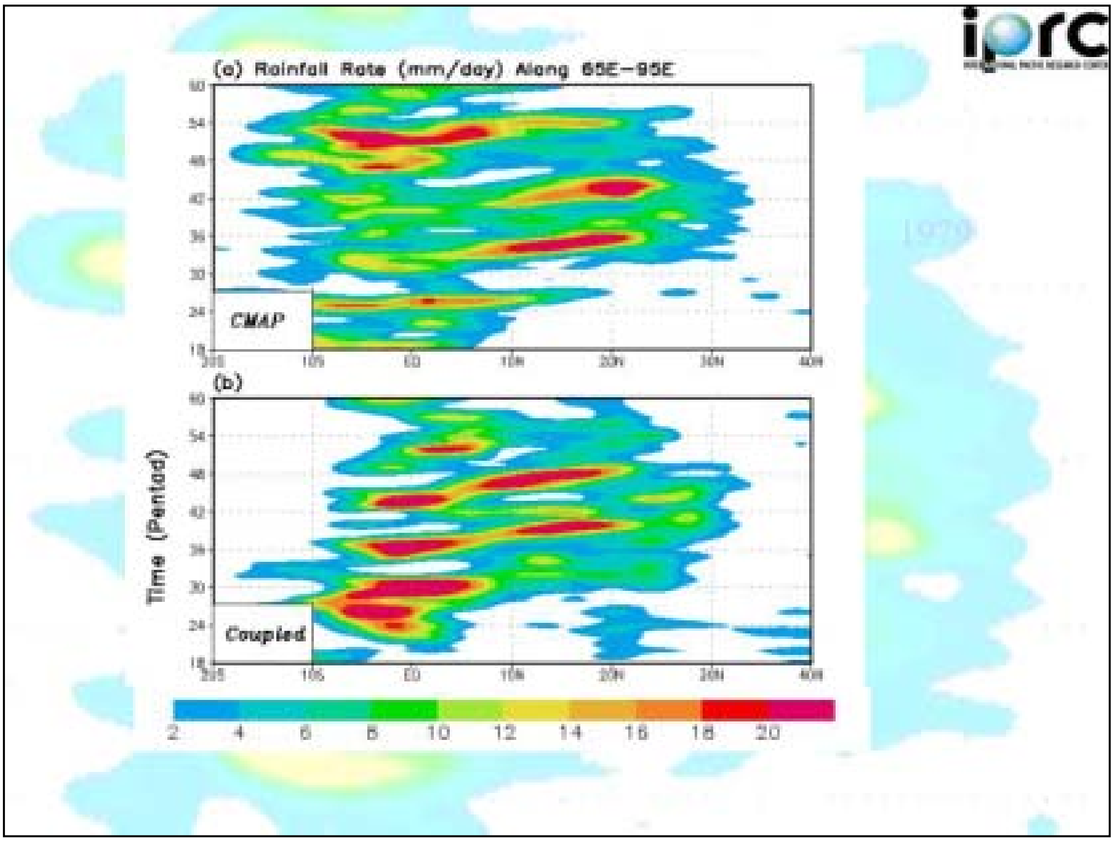

Simultatious
Rainfall
Leads SST
by 1-month
SST leads
Rainfall by
1-month
Rainfall-SST correlation from AMIP-type run

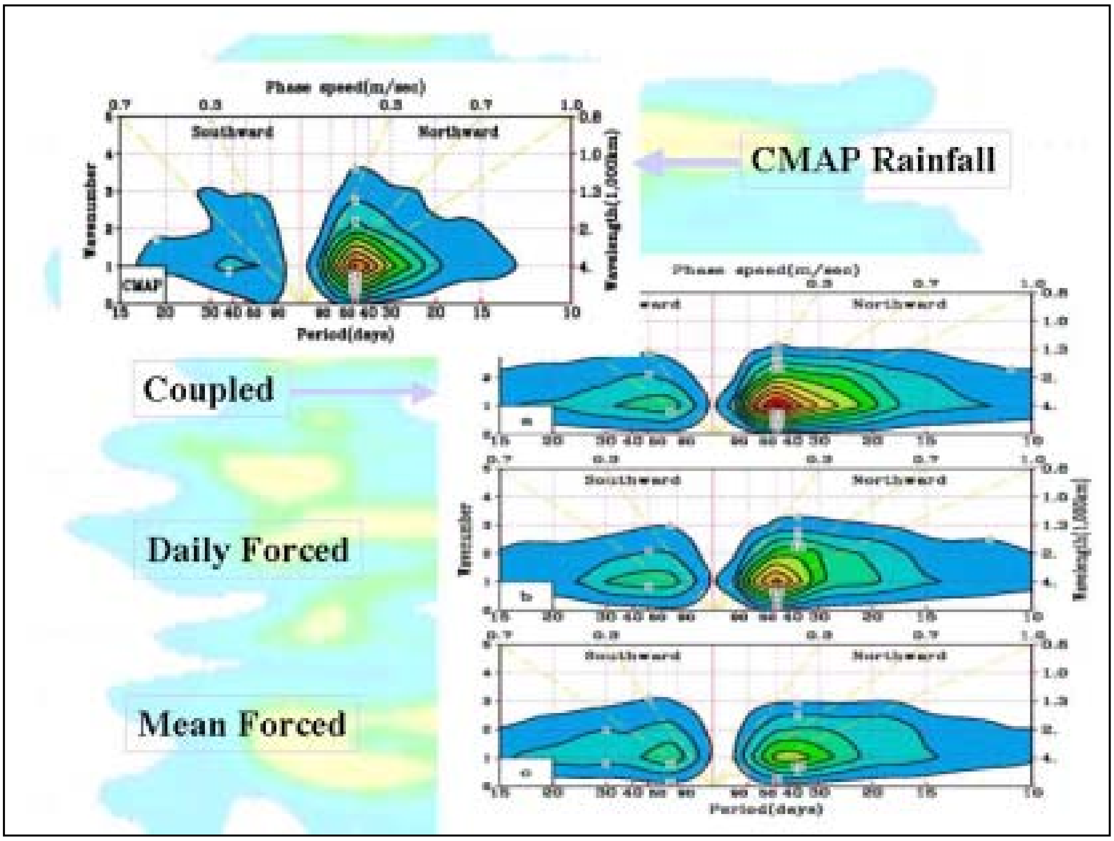
Fig.5

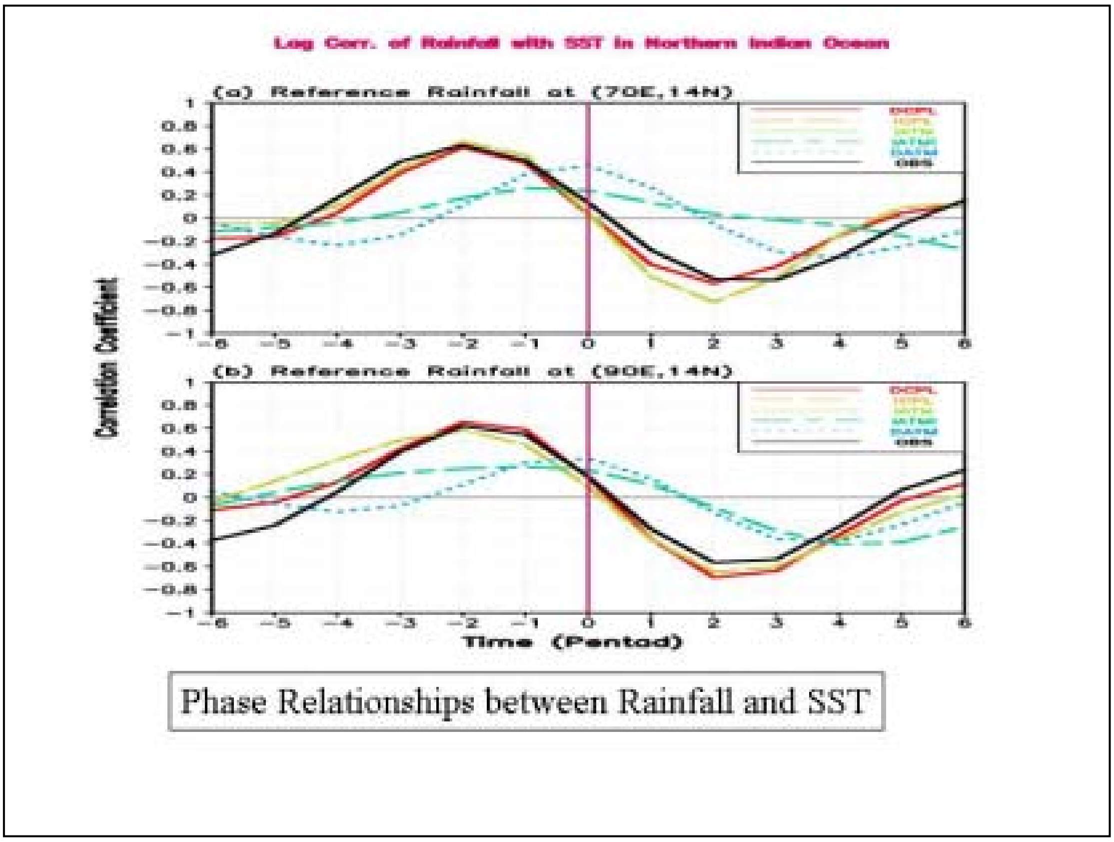
Predictability of the ISO

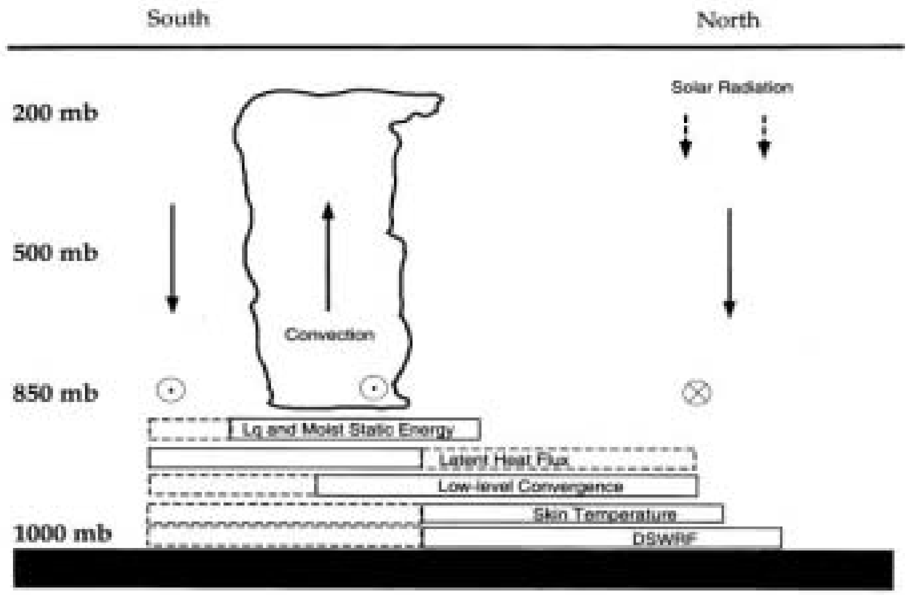
Are MJO or boreal summer ISO reproducible in forced AGCM simulations (AMIP-type)?

How important is the air-sea interaction in prediction of ISO?




CMAP Rainfall
Coupled
Daily Forced
Mean Forced
Phase speed(m/sec)
Southward
Northward
Wavenumber
Wavelength(1,000km)
Period(days)
CMAP


Lag Corr. of Rainfall with SST in Northern Indian Ocean
(a) Reference Rainfall at (70E,14N)
(b) Reference Rainfall at (90E,14N)
Correlation Coefficient
Time (Pentad)
OBS
Phase Relationships between Rainfall and SST



Kemball-Cook and Wang (2001)

Summary

AGCM alone can not reproduce realistic seasonal rainfall anomalies in summer Monsoon Convergence Zone (MCZ).

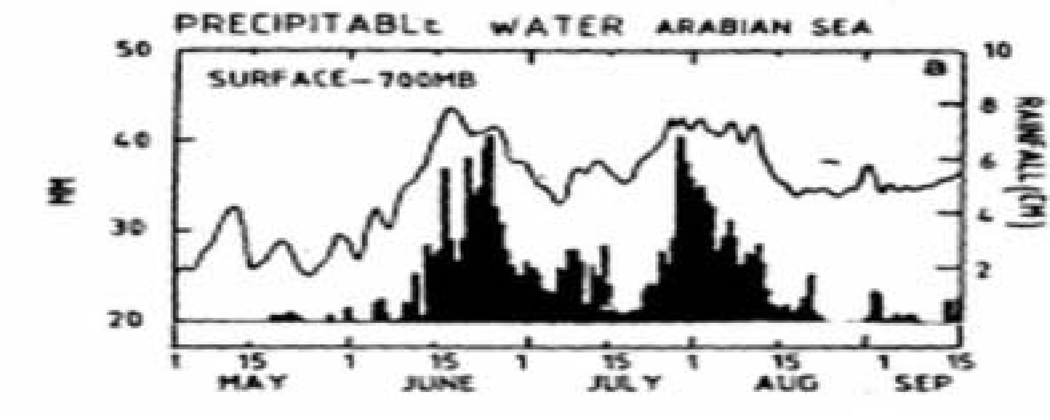
Caution should be taken when validating model or determining upper limit of predictability using AMIP approach.

Two-tier approach may be inherently inadequate for monsoon rainfall anomalies.

Atmospheric only model may loss significant amount of predictability on MJO.

Coupled and forced ISO solutions are two distinguished solutions. Chaos can be induced by both IC and BC errors.

Monsoon climate prediction must deal with ISO



Cadet 1986

Is ISO a noise or signal?

Impact of Atlantic SST Anomalies on the Summer Rainfall in East Asia

Riyu Lu[1] and Buwen Dong[2]

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1. Introduction

The summers (June-July-August, JJA) of 1997 and 1998 were marked by strikingly different climate conditions over East Asia. In the summer of 1997, there was severe drought in North China. In contrast, in summer 1998, East Asia experienced an extreme flood. More than 150% of normal rainfall was observed in the Yangtze River basin, Northeast China and Korean peninsula.

The period of 1997-1998 was also characterized by a major cycle of the El Niño-Southern Oscillation (ENSO) with a record breaking El Niño in 1997 and a modest La Niña in 1998. There have been many studies on the role of ENSO in the climate anomalies in East Asia, including analyses of observations (e.g., Huang and Wu 1989; Wang et al. 2000; Wang et al. 2001; Yu et al. 2001; Zhang et al. 1996 and 1999) and numerical simulations (e.g., Kawamura et al. 1998; Kawamura et al. 2001; Shen et al. 2001; Wang and Qian 2001). These studies showed that the ENSO phenomena play a significant role in influencing the East Asian summer climate.

The heating anomaly over the Philippine Sea is another crucial factor affecting the atmospheric circulation and precipitation over East Asia in summer. There have been many studies focused on the convection over the western North Pacific (Murakami and Matsumoto 1994; Ueda and Yasunari 1996; Wu and Wang 2001; Wu 2002), and on its linkage with the

East Asian climate (Nitta 1987; Kurihara 1989; Huang and Sun 1992; Lu 2001; Lu and Dong 2001) and with ENSO (Tanaka 1997; Wang et al. 2000; Wu and Wang 2000; Ailikun and Yasunari 2001).

Besides the Pacific SST anomalies associated with ENSO, there are also SST anomalies in other ocean basins, for example, in the Atlantic ocean. However, there have been few studies on the role of SST anomalies outside the Pacific and Indian ocean in East Asian rainfall.

2. Observational evidence

Figure 1 shows the observed SST anomalies (Reynolds and Smith 1994) in the summers of 1997 and 1998, respectively. In JJA 1997, the SST anomalies exhibited a typical El Niño pattern. In the Atlantic ocean, the SSTs were above normal in the northern tropics, and below normal in the southern tropics. In summer 1998, while a weak cold episode started abruptly in the equatorial central Pacific, strong positive SST anomalies covered the tropical Indian Ocean and tropical western Pacific, with an approximate maximum magnitude of 1~1.5 ^{o}C. In a broad region of the tropical Atlantic ocean, the SSTs were above normal.

Severe drought occurred in North China and the Korean peninsula in summer 1997, while extreme flooding affected Northeast China, the Yangtze River basin and Korean peninsula in summer 1998. These are illustrated in Fig.2, which shows the precipitation anomalies based on the Global Precipitation Climatology Project (GPCP) data (version 2, Huffman et al. 1997).

3. Model and experimental design

The numerical model used in this study is the Met Office Hadley Centre general circulation model (HadAM3). HadAM3 has a horizontal resolution of 2.5º in latitude and 3.75º in longitude and 19 levels. A detailed description of the model formulation and its performance is in Pope et al. (2000).

Three experiments were performed in order to investigate the impacts of SST anomalies. The control simulation was forced with climatological SSTs, averages over 30 years from 1961 to 1990 (Smith and Reynolds 1998). The global experiment was forced with global observed SSTs (Reynolds and Smith 1994). The “without Atlantic” experiment was forced with observed SSTs except in the Atlantic (latitude band 30ºS-75ºN) where the climatological SSTs were used. In order to separate externally forced variability from internal variability, an ensemble of ten integrations was performed for each experiment. These integrations were different only in their initial conditions, which were taken from the end of spin-up integrations. For the control integration, the spin-up was forced with climatological SSTs and lasted 1.5 years. Then the control experiment was run for 1 year beginning on December 1.

For the sensitivity experiments, the spin-up was forced with observed SSTs from June 1, 1996 to December 31, 1996. Then the sensitivity experiments were integrated from January 1, 1997 to August 31, 1998. The response to SST anomalies was estimated as the difference between the ensemble means of a pair of experiments, and a two-tailed t-test is adopted to assess local significance.

4. Experimental results

The simulations forced by the global SST anomalies capture the general features of observed tropical rainfall anomalies (Fig. 2) in the summers of 1997 and 1998. These are illustrated in Figure 3.

The above results suggest that the climate anomalies over East Asia in the summers of 1997 and 1998 arose in response to the anomalous SSTs. Did the dominant influence come from Pacific and Indian ocean SSTs or were Atlantic SST anomalies important? If so, what are the physical mechanisms? These will be addressed in the following.

Figure 4 shows the simulated rainfall anomalies forced by the SST anomalies outside the Atlantic. The simulated precipitation in 1997 bears similar features as those forced by global SST anomalies, in both tropics and subtropics (Fig. 4a). Such similarity in rainfall anomalies even exists over the Atlantic ocean and the surrounding areas, although the SSTs in the Atlantic are replaced by the climatological values. The results indicate that the major influences are from the Pacific and Indian Ocean with the SST anomalies in the Atlantic playing a minor role in summer 1997. The situation for 1998, however, is quite different. Most strikingly, the SST anomalies outside the Atlantic produce negative rainfall anomalies in part of the tropical eastern North Pacific and the equatorial western Atlantic (Fig. 4b), where positive rainfall anomalies are forced by the global SST anomalies (Fig. 3b).

To further illustrate the role of Atlantic SST anomalies, the differences between the experiment forced by global SST anomalies and that forced by SST anomalies outside the Atlantic are constructed. This difference gives a measure of the influence of Atlantic SSTs on the atmosphere. Figure 5 shows the rainfall anomalies implied by the Atlantic SST anomalies. In 1997, there are significant positive (negative) rainfall anomalies with a magnitude of 1 mm day^{-1} in the tropical North (South) Atlantic Ocean. However, the significant precipitation anomalies are confined over the tropical Atlantic sector with remote rainfall anomalies being small in magnitude and not showing well organized statistical significance.

In 1998, positive anomalies with a magnitude of about 2.5 mm day^{-1} occur in the tropical Atlantic and Caribbean Sea. The local response of rainfall is appreciably stronger in intensity and larger in area than in 1997. Furthermore, the positive rainfall anomalies extend westward into the tropical eastern North Pacific in JJA 1998, with a magnitude as high as 5 mm day^{-1}. The magnitude of positive anomalies in the tropical eastern North Pacific is even higher than that forced by the SST anomalies in the Pacific and Indian Ocean (Fig. 4b). Another feature is the significant negative precipitation anomalies over the central tropical Pacific, extending northwestward into the tropical western North Pacific with a magnitude of about 2.0 mm day^{-1}. In the tropical western North Pacific, which is specified as the region of (110-160ºE, 10-20ºN), identical to that of Wu and Wang (2001) and Lu (2000), area averaged rainfall anomaly is –1.32 mm day^{-1} in the global experiment, -0.44 mm day^{-1} in the "without Atlantic" experiment, and –0.88 mm day^{-1} in the "only Atlantic" result.

5. Tropical teleconnection mechanism for the role of Atlantic SST anomalies

There are two plausible types of mechanism for the influence of Atlantic SST anomalies on the climate in East Asia: a mid-latitude mechanism and a tropical mechanism. In the mid-latitude case, the anomalous SSTs in the Atlantic may influence the East Asian climate by direct impacts through atmospheric teleconnections or by indirect impacts through air-land interaction. No significant teleconnection is found in the atmospheric circulation anomalies in the middle latitudes implied by Atlantic SST anomalies, in particular for the summers of 1997 and 1998. However, the Atlantic SST anomalies, including those prior to summer, may also have indirect influence on the East Asian climate through changes in land surface conditions over the Asian continent. Both the direct and indirect impacts could be operating in the model simulations designed in this study. The mid-latitude mechanisms may not be simple to tackle based on these limited experiments.

The stationary equatorial wave response to Atlantic SST anomalies can be illustrated by the simulated streamfunction anomalies in the upper and lower troposphere. In summer 1997, streamfunction anomalies are weak and generally insignificant in both the upper and lower troposphere (Fig. 6), particularly in the eastern hemisphere.

In summer 1998, streamfunction anomalies clearly illustrate a stationary equatorial wave pattern. At upper levels, large-scale twin anticyclonic circulation anomalies appear to the west of the Atlantic Ocean, and weaker twin cyclonic circulation anomalies appear to the east of the Atlantic Ocean, extending eastward into the subtropics in the western Pacific (Fig. 7a). The streamfunction anomalies are reversed at lower levels (Fig. 7b), i.e., large-scale twin cyclones appear to the west of the Atlantic Ocean, and twin anticyclones appear to the east. In both the upper and lower troposphere, the zonal extent of the westward stationary disturbance is not sufficient to affect the western Pacific, but the eastward one extends clearly into the western Pacific, consistent with the higher speed of Kelvin waves compared to Rossby waves (e.g., Gill 1980).

6. Conclusions

The East Asian summer monsoon was characterized by severe drought in North China in 1997 and by extreme flood in the Yangtze River basin, Northeast China and Korean peninsula in 1998. In this study, we investigated the reproduction of these climate extremes by an AGCM (HadAM3) forced with the observed global SSTs. It was found that the model reproduces well the rainfall anomalies in East Asia in both summers.

In order to clarify the impact of Atlantic SST anomalies on the East Asian summer rainfall, which has been basically ignored by previous studies, we carried out an experiment forced with observed SSTs except in the Atlantic where the climatological SSTs were used. In comparison with the role of the SST anomalies outside the Atlantic, the SST anomalies in the Atlantic generally play a secondary role in influencing the rainfall anomalies in East Asia in summer 1997. However, the SST anomalies in the Atlantic played an important role in forcing anomalous circulation over the western North Pacific and rainfall anomalies in East Asia in summer 1998.

It was suggested that in summer 1998, the Atlantic SST anomalies triggered an equatorial Rossby wave and a Kelvin wave. The eastward equatorial stationary disturbance extended into the western Pacific, and may have reduced the precipitation anomalies in the tropical western North Pacific, by means of an anticyclonic circulation anomaly over the subtropical western North Pacific, which was superimposed on that forced by the SST anomalies outside the Atlantic. Thus, to a comparable extent, the SST anomalies in and outside the Atlantic together induced a strong anticyclonic circulation anomaly in the subtropical western North Pacific, leading to the flood in East Asia.

The results shown in this paper have significant implications for efforts at seasonal climate forecasting of the East Asian summer monsoon. The results suggest it is essential that the attention should be paid to accurate simulation of the Atlantic ocean state, as well as the states of the Pacific and Indian oceans in the development of seasonal forecasting systems. This said, we must be cautious. In this study, we only focused on two summers with one numerical model. Much of the analysis in this paper has been qualitative. There is a clear need for more quantitative analyses and to study more years in order to increase our confidence about the role of Atlantic SSTs in the East Asian climate.

Acknowledgment

The authors like to thank Chris Folland and David Parker for their valuable comments and suggestions. R. Lu was supported by the National Natural Science Foundation of China under Grant 40221503. B. Dong was supported by the UK Government Meteorological Research Programme. The simulations were performed when B. Dong was at the Centre for

Global Atmospheric Modelling (CGAM), which is funded by the UK Natural Environment Research Council.

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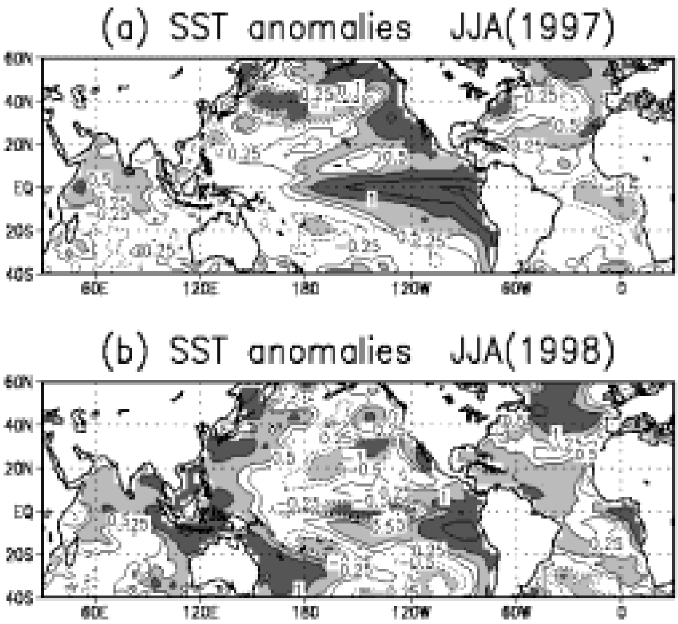

Fig. 1 Observed SST anomalies (ºC) in the summers of 1997 (a) and 1998 (b), respectively. They are based on the Reynolds SST data (Reynolds and Smith, 1994) and the years 1961 to 1990 are chosen as the reference period. Contours are plotted at ±0.25, ±0.5, ±1.0, ±2.0 and ±4.0ºC. Light and heavy shadings indicate the amplitude of anomalies greater than 0.5 and 1.0ºC, respectively.

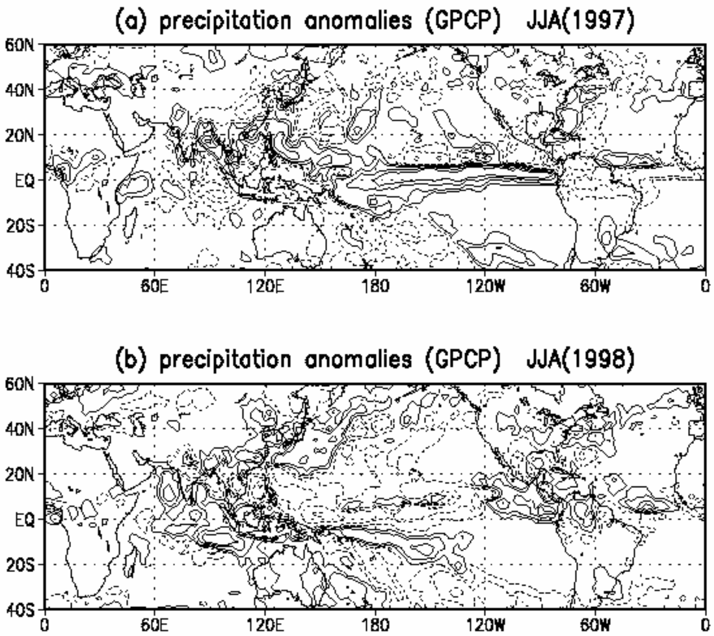

Fig. 2 Precipitation anomalies (mm day^{-1}) in the summers of 1997 (a) and 1998 (b), respectively. Precipitation data are GPCP data (Huffman et al. 1997). The anomalies are obtained with respect to the 1979-2002 base period. Contours are plotted at±0.5, ±1.5, ±3.5 and ±5.5 mm day^{-1}, using solid lines for positive values, dashed lines for negative values.

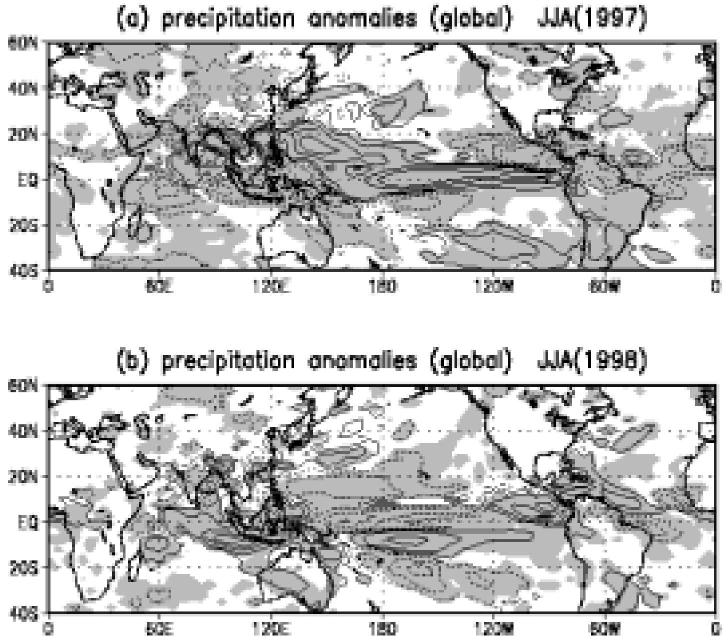

Fig. 3 Simulated precipitation anomalies (mm day^{-1}) in the summers of 1997 (a) and 1998 (b), respectively, forced by the global SST anomalies. Contours are plotted at ±0.5, ±1.5, ±3.5 and ±5.5 mm day^{-1}, using solid lines for positive values, dashed lines for negative values. The shaded regions indicate statistical significance at 95% level.

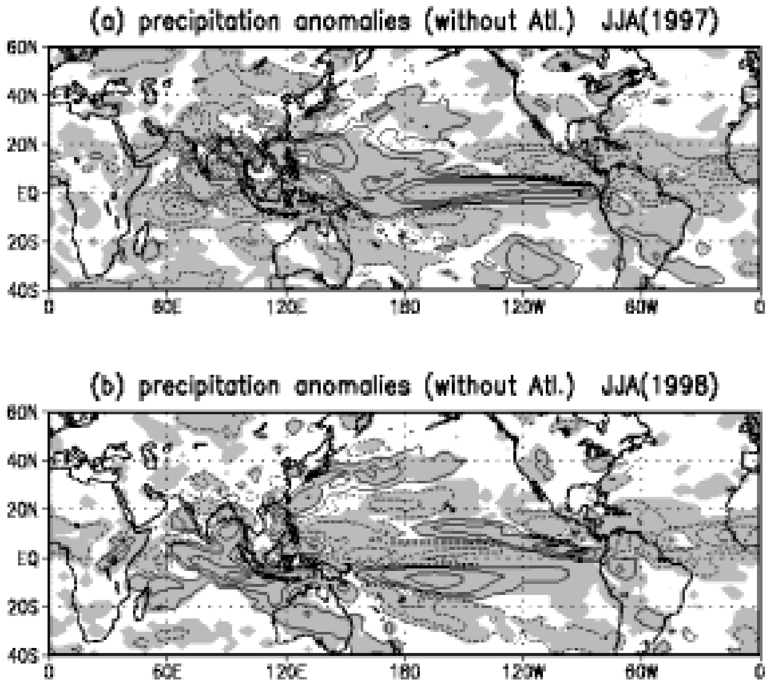

Fig. 4 Same as Fig. 3, but for the simulated anomalies forced by the SST anomalies outside the Atlantic.

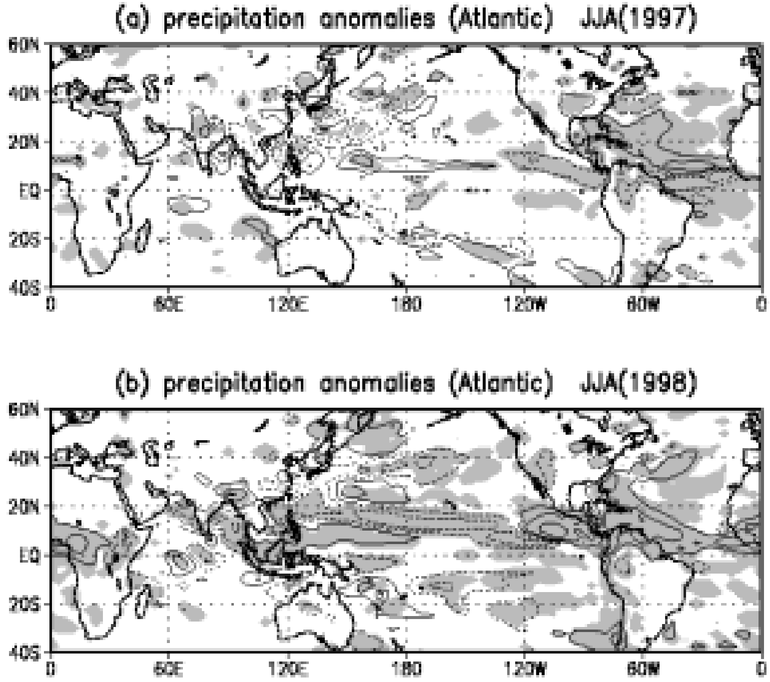

Fig. 5 Same as Fig. 3, but for the simulated anomalies implied by the Atlantic SST anomalies, i.e., the differences between the results forced by the global SST anomalies and forced by the SST anomalies outside the Atlantic.

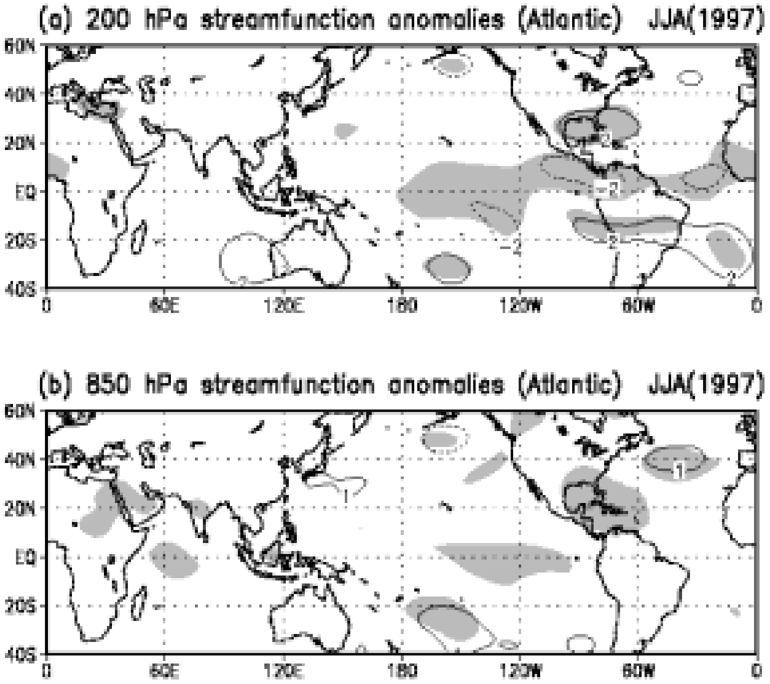

Fig. 6 Simulated streamfunction anomalies in the summers of 1997 at 200 hPa (a) and 850 hPa (b), implied by the Atlantic SST anomalies. Units are $10^6 m^2 s^{-1}$. Contour interval is 2 and 1 in (a) and (b), respectively, and zero line is not shown. The shaded regions indicate statistical significance at 95% level.

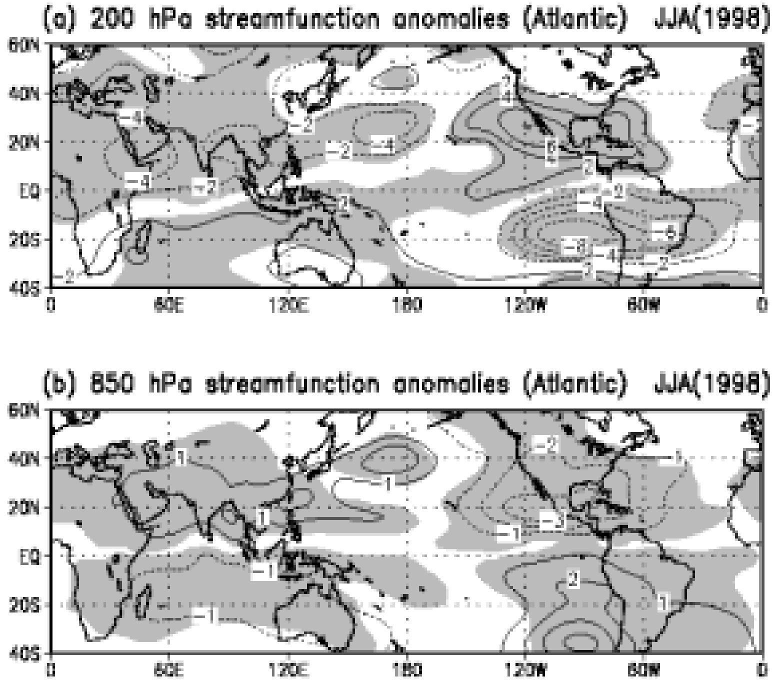

Fig. 7 Same as Fig. 6, but for the summer of 1998.

Meridional Propagation of the MJO/ISO and Asian - Australian Summer Monsoon Variability

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NASA/Goddard Space Flight Center Greenbelt

Outline

- Objective
  - To improve understanding of the MJO/ISO impact on the Asian-Australian summer monsoons.
  - To examine nature of meridional propagation.
- Approach
  - Composite analysis of 11 years of observational data.
  - AGCM experiments with idealized MJO/ISO heating.
- Results
  - Asian summer monsoon.
  - Australian summer monsoon.
  - Impact of SST on meridional propagation.
- Conclusions

Approach

- **Observations (1988-98)**
  - GPCP Pentad
  - Surface wind at 10M
  - ECMWF 200 hPa winds
- **AGCM Experiments (NSIPP-1)**
  - Control run (20yrs)

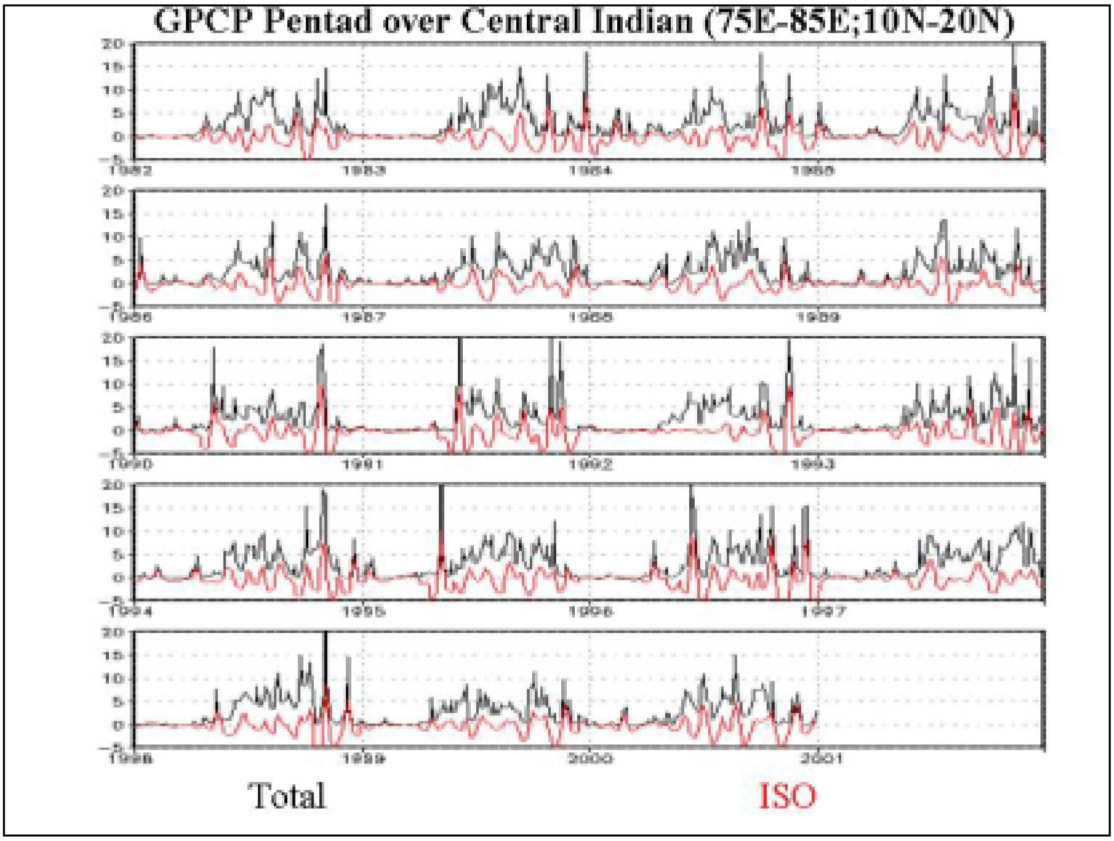
    Forced with a repeating annual cycle of climatological SST.
  - Primary experiments (10-member ensemble of 1yr simulation)

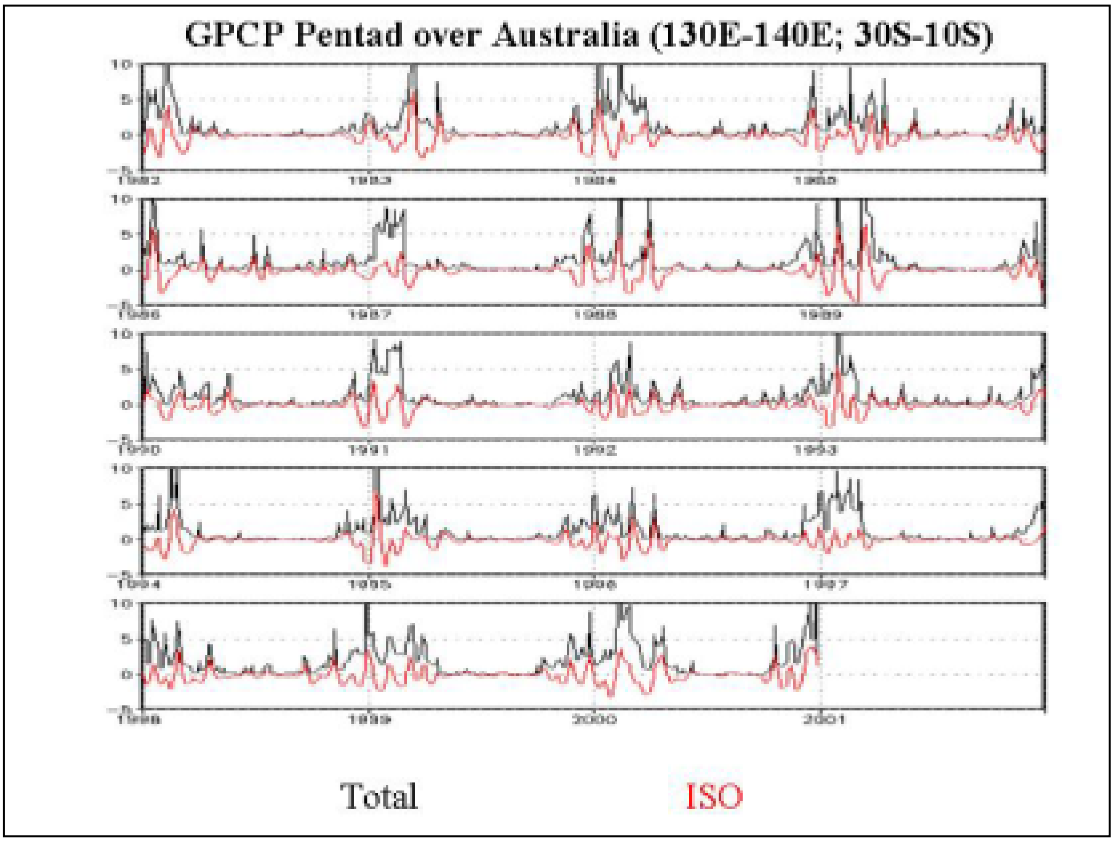
    Forced with idealized eastward propagating heating to mimic the canonical MJO heating.
  - Two additional experiments

    To understand the impact of the seasonal cycle in the SST on meridional propagation.

Approach (continue)

- EEOF analysis
- A simple composite method
  - Base mean time series of precipitation (varies between Indian Ocean and Western Pacific Ocean.)
  - 20 to 90 day filtered


GPCP Pentad over Central Indian (75E-85E;10N-20N)
Total
ISO

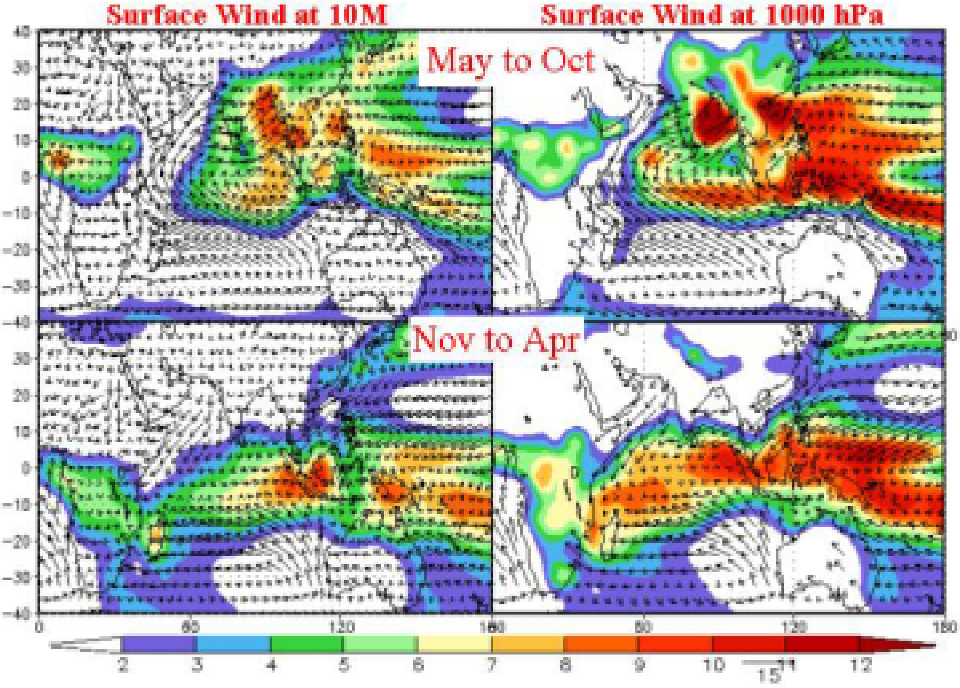

GPCP Pentad over Australia (130E-140E; 30S-10S)
Total
ISO

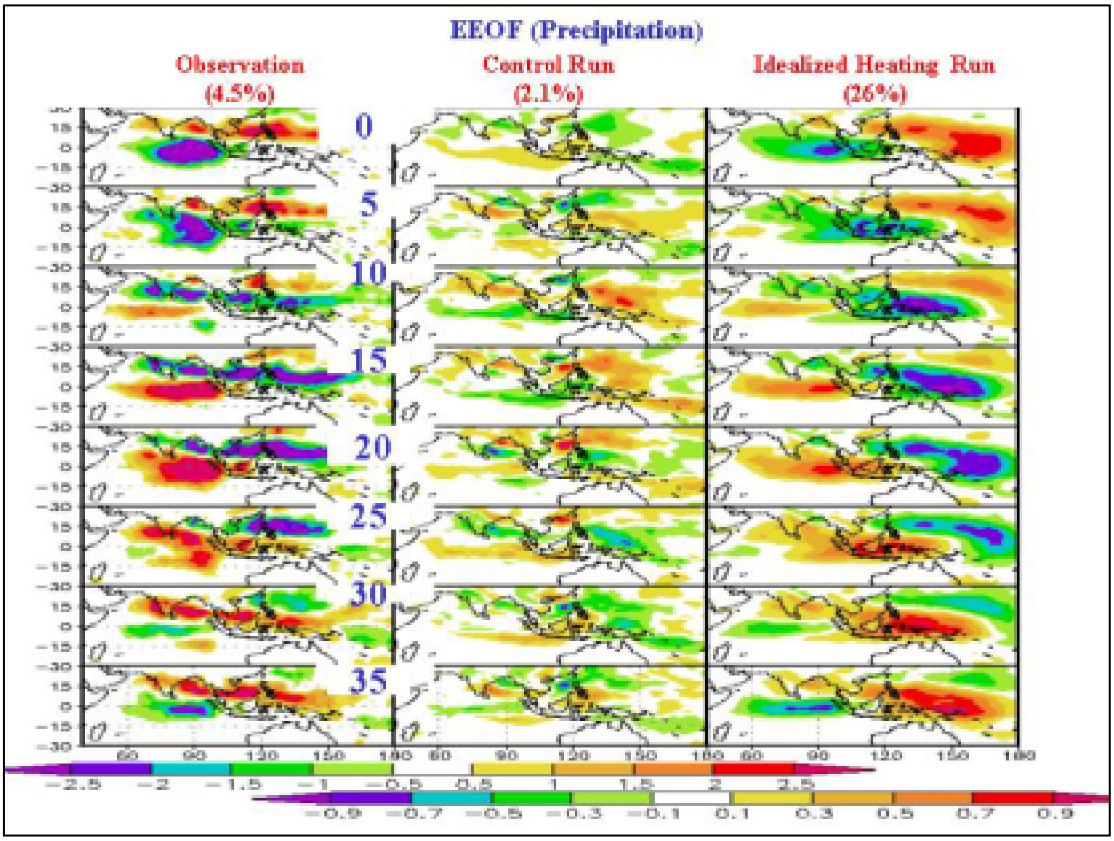
Model Performance

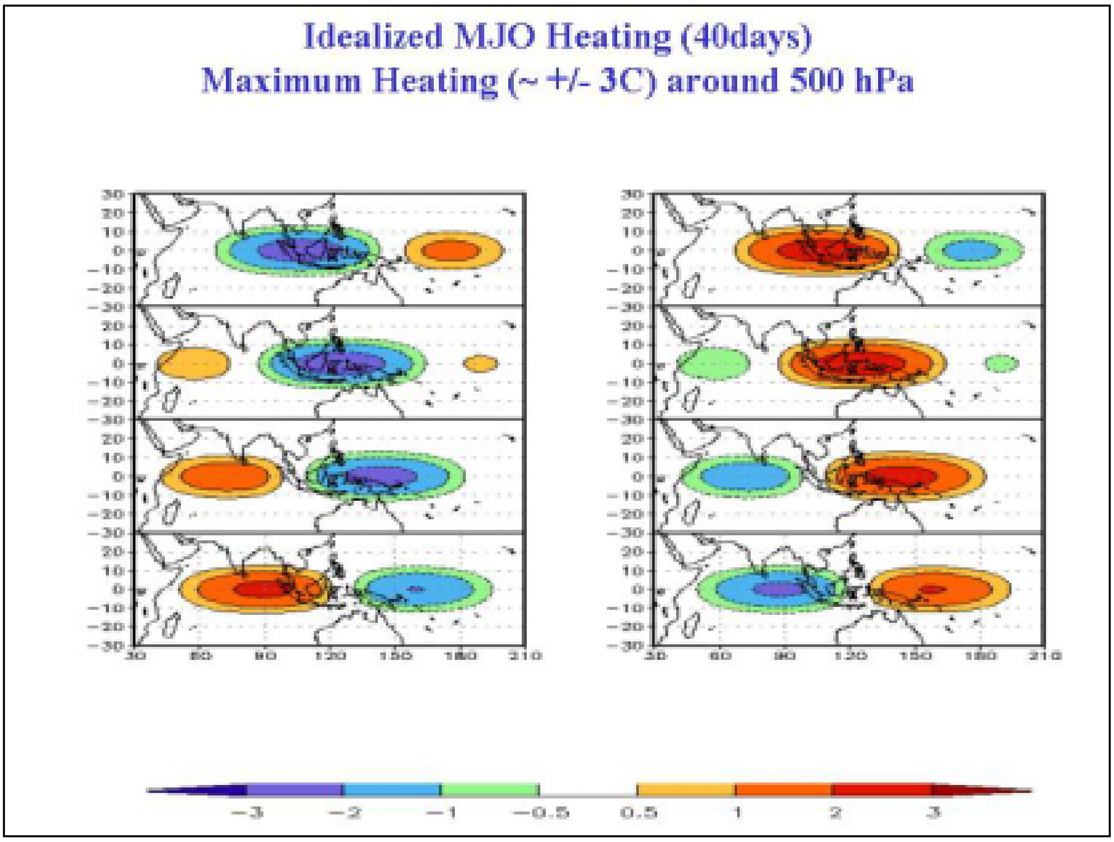
Precipitation and Surface Wind Climatology

Observation
Surface Wind at 10M

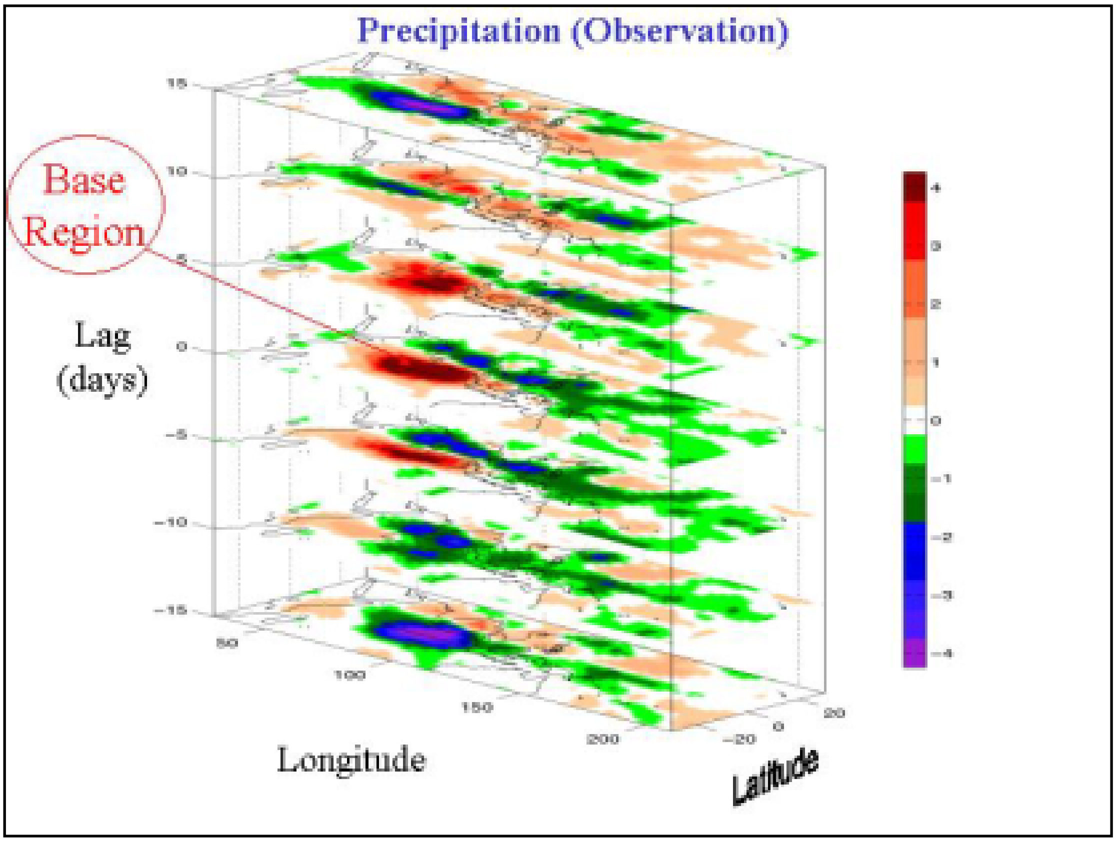
Simulation
Surface Wind at 1000 hPa

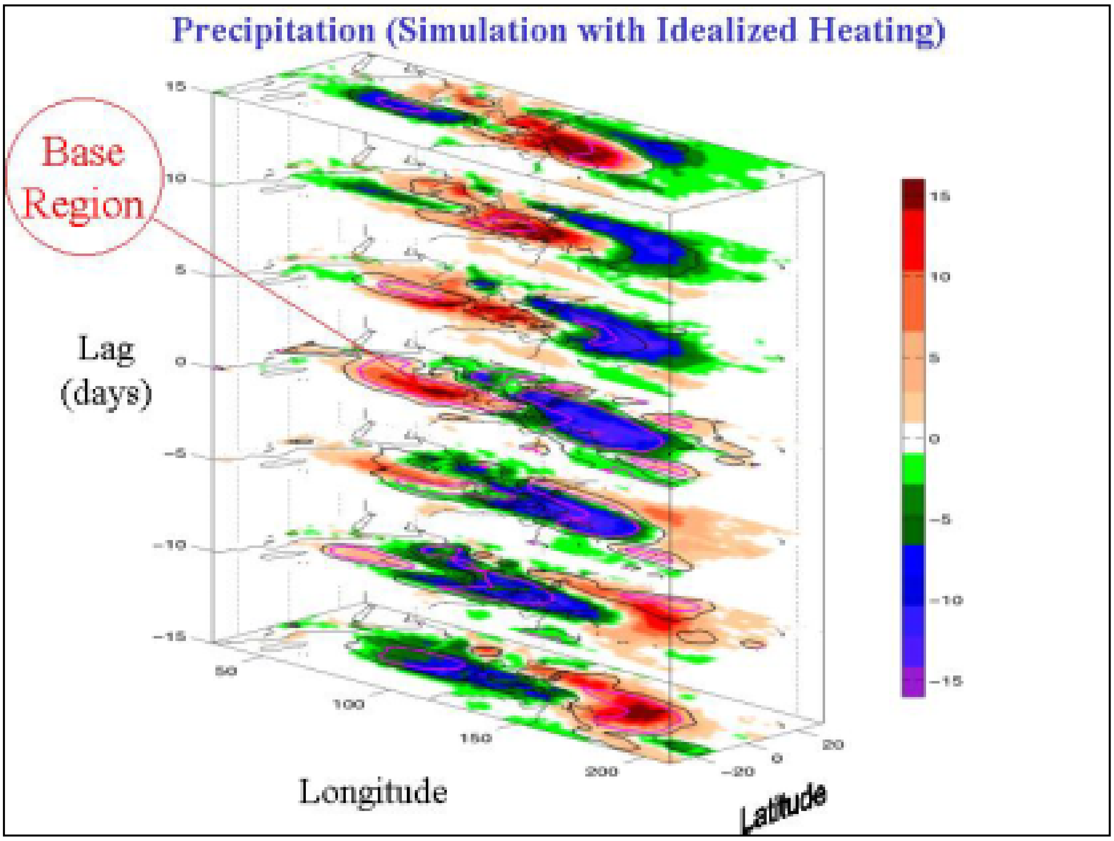


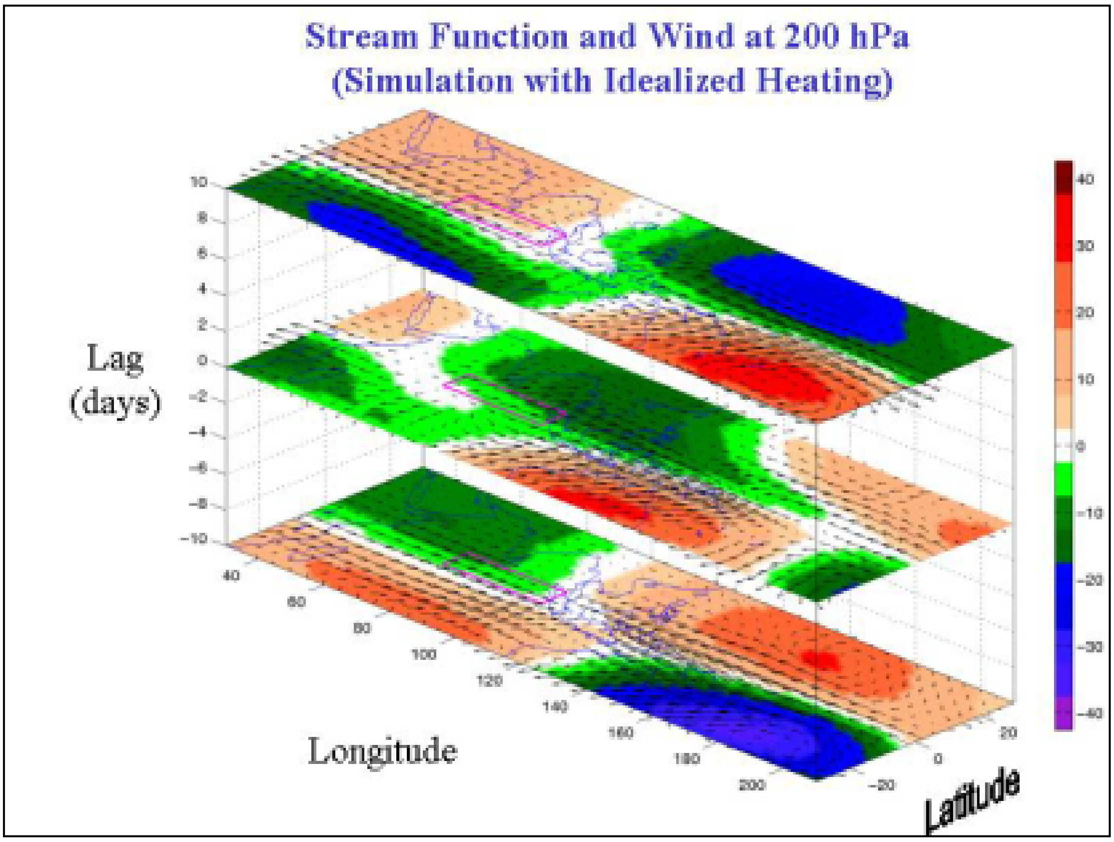

EEOF (Precipitation)
Observation (4.5%)
Control Run (2.1%)
Idealized Heating Run (26%)
0
5
10
15
20
25
30
35

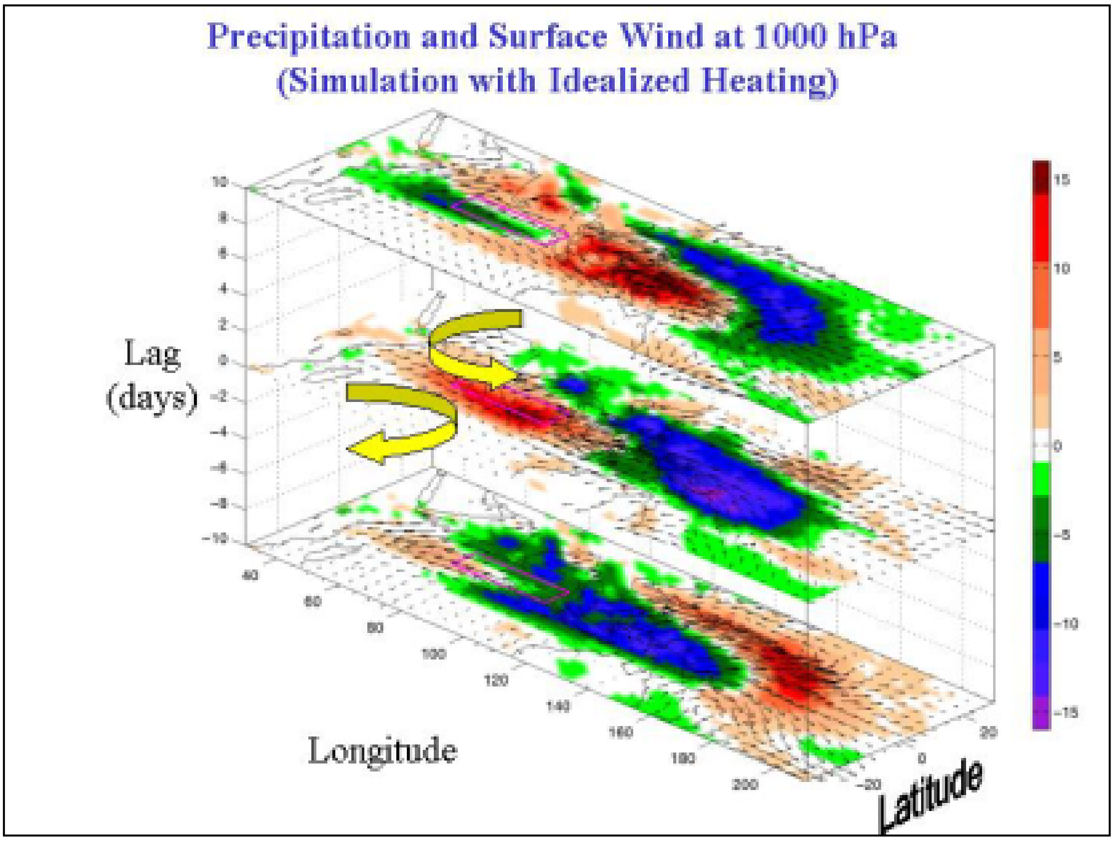

Idealized MJO Heating (40days)
Maximum Heating (~ +/- 3C) around 500 hPa

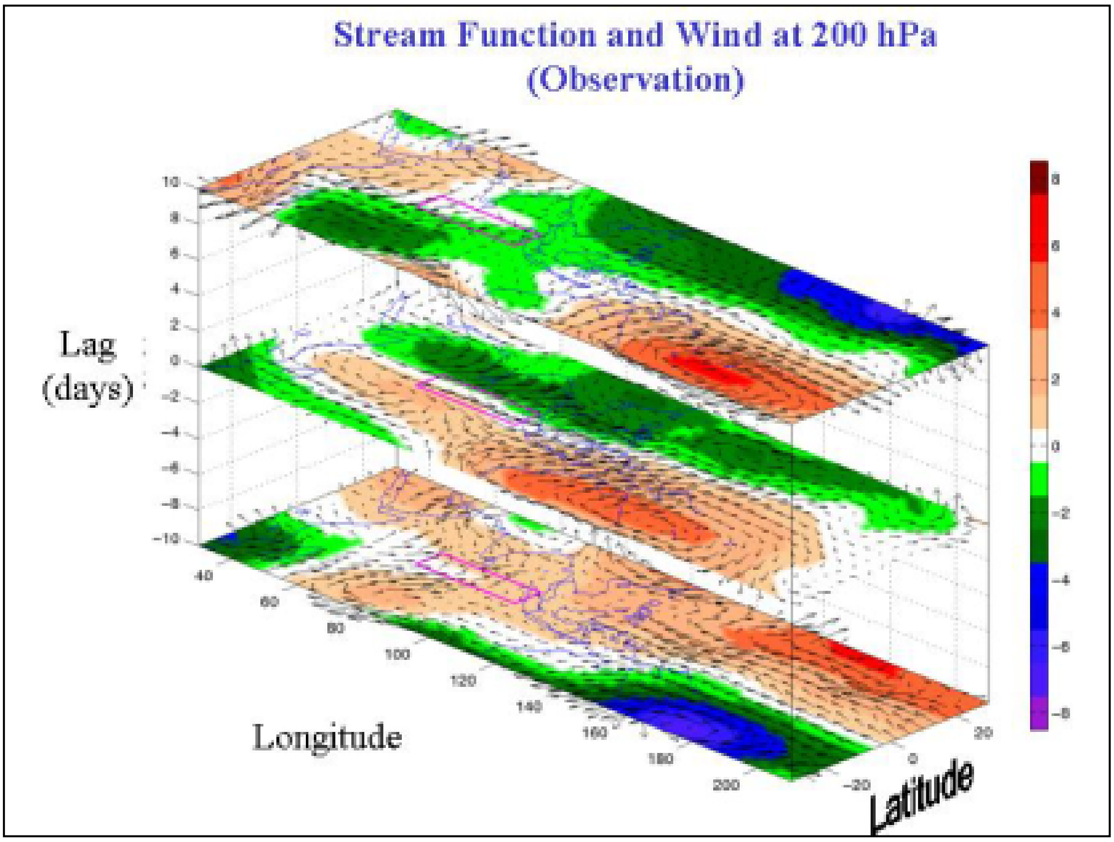
Focus on Asian Summer Monsoon (May to Oct)

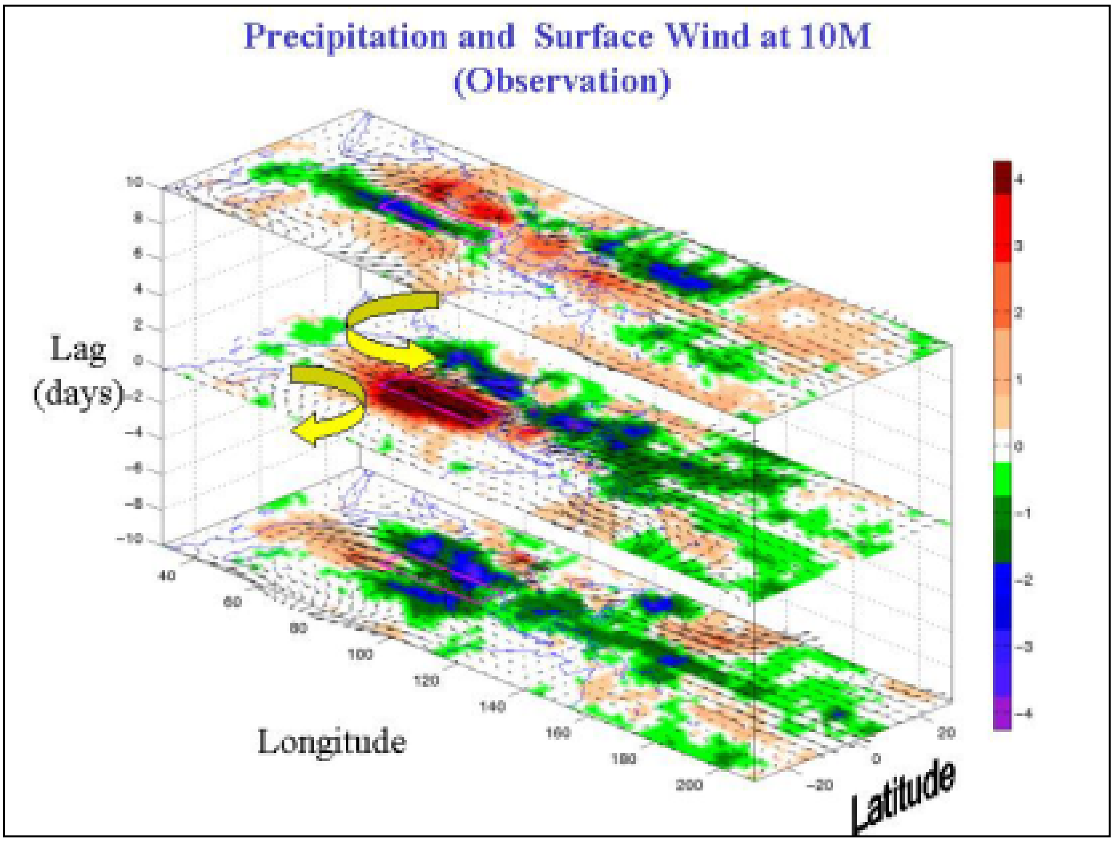



Precipitation (Simulation with Idealized Heating)
Base Region
Lag (days)
Longitude
Latitude

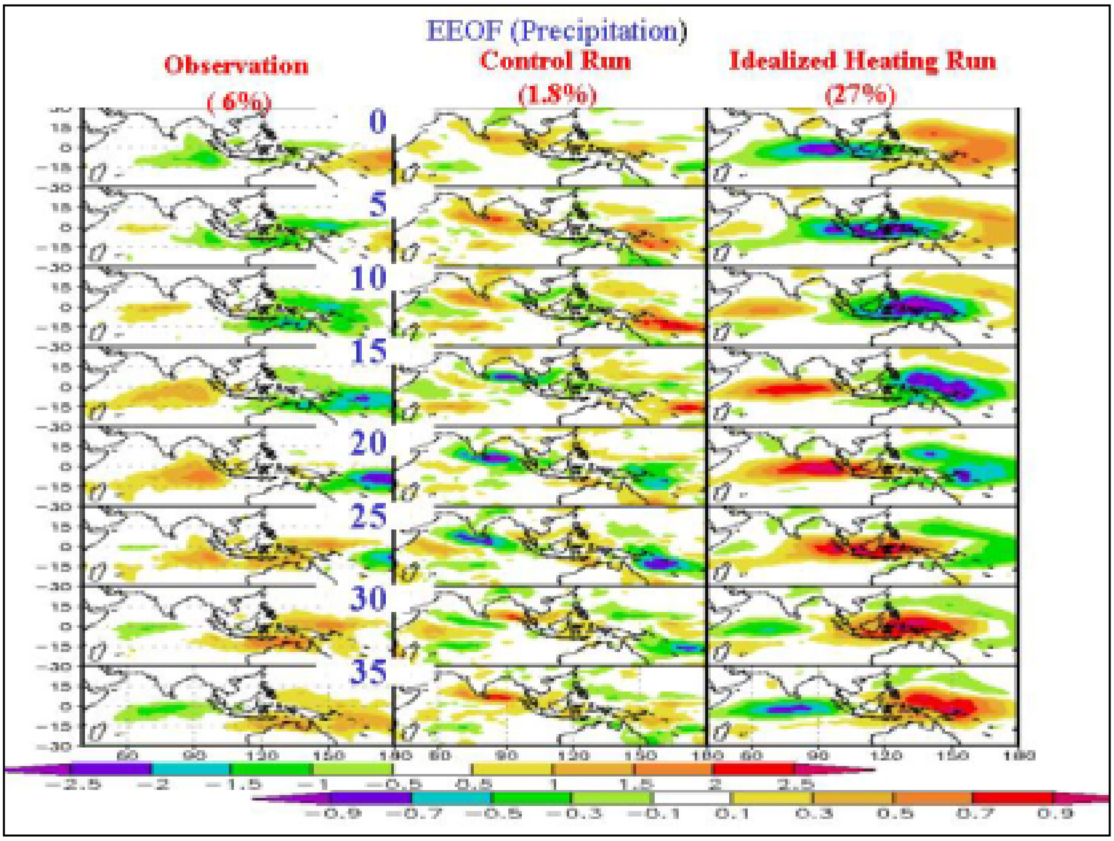

Stream Function and Wind at 200 hPa
(Simulation with Idealized Heating)
Lag (days)
Longitude
Latitude

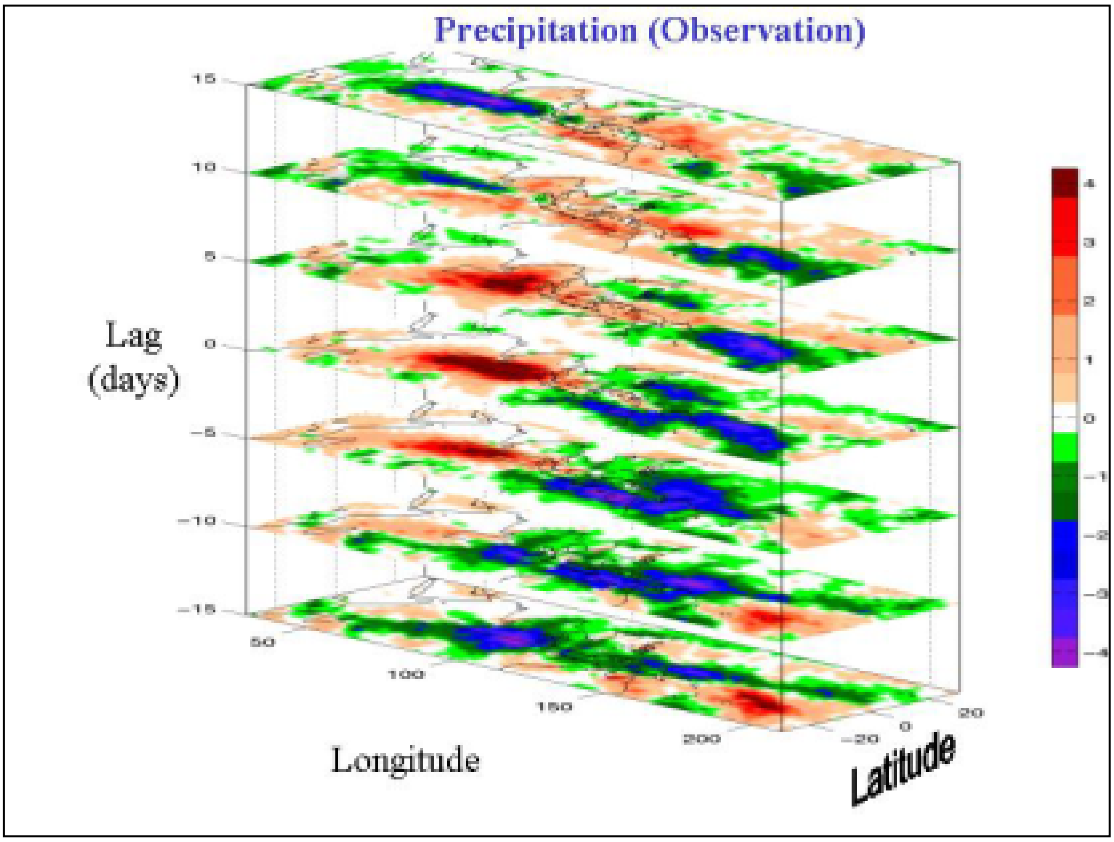

Precipitation and Surface Wind at 1000 hPa
(Simulation with Idealized Heating)
Lag
(days)
Longitude
Latitude

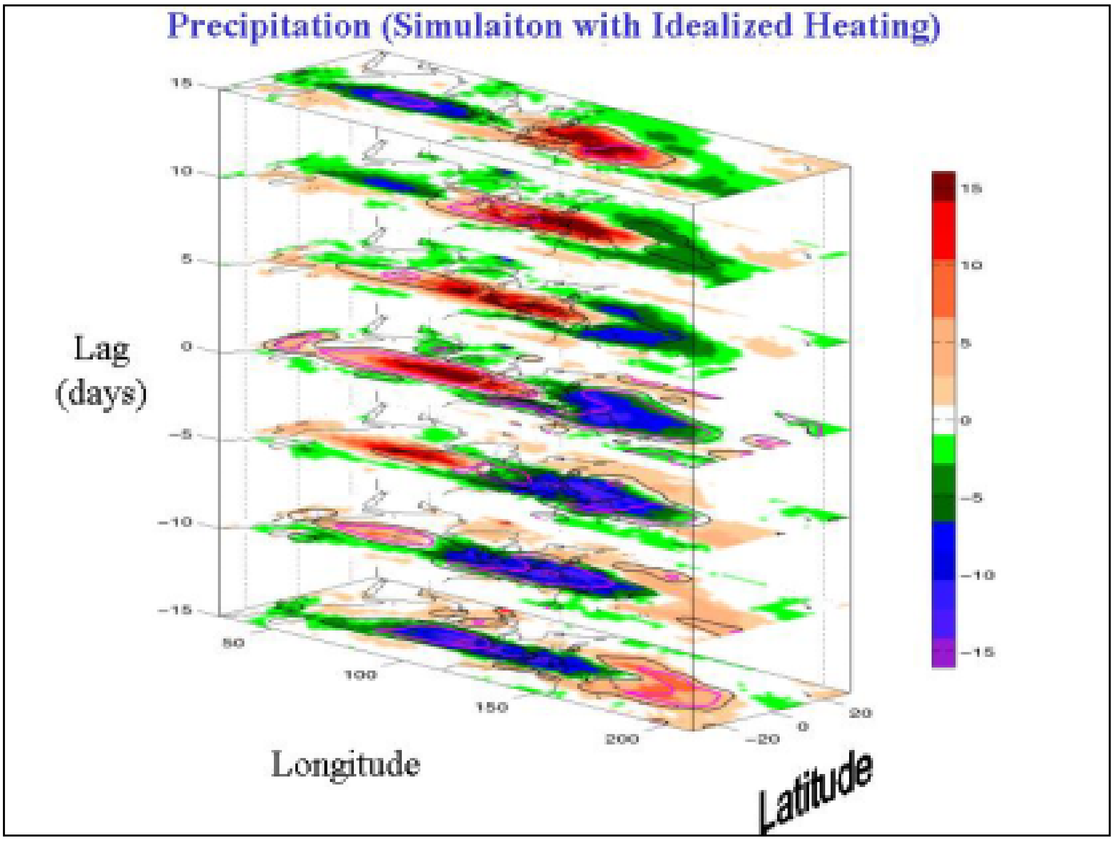

Stream Function and Wind at 200 hPa
(Observation)
Lag
(days)
Longitude
Latitude



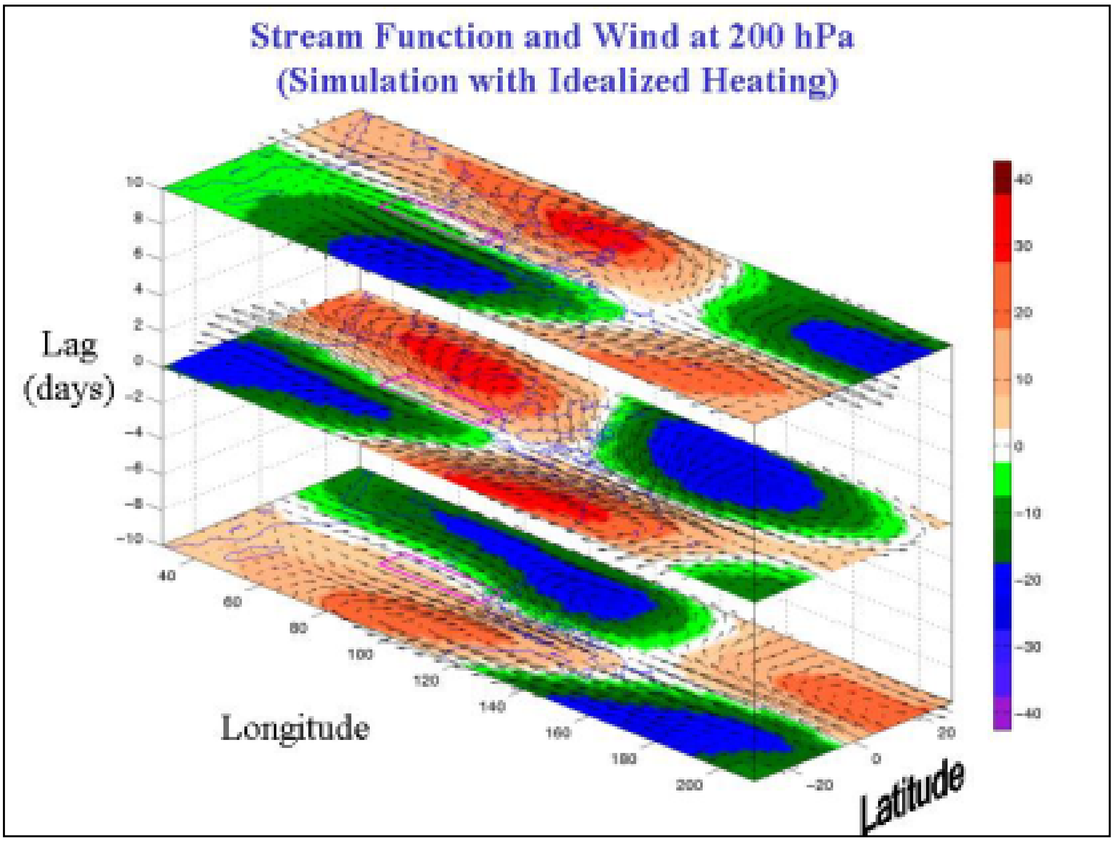
Focus on Australian Summer Monsoon (Nov to Apr)


EEOF (Precipitation)
Observation
(6%)
Control Run
(1.8%)
Idealized Heating Run
(27%)
0
5
10
15
20
25
30
35

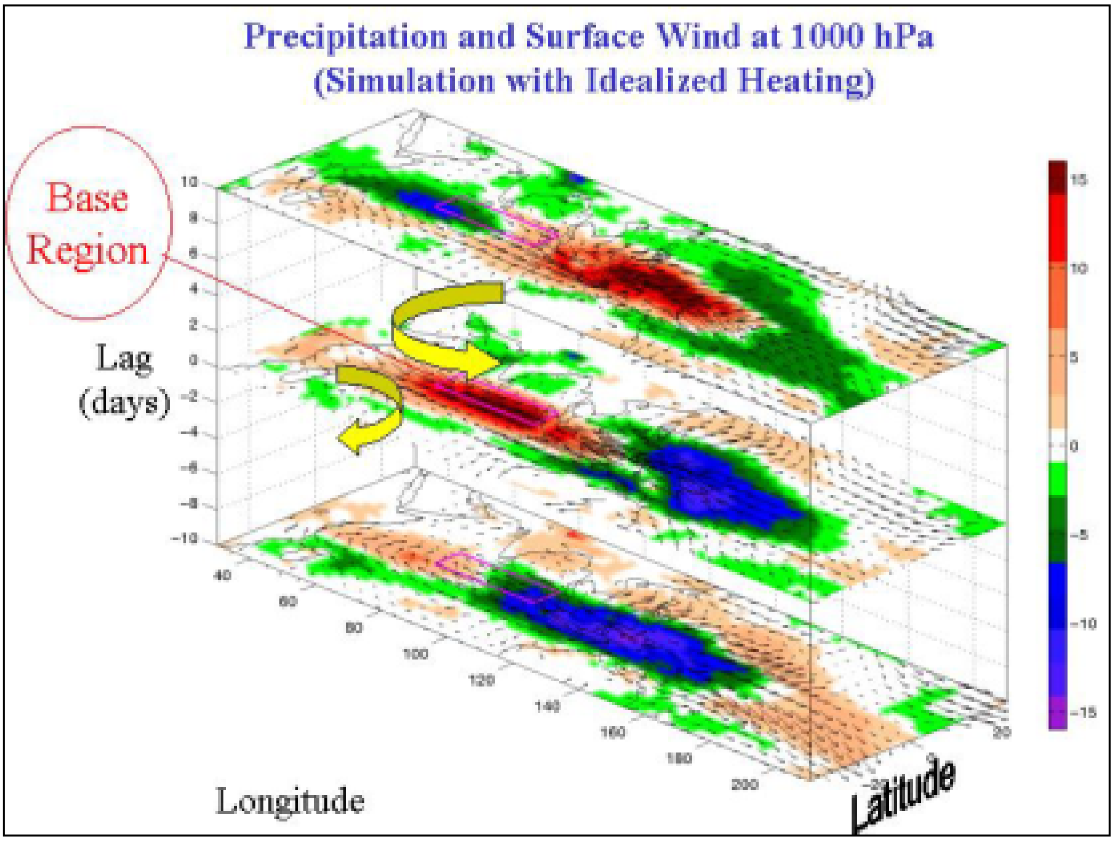

Precipitation (Observation)
Lag
(days)
Longitude
Latitude

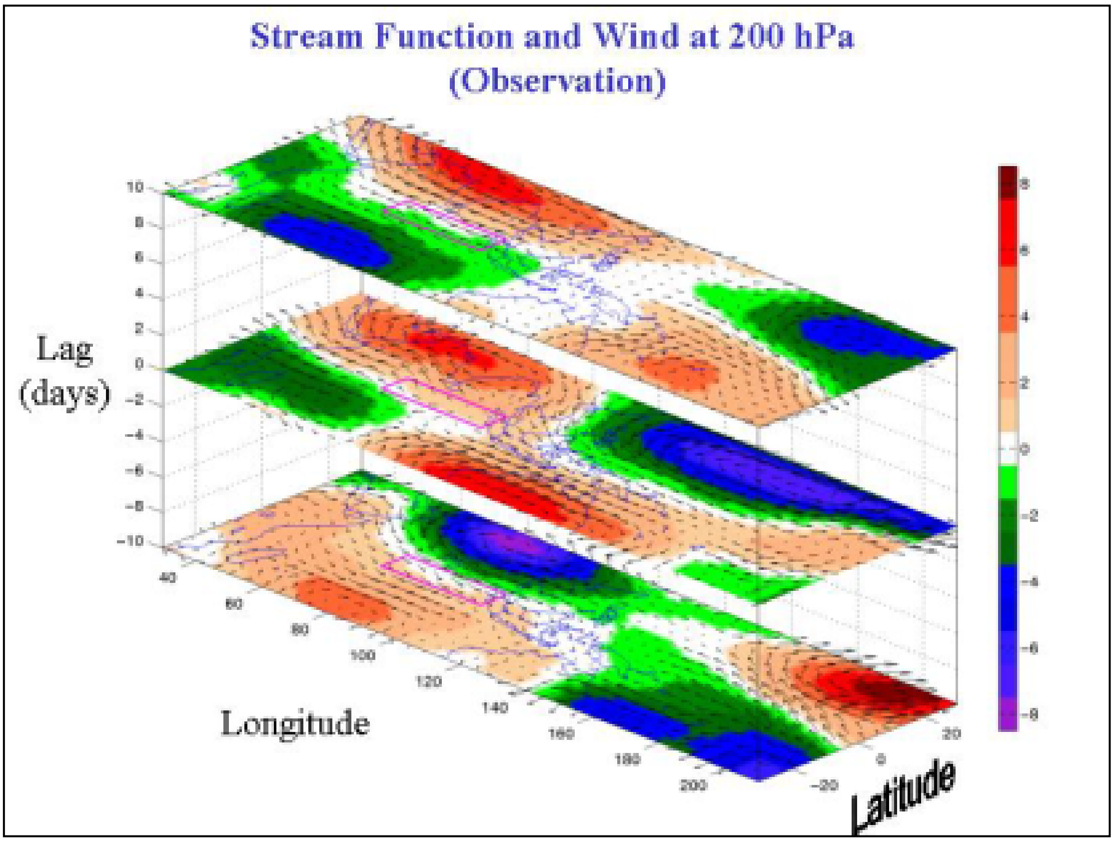


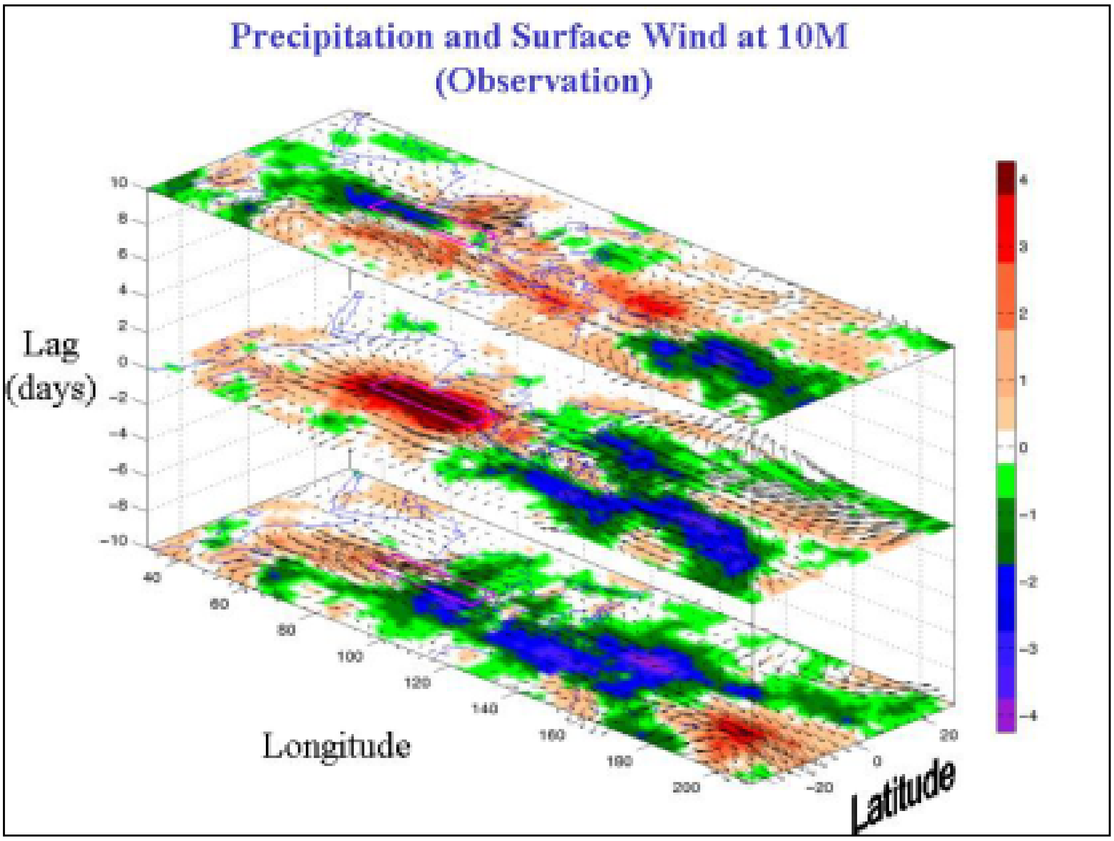
Precipitation (Simulaiton with Idealized Heating)
Lag
(days)
15
10
5
0
-5
-10
-15
50
100
150
200
Longitude
-20
0
20
Latitude
15
10
5
0
-5
-10
-15



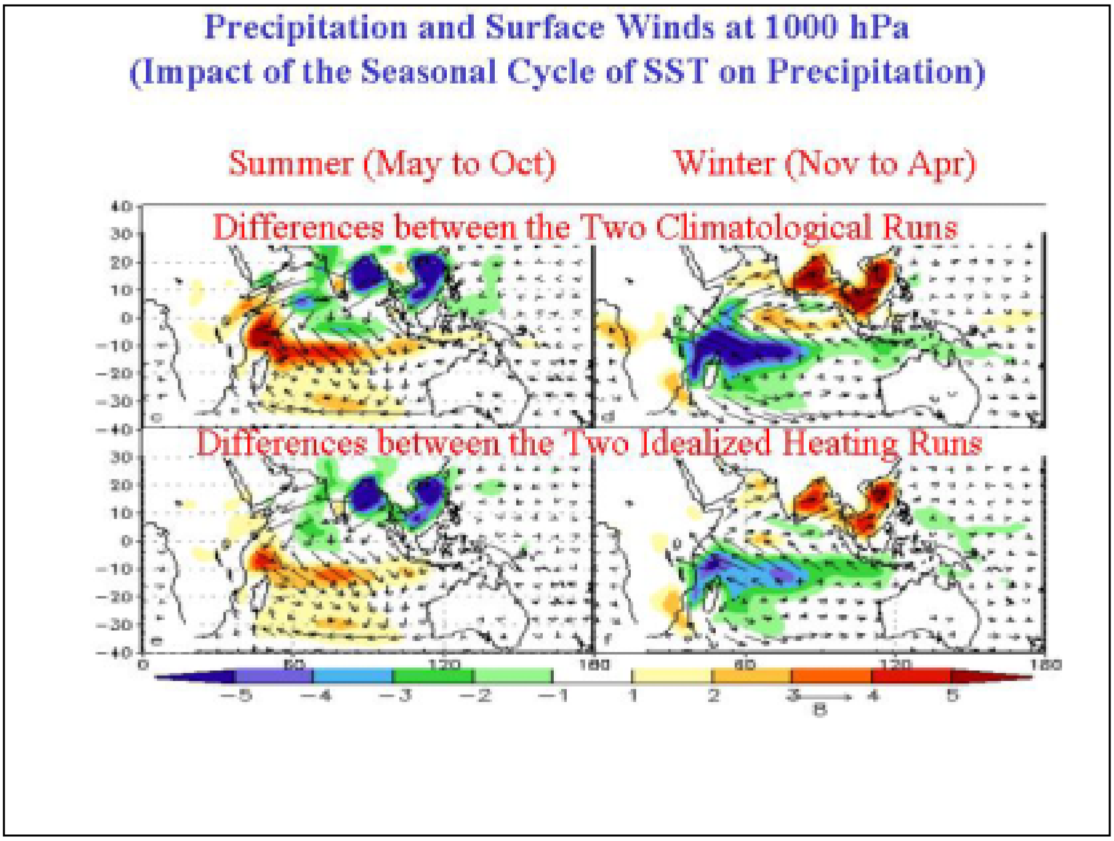
Stream Function and Wind at 200 hPa
(Simulation with Idealized Heating)
Lag
(days)
10
8
6
4
2
0
-2
-4
-6
-8
-10
40
60
80
100
120
140
160
180
200
Longitude
-20
0
20
Latitude
40
30
20
10
0
-10
-20
-30
-40

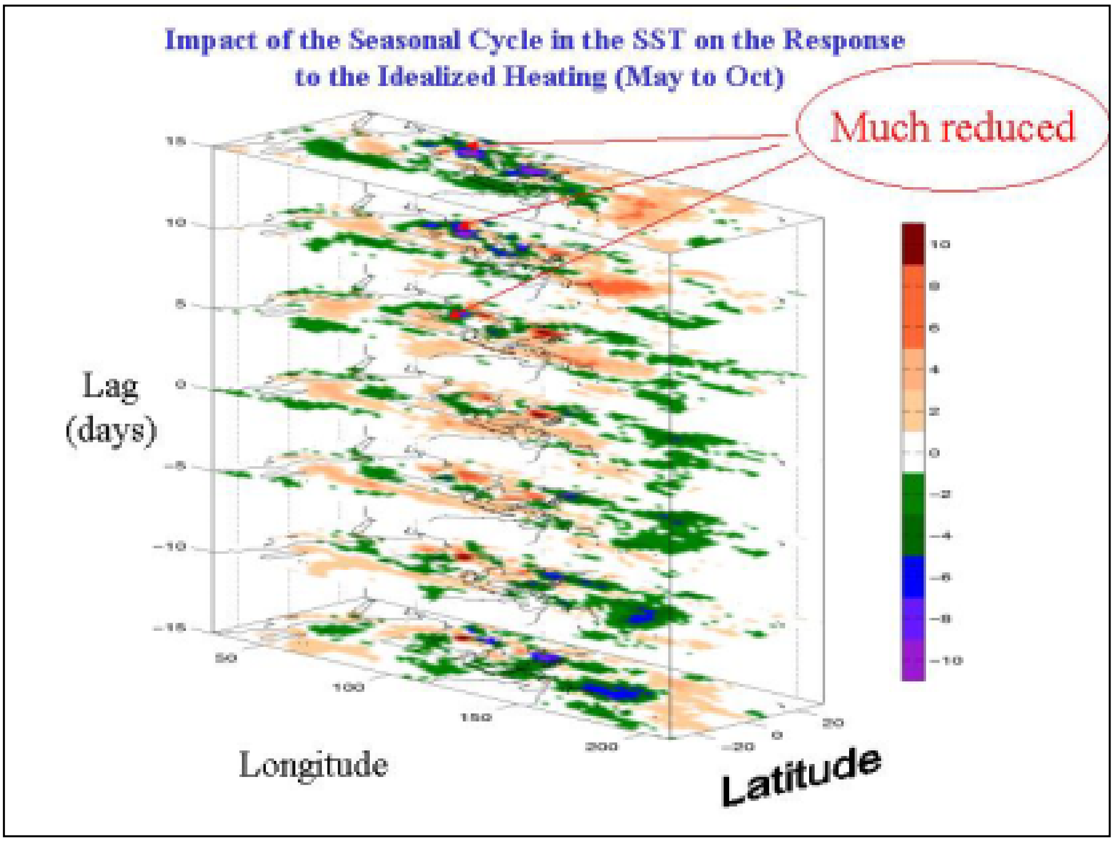

Precipitation and Surface Wind at 1000 hPa
(Simulation with Idealized Heating)
Base Region
Lag (days)
Longitude
Latitude

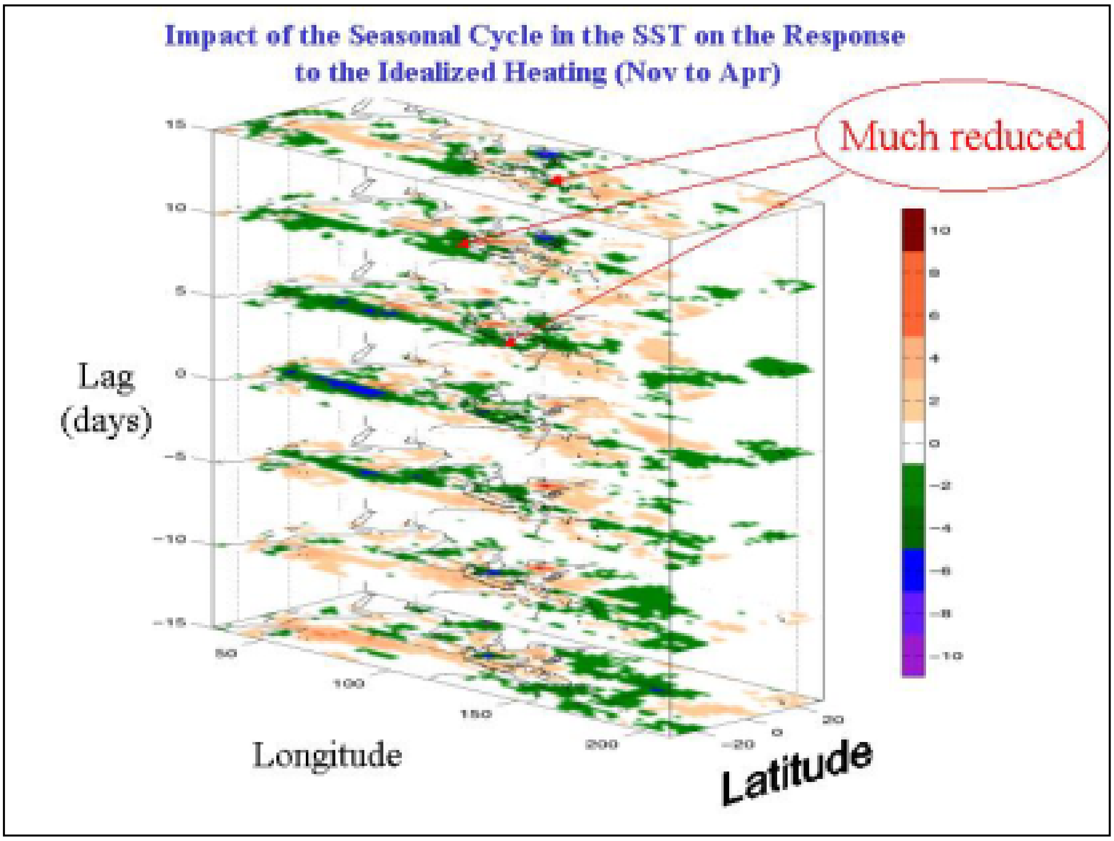

Stream Function and Wind at 200 hPa
(Observation)
Lag (days)
Longitude
Latitude

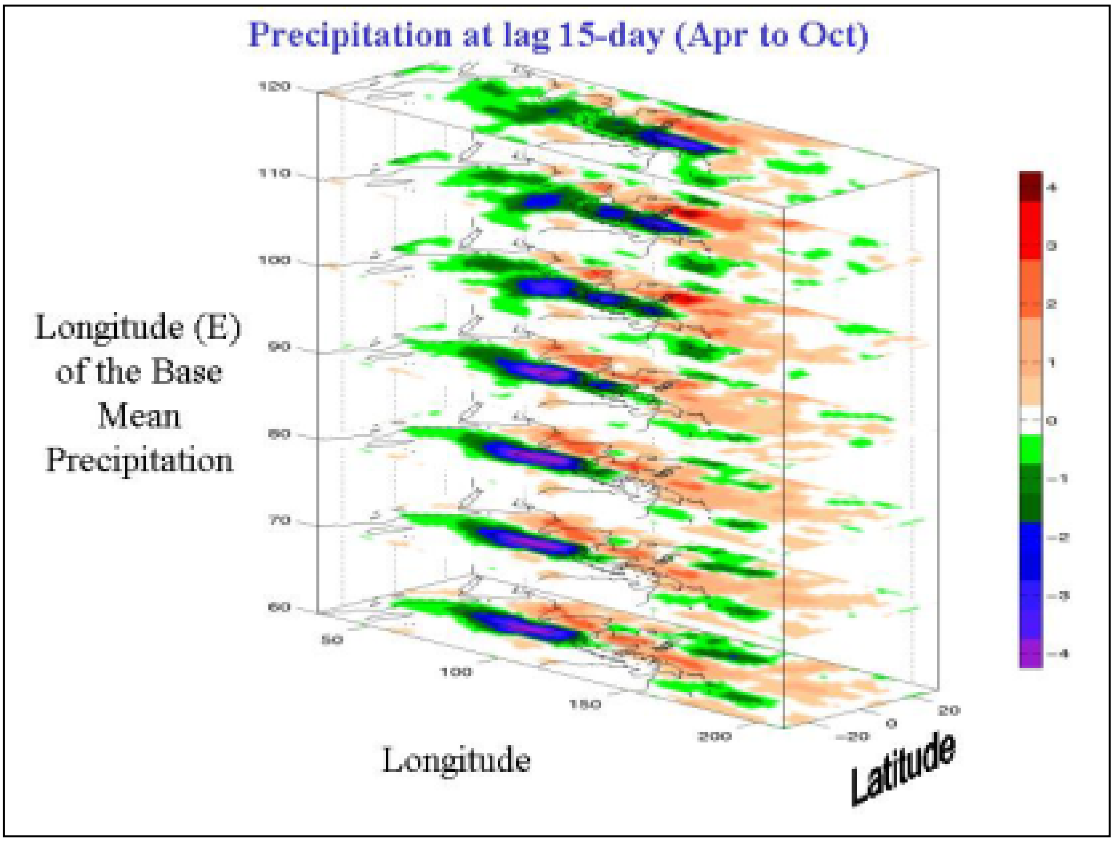


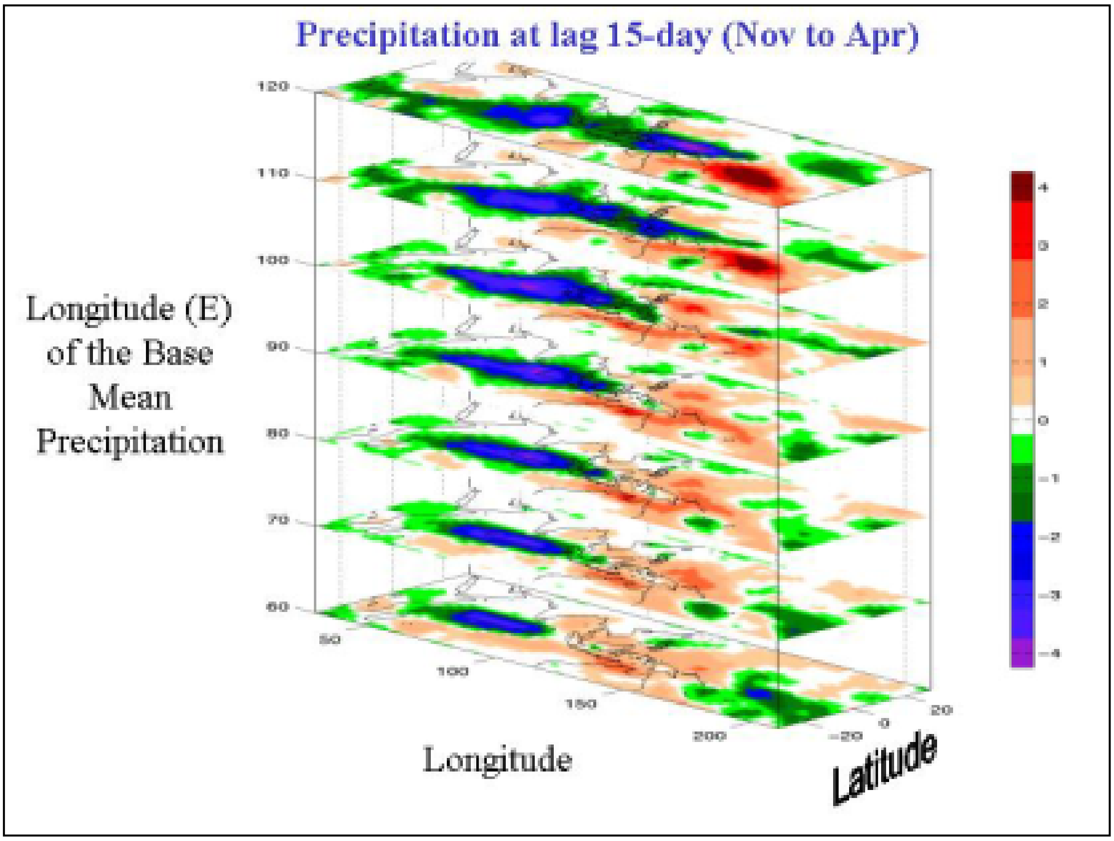
Imapact of SST on Meridional Propagation


Precipitation and Surface Winds at 1000 hPa
(Impact of the Seasonal Cycle of SST on Precipitation)
Summer (May to Oct)
Winter (Nov to Apr)
Differences between the Two Climatological Runs
Differences between the Two Idealized Heating Runs


Impact of the Seasonal Cycle in the SST on the Response
to the Idealized Heating (May to Oct)
Much reduced
Lag
(days)
Longitude
Latitude


Impact of the Seasonal Cycle in the SST on the Response
to the Idealized Heating (Nov to Apr)
Much reduced
Lag
(days)
Longitude
Latitude


Precipitation at lag 15-day (Apr to Oct)
Longitude (E)
of the Base
Mean
Precipitation
Longitude
Latitude



Conclusions

- The variability of the Asian-Australian summer monsoons is closely linked to the tropical MJO/ISO activity and heating.
- The MJO/ISO variability includes a well-known meridional propagation that affects the summer monsoons of both hemispheres.
- AGCM experiments with idealized eastward propagation MJO-like heating reproduce the observed meridional propagation including the observed seasonal differences.
- The results suggest that the winter/summer differences associated with the MJO are auxiliary features that depend on the MJO's environment (basic state and SST) and are not the result of fundamental differences in the MJO itself.

Performance of the KMA Global Model in Prediction of the Summertime Tropical Cyclone Activity

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Typhoon Research Center
Kongju National University

1. Introduction

Korea Meteorological Administration (KMA) runs the Global Data Assimilation and Prediction System (GDAPS) for the seasonal forecast, among which the seasonal tropical cyclone activity is included. The GDAPS has the horizontal resolution of T106 and 21 levels in the vertical direction. Under a certain initial state the model runs for several month including the three summer months, June, July and August. During the period, the model generates the typhoon-like vortices which we may consider as the tropical cyclone genesis and activity. The purpose of the investigation is to provide an insight on forecasting potential of the tropical cyclone activity with the utilization of the GDAPS long-term integration.

2. SMIP and HFP runs

Several seven-month runs are made by using the GDAPS T106 model with different initial time starting from at 00 UTC April 26 to at 12 UTC April 30, which produces ten ensemble members per year. Several four month runs are also made by using the same model with different initial time starting from at 00 UTC April 28 to at 12 UTC April 30, which produces six ensemble members per year. The observed SST is prescribed in the former runs (SMIP type), and the predicted SST in the latter run (HFP type). In both cases, typhoon-like vortices are generated within the model . The vortices that meet the following four conditions are considered as the tropical cyclone that exceeds TS(tropical storm) strength. (1) The central pressure at surface lower than 1012 hPa, (2) the 850 hPa wind greater than 25 kt, (3) the vorticity greater than 3 x 10-5 s-1, and (4) vortex lasts at least for 2 days. The real tropical storm is defined as the tropical cyclone of which maximum wind is greater than or equal to 34 kt. But considering the situation that we are viewing the model vortex in the context of the global model of which the horizontal resolution is only 1.875 degree, the comparable model vortex should be much weaker than the real one (Matsuura, et. al. 2002; Sugi, et. al. 2002).

Figure 1 shows the time history of the number of the observed and the model tropical cyclones during the three summer month (June - August). Although the difference in characteristics between the observed and the model tropical cyclones are taken into account, the model runs tend to underpredict (Table 1). The 21 year SMIP run underpredict the real one by 1.7 on the average and the HFP by 1.0.

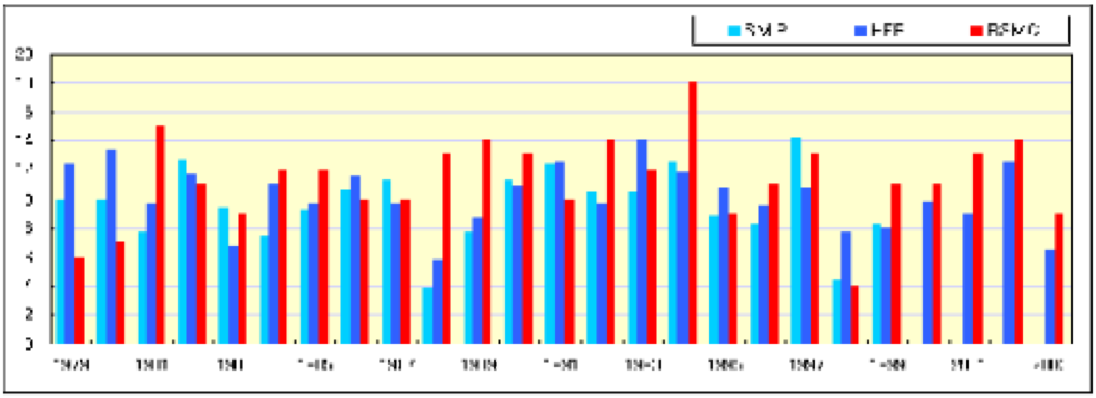

Fig. 1. Time history of the number of observed tropical cyclone (red) and those of SMIP(cyan) and HFP (blue) runs during the three summer months.

Table 1. The average number of tropical cyclones during the twenty-one year summertime(JJA)

	Mean	Bias
SMIP (1979 - 1999)	9.6	- 1.7
HFP (1979 - 1999)	10.3	- 1.0
RSMC (1979 - 1999)	11.3	N/A

Figure 2 shows the scatter plots of the observed TC number and the two model results. The correlation between the SMIP prediction and the observed TC number is 0.26 and that between the HFP and the observed ones is only 0.06. This low correlation seems to make the seasonal prediction with the use of the dynamics model somewhat nonsensical. However if we take a strategy differently rather than just predicting the real number of the tropical cyclones such as forecasting in category; below normal, normal and above normal, the model results may be useful.

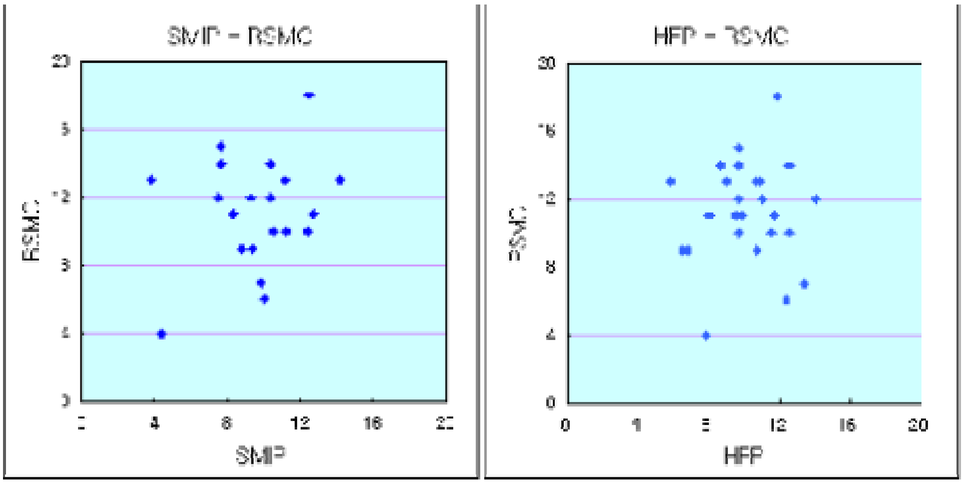

Fig. 2. Scatter plot of the observed TC number and the SMIP run (left) and the HFP runs (right).

The distribution of the observed number of tropical cyclones during the three summer months is examined to find out the category of the below normal, normal and the above normal, each category being one third of the total frequency distribution. The decision is by no means a clear-cut, but the 10-12 tropical cyclone occurrence may be considered as normal. But considering the model bias discussed in Table 1, 9-11 tropical cyclones may as well be considered as normal both in the SMIP and the HFP runs. Table 2 compares the model predicted and the observed number of tropical cyclones during the three summer months. The letter B, N, A in parentheses means below normal, normal and above normal, respectively. The case which the model correctly predict the observation with respect to the categorical forecast is shaded. The number of cases of the correct SMIP forecast is 8 among 21 years so that hit rate is 38%, while that of the HFP forecast is 10 out of 25 years which corresponds to 40% of hit rate. Considering that the chance of the correct prediction without any information may be 33.3%, 38% - 40% may show some potential in the seasonal prediction of the tropical cyclone activity using the ensemble prediction by global model.

Table 2. Comparison of model predicted and the observed number of tropical cyclones. The letter B, N, A means below normal, normal and above normal, respectively.

year	SMIP	HFP	RSMC
1979	10.0(N)	12.3(A)	6(B)
1980	9.9(N)	13.3(A)	7(B)
1981	7.7(B)	9.7(N)	15(A)
1982	12.7(A)	11.7(A)	11(N)
1983	9.4(N)	6.8(B)	9(B)
1984	7.5(B)	11.0(N)	12(N)
1985	9.3(N)	9.7(N)	12(N)
1986	10.5(N)	11.5(A)	10(N)
1987	11.3(A)	9.7(N)	10(N)
1988	3.8(B)	5.8(B)	13(A)
1989	7.7(B)	8.7(B)	14(A)
1990	11.2(A)	10.8(N)	13(A)
1991	12.4(A)	12.5(A)	10(N)
1992	10.4(N)	9.7(N)	14(A)
1993	10.4(N)	14.0(A)	12(N)
1994	12.5(A)	11.8(A)	18(A)
1995	8.8(B)	10.7(N)	9(B)
1996	8.3(B)	9.5(N)	11(N)
1997	14.2(A)	10.7(N)	13(A)
1998	4.4(B)	7.8(B)	4(B)
1999	8.3(B)	8.0(B)	11(N)
2000		9.8(N)	11(N)
2001		9.0(N)	13(A)
2000		12.5(A)	14(A)
2003		6.5(B)	9(B)

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Objective Comparison of Modeled and Observed Trends in Extremes of Temperature and Precipitation during the Second Half of the 20th Century

Dmitry Kiktev[1]
David Sexton[2], Lisa Alexander[2], and ChrisFolland[2]

[1]*Hydrometeorological Centre of Russia*
[2]*Hadley Centre for Climate Prediction and Research, Met Office*

We estimate gridded linear trends of annual values of various climate extreme indices, presenting a clearer picture of the patterns of trends in climate extremes than has been seen with raw station data. Station data were interpolated to regular grid taking into account spatial statistical structure of annual extreme indices (Kiktev et al., 2002).

The gridding allows us, for the first time, to objectively compare these observed trends with those simulated by a suite of climate model runs forced by observed changes in sea surface temperatures, sea-ice extent and various combinations of human-induced forcings. Atmosphere-only HadAM3 model integrations are used to test whether the observed changes can be simulated by observed SSTs alone.

Four measures of pattern similarity were used for comparison of observed and simulated trend patterns. To assess the uncertainty in the trend estimates and in their similarity, ensembles of «perturbed» trend patterns were constructed on the basis of observed and simulated time series using a novel resampling technique.

The comparisons indicate that the inclusion of anthropogenic effects in the model integrations, in particular increasing greenhouse gases, significantly improves the simulation of changing extremes in temperatures (Kiktev et al., 2003). The model shows little skill in simulating changing precipitation extremes.

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Kiktev D.B., Sexton,D.M., Alexander,L.V., Folland,C.K. (2003), Comparison of modelled and observed trends in indicators of daily climate extremes, J.Climate, in press

Application of Ensemble Prediction System to Economic Value Problem

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Climate Environment System Research Center
Seoul National University

1. Introduction

There is a air-conditioner among the representative products of weather-sensitive industry. The various weather events as well as the business situation affect the demand of air-conditioner. Recently, decision makers begin to recognize the fact that daily average temperature over between 26℃and 28℃ being continued, the potential demand for air-conditioner tend to change into the substantial demand and increase sales amounts. They try to make decision considering weather information in part of production planning, sales plan and marketing strategy. But, there are little research about decision making model reflected uncertainty of weather information or identified the potential loss at the manufacturing industry, the decision making using weather information depends on just individual experiments.

The decision problems in production planning management of air-conditioner should be considered the uncertainty of forecasts and it involves making repeated decisions over time. In other words, because the potential loss/benefit vary much with further weather events in the real world, it is necessary that we developed the decision model reflected that.

The approach of the decision making is first to forecast demand of air-conditioner, the second to calculate the probability of ensemble prediction system, the third is estimating expected return using SDP at each time step and the last to obtain total expected return for entire planning horizon and economic value of each decision variable.

2. Decision analysis

A useful mathematical model to model and structure decision problem as to production planning of air-conditioner involving the uncertainty of forecast is that of Decision Analysis (Clemen, 1996, Keeney, 1982). Especially, in this approach, the probability for the future events that are derived from ensemble prediction system is taken to this decision problem (Katz and Murphy, 1997).

As mentioned above, the process to establish production planning of air conditioner is very difficult due to its time-dependent characteristics. In other words, because that can be vary with production amount, benefit and future weather events at the dates that are determined to a serial decision process, that can’t be established independently from them. Giving in to the literature of decision analysis, the problems of this kind are classified by ‘dynamic decision making (Wilks and Wolfe, 1998)’. For dynamic decision making, the objective is non-separable because expected return depends on the returns achieved in all period. Therefore, it is necessary that the objective is maximizing expected return over the full sequence of planning horizon rather than the sum of individual returns

Stochastic dynamic programming (SDP) is often used to analyze problem of this type (Kennedy, 1986). In this paper, Our SDP analysis is based on methodology of the Andrew’s paper. The general solution of SDP is as follows. The planning horizon consist of *t=1…T*; The finite state of system is denoted by $s_t \in S_t$, The decision at each stage is denoted by qt, and is constrained by $q_t \in Q_t$. When decision maker takes some forecasts at each stage-this represent qt-uncertainty is reflected by at, which is conditional probabilities of the possible future weather events given that forecast. The state of the system in t+1 is described by the function, g^t (q^t, s^t, a^t) and the return in each period is r^t (q^t, s^t, a^t). The decision sequence is solved in reverse time using the recursion (Andrew, 1999).

$$f^t(s^t, a^t) = \max(r^t(q^t, s^t, a^t)$$

$$+ E[f^t(s^{t+1}, a^{t+1}) \mid a^t])$$

subject to :

$$s^{t+1} = g^t(q^t, s^t, a^t)$$

where f^t (s^t, a^t) is maximum expected total return from t to T given that the state of the system is (s^t, a^t) in period t.

The economic value for using climate forecast can be defined as follows (Katz and Murphy, 1997)

$$EV = \frac{ER_{climate} - ER_{forecast}}{ER_{climate} - ER_{perfect}}$$

where $EV_{climate}$ is expected return for using climatology, $EV_{forecast}$ is expected return for using forecast, $EV_{perfect}$ is expected return for perfect forecast. When EV is almost 1, the predictability of forecast is very high.

3. Demand forecast

There are few researches as to approach to air-conditioner demand forecasting. Thus, we first analyze the sales amount of air-conditioner according to time scale and compare that with economic index and weather index. In the paper, coincident composite index (CCI) is used as a economic index, monthly average observed temperature (MAT) is selected as a weather index. The main source of data as to demand forecast are from Korea National Statistical Office (KNSO). The period of data is monthly because the sale amount of air-conditioner is represented by monthly state data. Fig. 2 shows a plot of air-conditioner sales amount in Korea for each month between 1995 and 2003. One clear feature of sales amount is string seasonality throughout the year, which results in a difference of about 100,000 between summer and winter sales amount.

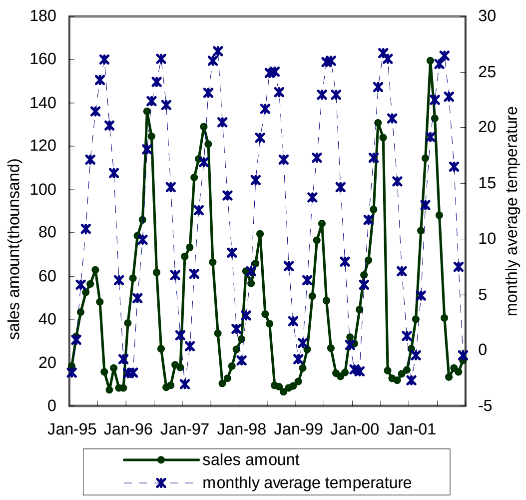

Fig. 1 Demand for air-conditioner in Korea in 1995-2001

The approach taken by analyzing the data is a time-series forecasting and separate regression model. Each method is based on Additive Winter's model of which the error can be linear relation with MAT and Multiple Linear Regression Model that has the CCI and MAT as explanatory variables. Comparing the result of demand forecasting methods, it proved that separate regression model comfortably dominate the method using additive winter's model. The demand forecast equation can be described as follows

$$DF = 1726 * CCI + 696 * MAT - 186748$$

In this paper, we do not estimate the uncertainty in demand forecast due to representation of SDP.

4. Ensemble prediction

The primary interest of climate forecasts here is monthly average temperature for upcoming three month. In the seasonal forecast, predictability is limited by model errors due to the approximate simulation of atmospheric process in a state-of-the-art numerical model.

But, in recent research, multi-model ensemble prediction system have been developed to improve the predictability and we use the specio-ensemble prediction system based on five dynamical models from different modeling groups of KMA, NASA, NCEP, SNU, and TWB. Prediction data utilized in this study are the 21-year hindcast products for 1979-99 from SMIP-II simulations of the three dynamical models of KMA, NCEP, and SNU and from AMIP-II simulations of NASA and TWB models.

This system is developed th method of a coupled pattern projection model (CPPM) to obtain the coupled pattern between large-scale circulation fields predicted by a dynamical model and an observed grid data. This predicted large-scale pattern, a priori obtained in the training period, is projected to the prediction data to produce a regional prediction. The statistical correction procedure using CPPM is applied to each model, and the final prediction of a regional climate is obtained by compositing the five predictions, statistically corrected.

The probability of forecast is obtained by Bayes' theorem for available future events at each stage. The above expected return in Eq. (1) is a probability-weighted average over frequencies of use of the possible probability forecast.

5. Model development

The model is programmed by JAVA™ to be independent of operation system of computer and be able to convert into form of World Wide Web. Fig. 2 shows the graphic use interface of both input and output when model operating.

Fig. 2 Display of model interface

6. Results

To estimate the economic value of ensemble prediction system, we assume that state of the system (entire horizon) is represented by three state variable (summer) and that three decision variable (using ensemble forecast, using climatology, using average sales amount) is made at each stage. Available future weather event is 12 state variables, which is defined that the error of forecast is from ±1 to ±6 times of standard deviation. It is assume that the production amounts are determined by demand forecast and the there is no error for demand forecast.

Fig. 3 shows the result of computation about maximum expected return between 1995 and 1999 for each decision variables.

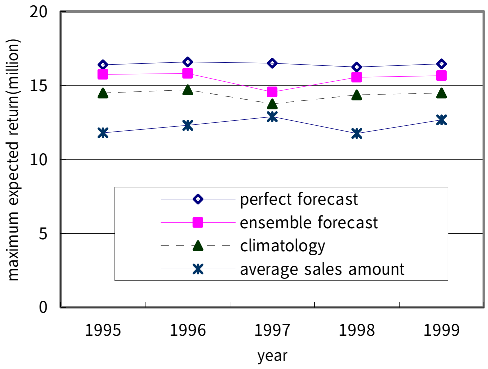

Fig. 3 Maximum expected return by decision variable

As a result, the expected value of ensemble prediction system is between 14.3 and 15.6 million dollars and that of climatology data is between 13.7 and 14.6 million dollars and that of average sales data is between 11.6 and 12.8 million dollars. For most scenarios, economic value of ensemble prediction system is above 0.6. If it assume that the cost of ensemble prediction system is 0.1 million dollars and it is defined that benefit is difference between the expected value of ensemble prediction system and that of average sales data , the ratio of cost/benefit is about 1 : 150. Also, from the results of each scenario, it is shown that the probability of forecast have influence on the expected value larger than economic index or weather data.

7. Summary and conclusion

We developed the decision support model using SDP method to estimate economic value of ensemble prediction system. For all period, the expected return of decision scenario using ensemble system was more than others and increases about 30% than that of scenario that decision make do not consider the forecast information. The accuracy of demand forecast and form of utility function according to each decision maker are area for future research.

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SI Forecasting in Roshydromet

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Hydrometeorological Center of Russia

1. Current state

Within the Federal Service of Russia for Hydrometeorology and Environmental Monitoring (Roshydromet) practical real-time Extended and Long Range Forecasting activity is concentrated mainly at the Hydrometcentre of Russia (WMC Moscow) and the Main Geophysical Observatory (MGO) in Saint-Petersburg. A number of 1-month and SI-products have been issued on the basis of statistical methods for the territory of Russia for many years in the framework of RSMC activity. Hydrodynamic-statistic 1-month forecasts have been issued since 2000.

About two years ago activity in experimental seasonal forecasting has begun. Since 2002 the MGO has participated in the APCN project. Dynamical seasonal forecasts of the WMC Moscow are currently available for internal use only.

Besides this there are some other institutions beyond Roshydromet dealing with modeling and theoretical studies of climate. These are Institute of Numerical Mathematics of the Russian Academy of Science (RAS) and Institute of Physics of the Atmosphere of RAS and some Universities.

2. Models

Main Geophysical Observatory (Saint-Petersburg)

Global spectral T42L14 AGCM coupled to the upper mixed ocean layer

Developed by the Main Geophysical Observatory.

The model versions T30L14 and T42L14 have been run in AMIP-II mode. Results of T30L14 version are available at PCMDI archive. Since 2002 the MGO model has participated in the APCN project.

Hydrometcentre of Russia (Moscow)

Two global AGCM and two-tier approach with persisted SST anomalies for the period up to 4 months are used. Coupling to OGCM is planned.

1 Spectral T41L15 AGCM

Developed by the Hydrometeorological Centre of Russia

2. Finite difference semi-Lagrangian model

Developed by the Hydrometcentre of Russia in collaboration with Institute of Numerical Mathematics of the Russian Academy of Science. Resolution 1.125/1.40625 degrees lat/lon, 28 sigma levels. Original vorticity-divergence semi-Lagrangian dynamics. Physical parameterizations - from operational Meteo-France ARPEGE/IFS model.

3. Plans

- To make dynamical seasonal forecasts of WMC Moscow available via Internet during 2004 after their calibration on multi-year hindcasts data;
- To progressively extended the list of available parameters and their verifications in order to converge toward the WMO recommendations;
- To develop multi-model products of the MGO, Hydrometcentre of Russia and other global producers.

On the Prediction of Summer Precipitation in China

Wenjie DONG, Peiqun ZHANG, Yongguang WANG, Leng SUN, Wanxiu AI, Zuqiang Zhang, Lanning WANG, Xueli SHI, Qingquan LI, Yiming LIU, Yong LUO, Weijing LI, Yihui DING, Guocai ZHANG

National Climate Center, China Meteorological Administration

1. Introduction

This paper is attempted to interpret the monthly, seasonal and annual climate prediction, especially summer precipitation prediction system developed in National Climate Center (NCC), China Meteorological Administration (CMA), in the past decade and their performance in the operational practice or the so-called preparatory period of the operational practice. However, in view of the major theme of this symposium, we will concentrate on the numerical model's development and their simulation and prediction while simply introduce the statistical methods' outputs.

2. Overview of Present Operational Climate Prediction System

The operational flooding-season precipitation prediction system of NCC at present is a very complicated data and method ensemble that involved numerous scientists, engineers and teachers from National Climate Center (NCC), Chinese Academy of Meteorological Sciences (CAMS), China Meteorological Administration (CMA), Institute of Atmospheric Physics (IAP), and Institute of Environment and Engineer in Arid and Cold Region, Chinese Academy of Science (CAS), Department of Atmospheric Sciences of Peking University, among which NCC plays a leading role on the final decision and issue of the prediction. Most of the groups participated in the Joint Flooding Season Precipitation Symposium use statistical forecast method, while two groups, one from IAP of CAS, another from NCC of CMA, use Coupled Atmosphere-Ocean Climate Model. However, because of short history of development of climate model prediction system and less chance of test of model-based prediction system comparing with the statistical methods. So far the statistical method are dominated in the operational climate forecast in China. Fig.1 shows the flow of the statistical method in NCC. And Fig.2 is the forecast score of the operational flooding-season precipitation forecast during recent 30 years. On average, monthly prediction is a lit bit better than flooding-season forecast (Tab.1). For a quick impression about forecast skill in recent years, we present two examples here. One is a representative for excellent forecast in 1998, shown in Fig 3. And another is for low skill forecast of 2003, illustrated in Fig.4. The quite unstable forecast scores demonstrate that there is a long way to make useful climate prediction and imply the urged and necessity for development of the operational climate prediction method which is named as Dynamical-statistical Prediction Method that is being discussed and designed.

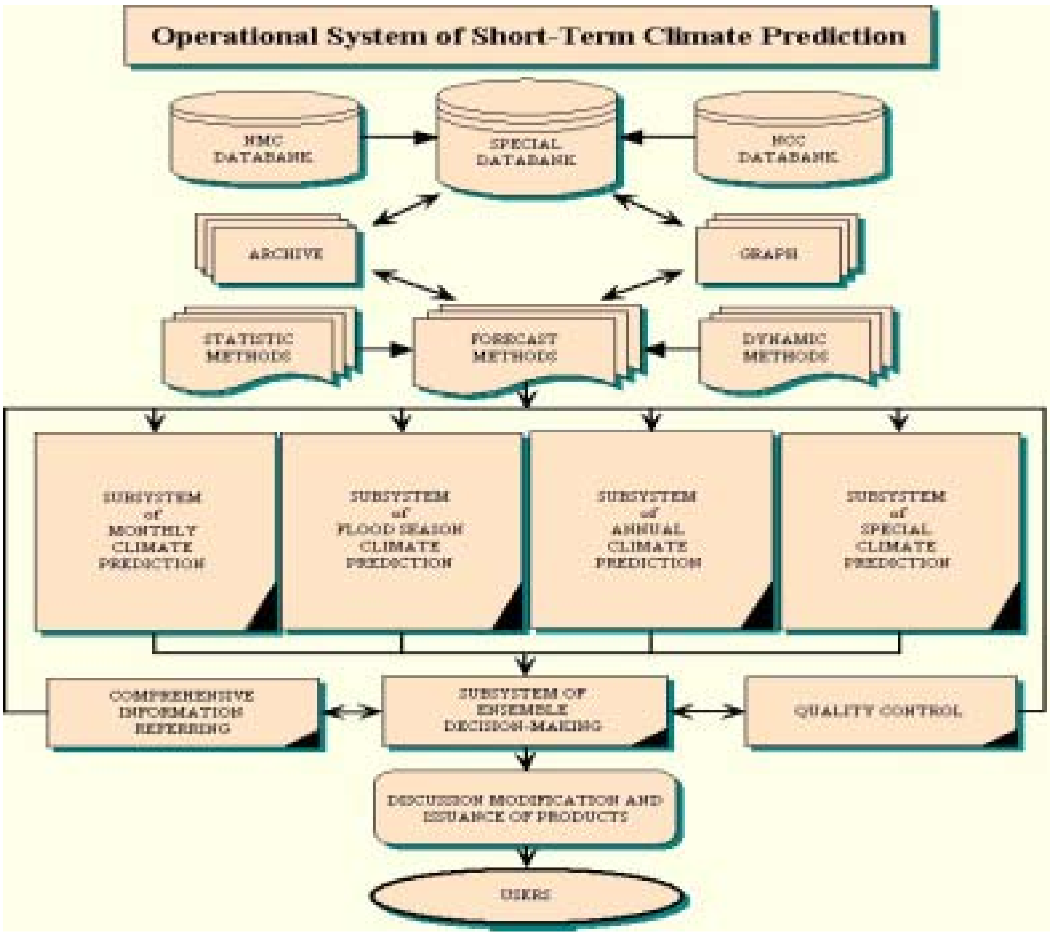


Fig.1 The flow of Present Operational Climate Prediction System in NCC

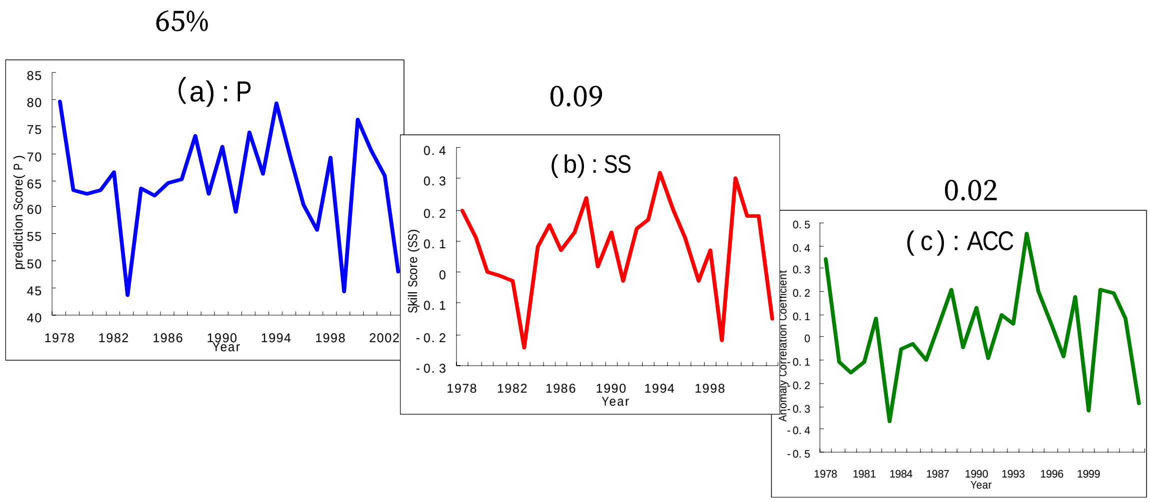


Fig.2 The forecast score of the operational flooding-season precipitation forecast during recent 30 years (a) for NCC Prediction assessment score, (b) for Skill Score and (c) for Anomaly Correlation Coefficient

Table 1 The average value of every assessment score during the last 30 years in NCC

Assessment Method	Summer Rainfall Prediction During 1978-2001	Monthly Scale Prediction			
		Precipitation Prediction		Temperature Prediction	
		During 1971-2001	During 1995-2001	During 1971-2001	During 1995-2001
P(%)*	65.26	60.7	61.81	66.07	71. 25
SS(%)*	9	17	21	-2	12
ACC*	0.03	0.02	0.07	0.05	0.13

***P(%),SS(%)and ACC: same as figure 2.**

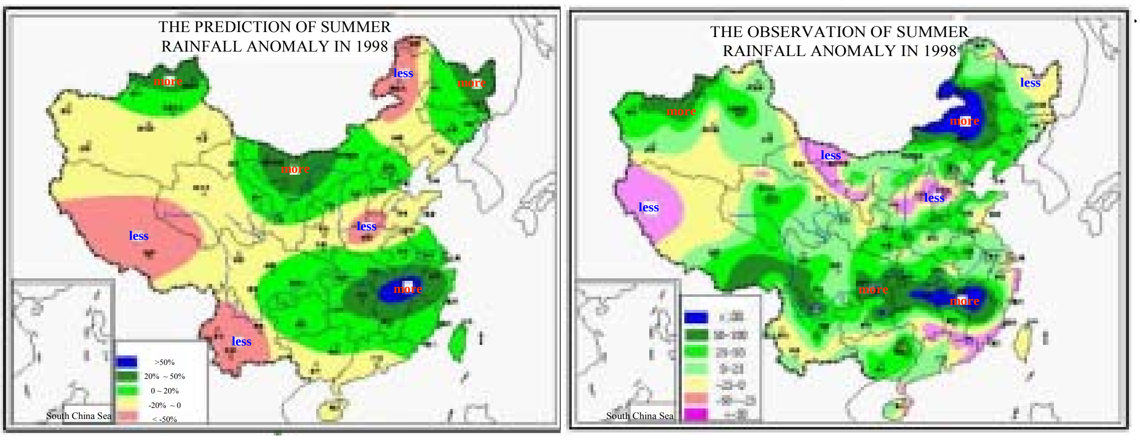


Fig.3 The prediction (left) and observation (right) of summer(June – August) rainfall anomaly in 1998

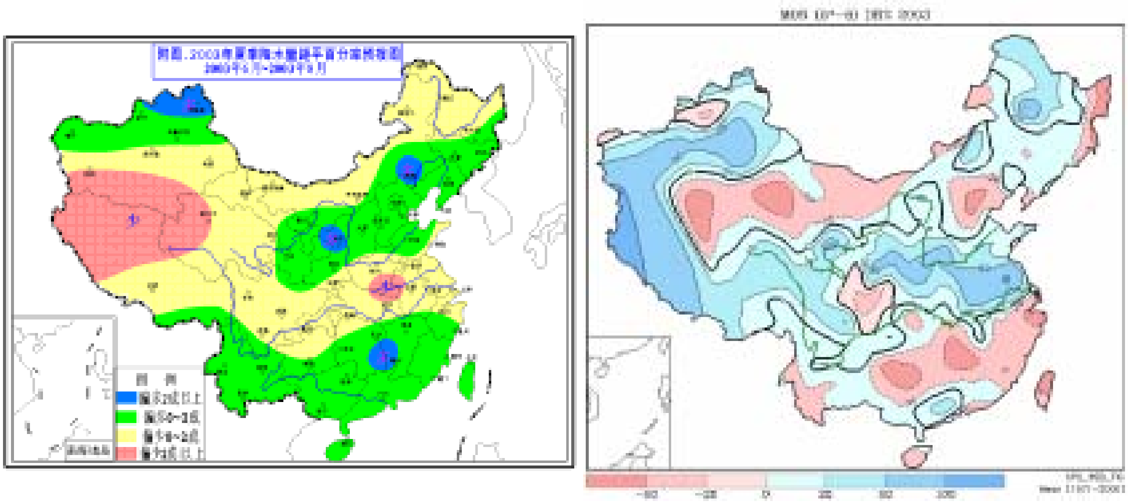
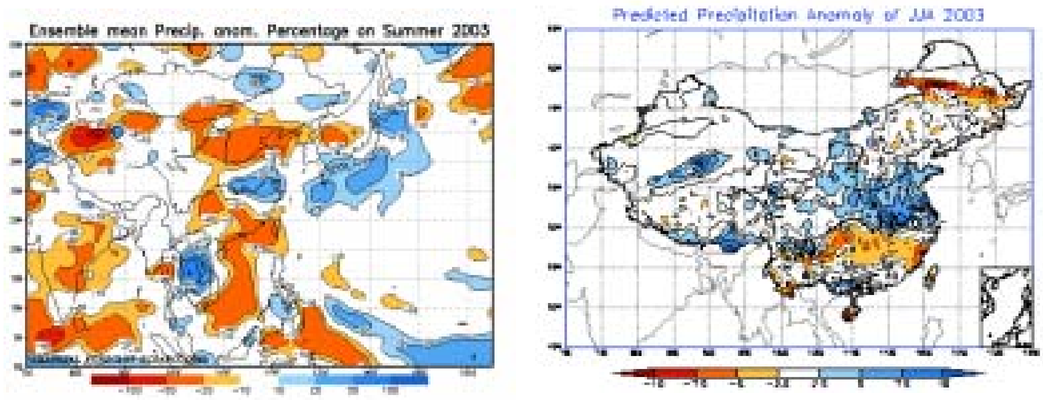


Fig.4 The prediction (left) and observation (right) of summer(June – August) rainfall anomaly in 2003

3. Performance of CGCM and ReGCM-NCC in 2003

Although the climate prediction derived from climate models is not wholly acknowledged by climate forecasters of nowadays operational forecast-maker. All the real-time prediction production, including monthly, seasonal and annual has been exhibited in Homepage of Beijing Climate Center (BCC), see http://bcc.cma.gov.cn for details, and updated each month. A fascinating phenomena is that the Nested Climate Model and Coupled Atmosphere-Ocean Model gave a fairly-well prediction on the summer precipitation, even summer hot-wave of China in 2003. The predictions are shown in Fig.5 (a) for CGCM-NCC and Fig 5(b) for ReGCM-NCC and the observed is shown in Fig.4 (right). Refer to climate prediction, generally speaking, it is difficult to estimate the capability of a method or a model by one case of course. Furthermore, to the most complicated climate system, what we have known only a very small portion compared with what we have not known. Maybe it is just coincided! But what encourages model developer is that the CGCM-NCC gave a fairly-well precipitation in spring in China as well. Fig.6 (a-b) shows the predicted and observed spring precipitation in China, respectively. In order to easily compare our model and some other models, Fig.7(a-d). shows the precipitation prediction by ECMWF (a), HadleyCenter (b), IRI (c) and observation (d) of spring (March – May) rainfall anomaly in 2003.



(a) (b)

Fig.5 The prediction on the summer (June – August) rainfall anomaly in 2003 (a) for CGCM-NCC and (b) for ReGCM-NCC

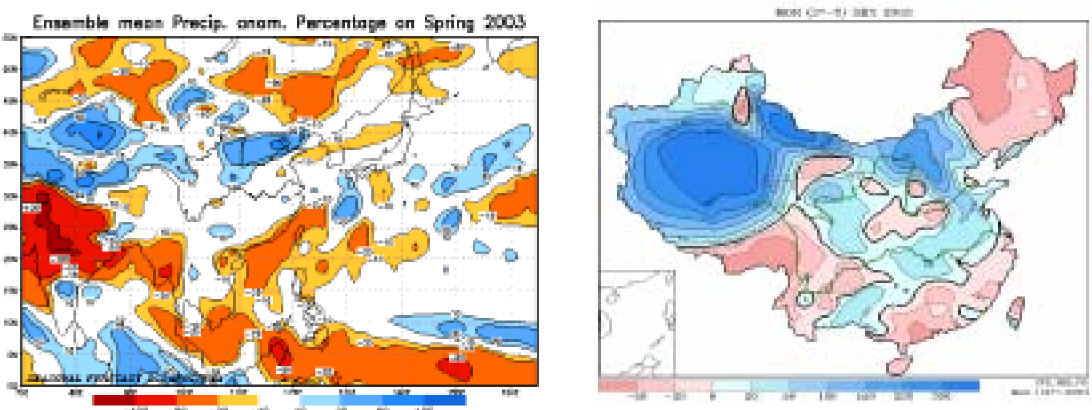


Fig.6 The prediction by CCM-NCC (left) and observation (right) of spring (March – May) rainfall anomaly in 2003

(a)
ECMWF
03/02/14

(d)
observed

(b)
HadleyCnter
03/03/01

(c)
IRI
03/02

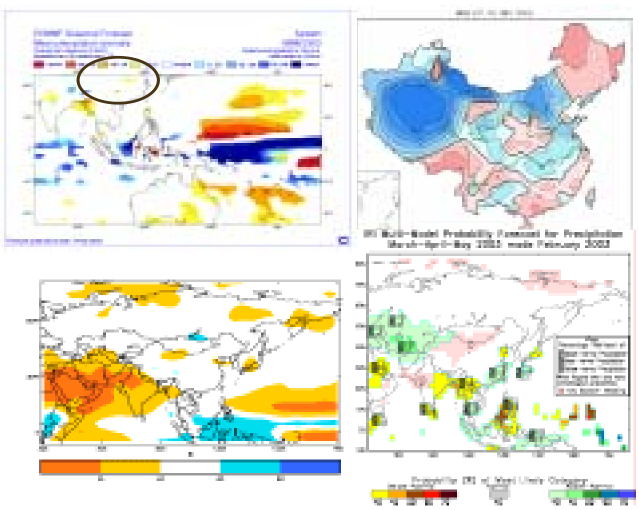


Fig.7 The prediction by ECMWF (a), HadleyCenter (c), IRI (c) and observation (d) of spring (March – May) rainfall anomaly in 2003

4. Statistical Behavior of NCC's Climate Models

For the purpose of assessing how much we can make our prediction depending on today's Climate Model System and statistically under what kind of conditions the Climate Model's prediction could be considered by operational forecast-maker. A ten-year run of the nested climate model ReGCM-NCC and 11-year run of the CGCM-NCC were undertaken. For each run, an eight-member of initial ensemble were taken to reduce the uncertainty due to initial field error. Based on the simulation data, a statistical analysis was carried out to identify the model's capability of flooding-season precipitation. Tab.2 (a-b) gives CGCM-NCC & ReGCM-NCC, respectively.

5. Brief Introduction of NCC's Model System

Let's go back to introduce briefly CGCM-NCC and ReGCM-NCC. Fig.7 shows the framework of Model Prediction System. It is composed with data block, Model block and Output block. There are two Models. They are CGCM-NCC & ReGCM-NCC which we have already repeatedly mentioned above. The former provides lateral force for the later. The present used CGCM-NCC is made up of a atmosphere model developed largely based on T63 of ECMWF and of a ocean model developed from a 30-layer 1×1 resolution ocean model originally designed by Xuehong Zhang et al. in LASG, State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics. The ReGCM-NCC is developed from MM4 in NCC by Xuejie Guo et al.

Table 2(a) Assessment score for flooding season rainfall forecast by CGCM-NCC during 1991-2001

Year	RATc	P	RMSSS	ACC	TS
1991	63.75	77.82	42.65	0.14	0.33
1992	42.5	56.32	53.2	-0.11	-0.7
1993	48.75	68.78	44.25	0.11	0.8
1994	53.75	72.93	14.86	-0.01	0.16
1995	51.88	66.13	70.58	0.03	0.13
1996	50	64.92	49.5	0.03	0.11
1997	53.75	70.35	57.3	0.05	0.11
1998	54.38	72.44	60.08	0.07	0.18
1999	52.5	65.98	52.65	0.005	0.11
2000	52.5	72.89	59.94	0.23	0.16
2001	47.5	59.79	38.96	0.005	0.2
AVE	51.93	68.03	49.45	0.05	0.12
Ave-NCC		67.9		0.02	0.08

Table 2(b) Assessment score for flooding season rainfall forecast by RegCM-NCC during 1991-2001

Year	预报准确率 (P)	随机预报的技巧评分（RATc)	气候预报的技巧评分（CLTc)	距平相关系数（ACC)	异常气候评分 TS
1991	61.50	0.02	0.17	0.00	0.14
1992	63.49	-0.02	0.14	0.05	0.14
1993	66.49	0.07	0.21	-0.02	0.18
1994	63.69	0.04	0.19	0.04	0.15
1995	62.90	-0.02	0.14	-0.07	0.13
1996	56.42	-0.12	0.05	0.00	0.11
1997	72.54	0.22	0.34	0.19	0.26
1998	56.04	-0.11	0.06	-0.05	0.13
1999	58.79	-0.12	0.05	0.04	0.14
2000	74.87	0.29	0.40	0.33	0.20
Ave	63.67	0.025	0.175	0.051	0.158
Ave-NCC	67.9	-0.03	0.08	0.02	0.08

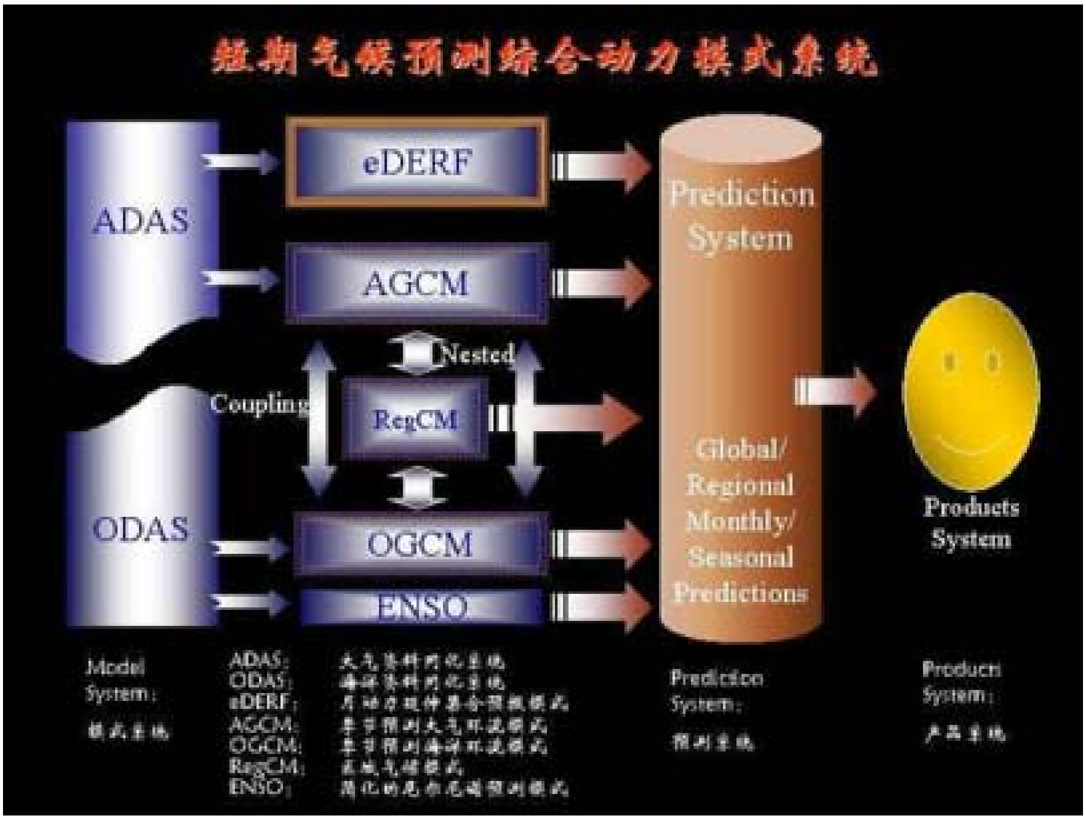


Fig.7 The framework of Model Prediction System for NCC

6. A Near Future Plan

In this section we will introduce the NCC's science plan for Climate System Model. In recent three years , NCC is planning to:

(1) improving its Atmospheric Component of CCSM;
(2) improving its Land Surface Component of CCSM;
(3) coupling the Dynamic Vegetation Component into CCSM.

7. Summary

Under the efforts of all NCC members, the prediction system has been established and put into operation. The prediction we issued seems good which can be deduced from the anomaly correlation coefficient between the rainfall forecast and observation (Fig. 8). Meanwhile, the dynamical climate models have been developed and updated, and made the routine prediction outputs at both global and regional scales. Prediction experiments have been designed and executed comprehensive hindcast to identify and validate the models, to improve the methods of forecast analysis, to enhance the model prediction accuracy and model products application capability. Recently, AGCM（T63L16）, OGCM（L30T63）, CGCM(Atmosphere-Ocean Coupled GCM), RCM, SOACM(Simplified Ocean-Atmosphere Coupled Model) and ensemble prediction (32 ensemble samples) have been applied in the routine climate prediction. The comprehensive climate system model is under study (Fig. 9).

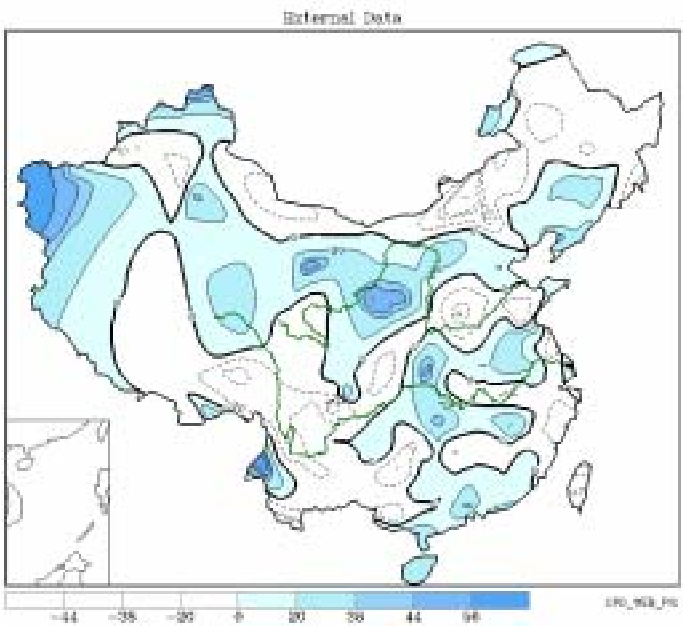


Fig.8 The correlation between rainfall forecast and observation during 1981-2000

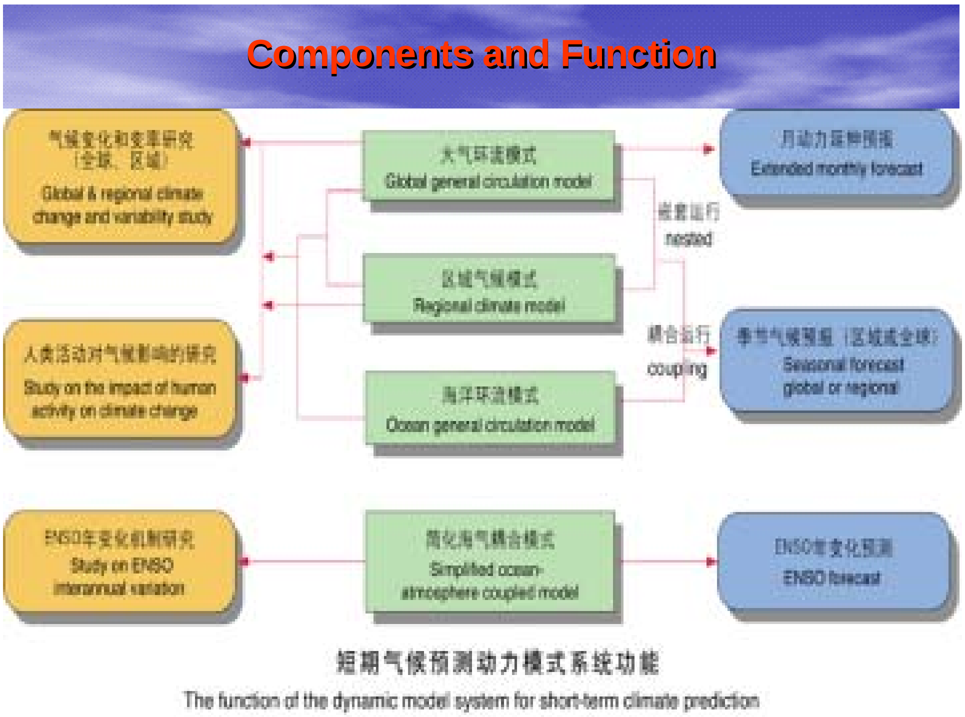


Fig.9 The framework of comprehensive clime system model

Recent Development of the Seasonal Prediction System

Tomoaki OSE

Climate Prediction Division
Japan Meteorological Agency

1. Recent Progress in JMA's Dynamical Seasonal Forecasting System

(The outline of the current operational system is summarized in the attached Table)

- Mar. 2003: JMA began dynamical three-month ensemble weather forecast with the fixed SST anomalies at their initials.
- Apr. 2003: JMA began to apply snow data analyzed from SSM/I (Special Sensor Microwave Imager) to the land data assimilation system, which started its operation in Apr. 2002 using only the SYNOP snow-depth report. The output from the land data assimilation is used as the initial condition for the land model incorporated in the seasonal forecast system.
- May. 2003: JMA updated the one-month ensemble weather forecast model. Cumulus convection scheme and related change in initial data assimilation scheme are improved.
- July 2003: JMA updated the El Nino Prediction model (atmosphere-ocean coupled model). The old version of the JMA atmospheric model had been used since the start of the coupled model in Aug. 1999. The prediction performance is greatly improved by the updated atmospheric model and ocean assimilation system.
- Sep. 2003: JMA started the dynamical ensemble forecast targeting the cold and warm seasons of December-January-February and June-July-August in a two-tiered way. The Nino3 (eastern-equatorial Pacific) SST anomalies are predicted with the El Nino

prediction model (atmosphere-ocean coupled model). Based on the MOS (Model Output Statistics) -corrected Nino3 SST anomalies, global SST anomalies for the forecast model (atmospheric model) are statistically obtained. JMA completed introducing numerical prediction technique into all ranges of operational seasonal forecasting in JMA.

- Sep. 2003: JMA began to disseminate GPVs (grid point values) and maps for three-month ensemble weather forecast to NMHSs (national meteorological and hydrological services) from JMA's Tokyo Climate Center (TCC) website in addition to the GPVs and maps for one-month weather forecast, which have been available since last October.

2. Recent Contact with the APCN

- May, 22 2003: JMA sent the monthly GPV data required for the APCN multi-model ensemble experiment from the results of a warm-season prediction experiment starting from Mar. 16, 2003. JMA also provided the APCN with the SMIP-2 date for verification.
- June 19 2003: JMA sent the JMA model description for three-month prediction and gave the contact person's information to the APCN by e-mail.
- Note: The monthly GPVs for the dynamical seasonal prediction covering DJF (JJA) are scheduled to be issued around 25 in Sep., Oct. and Nov. (Feb., Mar., Apr. and May) from the Tokyo Climate Center (TCC) website after next Feb.. JMA will be able to provide operational three-month predictions which meet APCN Secretariat's request. Hindcast data for each forecast is already available.

Table JMA's Numerical models for Seasonal Prediction September, 2003

Symbolic Name	One-month Prediction Model	Three-month Prediction Model	Warm and cold seasons Prediction	El Nino Prediction Model
Purpose	One-month Prediction	Three-month Prediction	Warm and cold seasons Prediction	El Nino Prediction for the coming six months
Specification	Atmospheric Model GSM0305 T106 (110km) L40 Top at 0.4 hPa	Atmospheric Model GSM0103 T63 (180km) L40 Top at 0.4 hPa	Atmospheric Model GSM0103 T63 (180km) L40 Top at 0.4 hPa	Atmosphere-Ocean Coupled Model Flux Adjustment Atmospheric Model: GSM0103 T42 (300km) L40 Ocean Model: 2.5 by (0.5 around the equator to 2.0 in high latitudes), 20 layers
Initial and Boundary Condition	Initial Condition: Atmosphere Data Assimilation (GANAL) Land Data Assimilation Boundary Condition Fixed SST anomalies at their initials	Initial Condition: Atmosphere Data Assimilation (GANAL) Land Data Assimilation Boundary Condition Fixed SST anomalies at their initials	Initial Condition: the same as the left box. Boundary Condition: Global SST anomalies are obtained statistically from MOS value for El Nino SST anomaly based on the El Nino atmosphere-ocean coupled model prediction except for first 3-months when SST anomalies are fixed at their initials.	Initial Condition: Atmospheric Data Assimilation (GANAL) Land Data Assimilation Ocean Data Assimilation (ODAS) Atmosphere-Ocean Coupling: daily
Ensemble Method	26 members BGM-Method (13 members on Wednesday and Thursday each)	31 members SV-Method	31 members SV-Method	6 members LAF-Method
Operation	Once a week 34-day Forecast	Once a month 120-day Forecast	210-day Forecast in Feb. and Sep. (complementary, in Mar., Apr. and Oct.)	Twice a month 525-day Forecast
Products and Issue Date	TCC(GPV,MAP) Every Friday	TCC(GPV,MAP) Around 25 in the month	TCC(GPV,MAP) Scheduled after Feb., 2004	TCC (time-sequence figure for Index) Around 15 in the month

The Dynamical Long-Range Forecast System in the Korea Meteorological Administration

Jong-Khun Kim

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1. Introduction

The Korea Meteorological Administration (KMA) has established and operated dynamic ensemble long-range forecast system since 1999. The system is consisted of one-month forecast, seasonal forecast and ENSO prediction. In addition, KMA has developed an inter-annual forecast system in 2001 and applied since 2002. The one-month forecast provides three ten-day forecasts in every ten days with one week in advance, and the seasonal forecast provides outlooks of temperature and precipitation anomaly before each season starts. The 6-month forecast is issued twice a year for temperature and precipitation anomaly over the Korean region. In this report, the dynamic long-range forecast and ENSO prediction system in the KMA will be briefly introduced.

2. Dynamic Long-range Forecast

2.1 Numerical Models

KMA utilizes two global spectral models for the long-range forecast. The Global Data Assimilation and Prediction System (GDAPS) with horizontal resolution of T106 and 21 vertical levels is operating twice a day for the one-month and the seasonal forecast. The Global Climate Prediction System (GCPS) is utilizing for the seasonal forecast. The GCPS has the same dynamics as the GDAPS, but different physics to improve predictability of East

Asian Monsoon and horizontal resolution (T63/L21). The characteristics of the models are summarized in Table 1.

Table 1. Comparison of main physical processes between the operational model and the experimental model

	GDAPS	GCPS
Resolution	T106/L21	T63/L21
Cumulus convection	Kuo	Simplified Arakawa-Schubert,
Land Surface & PBL	SiB, PBL-Yamada-Meller	LSM, Non-local PBL/Vertical diffusion
Radiation	Lacis & Hansen for SW, Roger & Walshaw; and others for LW	2-stream k-distribution radiation scheme

2.2 Operational Procedure

The long-range forecast system in the KMA is based on the lagged averaged forecast (LAF) of 20 ensemble members. The GDAPS is integrated up to 130 days, twice a day at 00 and 12UTC. The ten days ensemble is averaged to produce one-month forecast for three 10-days. The recent 10-days ensemble is averaged to produce seasonal forecast. The rest of each ensemble is used to check the consistency. The GCPS is utilized to produce the seasonal forecast only. The schematic procedure is illustrated in the Fig. 1.

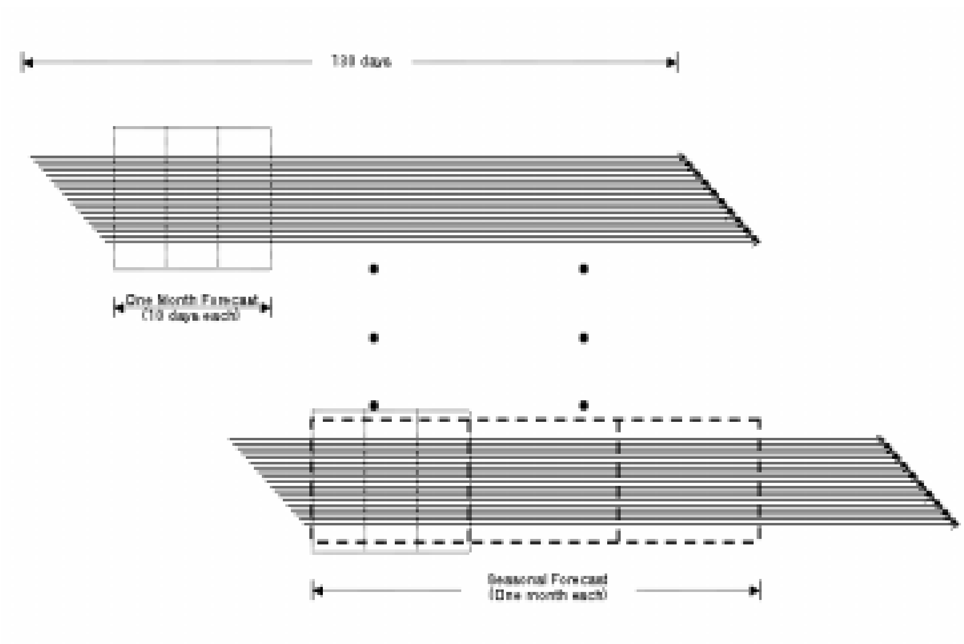


Fig. 1. The schematic procedure of long-range forecast

The anomalies of the ensemble mean are calculated from the model climate of the AMIP2 (1979~1995) simulation. The boundary conditions over the ocean are fixed throughout the integration period with the latest weekly SST anomalies added on the AMIP monthly SST climatology. Soil moisture and snow depth are initialized using climatological values.

2.3 Hindcast and verification

KMA had carried out long-term SMIP-type hindcast experiment for winter and summer period to obtain better model climatology. Table 2 is the details of SMIP-type hindcast experiment. Fig. 2 shows the anomaly correlation change of 500hPa geopotential height during the 7-month forecast period.

Table 2. The details of SMIP-type hindcast experiment

		GDAPS	GCPS
Resolution		T106L21	T63L21
Forecast Period		21 year (1979~1999), 7-month 10 member	
Initial Member	Summer	April 26~30 (00, 12Z), 10 member	
	Winter	October 27~31 (00, 12Z), 10 member	
Initial condition	Atmosphere	NCEP reanalysis-2: U, V, T, Q, GPH	
	Land surface	NCEP reanalysis-2: Ts, soil moisture, snow depth	
Boundary condition		AMIP2 Global SST and Sea ice	

(a) Summer (b) Winter

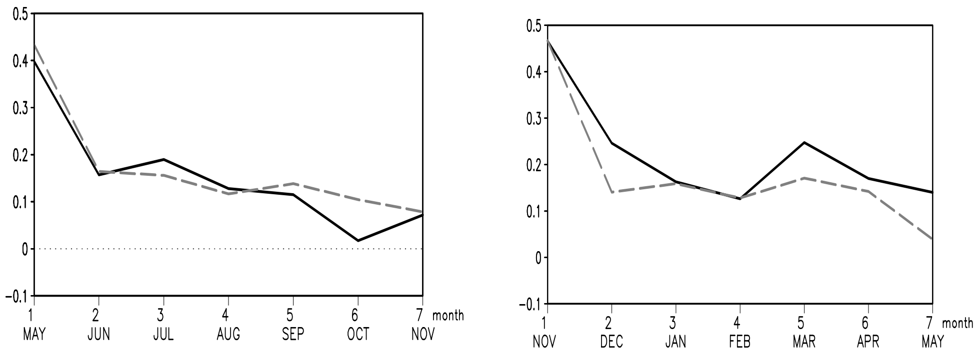


Fig. 2. Anomaly correlation of 500hPa geopotential height over the global domain for the GDAPS (solid line) and the GCPS (dotted line).

2.4 Access and Dissemination

The model results for one-month forecast and seasonal forecast are updated every 10-days and seasonally, respectively and are provided on the KMA Internet home page (http://www.kma.go.kr).

Table 3. Contents of dynamic prediction products at KMA Web site

	One-month forecast	Seasonal forecast
Frequency	3 times a month	4 times a year
Date of update	8th/18th/28th day of each month	Late in Feb./May/Aug./Nov.
Forecast range	1-month, 1-10day, 11-20day, 21-30day	3-month, 1st/2nd/3rd month
Products	850hPa temperature, 500 and 200hPa geopotential height, Sea-level pressure, Precipitation	
Format	Ensemble mean, anomaly, eddy anomaly	

3. ENSO Prediction

KMA has developed an El-Nino/La Nina prediction model using the intermediate-ocean and statistical-atmosphere coupled model. The present ocean model is modified version of the Lamont Model (Zebiak and Cane, 1987). The model predictability was improved by changing the ocean initialization method and by modifying the model dynamics, particularly the parameterization of subsurface temperature, introduction of statistical atmosphere model, and the use of NCEP reanalysis wind stress instead of FSU wind stress.

The hindcast experiments are carried out with the KMA El-Nino model with the two different sets of wind stress data for the period from January 1970 to December 1999. The forecast skill is improved by using NCEP reanalysis wind stress compared to that using FSU wind stress. Fig. 3 shows the anomaly correlation of sea surface temperature for 6-month and 12-month forecast.

A. Correlation between Observation And Forecast SSTA

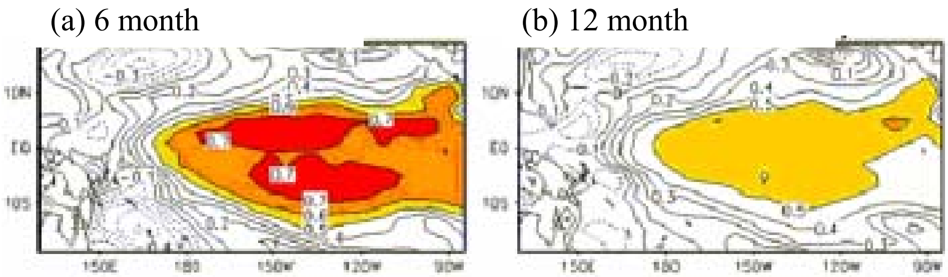


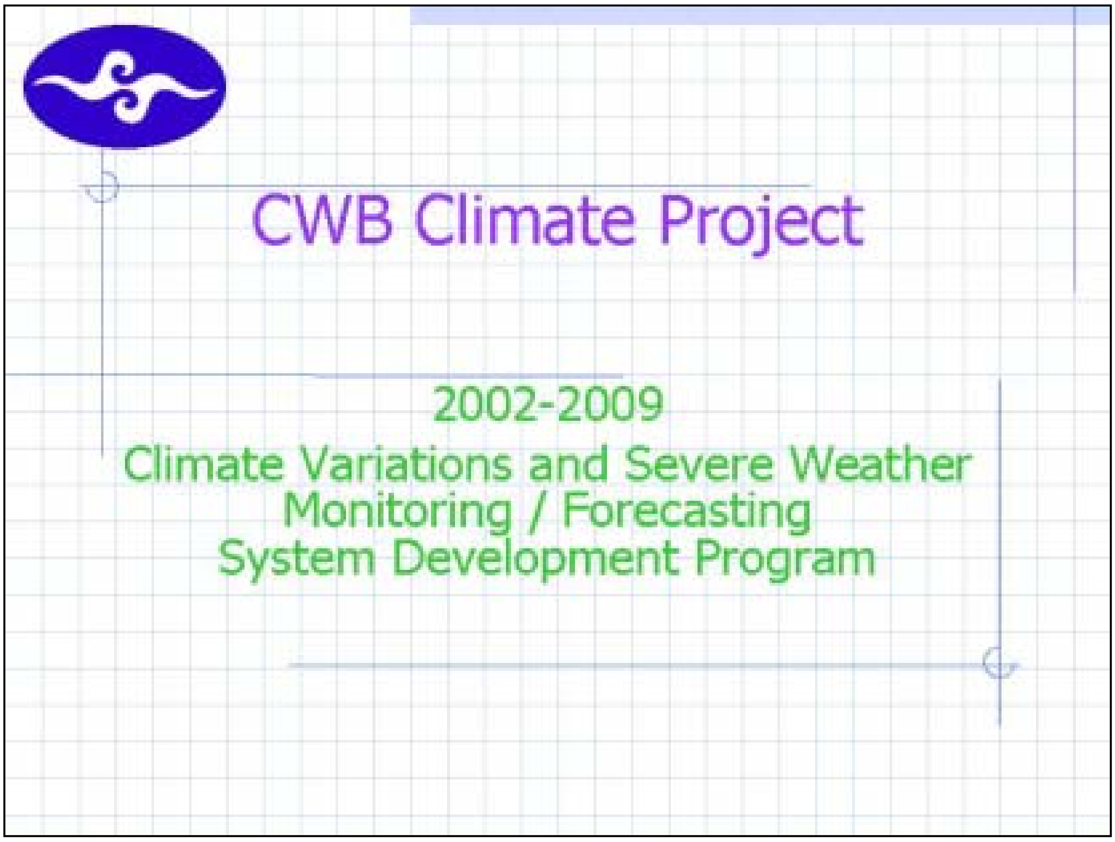
Fig. 3. Correlation between the model forecasted and observed sea surface temperature anomaly for (a) 6 month and (b) 12 month forecast.

The model results for 6-month prediction of tropical SST anomaly, thermocline depth, and indexes of Nino3 and Nino3.4 are updated every month and are provided on the KMA Internet home page (http://www.kma.go.kr).

The Current Status of CWB Climate Model

Jyh-Wen Hwu and Mong-Ming Lu

Research and Development Center
Central Weather Bureau



GOALS

- Build up in-house expertise in climate analysis and predictions
- Construct the infrastructure for climate monitoring, prediction and information dissemination
- Provide scientific basis for climate issues to governmental agencies and decision makers
- Enhance international and academic collaborations

COMPONENTS (research and development)

1. Continuous Improvement of CWB AGCM (2002-2009)
2. Establish the Ocean-Atmosphere Coupled Forecast Systems (2002-2009)
3. Develop Statistical Prediction Models (2002-2009)
4. Develop Statistical (downscaling) Modules for CWB Global Ocean-Atmosphere Coupled Forecast Systems (2005-2009)
5. Develop Statistical Tools for Making Use of the Products of Seasonal Prediction Models – Superensemble Techniques (2003-2009)

Continue

6. Develop Conceptual Models for Southeast Asia Climate Systems (2002-2009)
7. Improve Climate Monitoring and Analysis – Interannual and Intraseasonal Scales (2002-2009)
8. Climate Variations Analysis – Global Change (2002-2009)
9. Climate Variations Analysis – Decadal Scale Climate Variations (2002-2009)

Establish the Ocean-Atmosphere Coupled Forecast Systems (2002-2009)

- Intermediate couple model
- Hybrid couple model
- Full couple model (research)

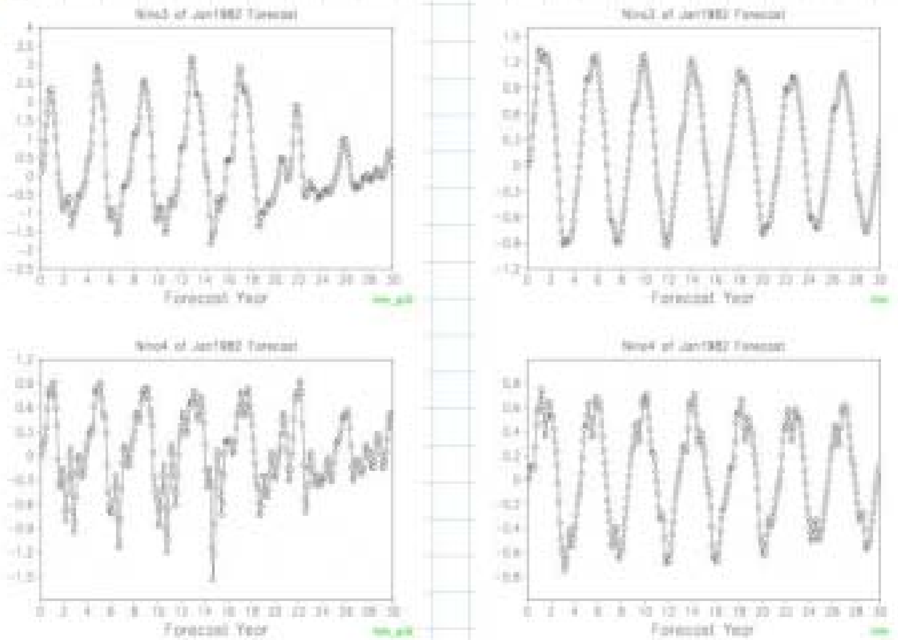
Models

- Atmosphere:
  1. Gill & statistics
  2. CWB GFS
  3. ECHAM
- Ocean:
  1. Cane-Zebiak
  2. Wang et al. (1995), 2 ½ layers
  3. MOM (GFDL)

Intermediate Couple Model

- Kang and Kug (2000)

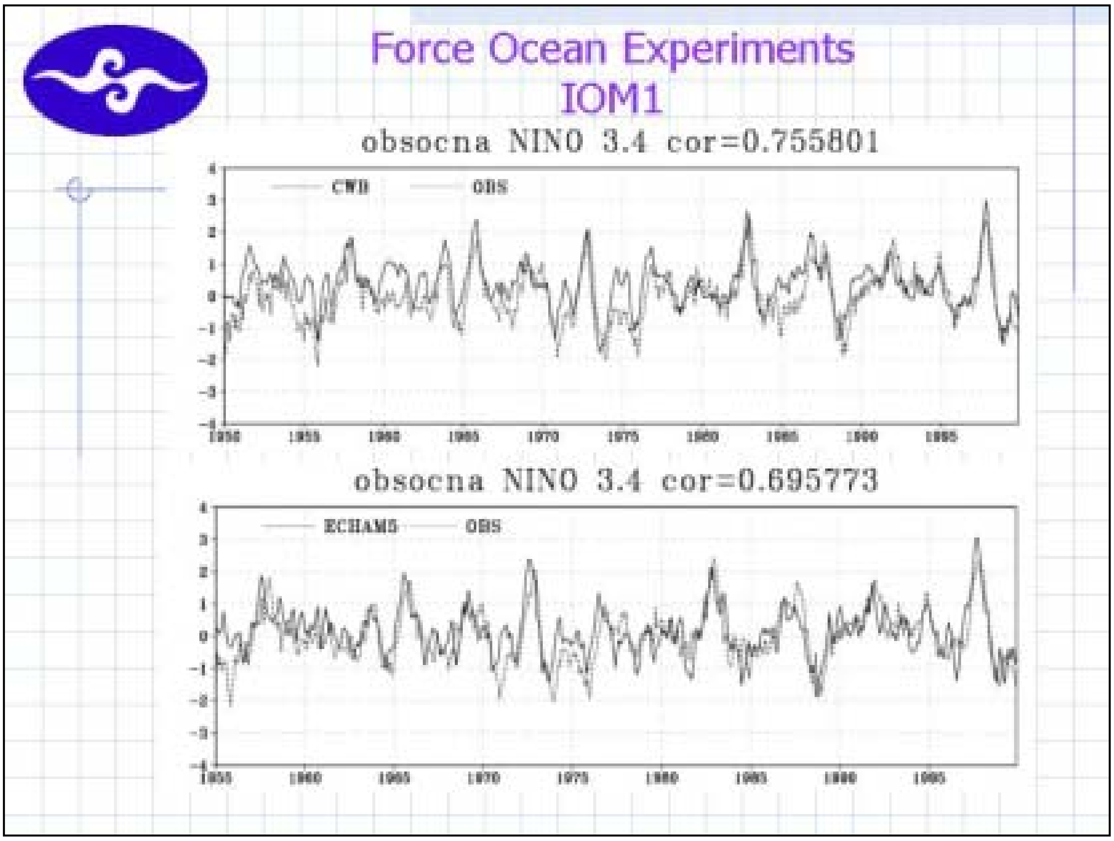
Forecast Experiments

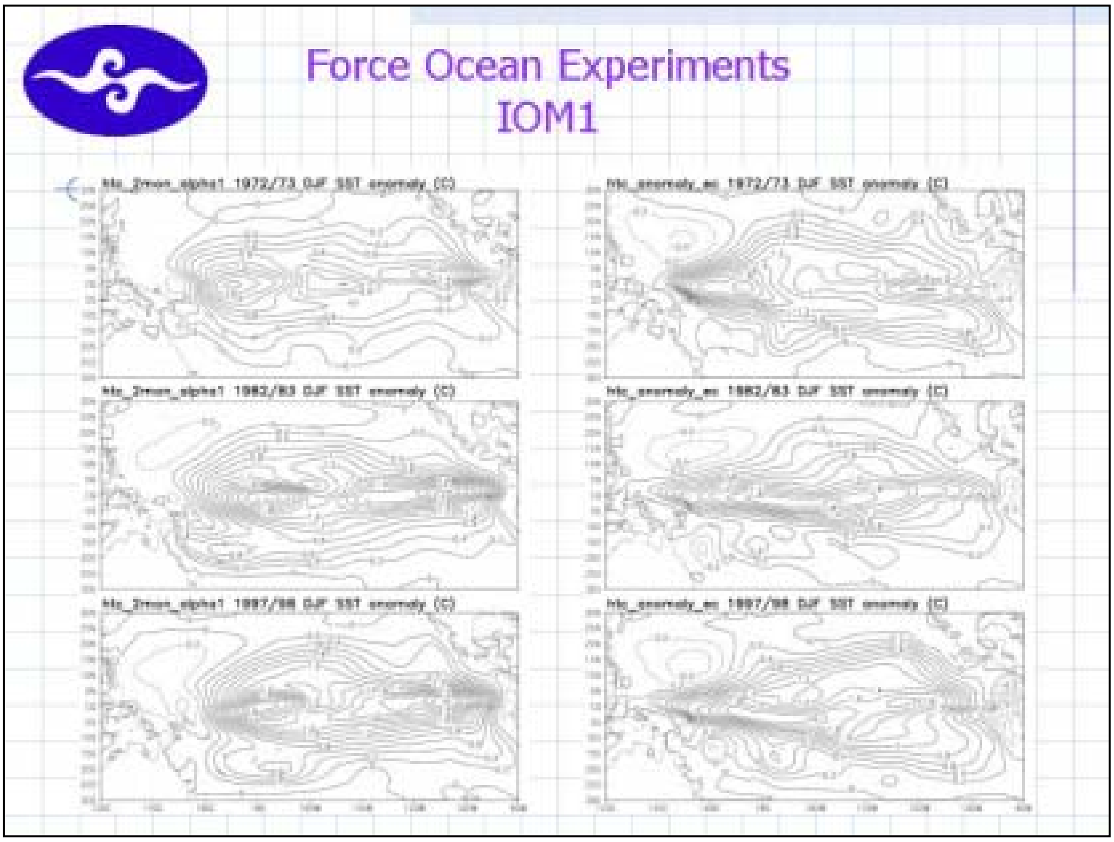


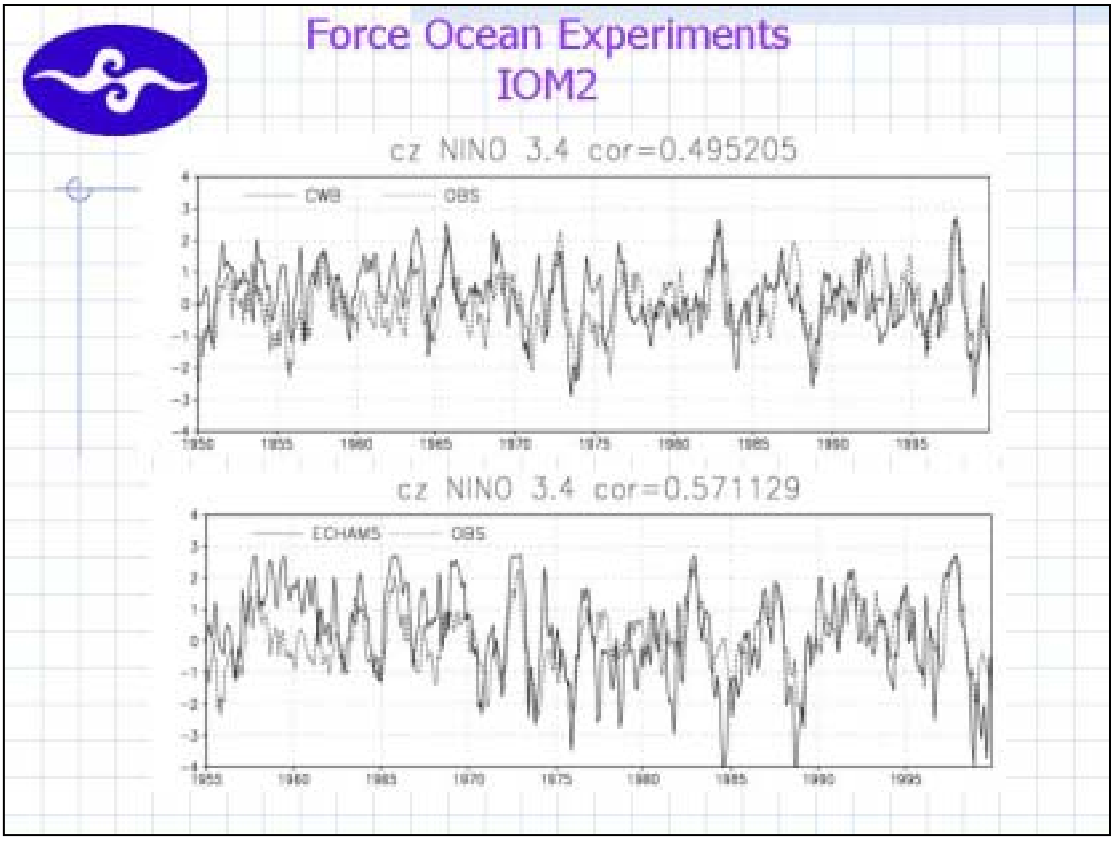
Hybrid Couple Model

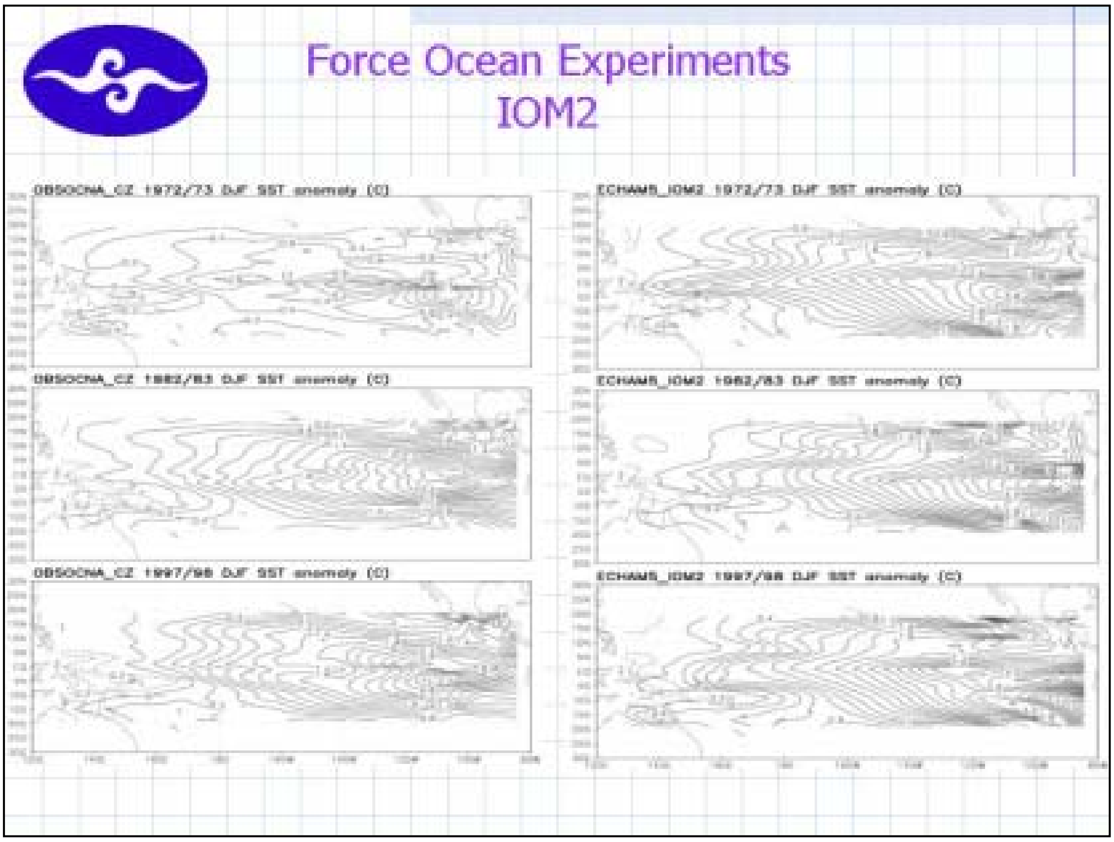
- Two atmosphere GCM: CWB GFS, ECHAM
- Three intermediate ocean Model

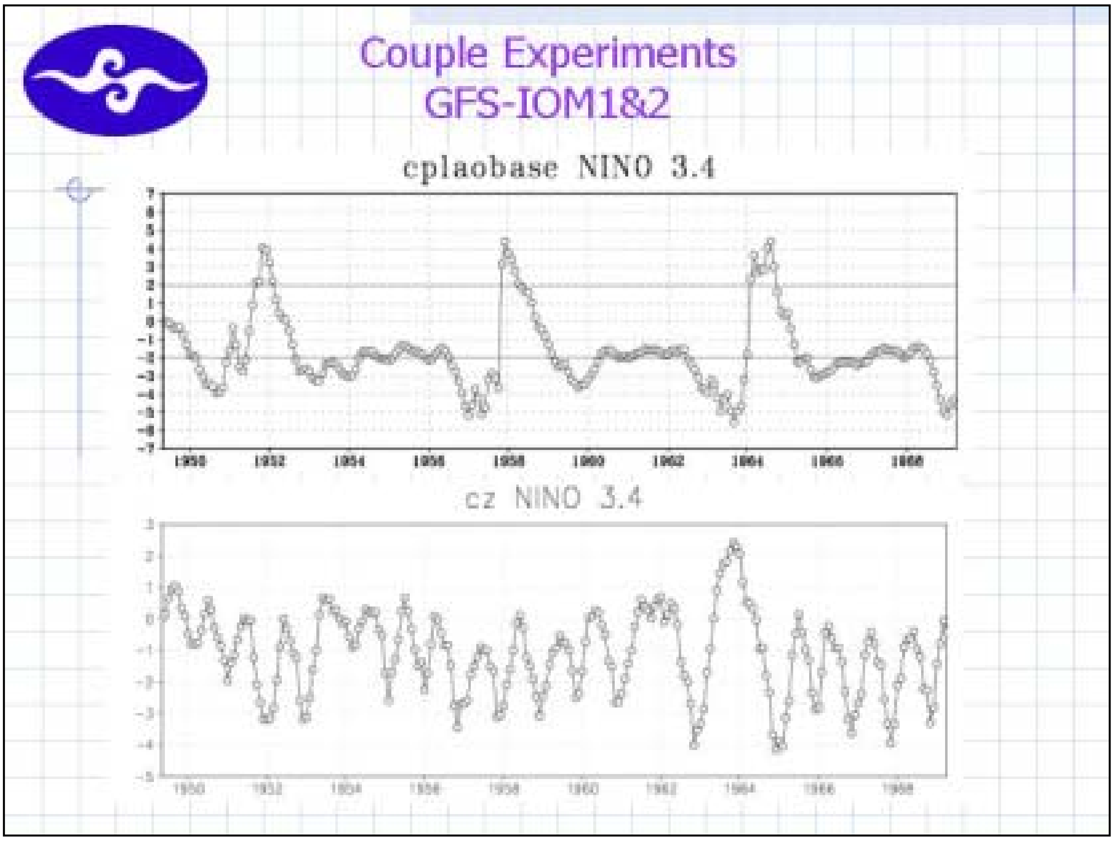
  1. IOM1: Kang and Kug (2000)
  2. IOM2: Chang (1994), Li and Philander (1996)
  3. IOM3: Wang et al. (1995)
- IOM1 and IOM2 are anomalies model

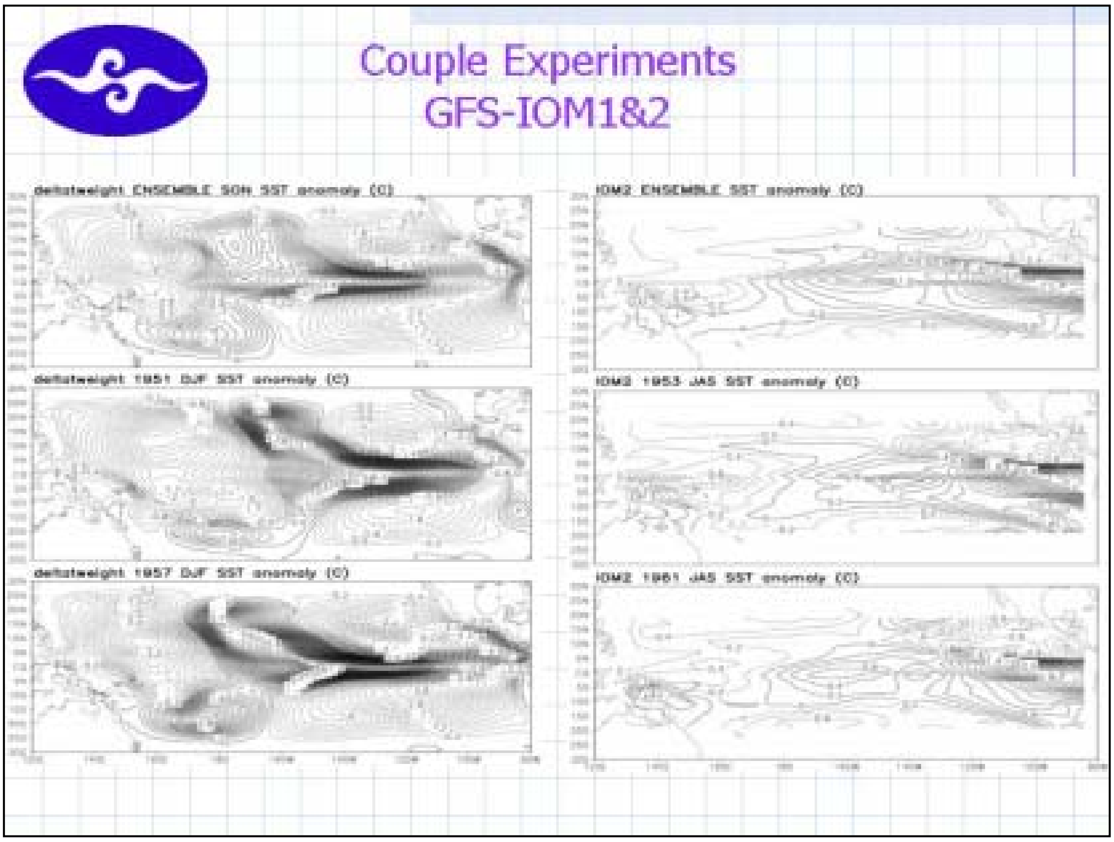

Force Ocean Experiments
IOM1
obsocna NINO 3.4 cor=0.755801
CWB
OBS
obsocna NINO 3.4 cor=0.695773
ECHAM5
OBS

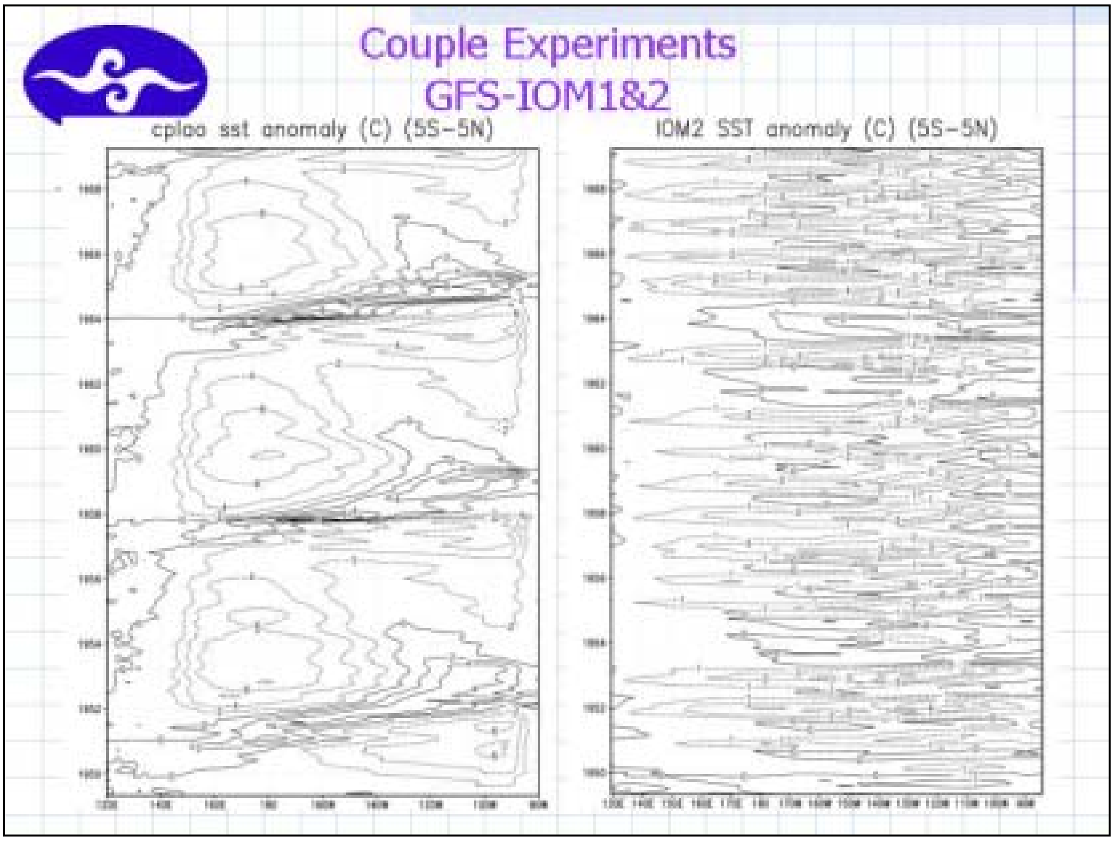

Force Ocean Experiments
IOM1

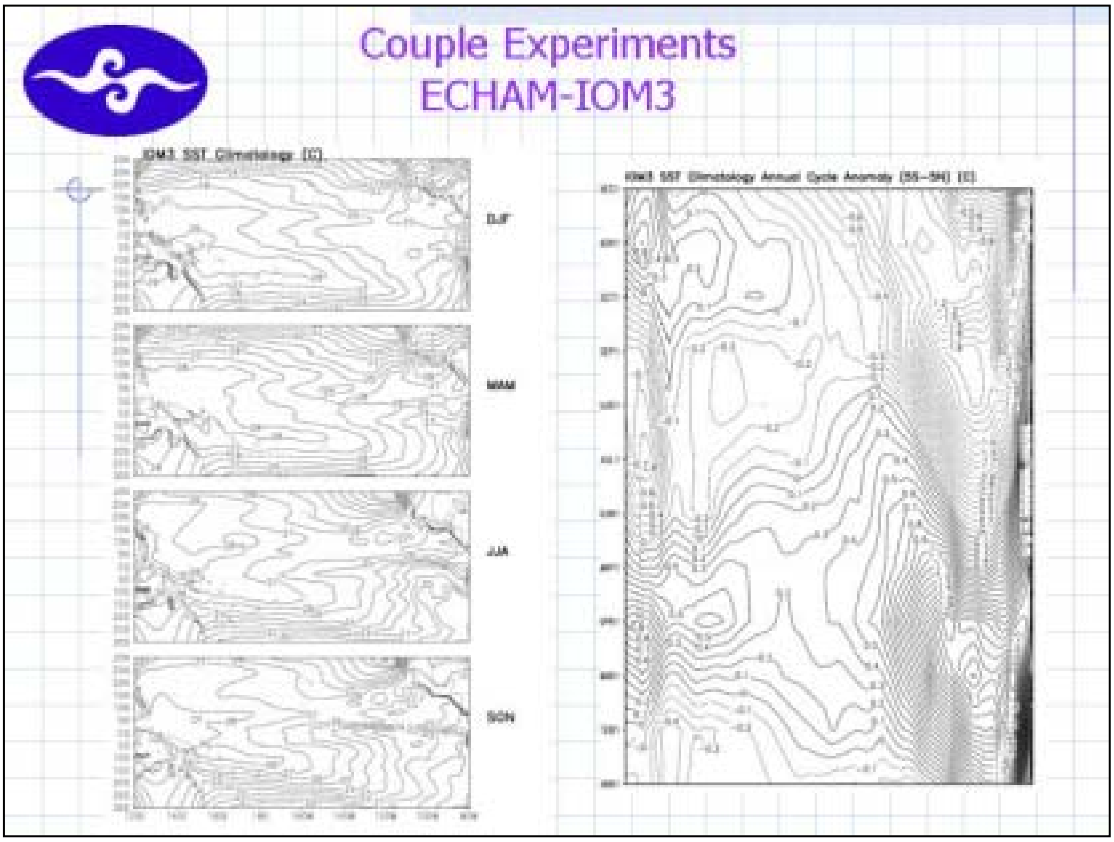

Force Ocean Experiments
IOM2
cz NINO 3.4 cor=0.495205
CWB
OBS
cz NINO 3.4 cor=0.571129
ECHAM5
OBS

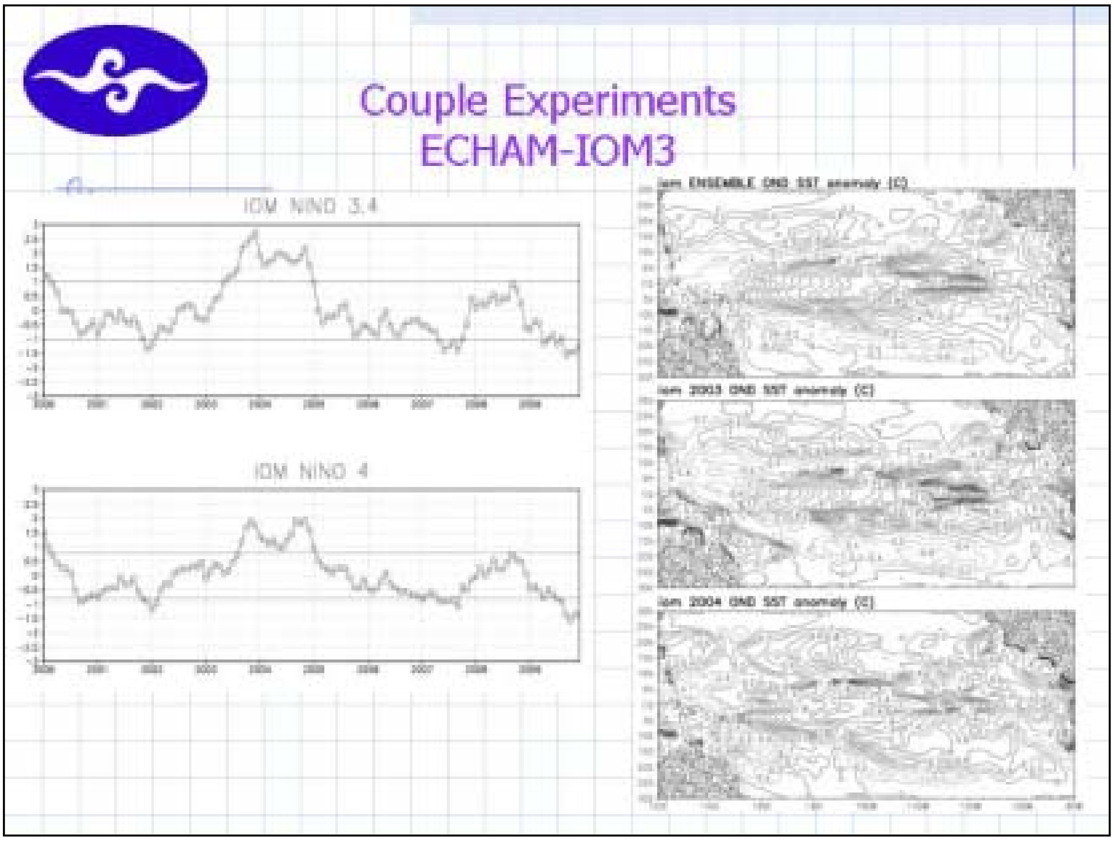

Force Ocean Experiments
IOM2
OBSOCNA_CZ 1972/73 DJF SST anomaly (C)
ECHAM5_IOM2 1972/73 DJF SST anomaly (C)
OBSOCNA_CZ 1982/83 DJF SST anomaly (C)
ECHAM5_IOM2 1982/83 DJF SST anomaly (C)
OBSOCNA_CZ 1997/98 DJF SST anomaly (C)
ECHAM5_IOM2 1997/98 DJF SST anomaly (C)


Couple Experiments
GFS-IOM1&2
cplaobase NINO 3.4
cz NINO 3.4


Couple Experiments
GFS-IOM1&2


Couple Experiments
GFS-IOM1&2
cplao sst anomaly (C) (5S–5N)
IOM2 SST anomaly (C) (5S–5N)


Couple Experiments
ECHAM-IOM3
IOM3 SST Climatology (C)
DJF
MAM
JJA
SON
IOM3 SST Climatology Annual Cycle Anomaly (5S–5N) (C)


Couple Experiments
ECHAM-IOM3
IOM NINO 3.4
IOM NINO 4
iom ENSEMBLE OND SST anomaly (C)
iom 2003 OND SST anomaly (C)
iom 2004 OND SST anomaly (C)

Short Range Climate Forecasting at the Hong Kong Observatory and Application of APCN and Other Web Site Products

Edwin W L Ginn and Karen K Y Shum

Hong Kong Observatory

1. Introduction

The Hong Kong Observatory (HKO) carried out a pilot study in 2001 to 2002 to examine the feasibility of issuing seasonal forecasts for Hong Kong (Chang and Yeung 2003). The study focused on investigating the predictability of the number of tropical cyclones affecting Hong Kong in a year, the annual rainfall in Hong Kong and the time of onset of the typhoon season in Hong Kong, and developing the methodology for forecasting these parameters. The major climate factor influencing these forecast parameters was found to be ENSO. For the annual rainfall in Hong Kong, the strength of monsoon in the preceding winter was also found to be an important factor. Whereas for the time of onset of the typhoon season, the Quasi-Biennial Oscillation also has some influence. Statistical methods for producing probabilistic forecasts on the number of tropical cyclones affecting Hong Kong in a year and the annual rainfall in Hong Kong were developed. Experimental forecasts were issued to the public for 2001 and 2002 in March of each year and verified at year's end. The forecast methods were found to possess skill. Regular forecast is issued to the public starting in 2003 (see web page at http://www.hko.gov.hk/wxinfo/season/season.htm given in Fig 1).

2003 Short Range Climate Forecast
(Issued on 21 March 2003)

	Forecast for 2003		
Annual rainfall in Hong Kong	20% chance near-normal	80% chance above normal	
Number of tropical cyclones affecting Hong Kong	20% chance 4 or fewer	50% chance 5 to 6	30% chance 7 or more

Fig 1 2003 Short Range Climate Forecast issued by HKO.

As part of the pilot study, the HKO with the help of the Experimental Climate Prediction Center (ECPC) of Scripps Institution of Oceanography adapted in 2001 the Regional Spectral Model of the National Centers for Environmental Prediction (NCEP) with a long-term view of complementing the statistical forecasts and to serve as a vehicle for understanding the response of climate in this part of the world to different climate factors. The Hong Kong Observatory Regional Climate Model (HKORCM) produces forecasts for 12 weeks ahead using boundary conditions by ECPC from the NCEP Global Spectral Model output. The HKORCM inner domain has 49 x 50 grid points on Hong Kong. The horizontal resolution is 15 km while there are 18 levels in the vertical. A description of the model is given in Hui et al. 2001.

2. Initial application of HKORCM

In 2002, experiments in dynamical downscaling of predicting May and June precipitation in Hong Kong were carried out using ensembles generated from HKORCM using the Lagged Average Forecasting (LAF) method of Dalchér et al. (1988). Preliminary results show that the ensemble method possesses skill in forecasting summer precipitation in Hong Kong (Hui et al. 2002). Another set of experiments would shortly be conducted using the LAF method to generate temperature forecasts for the winter in Hong Kong.

3. Seasonal forecasting using a multi-model ensemble approach

HKO began in 2003 to develop seasonal precipitation forecasts using the multi-model ensemble technique. The multi-model ensemble approach was chosen as it is considered to be one of the best forecast methodologies under resource constraints (Krishnamurti et al. 2000, Mylne 2000). In general, global climate models and regional climate models complement each other as global climate models predict large-scale climate anomalies while regional climate models depict finer details.

As a first attempt, a qualitative multi-model ensemble approach is employed in formulating a seasonal precipitation forecast advisory for July-August-September (JAS) 2003 based on dynamical models for internal reference (HKO 2003). Forecast charts from the HKORCM and those of APCN, ECMWF, ECPC and UKMO available on the Internet were used. For APCN and ECMWF, the ensemble forecast charts were used. As Hong Kong is essential a point on the map, at this stage, the forecast for south China was considered to avoid possible large errors due to small displacement of rain areas.

Direct model outputs from the HKORCM carry systematic bias. In order to remove the model systematic error, the anomaly forecast is computed by subtracting the model climate from the direct model output. It should be noted that only 4 years of hindcasts from 1998 to 2001 are available for compilation of the JAS model climate, which may not be a true representation of the long-term climate.

The descriptive JAS precipitation anomaly forecasts for south China are made using the forecast charts from the above centres (Table 1). As the APCN precipitation anomaly forecasts covers only the months of June-July-August (JJA), only the forecasts for July and August of this model are included in the discussion.

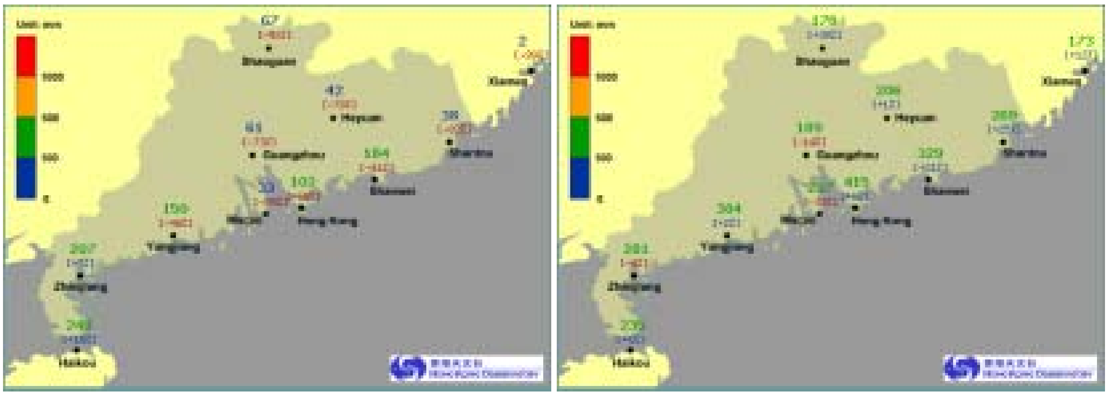
Table 1 JAS precipitation forecast based on dynamical models

Centres/Models	Forecast period	Descriptive precipitation forecast
HKORCM	JAS	slightly above normal in most parts of south China; slightly below normal in the coastal area of southeast China
ECMWF	JAS	+ve anomaly over the coastal areas of south China
UKMO	JAS	60-80% chance of above normal in south China
ECPC	JAS	Normal to below over the southern part of south China; Normal to above over the northern part of south China
APCN	J	Near normal (70-120% of climate normal) in south China; Small area of +ve anomaly near Hong Kong
	A	Near normal in south China

There is no consensus amongst the forecasts from APCN, ECMWF, ECPC, UKMO and HKO. While the chance of below normal precipitation cannot be ruled out, the majority of the models pointed to normal or above normal precipitation in south China.

Both the HKORCM and the ECPC global model show significant spatial variations in the precipitation forecast for south China. These forecasts, to a certain extent, reflect the stochastic nature of precipitation in JAS 2003 in the area.

In July 2003, south China was under the influence of a prolonged dry spell. The observed precipitation amounts were generally well below the climate normal (Fig 2a). In August 2003, some stations in the areas received more than the usual precipitation (Fig 2b). The full verification of the JAS forecasts will be conducted once the observations for September 2003 are available.



(a) Rainfall distribution in July 2003 (b) Rainfall distribution in August 2003

Fig 2 Observed monthly precipitation in mm and anomaly [in %] over south China. (Data source: National Meteorological Centre of the China Meteorological Administration and the Macao Meteorological and Geophysical Bureau)

It is encouraging to note that the HKORCM correctly predicted the spatial pattern of precipitation over south China in July and August. For the APCN Multi-Model Ensemble (MME) forecast, the July precipitation forecast was within one class for most of south China, i.e., the forecast was for ‘normal’ but the observed precipitation was ‘below normal’ while the August forecast is verified correct against the ‘normal’ precipitation over south China.

4. Feedback on APCN products

Products from the APCN web site are very useful in short range climate forecasting at the HKO. The July and August forecasts have been usefully employed in the HKO JAS precipitation advisory. Apart from the scheduled forecasts for December-January-February and JJA, it would be beneficial to APCN Members if precipitation anomaly forecasts for other months/seasons can be made available in the future. It is also desirable for APCN to increase the frequency of issuance of the forecasts as the duration of the rainy season varies from place to place. For example, the rainy season in Hong Kong spans April to September, during which more than 80% of the annual rainfall is received climatologically.

At present, the forecast products available on the APCN web site are in graphical form. If digital data is available to users, quantitative forecasts can then be made. Validation of the forecasts could also be carried out objectively.

5. Conclusion

Affordable and reliable computing systems have turned a new leaf in short range climate forecasting. Computational intensive global short range climate forecasts, previously beyond the reach of smaller meteorological services, are now available through fruitful international collaborations and from major meteorological centres. A notable success is APCN. Useful products are made available through a user-friendly interface on the APCN web site. The web site promulgates new ideas and helps to keep its Members abreast of the latest development in the field of dynamical short range climate forecasting. The HKO seasonal precipitation anomaly forecast is an example of utilizing the readily accessible seasonal forecast resources from the APCN web site and other major centres.

Acknowledgements. The HKORCM was kindly made available by ECPC, as were the boundary and initial conditions used to drive the model. This is gratefully acknowledged. We would like to express our thanks to APCN, ECMWF, ECPC and UKMO for their invaluable online seasonal forecast products.

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Report from Malaysia

Ling Leong Kwok

Malaysian Meteorological Service

Forecasts Issued

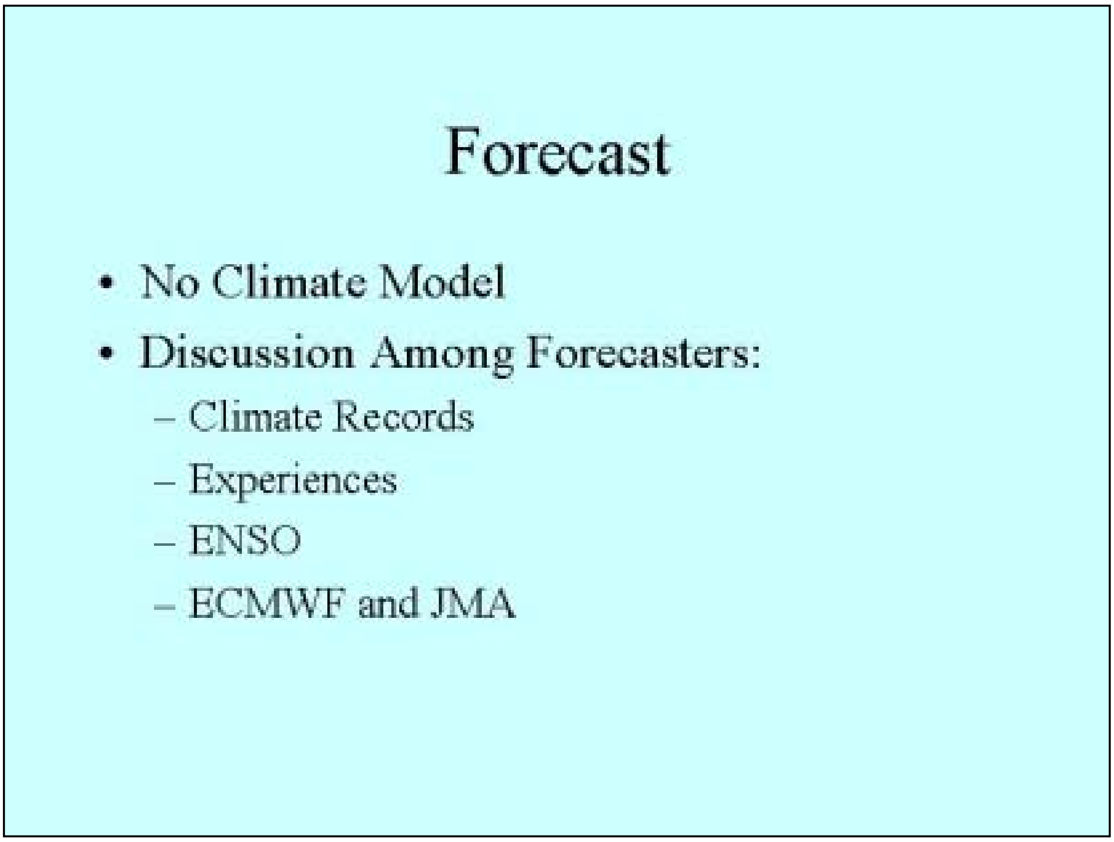
- Southwest Monsoon
- Northeast Monsoon
- The 2 Inter-Monsoon
- Monthly Weather Forecast
- Forecast for other time periods

Forecast Contents

- Rainfall Amount
  - Above Normal
  - Normal
  - Below Normal
- Variation of temperatures are not very significant

Lead Time

- Seasonal Forecasts
  - 1 to 3 months ahead
- Monthly Weather Forecast
  - A week ahead


Forecast
• No Climate Model
• Discussion Among Forecasters:
– Climate Records
– Experiences
– ENSO
– ECMWF and JMA

Season/Climate Prediction in Indonesia

Petrus Siregar

Bureau of Meteorological and Geophysical Agency

Indonsia have 100 national season prediction region, there are 63 in Java, 14 in Sumatera, 11 in Bali and Nusa Tenggara ,than 2 – 3 in Kalimantan, Maluku, Sulawesi and Irian Jaya.

Beurau Meteorological and Geophysical Agency (BMG) of republic of Indonesia have two seasons prediction , Monthly rain prediction and monthly rain evaluation. The two seasons prediction that are the begenning dry season and the beginning rainy season.

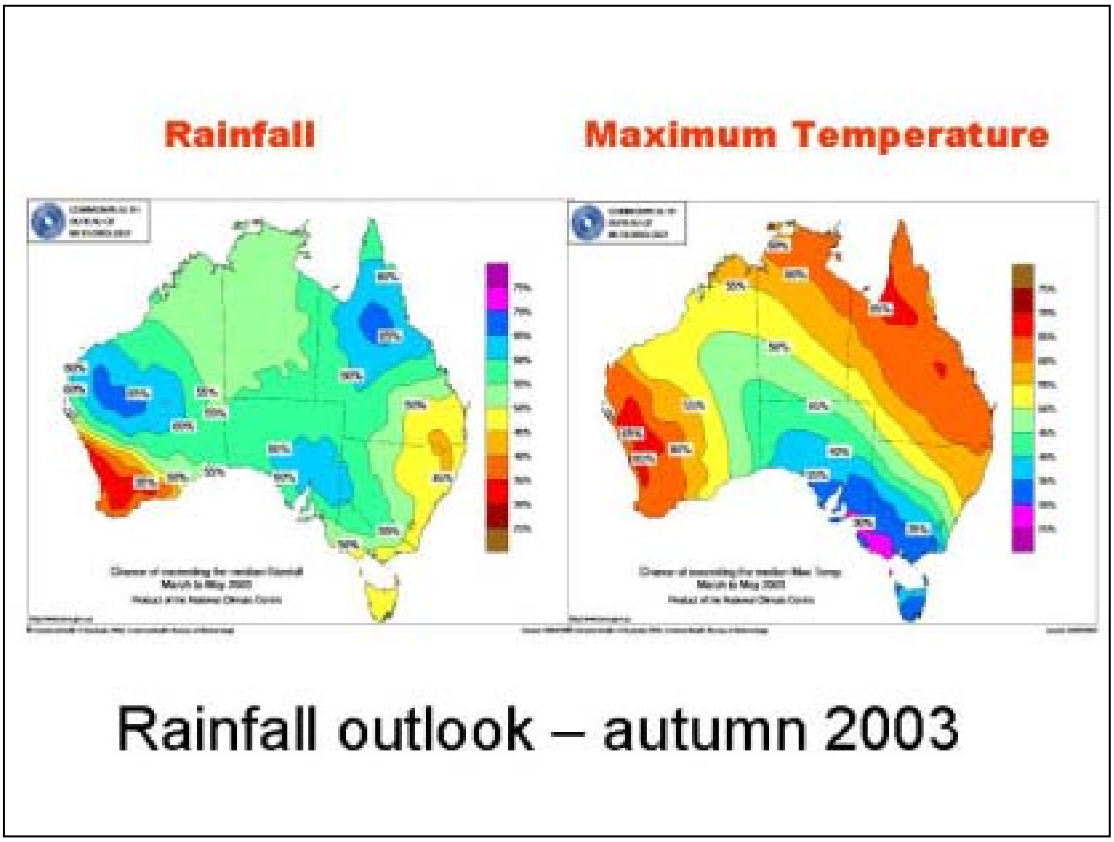
Indonesia uses the Southern Oscilation Index (SOI) and Statistical Model for make the prediction. In general Juni – October is dry season and January – May and November – December is rainy season. January and December are the higher rain, Augustus and September are the lowest.

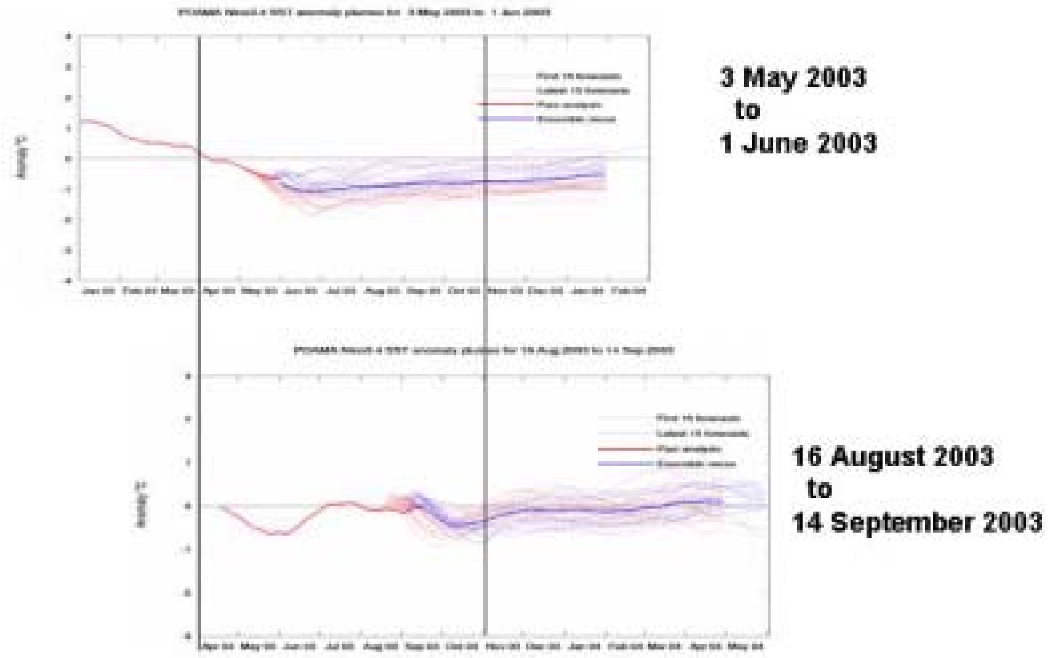
Climatologist always finds new climate prediction system to up grade the quality of prediction. BMG togethter with another institution studies to develop the prediction uses Emphirical Orthogonal Function (EOF) from Hindia Ocean sea surface temprature analysis (SST analysis) and Pacifik ocean as a predictor.

Implementing a Model-Based Seasonal Forecasting System in Australia

Michael Coughlan

National Climate Centre
Bureau of Meteorology



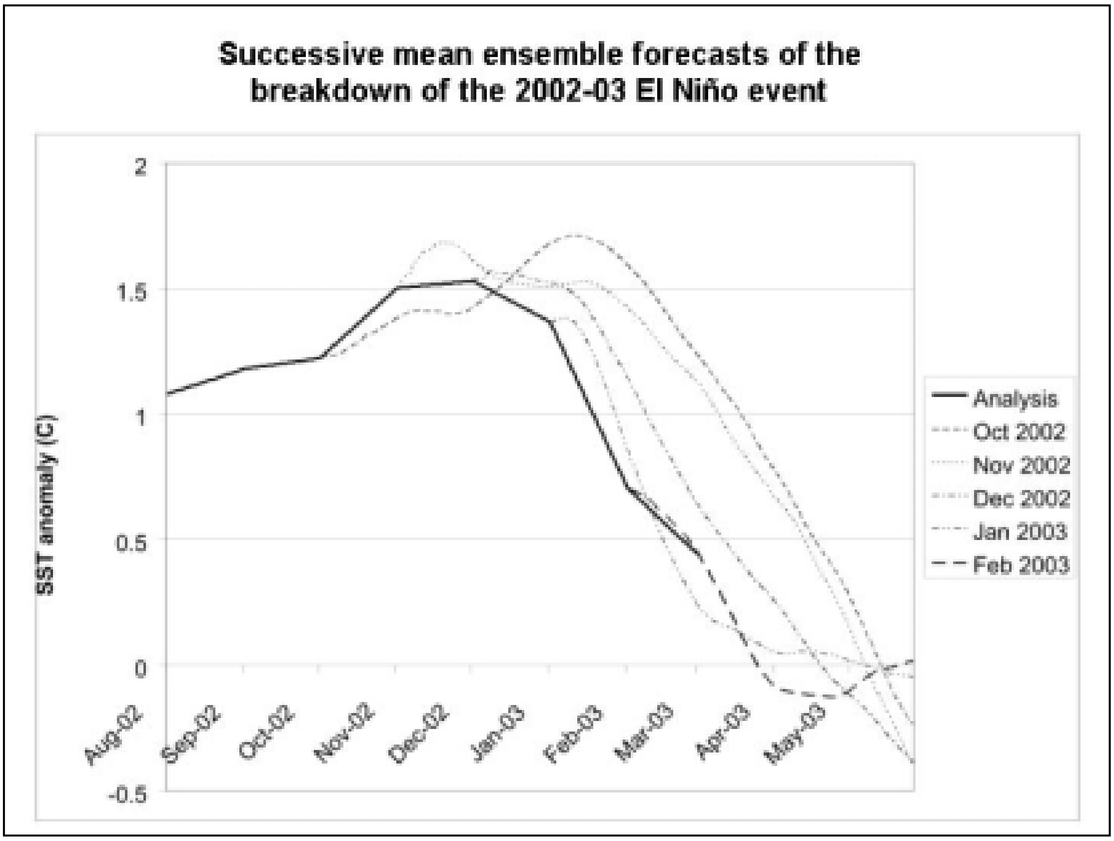


POAMA Niño 3.4 SST anomaly forecast plumes

Monthly average Niño 3 forecast SST anomaly calculated from most recent 30 forecast ensembles. Note that there must be at least 15 forecasts in a month for an average to be included here, and each of those forecasts must contain at least 15 days within a month.

Niño 3 <= -0.8	-0.8 <= Niño 3 < -0.4	-0.4 <= Niño 3 < 0.4	0.4 <= Niño 3 < 0.8	Niño 3 >= 0.8

DATE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20030901	-0.06	-0.05	-0.09	-0.08	-	-	-	-	-0.53	-0.31	-0.19	-0.10
20030831	-0.07	-0.07	-0.12	-0.09	-	-	-	-0.29	-0.54	-0.31	-0.20	-0.11
20030830	-0.07	-0.06	-0.12	-0.11	-	-	-	-0.31	-0.55	-0.30	-0.18	-0.10
20030829	-0.11	-0.10	-0.16	-0.12	-	-	-	-0.32	-0.57	-0.32	-0.21	-0.13
20030828	-0.12	-0.11	-0.17	-0.12	-	-	-	-0.34	-0.59	-0.33	-0.20	-0.13
20030827	-0.14	-0.13	-0.19	-0.12	-	-	-	-0.34	-0.60	-0.34	-0.22	-0.14
20030826	-0.12	-0.12	-0.17	-0.12	-	-	-	-0.33	-0.60	-0.34	-0.21	-0.13
20030825	-0.13	-0.13	-0.19	-0.12	-	-	-	-0.33	-0.62	-0.36	-0.22	-0.14
20030824	-0.15	-0.13	-0.19	-0.12	-	-	-	-0.31	-0.61	-0.37	-0.24	-0.15
20030823	-0.16	-0.14	-0.20	-0.12	-	-	-	-0.33	-0.62	-0.36	-0.24	-0.16
20030822	-0.15	-0.13	-0.19	-0.13	-	-	-	-0.33	-0.63	-0.36	-0.23	-0.16
20030821	-0.15	-0.12	-0.18	-0.12	-	-	-	-0.33	-0.64	-0.35	-0.23	-0.15
20030820	-0.16	-0.11	-0.17	-0.11	-	-	-	-0.34	-0.66	-0.35	-0.23	-0.16
20030819	-0.16	-0.12	-0.18	-0.12	-	-	-	-0.34	-0.67	-0.36	-0.24	-0.16
20030818	-0.17	-0.13	-0.20	-0.15	-	-	-	-0.34	-0.67	-0.37	-0.25	-0.16
20030817	-0.18	-0.16	-0.22	-0.17	-	-	-	-0.36	-0.69	-0.39	-0.27	-0.18
20030816	-0.18	-0.14	-0.20	-0.17	-	-	-	-0.37	-0.69	-0.36	-0.27	-0.17
20030815	-0.18	-0.15	-0.20	-0.15	-	-	-	-0.39	-0.68	-0.37	-0.27	-0.17
20030814	-0.19	-0.16	-0.20	-	-	-	-	-0.41	-0.70	-0.37	-0.28	-0.18
20030813	-0.19	-0.17	-0.19	-	-	-	-	-0.43	-0.70	-0.37	-0.28	-0.18
20030812	-0.18	-0.16	-0.19	-	-	-	-	-0.44	-0.69	-0.35	-0.26	-0.16
20030811	-0.19	-0.16	-0.20	-	-	-	-	-0.46	-0.70	-0.34	-0.25	-0.16



Verification

- The Commission for Basic Systems (CBS) of the World Meteorological Organisation (WMO) noted that there has been considerable progress in the development of long-range forecasting activities but that no comprehensive documentation of skill levels, measured according to a common standard, was available.

Verification

- There was agreement on the need for a more coherent approach to verification of long-range forecasts. The Commission agreed that its role was to develop procedures for the exchange of verification results, with a particular focus on the practical details of producing and exchanging appropriate verification scores.

WMO/CBS Expert team on

Verification System on Long-Range Forecasts

Terms of reference:

a) **Coordinate the provision of long-range forecast verification scores and related information to NMHSs and RCCs, real-time monitoring of forecasts and relevant exchange between participating centres and institutes**

b) **Encourage and monitor feed back from NMHSs and RCCs on the usefulness of verification information provided by producing centres under the scheme**

c) **Review the effectiveness of the verification scheme in assisting NMHSs and RCCs to use the global-scale products to provide end-user services**

d) **Contribute to further development of the activities of lead centre web sites with links to producing centres, and development and provision of relevant software to NMHSs and RCCs as capacity building measures to access information from producing centres and producing user friendly verification information.**

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Standardised Verification System (SVS) for Long-Range Forecasts (LRF)

- The Expert Team has produced a document* that presents the detailed specifications for the development of a Standardised Verification System (SVS) for Long-Range Forecasts (LRF) within the framework of a WMO exchange of forecast verification scores.

New Attachment II-9 to the
Manual on the GDPS (WMO-No. 485), Volume I

Standardised Verification System (SVS)
for
Long-Range Forecasts (LRF)

http://www.wmo.ch/web/www/DPS/LRF-verification-systems.html

VERIFICATION SYSTEMS FOR
LONG-RANGE FORECASTS -
REVISED EXPERIMENTAL SCORES TO BE
EXCHANGED

Formulation

The SVS is formulated in four parts:

1. Diagnostics. Diagnostic information required incorporates derived diagnostic measures and contingency tables. Three diagnostic measures are included and are closely defined. Estimates of the statistical significance of the scores achieved are also required. Additional diagnostic measures are suggested but are not incorporated into the Core SVS as yet. Use of the additional diagnostics is optional.

2. Parameters. Key variables and regions are proposed. However producers are not limited to these key parameters, thus all producers can contribute regardless of the structure of individual forecast systems. The parameters to be verified are defined on three levels:
   Level 1: Diagnostic measures aggregated over regions
   Level 2: Diagnostic measures evaluated at individual grid-points
   Level 3: Contingency tables provided for individual grid-points.

VERIFICATION SYSTEMS FOR
LONG-RANGE FORECASTS -
REVISED EXPERIMENTAL SCORES TO BE EXCHANGED

The SVS makes provision for a staged implementation of the three levels of information and the inclusion estimates of skill significance over a two year period.

3. **Verification data sets.** Key data sets of observations against which forecasts may be verified are proposed.

4. **System details.** Details of forecast systems employed.

Verification: Lead Centre Activity

- **A standard suite of skill scores (e.g., RMSS, ROCS) and standard verifying data will be used to assess outlooks issued by NMHS and select research establishments.**
- **Whilst one model cannot generally be directly compared with another, due to hindcast periods (some periods may contain more or less El Niño influences, for instance), spatial resolution or model internal variability, it will provide users with a guide as to the successful strategies employed by the different models**
- **The designated lead centres (Canadian Meteorological Centre and the Australian Bureau of Meteorology) will assist by establishing a web portal. NMHS can use this portal to obtain assistance with the LRFVS, such as: a standard suite of computer code for verification, data against which their models should be assessed, guidelines and advice on how to successfully assess their models within the LRFVS program, and eventually, a standard display system for models results.**

Verification: Lead Centre Activity

cont.

- **The lead centres will be meeting in Montreal Dec 1-5 to commence construction of the lead centre LRFVS portal, with the intention of an initial site being established early in 2004**
- **The assessments will only be available to NMHS, and in the first instance, may be restricted to those contributing to the project**
- **The LRFVS should progress the science and operational capabilities of climate models, both dynamical and statistical, by showing us where and how models achieve successful seasonal and longer range outlooks**

Overview of Coupled Modeling at BMRC: Summary and Future Plans

Oscar Alves

Bureau of Meteorology Research Centre

1. Introduction

The Bureau of Meteorology Research Centre (BMRC) has a project dedicated to the development of a coupled ocean-atmosphere model for seasonal prediction and climate variability studies. The first version of the coupled model called POAMA-1 (Predictive Ocean Atmosphere Model for Australia version 1) was developed jointly by BMRC and CSRIO Marine Research (CMR, Hobart). POAMA-1 has been run in real time by the operational branch of the Bureau of Meteorology since 1st October 2002. Experimental products are available on the POAMA web site:

http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA/index.htm.

POAMA products are issued to the public via the Bureau of Meteorology's National Climate Centre (NCC). The NCC also has a project aimed at developing operational POAMA products. Details of the POAMA-1 system are summarised below.

The next version of the coupled model prediction system, POAMA-2, is currently being developed and is likely to become operational in the first half of 2004. Forecasts from the POAMA-2 system will be provided to the APCN. Plans for this system as well as longer term plans are also discussed below.

In support of dynamical seasonal prediction, BMRC is also conducting several research projects using the POAMA coupled model to understand model performance and to investigate different aspects of climate variability. These are also summarised below.

2. Present system POAMA-1

See APCN presentation by Alves for full details

Focus: Prediction of tropical Pacific SST anomalies associated with ENSO

Atmosphere model: BMRC Atmosphere Model (BAM v3.0d), unified climate/NWP model. T47L17 resolution.

Ocean Model: Australian Community Ocean Model (ACOM2) based on GFDL MOM2.

Ocean Data Assimilation: Optimum interpolation using all available sub-surface ocean observations with dynamical adjustment of currents

Atmospheric initialisation: Bureau of Meteorology operational NWP analysis

Operational forecasts: 9-month forecasts produced each day within 2 days of real-time using latest ocean/atmosphere initial states

Operational implementation: 1st October 2002

Hind-cast set: 1 per month 1987-2001

Web site: http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA/index.htm

3. New system: POAMA-2

Focus: Prediction of tropical Pacific and Indian Ocean SSTs

Prediction of global variables such as rainfall and temperature

Provision of boundary conditions for regional models and for statistical downscaling

Extended-range to intra-seasonal prediction (eg MJO prediction)

Atmosphere model: BAM 4.0. T47L17 ? resolution. New land/surface scheme, new gravity wave drag scheme, improved convection parametrization.

Ocean Model: ACOM2

Ocean Data Assimilation: OI with current adjustment. Improved consistency between SST and sub-surface temperature.

Operational forecasts: 9-month forecasts produced each day within 2 days of real-time using latest ocean/atmosphere initial states. Intra-seasonal forecasts e.g. MJO.

Operational implementation: First half of 2004

Hind-cast set: At least 5 per month 1982-2003 out to 9 months lead time for seasonal prediction.

4. Using the POAMA coupled model to understand Climate Variability

A long integration (>100 years) of the POAMA-1 model has been performed. This is being used to understand the model characteristics and for various climate variability investigations. Topics being investigated include:

- Analysis of coupled model mean state, seasonal cycle and interannual variability.
- Representation of ENSO mode in coupled models.
- Role of air/sea coupling on the MJO.
- Role of the MJO in ENSO prediction.
- ENSO predictability.
- Relationship between ENSO and Indian Ocean variability.
- Rainfall predictability.
- Statistical/dynamical downscaling

5. Future plans: POAMA-3 and beyond

The continual improvement of coupled models for seasonal prediction remains a key priority for BMRC. There are several developments in progress that will significantly increase the quality of future versions of the POAMA system. These include:

- Continual development of the atmosphere model BAM, including significant increases in resolution.
- A new ocean model based on MOM4 with better physics and increased resolution.
- The development of an advanced data assimilation scheme based on the Ensemble Kalman Filter approach.
- A land surface initialisation scheme.
- Statistical/dynamical downscaling of global coupled model output.
- Research on aspects of climate variability from intra-seasonal to multi-decade using the coupled model as the main tool.

Climate Prediction: New Zealand and the Southwest Pacific

Jim Renwick

National Institute of Water & Atmospheric Research

1. Introduction

This presentation outlines the operational seasonal forecasting practices in New Zealand, and those facilitated from New Zealand, for the southwest Pacific. It describes the overall methodology and aspects of the dynamical and statistical model guidance used. Forecasts for New Zealand and for southwest Pacific Island nations have exhibited useful levels of skill over much of the last 3-4 years. Existing and potential applications of such forecasts are outlined.

2. The Island Climate Update

The Island Climate Update (ICU) is a co-operative effort to synthesise recent climate observations and seasonal forecast guidance for the southwest Pacific, and to present it in a format useful to business users and policy makers. It has been in production for approximately three years. The ICU is produced monthly and includes a summary of the past month’s climate anomalies plus a synthesis of climate outlook material for the coming three months.

Observational (rainfall) data comes from many Pacific Island nations, from the Solomon Islands in the west to Pitcairn in the east, plus New Zealand and eastern Australia. The seasonal rainfall outlook is generated after discussion (via a telephone conference) between researchers and operational forecasters from New Caledonia, Fiji, French Polynesia, Australia, and New Zealand. In recent months, the discussion has included PEAC in Hawaii, CPC in Washington DC, and the IRICP in New York.

The climate of the tropical and subtropical south Pacific is strongly influenced by the El Niño-Southern Oscillation (ENSO) cycle. ENSO modulates rainfall across the southwest Pacific through associated longitudinal shifts in near-Equatorial convection and through its effect on the location of the South Pacific Convergence Zone (SPCZ, Basher and Zheng 1998; Folland et al. 2002). Hence, the focus of the material in the ICU is on ENSO and patterns of rainfall and outgoing longwave radiation (OLR). ENSO is also known to modulate the location and frequency of tropical cyclone occurrence (Basher and Zheng 1995; Sinclair 2002). A discussion of tropical cyclones and their possible ENSO modulation is included throughout the cyclones season (October-April, approximately).

Seasonal rainfall outlooks are presented as tercile probability forecasts for each of 19 island groups in the southwest Pacific. The outlook is generated as a consensus amongst the participants, built on an assessment of available guidance material from international forecast centres. Guidance material on the state of ENSO and likely rainfall patterns for the tropical Pacific come from: Australian Bureau of Meteorology, CSIRO, NOAA/NCEP Climate Prediction Center, ECMWF, the UK Met Office, NASA (NSIPP), IRICP, and others. Statistical guidance forecasts are also generated locally in Fiji and New Caledonia. The ensemble of forecast information is tabulated by region and is assessed subjectively to arrive at the final rainfall tercile probabilities.

As might be expected in a region where ENSO forcing is very strong, forecast skill is high. This is especially true during significant ENSO events, over the rainy season (November-April). Forecast skill tends to be highest about and west of the Dateline and is lowest in the southeast, in the region of the Austral Islands and Pitcairn. Overall hit rates (frequency with which the observed tercile was assigned the highest predicted probability) are around 70%, are over 80% in the tropical western Pacific, and are 40-50% in the southeast of the region.

Such a level of skill has facilitated uptake of the forecast information in a number of Pacific Island nations. Forecasts are used to assist in disaster preparedness, especially in the tropical cyclone season, and for planning in agricultural, fisheries, energy, and tourism sectors. A new initiative to be funded from New Zealand will look at integrating and improving links between seasonal forecast information and user communities.

3. The Climate Update (New Zealand)

The Climate Update (CU) for New Zealand predates the ICU by about a year, have been in production for just over four years, since mid-1999. Features are shared between the two publications. The overall format is similar, with a synthesis of recent observations and an outlook for the coming three month season. Rather than concentrating solely on rainfall, the CU covers temperature, rainfall, soil moisture and river flows. The outlooks presented in the CU are again arrived at from a consensus-building discussion amongst New Zealand researchers and forecasters, built around an ensemble of climate prediction material from international centres and from local statistical guidance.

Global model guidance takes the form of predicted temperature, rainfall and circulation patterns (ECMWF, Met Office, NASA, IRICP, NCEP), and ENSO forecasts from a number of centres. ENSO teleconnections in the New Zealand region are manifested largely as a modulation of the westerlies: stronger (with a larger southerly component) during El Niño events, weaker (with a larger northerly component) during La Niña events. Such shifts in the circulation are associated with enhanced or reduced east-west rainfall gradients, through interaction with New Zealand's sharp topography, and with cooling or warming of seas surrounding the country (Gordon 1986; Kidson and Renwick 2002). There is considerable inter-event variability, as New Zealand lies in a region of strong intraseasonal mid-latitude circulation variability.

Two statistical prediction schemes encapsulate observed relationships between global sea surface temperatures (SSTs) and New Zealand climate (Mullan 1998). A regression-based scheme shows significant skill at predicting three-month mean regional temperatures (Zheng and Renwick 2003), and an SST and circulation analogue scheme (Mullan and Thompson 2003) predicts regional temperatures and rainfall anomalies, and local circulation patterns. Statistical model output is subjectively compared to GCM-based guidance to arrive at the final tercile probability forecasts. Once rainfall and temperature outlooks have been derived, a team of hydrological forecasters develops seasonal outlooks for soil moisture and river flows nationwide.

Forecast skill in the New Zealand region is more modest than that seen in the tropics. Hit rates for tercile probability forecasts (frequency with which the observed tercile was assigned the highest predicted probability) are around 45% for temperature, rising to over 50% during significant ENSO events. The overall hit rate for rainfall is around 40%, but has risen steadily since the inception of the CU in 1999, from the no-skill 33% level initially to around 45% over the past year. Temperatures are generally better forecast in the north of the country, where mid-latitude variability is weakest. Rainfalls are generally better forecast over the southern half of the country, where the orographic forcing and interaction with the westerly circulation are strongest. River flow forecast skill roughly matches that of rainfall forecasts.

A number of applications of CU-related information have developed over the past 3-5 years. A number of users in the agriculture sector, both business and government, make regular use of climate monitoring and outlook information for planning. There is developing use of climate information for prediction fish stock and commercial fish catch for a number of species in New Zealand coastal waters. A new research programme has recently started to quantify climatic effects on the supply of and demand for electricity. New Zealand electricity supply is especially sensitive to climate, as around two thirds of the total supply comes from hydro-electric generation.

4. Future plans

Further development is being put into statistical prediction schemes for New Zealand, particularly for rainfall. A number of approaches are being tested to develop simulation tools for climate variability. The aim is to generate simulated daily time series of rainfall, temperature, and other parameters, conditioned on the general seasonal outlook, state of ENSO, and so on. These will be based on statistical models of climate variability over New Zealand. Beyond such statistical approaches, NIWA are developing a regional configuration of the UK Met Office "Unified" climate model, with a view to using it for real-time seasonal ensemble forecasting in collaboration with the Met Office. The model is currently being tested in multi-decadal runs using observed SST forcing.

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Long Range Forecasts Progress Report of the Year 2002 at SENAMHI

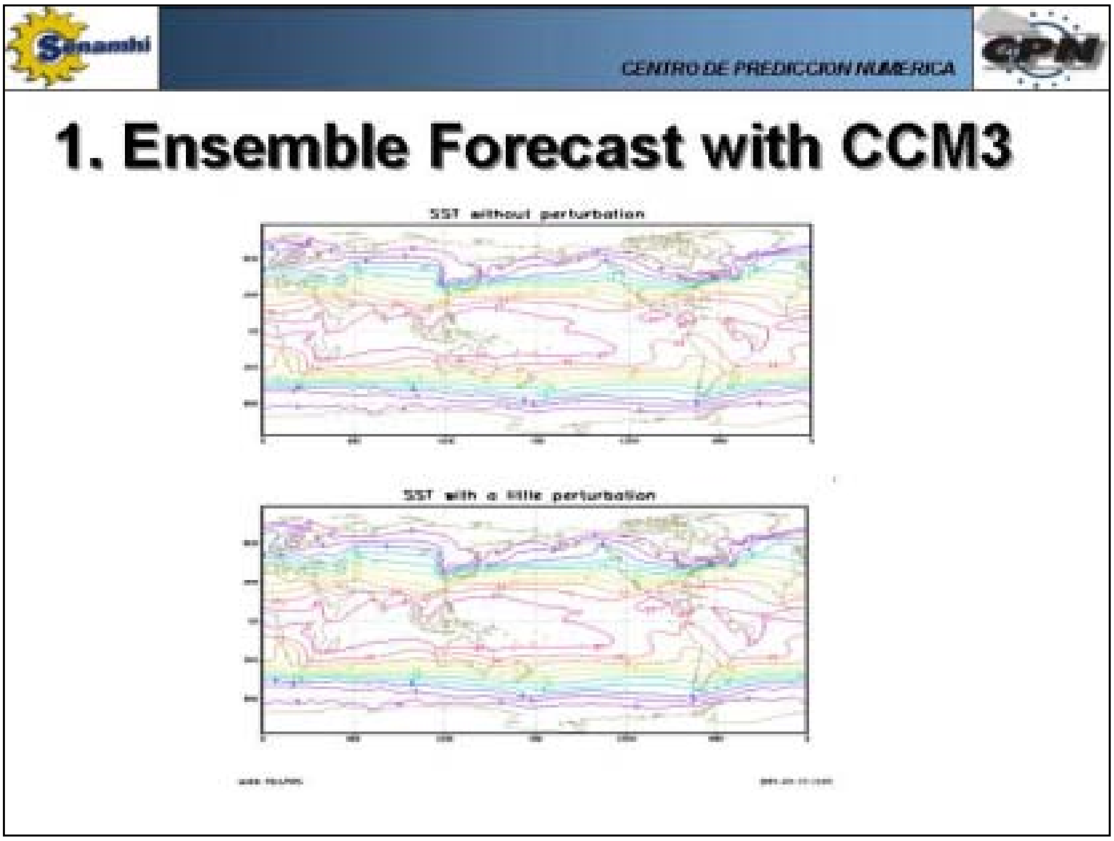
Eng. Carrillo Carlos Cruz

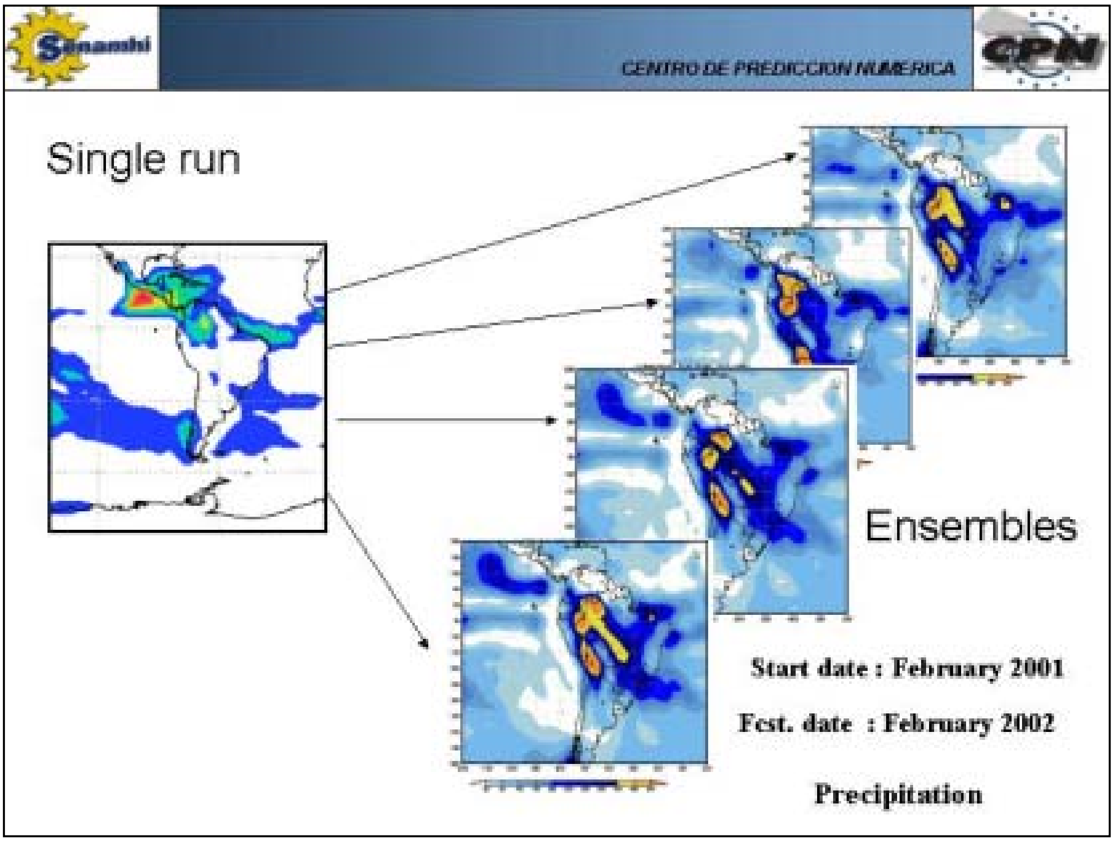
Peruvian National Meteorology and Hydrology Service

Senamhi CENTRO DE PREDICCION NUMERICA CPN

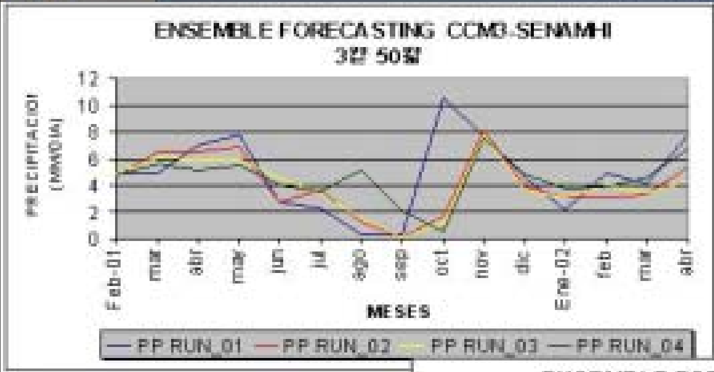
Summary

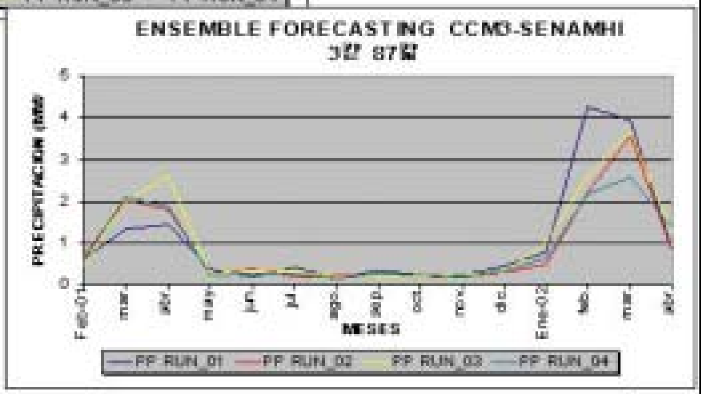
1. Ensemble forecast with CCM3.
2. Downscaling CCM3-RAMS.
3. Harvest Forecast.
4. Climatology of CCM3
5. Climate Scenarios.


CENTRO DE PREDICCION NUMERICA
1. Ensemble Forecast with CCM3
SST without perturbation
SST with a little perturbation


CENTRO DE PREDICCION NUMERICA
Single run
Ensembles
Start date : February 2001
Fcst. date : February 2002
Precipitation

CENTRO DE PREDICCION NUMERICA





CENTRO DE PREDICCION NUMERICA

Configuration of CCM3 model at SENAMHI

1. Espectral resolution**T42** (aprox. 2,8 x 2,8°).

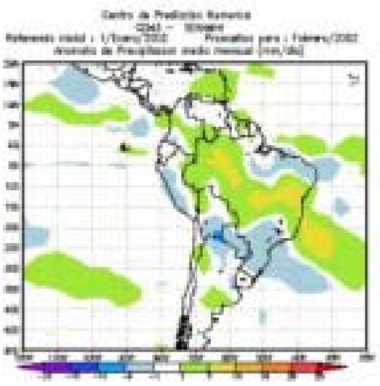
2. 18 vertical levels and a rigid level(2.917 mb).

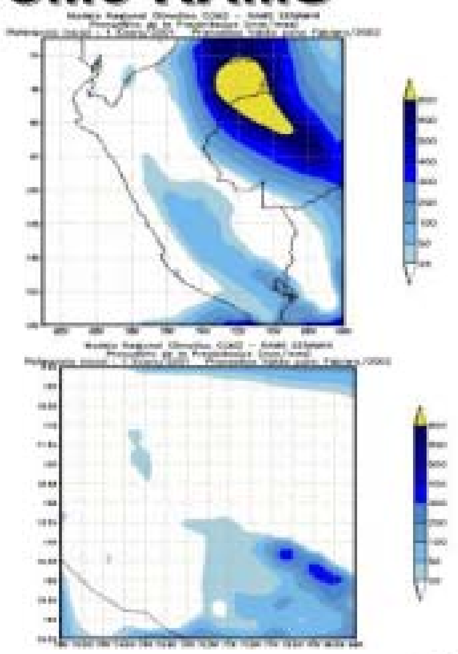
3. **Hibrid vertical** coordenate (Simmons y Strüfing, 1981).

4. Initial conditions: TSM Reynols

CENTRO DE PREDICCION NUMERICA

2. Downscaling CCM3-RAMS

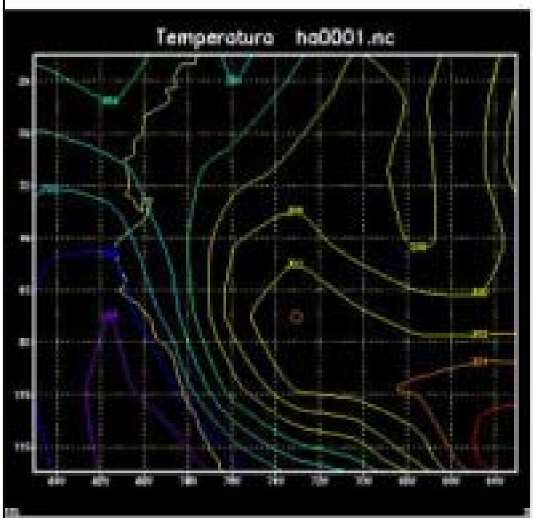




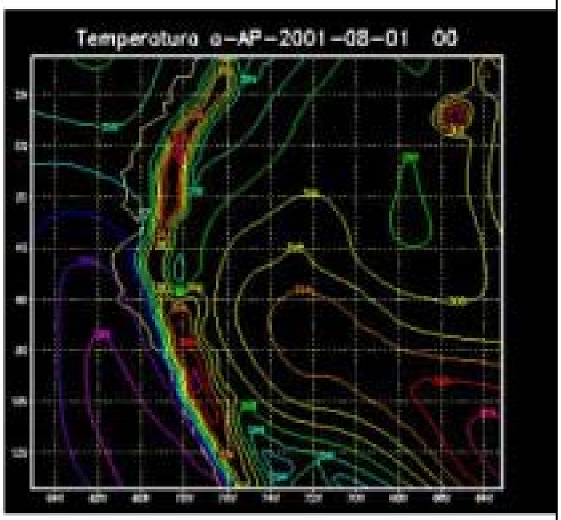
CENTRO DE PREDICCION NUMERICA

Temperature CCM3-RAMS

CCM3

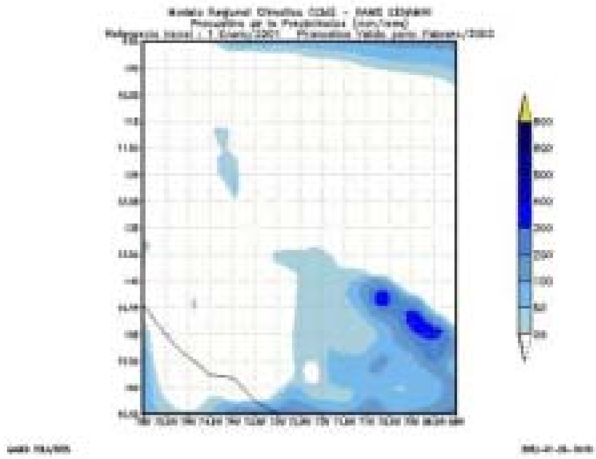


RAMS



CENTRO DE PREDICCION NUMERICA

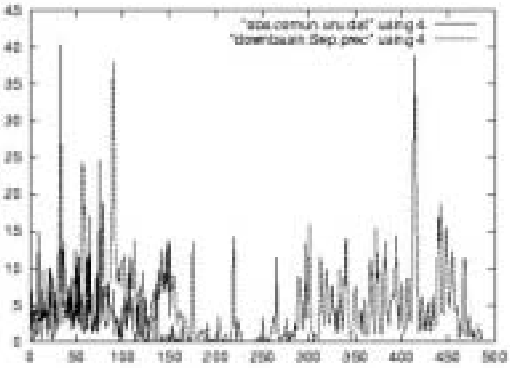
Urubamba's Domain



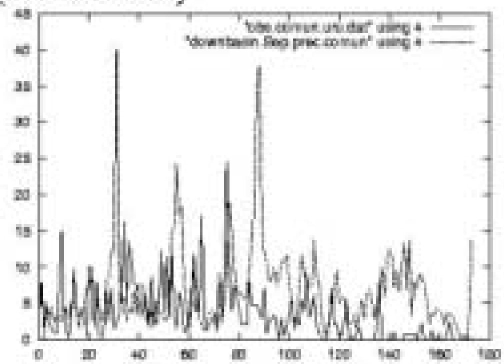
CENTRO DE PREDICCION NUMERICA

Precipitation in Urubamba (April)

Forecast – Observation

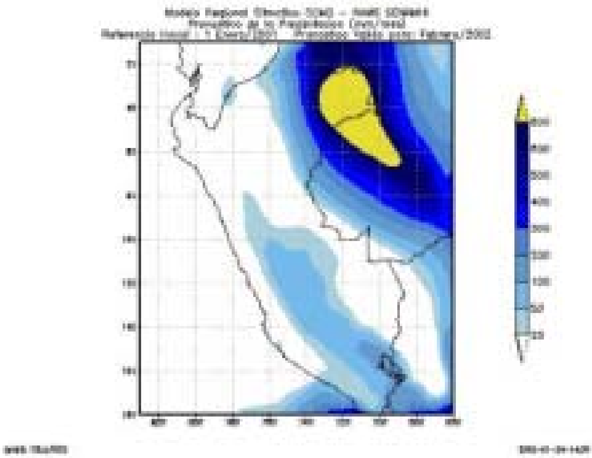


Forecast – Observation (intersection)



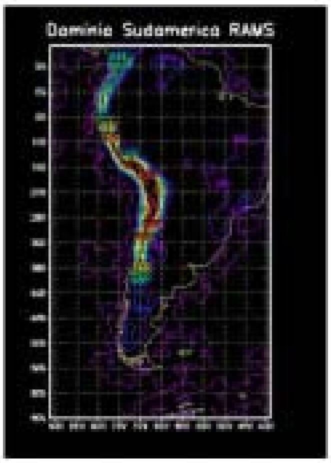
CENTRO DE PREDICCION NUMERICA

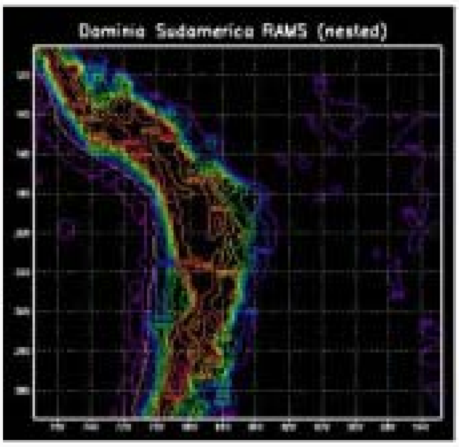
Peru’s domain

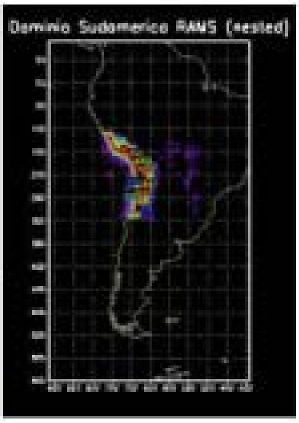


CENTRO DE PREDICCION NUMERICA

Nested Domain







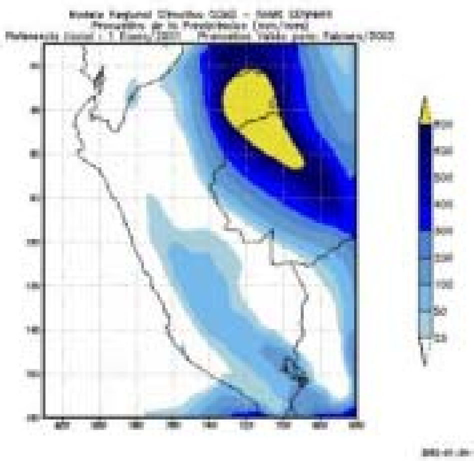
CENTRO DE PREDICCION NUMERICA

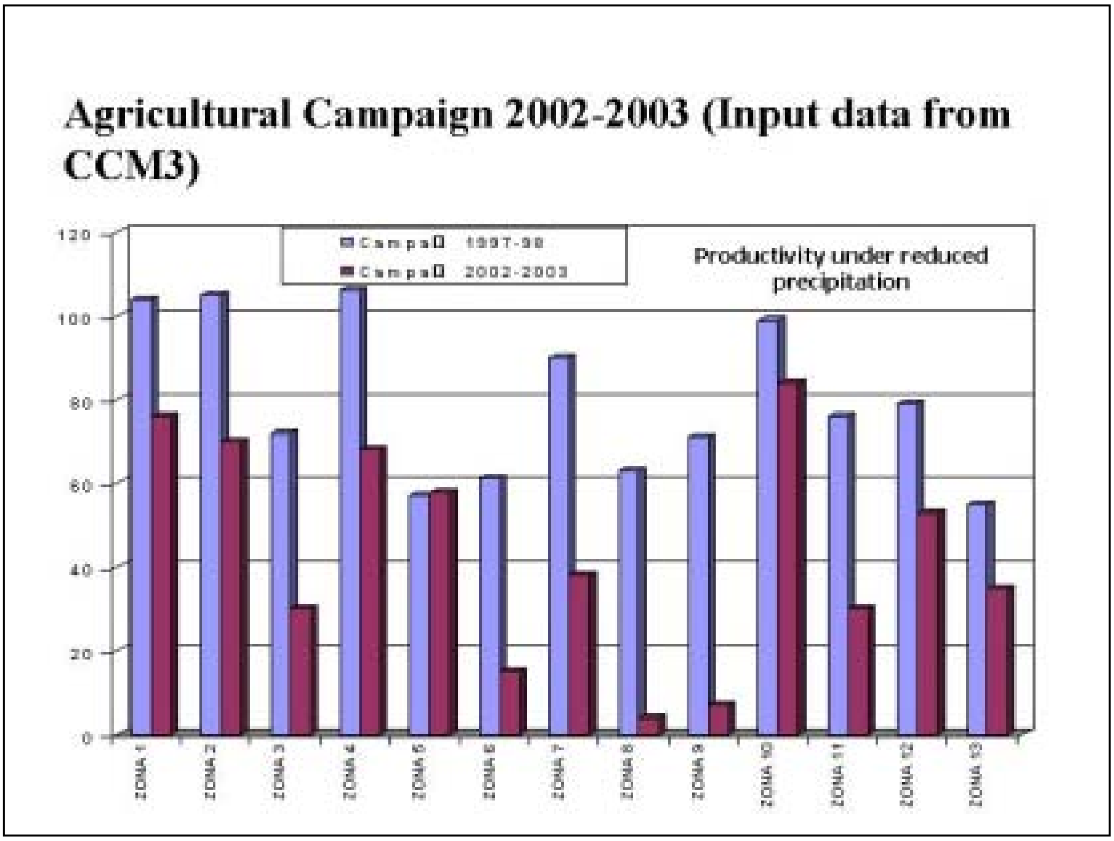
RAMS model Characteristics

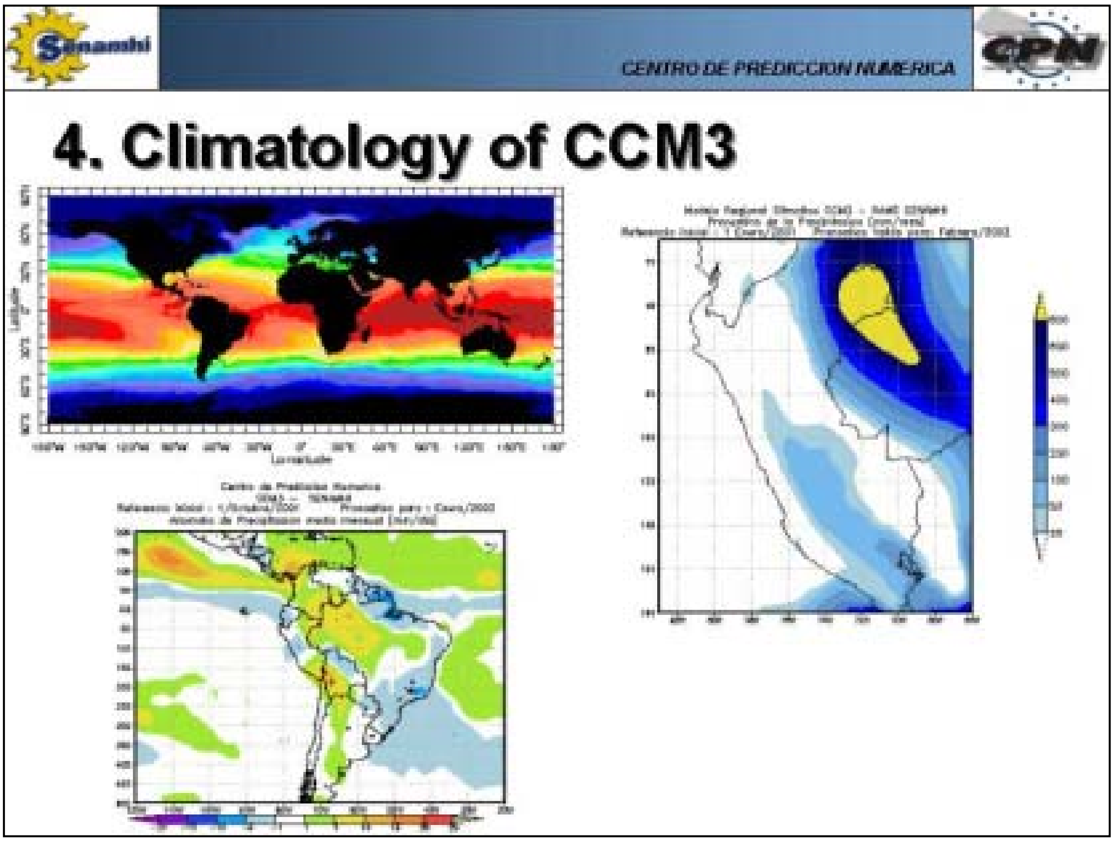
1. The Regional Atmospheric Modeling system is Licensed by Atmet (CO).
2. Atmospheric Model.
3. System to data assimilation (Objective Analysis from Barnes).
4. Nedted option and moving subdomains.
5. Visualization system.

CENTRO DE PREDICCION NUMERICA

3. Harvest Forecast

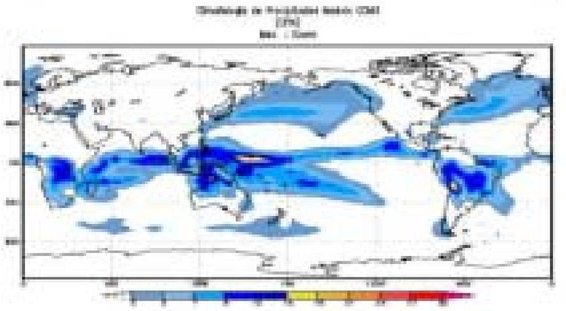


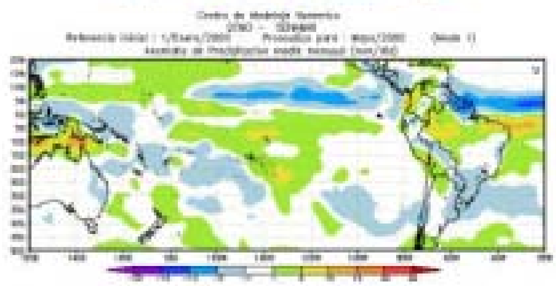

Agricultural Campaign 2002-2003 (Input data from CCM3)
Campa 1997-98
Campa 2002-2003
Productivity under reduced precipitation
120
100
80
60
40
20
0
ZONA 1
ZONA 2
ZONA 3
ZONA 4
ZONA 5
ZONA 6
ZONA 7
ZONA 8
ZONA 9
ZONA 10
ZONA 11
ZONA 12
ZONA 13


Senamhi
CENTRO DE PREDICCION NUMERICA
CPN
4. Climatology of CCM3

CENTRO DE PREDICCION NUMERICA

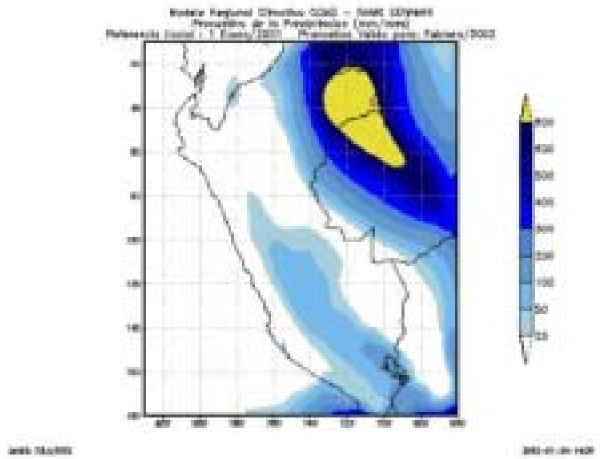
Precipitation and Anomaly

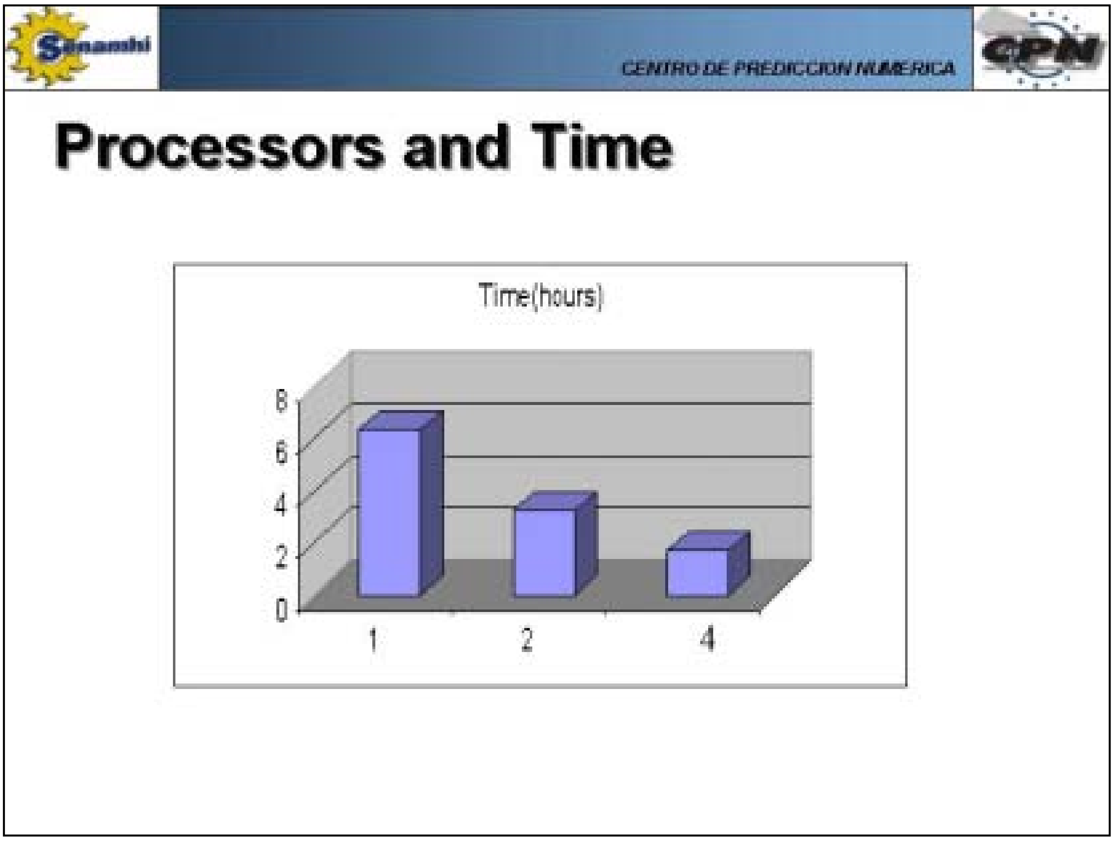




CENTRO DE PREDICCION NUMERICA

5. Climate Scenarios



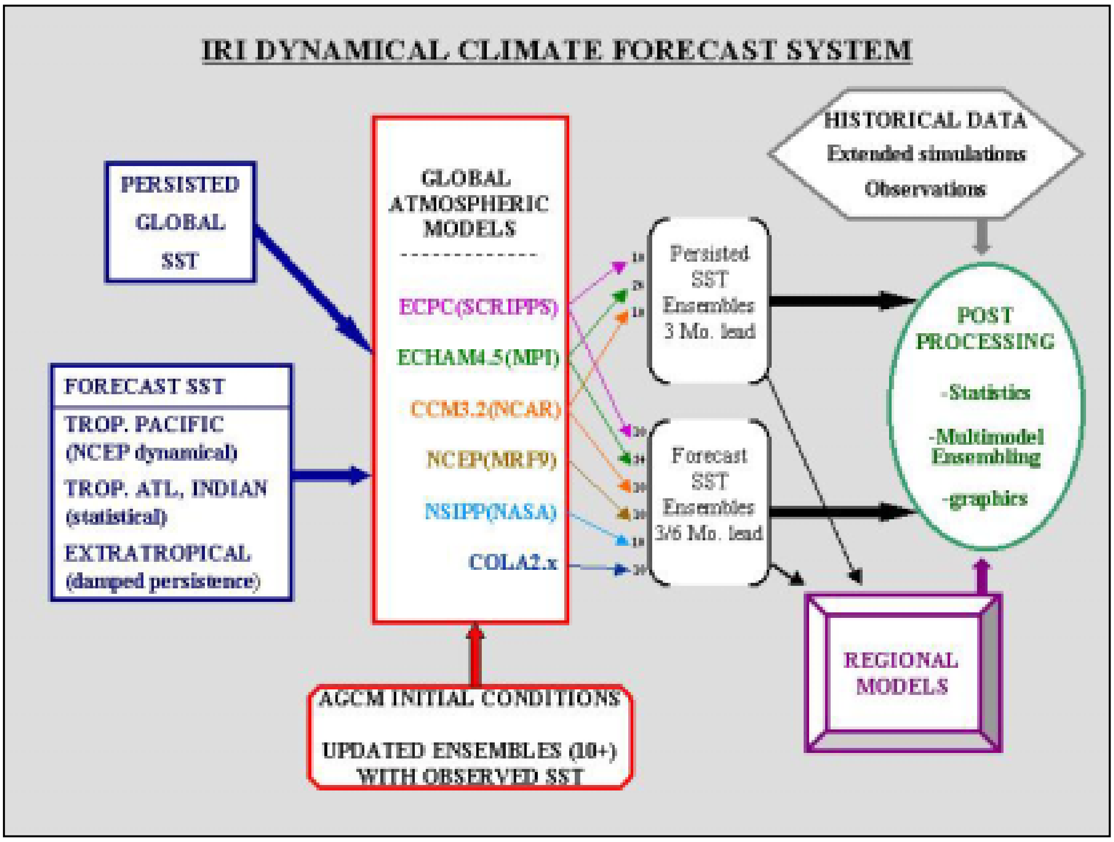


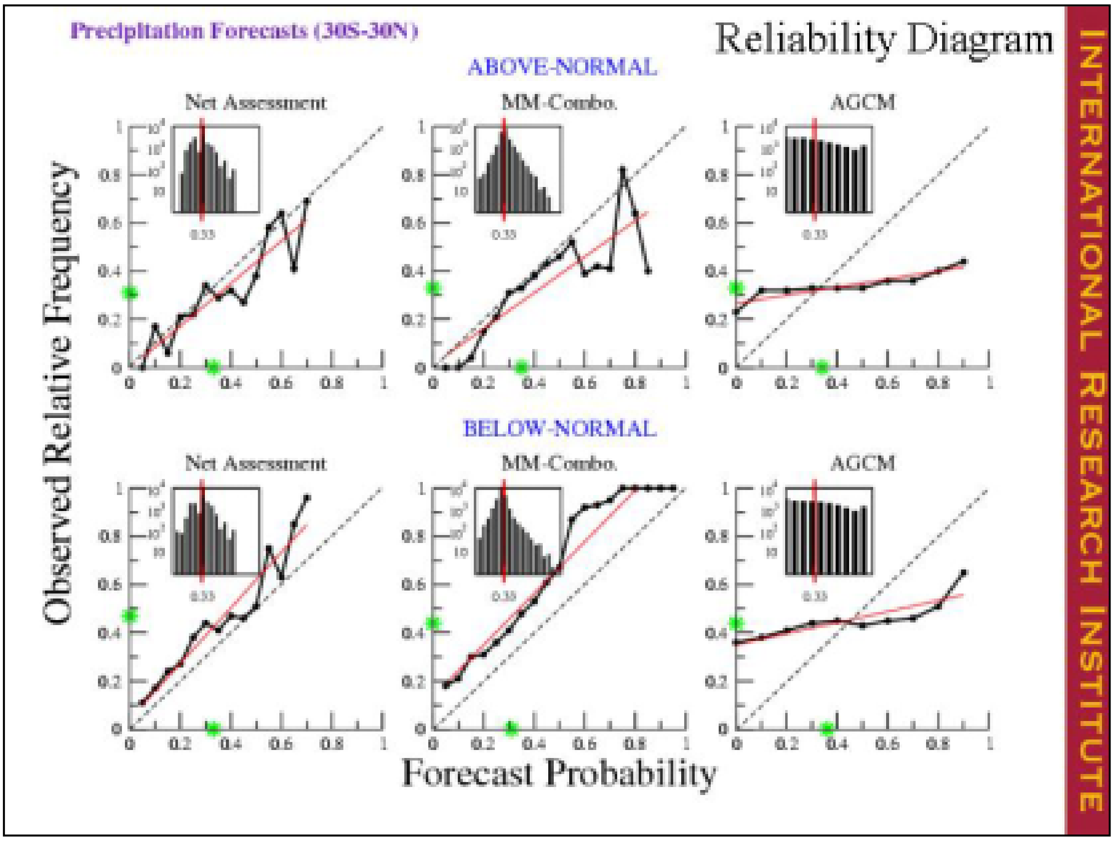
CENTRO DE PREDICCION NUMERICA
Processors and Time
Time(hours)
8
6
4
2
0
1
2
4

Multi-Model Ensemble Prediction at the IRI

S. J. Mason, A. G. Barnston and L. Goddard

International Research Institute for Climate Prediction




Precipitation Forecasts (30S-30N)
Reliability Diagram
ABOVE-NORMAL
Net Assessment
MM-Combo.
AGCM
BELOW-NORMAL
Net Assessment
MM-Combo.
AGCM
Observed Relative Frequency
Forecast Probability
INTERNATIONAL RESEARCH INSTITUTE

Recent Development in Dynamic Seasonal Climate Prediction at NCEP

JAE-KYUNG E. SCHEMM

Climate Prediction Center, NCEP/NWS/NOAA

Recent developments in seasonal climate prediction at NCEP include the formal implementation of the seasonal prediction system as part of the National Weather Service (NWS) operations. Following paragraph briefly describes the operational procedures. It also entails public availability of data associated with all GCM runs for the seasonal prediction from the NWS ftp server at;

ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/MT.clim_MR.fcst, and
ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/MT.clim_MR.hind.

A suite of 7-month prediction runs with the NCEP's SFM GCM (Kanamitsu, et al., 2002) is made for each month in preparation for CPC's operational seasonal climate prediction. The suite includes 21-year hindcasts for 1979-1999 period. For each year, 10 member ensemble runs are made with observed sea surface temperature (SST) as boundary condition. The GCM climatology and skill estimates are determined from the 21-year hindcasts. Then, 20-member ensemble forecasts are made with forecast SST from the NCEP's coupled ocean prediction model as boundary condition. For the 10-member ensemble runs in hindcast mode, the initial conditions are taken, at 12-hour intervals, from the first 5 days of the month prior to the first month of the 7-month forecast period. For the 20-member forecast runs, additional 10 initial conditions are taken from the last 5 days of the month prior to the month of the first 10 members.

In addition to the operational suite, CPC has been making additional 20-member ensemble forecast runs each month with SST forecast by the constructed analog (CA) procedure (van den Dool and Barnston, 1995). The CA procedure has proven to forecast the changes in SST over the tropical Pacific very well since 1998 (ref: ftp://ftpprd.ncep.noaa.gov/pub/wd51hd/index.html) and the additional runs complement the operational suite with SST forecast over global oceans in contrast to the SST predictions limited to the tropical Pacific from the NCEP coupled model system.

Using the observed SST in the hindcast procedure, the current system can only provide estimates of potential predictability. An example of more realistic predictability assessment is given in Figs. 1 and 2, where the hindcast suite for 1979-1999 was performed with the CA forecast SST as boundary conditions and September initial conditions. Fig. 1 illustrates the skill of CA forecast SST over the Tropical Pacific, where the anomaly correlation scores average between 0.5 and 0.7 for OND through JFM seasons over the 21-year period. The method does not work so well over the mid-latitude oceans where the average scores decrease to the level of 0.3. In Fig. 2, the skill of SFM forecast is compared in terms of precipitation over the Tropical Pacific. With predicted SST as boundary conditions, the level of predictability decreases to about half of what was estimated from the GCM runs with observed SST.

With the operational implementation of the SFM GCM, EMC/NCEP has embarked on the development of next generation coupled model system and a test procedure has been initiated for parallel seasonal forecast runs with the operational GFS GCM. Some preliminary assessment on the coupled model system also will be presented at the meeting.

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APCN Symposium on the Multi-Model Ensemble for Climate Prediction/
Second APCN Steering Committee Meeting and Third APCN Working Group Meeting
(Jeju Island, Korea, 7-10 October 2003)

Summary Report

1. Opening

The APEC Climate Network (APCN) Symposium on the Multi-Model Ensemble (MME) for Climate Prediction was held at the Seogwipo KAL Hotel, Seogwipo, Jeju Island, Republic of Korea from 7 to 10 October 2003. The Symposium, co-sponsored by Korea Meteorological Administration (KMA) and World Meteorological Organization (WMO), was jointly held with the Second APCN Steering Committee Meeting and the Third APCN Working Group Meeting.

The objective of the Symposium was to derive suggestions for the future direction of research and development for better Seasonal to Interannual (SI) forecasts, underscoring the limitations of the current state-of-the-art of climate dynamic prediction systems.

There were 60 participants from 36 institutes in 14 APEC Member Economies (Australia; Canada; China; Hong Kong, China; Indonesia; Japan; Korea; Malaysia; New Zealand; Peru; Russia; Chinese Taipei; Thailand; and United States), two non-APEC Members (United Kingdom and France), and representatives of World Meteorological Organization and European Centre for Medium-Range Weather Forecasts.

On behalf of Dr. Myung-Hwan Ahn, Administrator of the Korea Meteorological Administration (KMA), Mr. Wan-Tak Oh, Director-General of the Climate Bureau of KMA opened the Symposium at 09h00 on 7 October 2003. Mr. Oh welcomed all the participants to the Symposium. He noted with satisfaction the steady progress of the APCN during the preparatory stage over the past few years and expressed his appreciation for the cooperation that has contributed to the advancement of APCN since its beginning.

Mr. Oh expressed his belief that the years ahead should be devoted to cooperative research and development to produce better climate predictions. For this, he assured the support of KMA to increase the frequency of data exchange and the service of MME climate prediction and to establish a Visiting Scientist Program for joint research and development. He wished the Symposium success and the participants a pleasant stay in Jeju.

On behalf of Dr. Takeo Kitade, Director-General of Japan Meteorological Agency (JMA), Dr. Tomoyuki Ito, Director-General of the Department of Climate and Marine Department of JMA gave a keynote address and iterated that JMA would continue to cooperate with APCN to enhance the quality of climate information for APEC Members. Dr. Ling Leong Kwok, Meteorological Officer of the Malaysian Meteorological Service (MMS), on behalf of Dr. Chow Kok Kee, Director-General of MMS, stressed that regional cooperation should be promoted with a view to strengthening the capability of climate prediction in the Asia-Pacific region.

Keynote lectures were given by several distinguished representatives. Mr. Kenneth Davidson, Director of World Climate Program of WMO, gave a keynote lecture on WMO's climate and environment activities. Dr. Jagadish Shukla, George Mason University and Center for Ocean-Land-Atmosphere Studies (COLA) of the United States, gave a lecture on a systematic and comprehensive procedure for extracting predictability from a set of observations and forecasts.

Dr. Ming-Ji, Office of Global Programs of National Oceanic and Atmospheric Administration (OGP/NOAA), introduced the NOAA's Intra-Seasonal to Interannual Prediction (ISIP) Program. Professor Kil-Nam Chon, Korea Advanced Institute of Science and Technology (KAIST), gave a presentation on Asia-Pacific Advanced Network (APAN). The current status of APCN was presented by Dr. Chung-Kyu Park, Director of Climate Prediction Division, Climate Bureau, KMA.

2. APCN Symposium on MME for Climate Prediction

Presentations by participants at the Symposium were organized into four sessions:

- Session I. Multi-Model Ensemble: lessons learned, chaired by Professor Yihui Ding (China) and Professor Bin Wang (USA);
- Session II. Climate prediction and modeling, chaired by Dr. George Boer (Canada) and Dr. Valentin Meleshko (Russia);
- Session III. SST prediction and modeling, chaired by Dr. Ming Ji (USA); and
- Session IV. Issues and applications, chaired by Dr. Ngar-Cheung Lau (USA) and Dr. Siegfried Schubert (USA).

Summary from Panel Session

The Panel Discussion was held at the end of the Symposium. The panel members and topics were:

- Dr. Shukla (George Mason University/COLA, USA) – Chair;
- Professor Kang (SNU, Korea) – vision for APCN;
- Dr. Boer (Meteorological Service of Canada/University of Victoria, Canada) – current challenges;
- Professor Wang (University of Hawaii, USA) – research issues; and
- Dr. Schubert (NASA, USA) – research issues.

The Panel Discussion took the format of short statements made by selected panel members followed by questions and comments from the audience. A summary of Panel Discussion and issues raised is attached at APPENDIX I. The Panel Discussion was very successful and covered a wide range of issues. The main recommendations were:

- Seeking tier-1 forecasts from APCN members in addition to tier-2 forecasts and producing MME using both systems;
- Developing MME for SST and arranging for a few atmospheric models to use the MME SST product to produce seasonal forecasts;
- Encouraging members to provide historical forecasts that do not involve the use of information that would not have been available at the time of the forecast (e.g., not forecasts using observed SSTs);
- Verification of MME forecasts is essential for APCN and should follow the WMO CBS recommendations; and
- Strategic approaches to developing forecast applications and downscaling should be defined and discussion papers drawn up.

3. Second APCN Steering Committee Meeting

The Steering Committee adopted the agenda and discussed various matters.

3.1. New member and chair (Chair: Dr. Chung-Kyu Park, Korea)

The Steering Committee welcomed Professor Yihui Ding (China), Dr. Michael Coughlan (Australia) and Dr. Oscar Alves (Australia) as new members.

The Committee agreed that members should serve for an initial 3-year term, but with some serving an initial longer term to ensure continuity. The Steering Committee is to be comprised of eminent scientists and of representatives from APCN members. It should be reported to the APEC Industrial Science and Technology Working Group (ISTWG).

The Committee defined an initial term of 3 years for the chair. Dr. Park will remain chair for the next two years. The Steering Committee will establish draft guidelines for the selection of a chair and these will be available for discussion at the next Steering Committee Meeting.

3.2. NOAA-KMA collaboration: topics and sub-committee (Chair: Professor In-Sik Kang, Korea)

The Committee recognized the need for a multi-institutional research project on a core set of scientific problems on MME prediction to improve the APCN prediction system.

The Committee recommended the formation of an ad-hoc Working Group to develop a draft plan on a joint US-Korea pilot activity in MME prediction research for review by the APCN Steering Committee. The Committee appointed Professors Kang and Wang to set up the working group. The plan will be used as the basis for the US and Korean members of the APCN to seek future enhancement in support from their respective Government funding agencies.

3.3. Guidelines on APCN activities: strategy (Chair: Dr. Michael Coughlan, Australia)

The Steering Committee discussed the linkage between APCN and WMO and how to develop APCN as part of WMO-recognized activities. In opening discussions on this topic, it was suggested that there were three principal areas that required APCN in each case to adopt a strategic approach in drawing up its overall master plan.

The first is related to the geo-political framework within which APCN was established, viz. APEC. However, there are other regional bodies active within the Asia-Pacific region, to whom the APCN has something to offer; these include ASEAN, ESCAP, the Pacific Island Forum and possibly others.

The second strategic area is that of research. While the World Climate Research Programme should be a principal focus for APCN in terms of establishing an overall framework for the relevance of its research activities, it was noted that in recent years there had been several bi-lateral arrangements on climate science between countries from which APCN currently draws its membership. There is sufficient flexibility within these arrangements for them to recognize activities common to the interests of more than one of the bi-laterals, i.e., for the establishment or recognition of new multi-lateral partnerships.

The third strategic area is that of operations. While much of what is currently being perceived for APCN lies within the research domain, it has become evident that in the particular area of seasonal forecasting, the line between what is considered research and what is considered operational has become increasingly blurred. Many research groups are now running routine coupled models in real- or quasi-real-time forecast mode~~,~~ and making the outputs of the forecasts available over the Internet. Notwithstanding this increasingly "open skies" approach to seasonal forecasting, there remains recognition of the need for some rigor in the establishment and application of standards and procedures for formal operational forecasting. There are several activities underway within the structures of the WMO, notably its Commissions for Basic Systems and Climatology, to put these in place. Further, WMO has four Regional Associations that overlap the APCN geographical area of interest.

The need for the outputs of the APCN program to be relevant to end-users was highlighted during the Symposium, which raised the issue of how best to incorporate applications. The Committee agreed that this would also require a strategic approach, but noted that there was already considerable activity in the Asia-Pacific region related to the applications of climate information in the context of both climate variability and climate change. The Committee decided that it would be appropriate as a first step in this area to explore how best current and future APCN activities might contribute to existing applications activities being conducted under various sponsoring organizations such as WMO/CLIPS, ADPC, SPREP, SOPAC, PEAC, IRI and others. It was agreed that a discussion paper should be drawn up on this topic for consideration by the Committee.

The need for APCN to demonstrate its relevance and hence attend to all of these strategic areas as it develops and begins to implement its master plan, poses some significant challenges. It will be important to obtain commitments from individuals participating in APCN activities to use the ongoing occasions that most already have in one or more of the strategic areas outlined above to promote the program, including the opportunities they will offer for advancing both science and operations. In addition, it will be appropriate for APCN organizationally to seek out specific opportunities to present its plans and activities at various forums associated with each of the strategic areas. Such occasions might include selected APEC and other regional forums, meetings of pertinent WCRP committees and working groups, and at the relevant meetings of WMO Commissions and Regional Associations.

3.4. Guidelines on APCN activities: science (Chair: Dr. George Boer, Canada)

The Steering Committee discussed the future development of the APCN MME System, recommendations on data collection, verification and dissemination:

- Inclusion of tier-1 forecasts;
- Encouraging all participating models to provide historical runs in an “operational” mode;
- Definition of appropriate MME techniques;
- Adoption of WMO CBS verification recommendations (Canada and Australia as Lead Centres can facilitate);
- Tier-2 system using multi-model ensemble SST to be developed by APCN Korea; and
- Setting up a working group to collaborate with existing regional downscaling activities (e.g., IRI, CMA) as there are major implications for data requirements in the form of boundary forcing fields and verification data.

3.5. Other issues (Chair: Dr. Chung-Kyu Park, Korea)

The Steering Committee discussed other issues including the APCN Visiting Scientist Program (VSP). The Committee expressed its appreciation to KMA for providing funding for the Program and noted with satisfaction the budget allocation for 2004. The Committee requested each of its members to recommend qualified scientists. The Steering Committee recommended that the main focus of the program be on research rather than the operational real-time forecast system, and that the funds also be used to facilitate short term visiting scientists (weeks to months).

4. Third APCN Working Group Meeting

Climate prediction activities were reported by the APEC Members, chaired by Dr. Jae-Kyung E. Schemm (USA), Dr. Tomoaki Ose (Japan) and Dr. Dong Wenjie (China). The Working Group discussed the APCN guidelines on data exchange for the multi-model ensemble. It recommended that APCN devote some effort on outreach to government agencies and to users to raise the profile of the seasonal forecasting activities and possible applications. It also recommended that APCN facilitate the sharing of knowledge and resources between members such that experienced members in seasonal prediction can assist those with less experience and fewer resources. The Working Group Members are encouraged to access the APCN products and provide feedback.

The guidelines recommended by the Working Group are listed in APPENDIX II, and the recommendations for APCN MME data exchange are provided in APPENDIX III.

The Working Group also discussed the policy on the distribution of prediction data to both APEC and non-APEC Members. It was agreed that the access to MME output should be password-protected, and that the password be made available upon request. It was also agreed that the output from an individual member might be distributed only with the permission of that member.

5. Closure of the APCN Symposium

The APCN Symposium on the Multi-Model Ensemble for Climate Prediction, jointly held with the Second APCN Steering Committee Meeting and the Third APCN Working Group Meeting, was closed at 17h30 on 9 October 2003.

APPENDIX I.

Summary of Panel Discussion and issues raised

1. Statement by Professor Kang (SNU, Korea)**: Vision for APCN**

The vision of APCN is primarily to develop a reliable seasonal prediction system by utilizing forecast products available from organizations currently generating dynamical forecasts and by optimally coordinating research and operational resources over the APEC region, and ultimately to develop a next generation seasonal prediction system applicable to various sectors. The first vision can be achieved by coordinated activities, but the ultimate goal should be achieved by an institutional organization.

2. Statement by Dr. Boer (Meteorological Service of Canada/University of Victoria, Canada): **Current challenges**

The first generation MME system concentrates on the collection of existing tier-1 and tier-2 forecasts and associated skill measures, and the use of these forecasts to produce MME forecasts. The second generation will evolve from research over the next several years. See research issues below.

It is natural for APCN to proceed on parallel tracks by developing the first generation of the APCN MME forecast system while also promoting the research and development for the next generation.

The immediate challenges that are faced include: the collection of historical forecasts that do not involve the use of information that would not have been available at the time of the forecast (e.g., not forcing with observed SST); the choice of the best MME approach based on comprehensive skill measures; the determination of approaches to ensure integrity of products while allowing for the evolution of participating models; the development of downscaling and application of forecast products; and the building of needed human and resource capacity. Meeting these challenges in the first generation APCN forecast system should provide the basis for the second generation system as well as the organizational support for an enhanced APCN climate research and forecasting enterprise.

3. Statement by Dr. Schubert (NASA, USA) / **Professor Wang** (University of Hawaii, USA)

A number of research directions were identified as being critical to extending and/or improving upon the MME prediction approach. It was further recognized that improving the utility of the forecasts requires that APCN engage the applications community. To those ends, several high-priority research directions were identified, including dynamical and statistical downscaling, applications modeling, tier-1 versus tier-2 methodologies, boundary forcing including soil moisture interactions and the impact of SSTs for regions outside the eastern tropical Pacific, and sub-seasonal prediction with a special focus on the MJO/ISO.

4. General issues raised

Although tier-2 forecast systems need good SST forecasts, SSTs are forecast reasonably well over the tropical eastern Pacific, while ocean temperatures in the rest of the world are not adequately predicted.

Can coupled GCMs be used to provide SSTs for tier-2 forecasts? Do statistical methods outperform the dynamical approaches? What is the role of the mid-latitude SSTs – are they a source of predictability? If not, tropical SST predictions may be sufficient.

Tier-1 systems are used in Europe, USA and Australia, and there is some emerging evidence that the tier-1 systems are now approaching the skill of tier-2 system for the first season, but more rigorous comparisons are required, including the use of the coupled model SST forecasts in the tier-2 systems rather than simple persisted SSTAs. APCN should start collecting tier-1 forecast data.

Most downscaling activities within the APCN members are based on statistical techniques. Output from regional modeling approaches should be compared with those from statistical methods.

Sub-seasonal variability – is the MJO a predictable part of climate? Some models have minimal intra-seasonal variability. While individual events may not be predictable, some aspects of the statistics may be, e.g., the level of MJO activity, tropical cyclones, extreme events, etc.

MME issues are:
- Diminishing returns in fine-tuning the system;
- Reliance on other centers with other research priorities;
- Targeted research - temporal and spatial downscaling; and
- Application models.

More focus is required on applications, but:
- Data availability is very limited; and
- There is a lack of expertise – need to develop manpower.

A first step could be to allow the Meteorological Services access to the APCN forecasts to provide some initial feedback.

Downscaling will be a key component for developing usable forecast products.

Is it necessary to choose between tier-1 and tier-2 system? The ultimate interest is in the rainfall and other surface parameters, so both tiers could go into an MME. But tier-2 systems have longer verification histories, and it is important to have realistic forecast skill estimates with the operational forecasts.

Will very-high-resolution global forecasts that may be available fairly soon mean that we can by-pass downscaling? Probably not. More is required than just the computing time – GCMs will require substantial work on retuning convective schemes, for example. Also, demands for increased temporal and spatial resolution will undoubtedly exceed capabilities for the foreseeable future. It is likely that some kind of local downscaling will add value to the dynamical global forecasts. Furthermore, the limits of predictability need to be communicated.

Complete information on forecast lead times and forecast periods required by APCN should be provided.

Soil moisture and snow data are important for forecast initial conditions. The availability and use of these data need to be investigated further.

Given that most seasonal to inter-annual predictability in the APCN region is from ENSO, for robust skill estimates a reasonably large number of ENSO events need to be included in the verification sample, thus requiring fairly long sets of hindcasts. Although most sub-surface data is available only for the last few years, forecast schemes should not focus only on the last few years of rich data availability.

Verification should be a major component of APCN activities including the MME skill for the seasonal march of major rain belt in East Asia (onset, northward advance, and withdrawal).

Some users may require forecasts in digital form. APCN should explore the feasibility of doing this.

It is desirable that APCN should develop into an international institution. This will require contributions from APEC members.

APPENDIX II.

Guidelines recommended by Working Group

1. Services

- Full papers and powerpoint files presented at the meeting should be made available on a CD-ROM or on the APCN web site;
- On-line training through the web site, e.g., posting lecture note or materials from training workshop and seminar; and
- Publicizing future events on the web site well in advance.

2. Products and Information

- Desirable to increase frequency of issuance of forecast since the span of rainy season varies from place to place, i.e., significant rainfall outside JJA;
- Providing guidelines on use, interpretation and limitations of the products on the APCN web site;
- Providing higher resolution graphics with better labeling and explanation of products;
- Providing data in digital form for manipulation by users and for objective verification;
- Soliciting user requirements for APCN products;
- Establishing a set of standard verification scores, down to sub-seasonal scale if possible; and
- Establishing common datasets for verification with detailed descriptions and making them available to all APCN members.

3. APCN website

- Providing relevant links to operational and research centers;
- Providing ftp service for data;
- Developing a glossary/reference section; and
- Monitoring the website closely – most popular pages, visitor statistics, etc.

APPENDIX III.

Recommendations for the APCN Multi-Model Ensemble Data Exchange

1. Experiment frequency and time period of data exchange

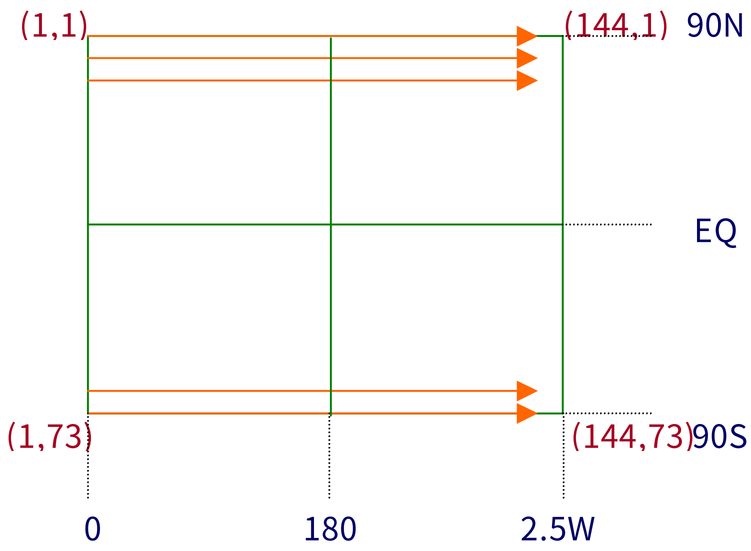
- Four times a year: DJF, MAM, JJA, and SON; and
- Submission dates: first ten days of the preceding month prior to the beginning of target season.

2. Variables

- Surface (2 m) air temperature and SST [K];
- Total precipitation rate [kg/m^2sec];
- Mean sea level pressure [hPa];
- Outgoing longwave radiation [W/m^2];
- 850-hPa temperature [K];
- 500-hPa geopotential height [m];
- 850-hPa zonal and meridional velocity [m/sec]; and
- 200-hPa zonal and meridional velocity [m/sec].

3. Data type and format

- Data type
  - Monthly mean and daily mean data (four-time average a day) for individual ensemble member;
  - Climatology for each variable;
- Format: GRIB1/2; and
- Resolution: 2.5 x 2.5 degrees.



4. Hindcast data request

- Experimental design: SMIP-2/HFP type simulation with more than five-member ensemble
  - Period from at least 1979 to 2002 (24 years); and
  - Forecast made in “operational” mode.
- Data type: historical monthly mean data for each member
  - Variables, format and resolution should be consistent with forecasts.

5. The APCN Working Group noted the need for the data production procedure, including model updates, to be reported to the APCN Secretariat. It is important to provide new hindcast data if models are changed.

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Printed for:

The APEC Secretariat
35, Heng Mui Keng Terrace, Singapore 119616
Tel: 65-6775-6012 Fax: 65-6775-6013
E-mail: info@mail.apecsec.org.sg
Website: **http://www.apec.org**

ISBN 89-954715-0-6 93450
APEC#203-IT-04.1