National reports prepared for 4th CLIVAR/AAMP meeting

There are many regional activities upon the Asian-Australian monsoon studies. Some of them have been well coordinated within the CLIVAR and other international scientific frameworks (e.g., GEWEX and IGBP). Some have not.

The follows are those reported at the 4th CLIVAR/AAMP meeting, 29-31 August 2001, University of Reading, which highlight the recent approaches in the different nations towards the common target - the variability and predictability of the monsoons. They are from:

- Australia
- China
- India
- Japan
- Korea
- UK and
- US

Information of the regional advances is helpful for the Panel and will be updated from time to time. It may be submitted to the Panel members or the ICPO.

A-A Monsoon Studies in Australia

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1. Diagnostic & predictability studies - large-scale.

The APN Network for Climate Extremes is a group of scientists in the Asia Pacific region who are collaborating to enhance the capability of nations in the region to monitor and analyse trends and variations in extreme climate events. The Network is supported by the Asia Pacific Network for Global Change Research and involves participants from seventeen countries in the Asia Pacific region: Australia, Cambodia, China, Fiji, French Polynesia, Indonesia, Japan, Malaysia, Myanmar, New Caledonia, New Zealand, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, and Vietnam. Three workshops have been held, hosted by BMRC in Melbourne, and a paper published. An interesting result is that the number of extreme hot days and nights has increased throughout the region over the past 40 years, while the number of cold extremes has decreased. Further details are available at the Network's website: http://www.bom.gov.au/bmrc/csr/apn/index.html.

Analysis and Interpretation of ocean thermal structure: Susan Wijffels and Gary Meyers (CSIRO Marine Research) are documenting variability of mass, temperature and salinity transport of Indonesian throughflow (ITF) and its relationship to winds over the Pacific and Indian Oceans. A key result is that heave of the thermocline along the northern side of ITF (i.e. Indonesian coast) affects SST by upwelling, and this is driven by winds over the Indian Ocean. Ming Feng, Susan Wijffels and Gary Meyers are analysing the large scale propagating features seen in altimeter and XBT data. Tara Ansell (a PhD student at Melbourne University) is using XBT data and ocean-model results to identify the mechanisms that cause SST variability in the eastern and western poles of the Indian Ocean Dipole.

BMRC is studying the coherence and predictability of seasonal rainfall in the maritime continent.

Seasonal variations appear to be predictable during the dry season in this region, but not generally during the wet season (e.g., 'Spatial coherence and predictability of Indonesian wet season rainfall', Haylock & McBride, J. Climate, in press). Further evidence of this seasonal/spatial variation in predictability emerged at the Third Workshop on Regional Climate Prediction and Applications - Tropical Pacific Islands and Rim (University of Oklahoma, April-June 2001). Contact: John McBride, BMRC.

BMRC continues investigations of the possible effects of Indian Ocean sea surface temperatures on the climate of Australia and the surrounding region. This work indicates that an Indian Ocean Dipole, independent of the El Niño - Southern Oscillation, is rare. Most 'dipole-like' behaviour of the Indian Ocean appears to be a response to the El Niño - Southern Oscillation. A paper discussing some of this work was presented at the AMS Annual Meeting in January, and an article has been submitted to CLIVAR-Exchanges. Contact: Neville Nicholls, BMRC.

2. Modelling studies - large-scale.

The Regional Model Intercomparison Project (RMIP), is an intercomparison of regional models over a large Asian domain (about 50E-150E and 5N-60N), run for an 18-month period (March 1997 to August 1998) at a resolution of about 60 km. Eleven models have run the simulations with lateral boundary forcing supplied by NCEP reanalyses. John McGregor and Jack Katzfey (CSIRO Atmospheric Research) have submitted 2 runs, one for DARLAM and one for the CSIRO conformal-cubic (C-C) model (using a stretched global grid). RMIP is an APN project. Results are being analysed by Congbin Fu's group at IAP in Beijing. An interesting result is that most, but not all, models have a tendency to shift the East Asia monsoonal rainfall too far northwards.

Stuart Godfrey, Rui-Jin Hu and Andreas Schiller (CSIRO Marine Research) are exploring the dynamics and thermodynamics of the Indian Ocean in their global MOM model, to better understand what sets long-term mean surface heat fluxes and SST variations within it. They find that mixing within the Somali Current, down to depths of 1000m or so, sets the depth and temperature distribution of the entire Indian Ocean north of the Indonesian Throughflow at 7°S. This in turn sets the depth distribution of the zonal Indonesian Throughflow jet via geostrophy, which then supplies the western boundary current feeding the Somali Current. Hence mixing events in the Somali Current determine the long-term mean heat transport and surface heat flux into the northern Indian Ocean, rather than the other way round. This may have implications for the design of an ocean monitoring system for climate, in the Indian Ocean.

Coupled model of Indian-Pacific Ocean: Jaci Brown and Stuart Godfrey (CSIRO Marine Research) are working on extending the Kleeman intermediate coupled model of the Pacific Ocean to include the Indian Ocean.

3. Intraseasonal variability.

BMRC is enhancing its empirical studies of intraseasonal oscillations, with the aim of attempting to predict these, especially with statistical methods. The approach is to use real-time filtering of OLR data to monitor and predict the convective variations of the Madden-Julian oscillation and various convectively coupled equatorial waves, based on the "climatological" spectral peaks of a long record of satellite-observed data. More information is available at http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/maproom.html

Andreas Schiller and Stuart Godfrey (CSIRO Marine Research) have explored intraseasonal SST variability in their ocean GCM. Good simulations are achieved, in which surface heat flux variations are found (as in simpler models) to be the dominant term. However, entrainment through the mixed layer base contributes locally; barrier-layer formation occurs before onset of strong winds; and different processes control intraseasonal dynamics in different events.

Relation of Indian Ocean Variability to Australian Winter Rain: Tara Ansell and Stuart Godfrey (CSIRO Marine Research) have examined moisture flux towards Australia and rainfall onto Australia during intraseasonal oscillation events, using a composite provided by Peter Webster. 5-10 days after a maximum of rainfall over the equatorial Bay of Bengal, a 'northwest cloudband' develops with strong moisture fluxes from south of Sumatra extending over Australia; strong rain develops, as a composite average. There is a statistically significant relation (correlation coefficient 0.61) between number of ISOs each northern summer, and the Indian Ocean Dipole Index (IODI). There are about four Northwest Cloud Bands each winter that are not associated with an ISO event for every one that is; but the unrelated ISOs bring less rain to Australia. Composites of the cloud bands that are not related to ISO events are also associated with strong patterns over the equatorial Indian Ocean 6 days earlier, but the associated wind patterns are qualitatively different from ISOs.

4. Applications and impacts.

Several collaborative projects focussed on the application of seasonal climate predictions for agriculture, health, and environmental management, have commenced. Some of the agricultural projects (e.g., in Pakistan, India) are organised through the START CLIMAG program (contact: Holger Meinke, Department of Primary Industry, Queensland). The effects of the El Niño - Southern Oscillation on marine animals (dugongs) and birds are being studied (contact: Neville Nicholls, BMRC).

A pilot project titled "Capturing the Benefits of Seasonal Forecasts in agricultural management" has been carried out under the Australian Centre for International Agricultural Research. This 3-year program involved field sites in Matopos Zimbabwe (grazing management), Tamil Nadu India (farm decision making), and Mataram Indonesia (Water and Crop management). The lead scientists in Australia are drawn from the Queensland Department of Primary Industries, the Queensland Department of Natural Resources and the Bureau of Meteorology Research Centre (contact J. McBride, BMRC).

Oceans to Farms: This multi-disciplinary project is a study of the way seasonal climate forecasts can best be used to manage farming and farm-related industries. A lagged statistical relationship is established between ocean surface temperatures and variables such as plant growth and rainfall. The forecast system is tailored for specific regions, industries and decision points in the farming cycle. Different management strategies are tested using 100 years of historical data. A key result is that it is often better to predict plant growth rather than rainfall. Another key result is that skill at predicting rainfall or growth is only one factor in farm management decision-making; the same forecast can end up with very different usefulness in different contexts. The economic and conservation value of this forecast system has been studied in most detail for the northern Queensland extensive grazing industry. This experiment indicates that production increases of 16% are possible at the same time as a 12% reduction in soil loss, given appropriate management strategies based on the forecast. These benefits exceed those obtained using a forecast based on the Southern Oscillation Index (SOI). Somewhat surprisingly, the ocean-based forecasts also perform slightly better than a perfect knowledge of seasonal rainfall totals. This is because rainfall distribution is important, and predicting an index of plant growth takes this into account. Contact: Pater McIntosh, CSIRO Marine Research.

5. Sustained observations.

The Darwin Climate Monitoring and Research Station (DCMRS), a cooperative network run by the BMRC and the Northern Territory Regional Office of the Bureau of Meteorology, provides a basis for research activities in a tropical monsoon environment, including support for TRMM and the

Atmospheric Radiation Measurement (ARM) program of the US Dept of Energy. The DCMRS undertakes climatological observations and research relevant to the systematic measurement of tropical rainfall, cloud properties and their impact on radiation in the monsoon environment. Emphasis is on providing ground truth data for TRMM and ARM, and process studies including special observing projects on the four-dimensional structure, dynamics and microphysical properties of tropical convection and associated radiation. (Contact: Tom Keenan, BMRC).

Indian Ocean Sustained Observations - XBT Network: The lines IX1, 12, 22, 29 and PX2 (Banda Sea) were started in 1983-1986. The lines are now operational (i.e. long-term maintenance assured in an appropriation budget) under direction of the Joint Australian (CMR/BMRC) Facility for Ocean Observing Systems (JAFOOS). JAFOOS also operates the WOCE Upper Ocean Thermal Data Assembly Centre, where all Indian Ocean XBT data are assembled annually and given scientific quality control following published standards and procedures. The assembled data sets are available now for 1990-97. JAFOOS and International Pacific Research Centre (IPRC) are jointly proposing to use the WOCE procedure to QC all T(Z) data in the Indian Ocean for the 20th century. The panel is requested to consider and endorse the idea in principle, pending review of the final draft of the proposal. Contact: Gary Meyers, CSIRO Marine Research).

Argo network: Australia has initiated an Argo float network to collect temperature and salinity profiles to a depth of 2000m. Initially 10 floats were placed in the eastern Indian Ocean between NW Australia and Indonesia. Resources are available to maintain and extend the array southward to the SW corner of Australia and about 1000 km offshore. Contact: Neville Smith, BMRC.

To other national reports

A-A Monsoon Studies in China

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1. National research programs

1.1 South China Sea Monsoon Experiment (SCSMEX, 1997-2001) - State Key Project supported by the Ministry of Science and Technology (MOST)

Aims:

- To provide a better understanding of the key physical processes for the onset, maintenance and variability of the monsoon over Southeast Asia and southern China leading to improved predictions;
- To describe and document the space-time evolution of the large-scale atmospheric circulation and thermodynamic fields, as well as basic oceanic flow patterns and thermohaline structures associated with the SCS monsoon;
- To identify the influence of heating contrast between the SCS and surrounding regions and the roles of early monsoon (April-May) convection and multi-scale processes in the SCS during the abrupt transition and subsequent evolution of the East Asian monsoon;
- To elucidate physical processes in oceanic response to monsoon forcing and air-sea interaction in the SCS and relationships with adjacent oceans; and
- To assess and improve the ability of regional and global models in simulations and predictions of the monsoon onset in Southeast Asia and in southern China.

Achievements:

- With a dual-Doppler radar array formed by TOGA Doppler radar on R/V Shiyan#3 and C-Pol radar on Dongsha island, information of the evolution of multi-scale convective systems during the onset and development of the summer monsoon was obtained - tropical squall lines and waterspout in the monsoon trough were found for the first time over the SCS;
- Comprehensive atmospheric and oceanic datasets over a large area of East Asia and the Western Pacific Ocean in the summer of 1998, with resolution of 100-200km in the SCS region, have been collected - which may be used to analyse the interaction of multi-scale systems in the monsoon aircurrent;
- With the Areosonde at Dongsha Island, 19 monitoring flights were carried out to obtain basic data describing atmospheric boundary layer features under stable weather situation - some local abrupt changes during the evolution of monsoon were captured;
- The SCS monsoon activities in 1998 were mainly controlled by the activities of the equatorial Indian westerlies and its enhancement and northward movement was influenced by the eastward extension of this monsoonal airflow;
- The SCS monsoon broke out with two phases - the first phase was baroclinic and controlled by the interaction between the weather systems in mid-latitude and monsoon aircurrent; the second large-scale onset was linked to the significant change or adjustment of the extensive tropical circulation;
- May 23, 1998 was identified as build-up date of the SCS summer monsoon for this year, with the rapid eastward withdrawal of the subtropical high as a main process - this influenced the circulation and weather through the convective activities and teleconnection such as EPA wave propagation;
- Prior/post to the SCS monsoon onset, the SST changes over the southern and central part of the SCS was determined by the heat flux over the sea surface - before the monsoon onset, the SST was prominently high, while after the monsoon onset, the SST was low for a short time period and then rapidly restored;
- Marine PBL was observed with two research vessels and two island stations (Xisha and Dongsha Islands), and sea surface fluxes have been estimated to obtain a regional net energy budget;
- 30 to 60 daysÌ oscillation was found over the SCS, whose northward movement plays an important role in the occurrence of rainstorm over the Yangtze River Basin; and
- An atmospheric and oceanic data assimilation system over the SCS has been developed.

Further research foci:

- Facts and mechanism of onset and evolution of the SCS monsoons and their tele-connections with weather and climate over East Asia, and over remote areas such as North America;
- Relationship between air-sea interface flux and monsoon activities;
- Interconnections between oceanic conditions of the SCS and monsoons; and
- Development of global / regional air-sea coupled models and relevant numerical monsoon simulation.

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1.2 Formation Mechanism and Prediction Theory of Heavy Climatic Disasters in China (1998-2003) - State Key Project supported by MOST

Research foci:

- Study on the Dynamical Theory of the Climatic System - To analyze the dynamical characteristics of global coupled climatic system, the nonlinear interaction in the system and variability of different timescales.
- Dynamics and Prediction Theory of ENSO - To study the dynamics of ENSO cycles and the theories of forecasting the formation of El Niño and La Niña events.
- Monsoon Anomalies and Prediction Theory of Heavy Droughts and Floods - To study the variability and dynamical theory of the Asian monsoon system, the interaction between ENSO cycles and Asian monsoon; the mechanism for formation of serious floods and droughts, and the seasonal and interannual forecast on the serious droughts and floods in China.
- Influences of Tibetan Plateau and Land Surface Processes - To study the effects of Tibetan Plateau on the climatic disasters in China; to obtain the relevant parameters of the land-air interaction by the observation experiment of the land-air interaction in the arid areas in Northwest China; to analyze the characteristics of the surface boundary processes of the arid and semi-arid areas in China, and the impacts of the boundary processes on the interannual climatic variations in China.
- Design of an Up-to-date Climate Model and Study on Numerical Prediction - To improve the existing ocean-land-air coupling model and perform interannual forecast experiments on the serious climatic disasters in China.

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1.3 Variation Mechanism of Subtropical Anticyclone Belt (1998-2000) - Key Project Supported by National Natural Science Foundation of China (NSFC)

Subtropical anticyclone (SA) belt affects the motion of weather system, moisture transport, as well as the persistent anomalies of the weather and climate in subtropical regions. The structure, activity, and their relationship with the weather and climate in China and the East Asian monsoon have long been studied. However, there is lack of systematic knowledge on its variation mechanism. Of weather and climate dynamics, the dynamics of subtropical anticyclone is a challenge to scientists. The project launched comprehensive studies of the mechanism of the SA variation through data diagnosis, numerical modelling and theoretical analysis. Many significant achievements have been gained and the insight into the configuration and formation mechanism of subtropical anticyclone has been renewed.

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1.4 Analytical Study on the Seasonal-Interannual Variation of the Atmospheric General Circulation (1998-2001) - Key Project Supported by NSFC

Aims:

- To analyse the seasonal variation of the Asian and global atmospheric circulation and interannual variability;
- To validate the climate modelÌs capability in simulating the seasonal-interannual variability of Asian climate and atmospheric circulation; and
- To understand the physical mechanisms that influence the seasonal-interannual variability of Asian climate and atmospheric circulation, including the roles of sea surface temperature and land surface processes.

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1.5 The Study on ENSO-East Asian Monsoon Relationship (1997-2000) - Key Project Supported by NSFC

Aims:

- To reveal the influences of ENSO cycles at the different stages on the Asian monsoon and reveal the effects of anomalous Asian monsoon activity on ENSO events;
- To study the physical mechanisms for the interaction between Asian monsoon and ENSO cycles;
- To analyse the influences of ENSO cycles on the predictability of the interannual variability of East Asian summer monsoon; and
- To improve the forecast of the East Asian monsoon, occurrence of ENSO events and summer rainfall anomaly in eastern China.

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2. Major scientific advances

2.1 On the seasonal variation of atmospheric circulation

By applying the definition of Zeng and Zhang (1992), the seasonality of the global wind field is analysed by Xue and Zeng (1999). They found that in the lower troposphere, in addition to the classic tropical monsoon regions, there are regions with maximum of seasonality in the subtropics and in high latitudes respectively, due to seasonal migration of the subtropical highs and seasonal variation of storm tracks of the westerlies. These regions can be called the subtropical and temperate-frigid monsoon region respectively. The subtropical monsoon tends to approach the tropical one with height and eventually the tropical monsoon and subtropical monsoon merge into a whole planetary monsoon system in the upper troposphere. In the stratosphere, seasonality is much larger than that in the troposphere, and there is a well-defined belt with very large seasonality in each hemisphere caused by the opposite circulation between summer and winter and by the establishment and collapse of the night jet. In general, the baroclinic structure of seasonal variation of the atmospheric general circulation reflects the interaction between the lower levels and higher levels of the atmosphere or between the troposphere and the stratosphere.

Seasonality of the large-scale monsoon may generally be attributed to that of the zonal wind because the atmospheric general circulation is dominated by its zonal components. In some regions such as East Asian monsoon region, however, the meridional wind plays an important role in seasonal variation of East Asian monsoon, hence the monsoon intensity index defined by Webster and Yang (1992) is not well suitable for East Asian monsoon. In order to accurately depict the intensity change of East Asian monsoon, it is evident that the zonal and the meridional wind components must be considered simultaneously.

The result also shows that interannual variation of the atmospheric general circulation is closely related to seasonal variation of monsoon in monsoon regions. In the tropical Pacific, however, interannual variation caused by the external factors such as SST anomalies associated with ENSO cycle is possibly larger than that caused by the internally seasonal variation in the atmosphere.

Based on the similar method, Xue and Zeng (2001) defined an index to express the abruptness of the seasonal variation of atmospheric circulation. They find that such abruptness is generally larger in the monsoon regions than in the global average. In terms of the vertical structure, the upper troposphere is of larger abruptness in the seasonal variation.

References:

Zeng, Qing-Cun, and Bang-Lin Zhang, 1992: On the seasonal variation of the atmospheric general circulation and monsoon. Chinese J. Atmos. Sci., 22, 505-813. (in Chinese).

Xue, Feng, and Qing-Cun Zeng, 1999: Diagnostic study on seasonality and interannual variability of wind field. Adv. Atmos. Sci., 16, 537-543.

Xue, Feng, and Qing-Cun Zeng, 2001: The seasonal abruptness of the general circulation as revealed from the data analysis. Chinese J. Atmos. Sci., in press.

2.2 On the East Asian winter monsoon

Sun and Sun (1995) analysed the atmospheric circulation in the composed flood years and drought years in the Yangtze River and Huai River valleys. They revealed that the preceding winter monsoon circulation in East Asia is anomalous for the drought years. The anomalies of the preceding winter circulation include the larger meridionality of the 500 hPa geopotential height over the Eurasia, the stronger East Asian trough, frequent cold serge activities, stronger cross-equatorial flow, and stronger convective activities around the Philippines. While the preceding winter circulation anomalies for the flood years are almost opposite to those for the draught years.

Gong et al. (2001) analysed the connection between Arctic Oscillation (AO) and variability of East Asian monsoon. Two indices are chosen to describe the winter monsoon. One is the intensity of the Siberian High, defined as the average sea-level pressure (SLP) over the centre region, and the other is the temperature of Eastern China, averaged over 76 surface stations. These are two closely related components, correlated at -0.62 for the period 1951-99. Temperature drops by 0.64 degrees Celsius in association with a one standard deviation increase in Siberian high intensity. It is find that there are significant out-of-phase relationships between AO and the East Asian winter monsoon. The correlation coefficient between AO and Siberian High intensity index is ?0.48 for period 1958-98. AO is also significantly correlated with the temperature of eastern China at 0.34. However, when the linear trend is removed, the correlation is no longer significant. But the strong correlation between AO and Siberian high and temperature are still significant. These results reveal that the impact of AO influences the East Asian winter monsoon through the impact on the Siberian high. Negative phase of the AO is concurrent with a stronger East Asian trough and an anomalous anticyclonic flow over Urals at the middle troposphere (500 hPa). Both the AO and the Eurasian pattern play important roles in the changes of the Siberian High and/or East Asian monsoon. They account for 13% and 36% of the variance in the Siberian High respectively.

The Asian winter monsoon (AWM) response to global warming was investigated trough a long-term integration of the transient greenhouse warming with the ECHAM4/OPYC3 CGCM (Hu et al., 2000). The physics of the response was studied through analyses of the impact of global warming on the variation of the ocean and land contrast near the ground over the Asian and western Pacific region and the east Asian trough and jet stream in the middle and upper troposphere. Forcing of transient eddy activity on the zonal circulation over the Asian and western Pacific region was also analysed. It is found that in the global warming scenario the winter northeasterlies along the Pacific coast of Eurasian continent weaken systematically and significantly, and intensity of the AWM reduces evidently, but the AWM variances on the interannual and interdecadal scales are not affected much by global warming. It is suggested that global warming makes the climate over the most part of Asia be milder with enhanced moisture in winter. In the global warming scenario the contrast of the sea-level pressure and the near-surface temperature between the Asian continent and the Pacific ocean becomes significantly smaller, northward and eastward shifts and weakening of the east Asian trough and jet stream in the middle and upper troposphere are found. As a consequence, the cold air in the AWM originated from the East Asian trough and high latitudes is less powerful. In addition, feedback of the transient activity also makes a considerable contribution to the higher-latitude shift of the jet stream over the North Pacific in the global warming scenario.

References:

Sun, Shu-Qing, and Bo-Min Sun, 1995: The anomalous East Asian winter monsoon circulation and the flood and drought in the Yangtze River and Huaihe River Valleys, Acta Meteorologica Sinica, 53, 440-450.

Gong, Dao-yi, Shao-Wu Wang, and Jin-Hong Zhu, 2001: East Asian winter monsoon and Arctic oscillation. Geophys. Res. Lett., 28, 2073-2076.

Hu, Zeng-Zhen, L. Bengtsson, and K. Arpe, 2000: Impacts of global warming on the Asian winter monsoon in a coupled GCM. J. Geophys. Res., 105, 4607-4624.

2.3 Bimodality of the South Asia High (SAH) and its long-term variability

Zhang et al. (2000) found that there exists bimodality in the longitude location of the SAH. According to the two regions where the SAH prefers to stay, the SAH is classified into the Tibetan Mode (TM) and the Iranian Model (IM), respectively. The studies on the maintenance mechanism both from circulation structure and thermal structure manifest the different features of the TM and IM. The diagnosis based on the thermodynamic equation further reveals that the TM is closely related to the diabatic heating of the Tibetan Plateau whereas the IM is more associated with the adiabatic heating in the free atmosphere, as well as the diabatic heating near the surface.

The composite corresponding to the two modes shows that the bimodality has strong impacts on the large area climate anomalies in Asia. In the TM case, the abnormal warm centre appears over the Tibetan Plateau region accompanied by enhanced northerly airflow in the middle-high latitudes and southerly airflow in the subtropics, forming a convergence zone near 30oN and resulting in more precipitation in the areas extending from the Tibetan Plateau to the Yangtze River Valley, to the south of Japan, as well as in South China Sea and the surrounding areas. As to the IM case, opposite anomaly patterns are detected in the surface air temperature, lower troposphere circulation, and precipitation.

Zhang et al. (2001) also analysed the long-term variability of SAH. From late 1970s, the alternation of the SAH bimodality in its longitude location takes on a more low-frequency variability. More

TM cases appear in 1980s and more IM cases in 1990s. The detrended time series of the SAH intensity index shows that the signals with large variability mainly happen on the decadal scale. There is a remarkable phase transition occurring in late 1970s. The interannual variability is weak, especially before the mid-1980s.

References:
Zhang, Q., G.X. Wu and Y. F. Qian, 2001: Long-term variability of the South Asia High and its relation to tropospheric geopotential height and global SST. (Submitted to Theoretical and Applied Climatology.)
Zhang, Q., G.X. Wu and Y. F. Qian, 2000: The bimodality of the 100hPa South Asia High and its association on the climate anomaly over Asia in summer. (Submitted to Journal of the Meteorologocal Society of Japan.)

2.4 Decadal variations of the East Asian Monsoon Circulation and the monsoon-ENSO connection

As revealed by Wang (2001a), the transition of the global atmospheric circulation in the end of 1970Ìs can clearly be detected in the atmospheric temperature, wind velocity, and so on. Wavelet analysis reveals that the temporal scale of this change is larger than 20 years. The global annual mean free air temperature undergoes a transition in the end of 1970Ìs to a warmer period at all the pressure levels below 200 hPa, with the reverse change at levels near 50 hPa. As for the spatial pattern of the transition, the mid-latitudes Asia has its clear speciality where the change of air temperature is opposite to that of the global average at levels below 200 hPa. The Asian and African summer monsoon circulation becomes weaker after this transition. The trade wind over the tropical eastern Pacific in summer and winter is weakened after 1970Ìs, and, accordingly, the SST over the Nino3 region increased at the same time. The summer precipitation in some parts of China undergoes a transition as well, especially over the Yangtze, Yellow, and Huai River valleys.
The instability in the relationship between the East Asian summer monsoon and the ENSO cycle in the long-term variation was studied by Wang (2001b). By instability, we mean that high inter-relation exists in some periods but low inter-relation may appear in some other periods. It is revealed that the interannual variation of the summer atmospheric circulation during the Îhigh correlationÌ periods (HCP) is significantly different from that during the Îlow correlationÌ periods (LCP). Larger interannual variability is found during HCP for trade wind over the south eastern Pacific, the low-level air temperature over the tropical eastern pacific, the subtropical high pressure systems in the two hemispheres, and so on. The correlation between summer rainfall over China and ENSO is different as well between HCP and LCP.

References:
Wang Hui-Jun, 2001a, The Weakening of the Asian Monsoon Circulation after the End of 1970Ìs, Adv. Atmos. Sci.,18, 376-386.
Wang Hui-Jun, 2001b: The Discontinuity in the East Asian Summer monsoon-ENSO Relations, Adv. Atmos. Sci., (in press).

2.5 Variation Mechanism of Subtropical Anticyclone Belt

The dynamics of the mobile interface between the mid-latitude westerly and the tropical easterly is developed. A complete form of vorticity equation is deduced to study the interactions among each climate subsystems. The "Thermal adaptation" theory is established to reveal the atmospheric responses to external thermal forcing. Based upon theoretical study and numerical simulation, vertical inhomogeneous heating and spherical effect are proved to be the basic factors determining the configuration of subtropical anticyclone. The mechanisms of land surface sensible heating and

deep convective condensation heating in forming each of the isolated SA are revealed. Horizontal inhomogeneous heating is proved to be a key factor in connecting the anomaly of the subtropical anticyclone to the anomaly of circulation in mid-high latitudes. "Two-stage thermal adaptation" theory is constructed and the "Lindzen-Nigam" theory is extended to investigate the mechanism of how the tropical SSTA in Indian Ocean affects the abnormality of the subtropical anticyclone. This then provides a new method for short-term climate predictions.
The relationship between the abnormal strength of the subtropical anticyclone over the western Pacific and the anomalies in tropical and western Pacific general circulations, as well as sea surface temperature has been established in this study. The activities of the SA over the western Pacific in different time-scales ranging from decadal, annual, seasonal, intra- seasonal and 5-10-day period have been discovered. The influences of such persistent anomalies on the weather and climate over the basins of Yangtze River and Huaihe River are also studied.
The aforementioned results have rectified parts of the traditional knowledge about the SA formation. It has been proved that vertically sinking motion cannot be used to explain the formation of subtropical anticyclones in the upper and middle troposphere. The forming mechanism of the SA over the eastern Pacific is different from that over the western Pacific. These two anticyclones cannot be regarded as one unit system. The relationship between summer precipitation over China and the SA over the western Pacific is a kind of interaction, instead of cause and effect. Therefore it was concluded that forecasting the anomaly of summer climate must consider the anomalies of external heating sources.

2.6 Studies on the predictability and prediction of East Asian monsoon climate

2.6.1 Hindcast experiment of 1998 flood in China by the AGCM

Sets of numerical hindcast experiments were carried out to study the excessive rain happened over China in 1998 by using an atmospheric general circulation model (Wang et al., 2000). The monthly sea surface temperatures for 1998 were prescribed as the model boundary conditions. The initial atmospheric conditions for each of the 30 member simulations were obtained from the daily reanalysis data for 00 UTC from April 1 to April 30, 1998. The initial conditions for snow mass, soil temperature, and soil wetness was prescribed as those of the model climatology. The CCSR/NIES model could reproduce a reasonable degree of outlook of the summer climate anomalies over East Asia including the rain over China in 1998 given the observed monthly SSTs and the initial atmospheric conditions in April. The simulated anomalies in JJA geopotential height at 500 hPa agree well with observations over Eurasia and the tropical western Pacific. The stronger wind over 850 hPa for JJA is reasonably reproduced. The model also captures the weakness of Indian monsoon and the negative precipitation anomaly over the tropical western Pacific. The simulated subtropical high over the South China Sea is also realistic.
Discrepancies between the ensemble simulation and the observation can be found in several aspects. One of them is the overestimation of wind anomalies at 850 hPa and the OLR anomalies over the tropical western Pacific. The model simulates a northward shift of heavy rain area over China compared to the observation, and it fails to simulate the negative anomaly in JJA GH5 over the Berling Sea along the date line.
This research suggests that the initial atmospheric anomalies in April may have strong impacts on the simulated Eurasia flow pattern and the precipitation anomalies over the East Asia in the subsequent summer. However, studies of such impacts in other years would be necessary to confirm the above results. At the same time, the study on physical processes responsible for possible relationship between winter (or spring) and summer conditions over Eurasia is required.
The result shows that the enhancement of the western Pacific high-pressure system as well as the related change of the flow pattern at 850 hPa over the western Pacific and East Asia were caused mainly by the global SST anomalies. But, which part of the SST anomalies played the key role in this regard remains unknown, and may become clear through more diagnostic analysis and

numerical experiments.
Since the year 1998 was a special year both in SST anomalies and in atmospheric anomalies over East Asia, hindcast studies for other years would be much valuable.

2.6.2 ENSO prediction system based on CGCM

Zhou and Zeng (2001) developed an ENSO prediction system based on the coupled atmosphere-ocean GCM developed in Institute of Atmospheric Physics, Chinese Academy of Sciences. The modelÌs climate drift was removed by using a statistic method to correct the atmospheric variables at air-sea interface, and the climate variations in interannual scales are simulated consistent with ENSO cycle in many aspects.
An initialisation scheme was designed for inducing climate anomalies by using SST anomalies in the tropical Pacific at the background of the model climatology. The numerical experiment showed that the initialisation was successful in creating interannual variability that was needed in ENSO predictions.
The forecast system was tested by performing a series of 24-month hindcast experiments, one per month for the period of November 1981 to December 1997. The system was found to produce generally good hindcasts of SST anomalies in the eastern tropical Pacific. The correlations of SST anomaly in Nino3 region exceed 0.54 up to 15 months in advance though they are lower than the persistence in the first few months. The rsm errors are less than 0.9oC for the same forecast length. Further analyses show that the system is more skilful in predicting SST anomalies in the 1980s and less in the 1990s. This is a common discrepancy in most other dynamical forecast systems. The model skills are also seasonal-dependent, lower for the predictions starting from later autumn to winter and higher for those from spring to autumn in a year-time forecast length, especially from July to September the system performs very higher skills with anomaly correlations exceeding 0.6 up to about one and half years. It is encouraging that the prediction, beginning from March, persists 8 months long with the correlation exceeding 0.6. This is operationally useful in predictions of summer rainfall in China (Lin et al., 1999, 2000).
The results from this study are encouraging, but there are also many aspects to be improved. The initial conditions created by using the SST anomalies in the tropical Pacific are less accurate in the anomalous structure of the ocean thermocline in which the memory of the coupled system for the ENSO variability is contained. We are developing a data assimilation system similar to that of Derber and Rosati (1989), which is obviously an efficient way for inserting ocean subsurface data into the coupled system to created more accurate initial conditions that are physically in balance with the model through some appropriate modification. There are deficiencies in the present coupled model. The amplitude of the simulated interannual variability is smaller than the observation, which is presented in most coupled general circulation models. The reasons are not well known. One of the possible reasons is the coarse modelsÌ resolution, especially that the horizontal resolution in the ocean model is not higher enough in simulating the Kelvin wave well in the tropical waveguide which is regarded as the control mechanism in the ENSO evolution. Another possible reason is maybe from the coupling scheme and/or the two-component modelÌs performance themselves, such as physical parameterisation, the limited tropical region of the ocean model and so on, which suppress and/or modify the feedback between atmosphere and ocean. They are currently improving the modelÌs simulations for both climatology and climate variation by increasing the modelÌs resolution and modifying the coupling techniques. Another obvious deficiency is the lower skills in the 1990Ìs predictions. Most coupled forecast systems based on dynamical frames show the similar performance. The development of ENSO in the earlier 1990s is different from that in the 1980s and this period is sometimes referred as an irregular developing period. Some researches indicated that the longer-than-interannual time scale variability (e.g. decadal variation) maybe plays an important role, which is regarded as the interaction between tropics and extratropics (Zhang et al, 1999). The coupled model applied in this forecast system is failing in simulating this long-term variation because the modelÌs ocean is restricted in the tropical Pacific belt. In theory, therefore, the application of a global ocean model instead of the tropical one is maybe a good way to improve the forecasts, but the other difficulties caused by the global

simulation could prevent the system achieving this improvement.

2.6.3 Prediction of monsoon rainfall anomalies by AGCM

Early in 1989, the experimental extraseasonal predictions of summer monsoon rainfall anomaly by GCMs had been carried out in the Institute of Atmospheric Physics, Chinese Academy of Sciences ((IAP/CAS), and the prediction result was shown to be encouraging (Zeng et al., 1990). Since then, many efforts have been taken for the establishment and improvement of the IAP Prediction System for Short-term Climate Anomaly (PSSCA) as summarized by Zeng et. al. (1997). After its establishment, IAP PSSCA has been applied to the semi-operational real time climate prediction from 1989 to 1997 (Yuan et al., 1996; Zeng et al., 1997), verifications show that IAP PSSCA can well predict the large positive and negative anomalies of summer rainfall resulting in disastrous climate events, such as the severe flooding in the Huai and Yangtze River regions in 1991, and the severe drought in the Huai and Yangtze River regions in 1994. Generally speaking, the prediction skill for IAP PSSCA is relatively large over Eastern part of China and Southern China, which maybe ascribed to the relative high seasonal predictability over these regions (Wang, et al. 1997). In 1998, an improved version of the IAP prediction system was achieved, with major improvements in the better representation of land surface processes, the establishment and incorporation of ENSO prediction system, and the improvement of correction system etc. (Lin et al., 1998; Zhou et al., 1998). The real-time prediction results are shown to be promising, for example, the positive rainfall anomalies over Yangtze River Valley and Northeast China during the summer of 1998, the positive rainfall anomalies over Southern China and the drought over most part of North China during the summer of 1999 have all been quite well predicted by the IAP seasonal prediction system.

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To other national reports

AA Monsoon Studies in India

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1. Introduction

Considering the fact that the monsoons have a predominant influence on the society and national economy of India, monsoon variability and prediction have been the major focus of climate research in the country, in almost all the major centres of meteorological and allied studies. These centres, through their individual endeavours as well as national and international collaborative efforts, have contributed significantly to the understanding of monsoon variability on different spatio-temporal scales. In this context, the CLIVAR Asian-Australian Monsoon Panel (AAMP), which held its first meeting in India, is widely considered by the Indian groups as an effective platform to discuss the outstanding scientific issues related to regional aspects of the monsoons from a global perspective and draw up well-coordinated research initiatives in monsoon modelling as well as observational programmes. In recent years, one of the major highlights of climate research in India has been the Indian Climate Research Programme (ICRP) established by the Department of Science & Technology, Government of India, under which a wide variety of research projects related to monsoon variability are supported. The Indian research groups also actively participate in the international programmes like the WCRP, IGBP, START, etc. In addition to these initiatives, India also has active bilateral collaborative research programmes on monsoon-related aspects with many countries, e.g., USA, UK, France, China, Russia, Japan, Brazil, etc. A synthesis of the regional consequences of global change in India was completed recently under the aegis of IGBP/START, with the participation of scientists representing several major groups from South Asia. In the following paragraphs, an attempt is made to provide a brief overview of the recent activities in India, related to monsoon research.

2. Major Centres of Monsoon Research in India

The following are the major organizations/institutes/centres/departments in India, which have active research groups working on various aspects of monsoon variability and prediction:

Indian Institute of Tropical Meteorology (IITM), Pune
India Meteorological Department (IMD)
National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi
Centre for Atmospheric & Oceanic Sciences (CAOS), Indian Institute of Science (IISc), Bangalore
Centre for Mathematical Modelling and Computer Simulation (C-MMACS), Bangalore;
National Institute of Oceanography (NIO), Goa
Naval Physical and Oceanographic Laboratory (NPOL), Cochin
Space Application Centre (SAC), Ahmedabad
Centre for Atmospheric Sciences, Indian Institute of Technology, (IITD), New Delhi
Department of Science and Technology (DST), New Delhi
Department of Ocean Development (DOD), New Delhi
Physical Research Laboratory (PRL), Ahmedabad
National Remote Sensing Agency (NRSA), Hyderabad
Department of Meteorology & Oceanography, Andhra University (AU), Visakhapatnam
Department of Atmospheric Sciences, Cochin University of Science & Technology, Kochi
Department of Geophysics, Banaras Hindu University, Varanasi
Department of Physics, University of Pune

3. Indian Climate Research Programme (ICRP)

ICRP, as formulated in its Science Plan in 1996, is a multi-agency programme coordinated by the Department of Science and Technology, which is focussed on the following major objectives:

Understanding the physical processes responsible for variability on subseasonal, seasonal, interannual and decadal time scales of the monsoon, the oceans (specifically the Indian Seas and the equatorial Indian Ocean) and the coupled atmosphere-ocean-land system.

Study of the space-time variation of the monsoons from subseasonal, interannual to decadal scales for assessing the feasibility for climate prediction and development of methods for prediction.

Study of change in climate and its variability (on centennial and longer time scales) generated by natural and anthropogenic factors.

Investigation of the links between climate variability and critical resources such as agricultural productivity to provide a basis for deriving agricultural strategies for maximising the sustainable yield in the presence of climate variability and for realistic assessment of impact of climate change.

ICRP addresses the above objectives in three components, viz., (i) Monsoon Variability (MONVAR), (ii) Past Climates and Climate Change (PCCC) and (iii) Climate and Agriculture (CLIMAG). A majority of the activities under ICRP are directly relevant to AAMP interests.

A major highlight of the activities spearheaded by the ICRP is the observational programme Bay of Bengal Monsoon Field Experiment (BOBMEX) already completed and the Arabian Sea Monsoon Experiment (ARMEX) which is in the final phase of planning. BOBMEX was successfully carried out during July 16 through August 31, 1999. Two research vessels and two deep ocean buoys were used as special observation platforms, with simultaneous additional observational support from the coastal network. Analysis of BOBMEX data is in progress and some results have already been published. Under ARMEX, monsoon convection off the west coast of India will be studied in Phase I. Phase II will focus on the pre-monsoon southeastern Arabian Sea warm pool and its relationship with monsoon onset.

4. Observational Activities

India has a long history of instrumental records of climatic data, with a large number of well-distributed observatories (557 surface, 35 RS/RW, 65 PB, 199 Agromet, 45 radiation, 5000 rainfall stations, etc.). Some of these observatories have surface data extending back to more than 130 years. Special scientific expeditions sent to Antarctica have taken systematic meteorological observations including vertical ozone profiling from the Indian stations. Satellite based observation and derived data are also available from INSAT. Marine meteorological data and data from special oceanographic cruises are also archived. The climate data are archived at the National Data Centre of IMD.

NIO has a long-term observational programme in the Indian seas. XBT observations are being carried out along 4 shipping routes, viz., Chennai-Port Blair, Kolkata-Port Blair, Bombay-Mauritius and Chennai-Singapore. The Bay of Bengal XBT lines will be enhanced to include met parameters, chlorophyll and phytoplankton. DOD has an ongoing programme on ocean observation systems to continuously monitor meteorological and oceanographic parameters from drifting and moored buoys. This programme is expected to be enhanced substantially in the next few years.

IITM organized a special Land Surface Processes Experiment (LASPEX) during 1997-99, in which a large amount of surface and upper air data have been collected for 2 years at five experimental sites in the Sabarmati river basin of Gujarat.

IMD has recently started a National Climate Centre (NCC) at Pune, for climate monitoring and diagnostics services. NCC brings out monthly and seasonal 'Climate Diagnostics Bulletin of India', and other publications related to extreme climatic events and special climatological reports.

IITM has developed long-period homogeneous monthly rainfall data sets on sub-divisional/regional/all-India scale. These data sets for the period 1871-1999 are available for download on http://www.tropmet.res.in. Regional-mean monthly surface-air temperature data are also available at the same web site for the period 1901-90.

5. Modelling Activities

The major institutes in the country extensively dealing with modelling studies are IITM, NCMRWF, IITD, IISc, SAC, NIO, CMMACS, AU, etc. These groups are involved in a variety of modelling activities related to the monsoons. Extensive sensitivity studies and experimental seasonal forecasts have been made at IITM using the COLA and UKMO atmospheric general circulation models (GCMs). IITM participated in the CLIVAR Asian-Australian Monsoon AGCM Inter-comparison Project to study the impact of 1997-98 El Nino on the Asian monsoon. Different groups have also been involved in model output diagnostics for validation of monsoon simulations in atmospheric as well as coupled GCMs. Attempts have been made to develop future scenarios for the monsoon using model data from climate change experiments. Major programmes of work have now been undertaken to use high-resolution regional climate models for climate change scenario development for impact assessments. Several groups have used basin scale ocean models to understand intraseasonal to interannual variability of circulation and SST of the Indian Ocean.

6. Seasonal Forecasting of the Indian Summer Monsoon Rainfall

IMD has been issuing operational seasonal forecasts since 1988, of the Indian summer monsoon rainfall over the country as a whole. The forecast is mainly based on a "power regression" model based on 16 parameters. In the year 2000, the model was updated by replacing four out of the 16 parameters. Prominent among the dropped predictors was the April 500 hPa ridge location. IMD also issues seasonal forecasts for a few homogenous monsoon regions, viz., northwest India, peninsula, and northeast India. Experimental long-range forecasts have also been attempted by some groups in the country, based on empirical techniques, neural networks and GCMs.

7. Major Ongoing Research Projects

The following are some of the major areas relevant to monsoon research, in which the various groups in the country are engaged:

- Climate change and variability on regional scale, with special emphasis on the Indian summer monsoon
- Studies of interannual variability of the summer monsoon and its teleconnections, role of global atmospheric/oceanic phenomena such as ENSO, QBO and other anomalies of the global general circulation as well as land surface conditions
- Intraseasonal variability of summer monsoon rainfall and its role in the interannual variability of the monsoon
- Seasonal prediction of the Indian summer monsoon by empirical and dynamical methods, and also development of long-range prediction products on smaller spatial and temporal scales
- AGCM studies of the interannual variability of the monsoon and its sensitivity to various regional/global forcings
- Model output diagnostics for the validation of monsoon simulation by major atmospheric and coupled GCMs

- Development of regional climate change scenarios for the monsoon and impact assessments Observational studies of coupled land-ocean-atmosphere processes involved in monsoon variability
- Use of reanalysis data products for understanding monsoon processes and also possible applications in seasonal prediction
- Application of satellite-derived data products in observational/modelling studies of the monsoon
- Palaeoclimatic studies based on tree rings, corals, marine sediments, etc. to reconstruct the past monsoon variations

8. Future Programmes

Modelling studies will continue to be a major focus of monsoon research in the country, with the primary objectives (i) validating the monsoon simulations and identifying the biases, (ii) sensitivity studies of various regional/global forcings; (iii) model output diagnostics of monsoon processes; and (iv) future climatic scenario development. The coming years will also see a greater emphasis on the role of the Indian Ocean and the adjacent Indian seas in monsoon variability, by means of special observational studies. Development of long-period homogeneous observational data products on monsoon rainfall and related parameters with a higher spatial and temporal resolution will be actively pursued.

To other national reports

AA Monsoon Studies in Japan

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The Frontier Research System for Global Change (FRSGC) is investigating the atmosphere-ocean circulations and their variability associated with the Asian-Australian monsoon using atmospheric and/or oceanic GCMs and coupled GCMs. The Japan Meteorological Agency (JMA) also investigates the large-scale and the regional-scale variability in the atmospheric circulations and the predictability of the variability using the observed data and the numerical models. The intraseasonal variability in the tropical regions of the Indo-Pacific area, the seasonal variations in the Asian-Australian monsoon regions, and the interannual variations associated with the ENSO and the Indian Ocean Dipole Mode are the main targets of the research.

The Frontier Observational Research System for Global Change (FORSGC) is conducting intensive field observations in the Asia/Eurasian region and the Indian and the Pacific Oceans to investigate the atmosphere-ocean-land interactions associated with the climate variability in the Indo-Pacific sector. The atmosphere-land observations include (a) deployment of the in-situ automatic flux measurements network in the Eurasian continent, (b) Doppler radars, the wind profiler system, radiosonde observations in the eastern Asia (Meiyu or Baiu frontal zone) and the western tropical Pacific (the warm water pool region), and (c) the comprehensive network of the radiosonde observations, GPS water vapour measurements, and stable isotope hydrological measurements in the Asia/Pacific monsoon region as well as Aerosonde observations in the western tropical Pacific Ocean. The ocean observations are (a) ADCP mooring at 90E on the equator from November 2000 for at least 4 years, (b) about 10 ARGO floats deployment per year in the Indian Ocean and more in the Pacific Ocean, (c) several surface drifter deployments. In addition, the FORSGC and the JMA and the Fishery Agency jointly maintain three VOS XBT/XCTD lines in the Indian Ocean and the western tropical Pacific Ocean as well as several other XBT observations in the Indian Ocean by the voluntary ships. The Japan Marine Science and Technology Centre (JAMSTEC) is maintaining the TRITON buoys in the western tropical Pacific ocean and is planning to deploy two TRITON buoys in the tropical eastern Indian Ocean in October 2001. The R/V Mirai of JAMSTEC goes to the eastern Indian Ocean once a year.

There are other individual research activities on the A-A monsoons by the scientists in the universities. The above FRSGC and FORSGC projects are carrying out under the strong cooperation with the university scientists.

To other national reports

AA Monsoon Studies in Korea

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Korea reports two sets of monsoon-related activities at the 2001 Asian-Australian Monsoon Panel. The first is the Asia-Pacific Economic Cooperation (APEC) Climate Network (APCN) initiated by Korea Meteorological Administration, and the second is the activities of new institute, the Climate Environment System Research Centre (CES) established in Seoul National University, September 2000. The objective of the APCN is to establish a climate network in the Asian-Pacific region and to produce experimental multi-model ensemble prediction for APEC member countries. It is expected that the APCN will gather the dynamical seasonal prediction products from Australia, Canada, China, Japan, Korea, Russia, USA, and Chinese Taipei to produce the multi-model ensemble seasonal prediction and disseminate the climate prediction information to APEC member countries. The APCN will particularly focus on the prediction of Asian summer Monsoon, which controls the regional climate over the Pacific-Asian sector.

The CES is a Korean national science centre endorsed by the Ministry of Science and Technology and financially supported by the Korean Science and Engineering Foundation for 9 years. The objective of the CES is to provide the tool of integrated prediction system for regional climate and atmospheric environment. The CES consists of three research groups: The process study group, atmospheric environment group, and the climate modelling and prediction group. The CES is a kind of virtual institute with a core facility at Seoul National University, which support twenty professors from six domestic universities. The CES will play as a Korean national focal point of various international climate programs, particularly WCRP/CLIVAR. It is particularly mentioned that the CES has been coordinating the Cyber Institute of Pacific-Asian Climate System (CIPACS) to promote international cooperative researches in the regional climate problems, particularly the East Asian Monsoon variability. At present, the scientists participating in the CIPACS are from various institutes in the Asia-Pacific region such as NASA, the University of Tokyo, Institute of Atmospheric Physics (IAP, China), The National Taiwan University, the University of Hawaii/IPRC, and others, and the CES provides a central facility for the CIPACS.

To other national reports

A-A Monsoon Studies in the US

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Executive Summary

The Asian-Australian Monsoon (AAM) is an integral component of the earthÌs climate system, involving complex interactions of the atmosphere, the hydrosphere and the biosphere. Monsoon rainfall sustains life for more than 60% of the world population. The re-distribution of AAM heat sources and sinks may alter the large- scale circulation thus affecting weather and climate in regions far away from the AAM. Disruption in agricultural and industrial production, property damage and fatality, and spreading of diseases caused by AAM droughts and floods not only have devastating effects in monsoon countries, but also pose serious threats on the global economy, with possible security implications for the USA and other highly industrialized countries of the world. Understanding and improving the predictions of the monsoon are therefore extremely important and should be considered high- priority research with immediate benefit for mankind.

Recent studies have revealed that aspects of global climate change may be rooted in rising sea surface temperature and increased deep convection in the Indo-Pacific region. It is likely that a major impediment to making reliable projections of global warming may lie in our inability to understand and model the global re-distribution of AAM heat sources and sinks in global change scenarios. Therefore developing a strong AAM research program is paramount in meeting one of major goal of CLIVAR: to identify and understand the major patterns of climate variability on seasonal and long time scales, including climate change and evaluate their predictability and to improve their predictions.

Currently, CLIVAR has focused on natural variability of the coupled ocean-atmosphere system, while GEWEX has been devoted to interactions of the land and the atmosphere. Both programs are now poised to explore and exploit the predictability and predictions of components of the climate systems that involve full ocean-atmosphere-land-biosphere interactions. The AAM is therefore at the core of CLIVAR and GEWEX. US scientists have traditionally exerted strong leadership in international AAM research. However, this leadership will soon be forfeited unless an organized AAM research effort is put into place in the US. Given the importance of AAM in climate research and its linkages to various components of the US CLIVAR program, it is imperative that a coherent US strategy for studying the AAM be developed and integrated into the US CLIVAR program.

In this document, we present a 5-year research plan for the AAM under the US CLIVAR program. The AAM research plan is developed with the following overarching goal: To understand and predict AA-monsoon variability and its interaction with other parts of the EarthÌs climate system

The AAM research plan is discussed in terms of five components: empirical studies, modelling, process studies including field campaigns, long-term observations, and data initiatives. A summary of recommendations includes:

- Conduct empirical diagnostic studies to better understand monsoon-ocean processes in the Indian and western Pacific Oceans, monsoon-land processes over Eurasia and maritime continent, intraseasonal oscillations and global teleconnections associated with the redistribution of AAM heat sources and sinks.

- Carry out model intercomparison experiments using a hierarchy of models, especially coupled models, to explore physical mechanisms and predictability associated with slow changing boundary conditions at the ocean and land interfaces, and possible role of intraseasonal oscillations. Coordinate efforts in improving model physical representation of monsoon processes.

- Begin planning of a coupled ocean-atmosphere process study involving a field campaign in the tropical eastern Indian Ocean within the next 5 years in conjunction with related national and international programs.

- Design an observational network for long-term monitoring of the Indian Ocean in close cooperation with international CLIVAR and relevant global observation systems.

- Support a data mining effort to collect, standardize, archive and distribute historical data from all

monsoon regions to provide comprehensive and research quality data to the scientific community.

Linkages of the US AAM research to international monsoon research especially to ongoing CLIVAR and GEWEX activities are emphasized. The research plan presented here is expected to be a dynamic one. The AAMWG will continue to work with the US CLIVAR panel to further develop and modify the research plan as the need arises.

To other national reports

Last update: 1/16/02 by Andreas Villwock