Report of the 1st Indian Ocean Panel & 6th Asian-Australian Monsoon Panel Joint Meeting

18-20 February 2004, Indian Institute of Tropical Meteorology, Pune, India

Contents

Action List

Action from AAMP5: Webster/Schiller write a letter to the Argo Science Team with a copy to the GODAE Steering Team to summarizing the Panel's ongoing effort to develop recommendations of how to deploy the floats in order to efficiently monitor intra-seasonal oscillation in the tropical oceans.
Action 1: AAMP and IOP (McCreary, Slingo, Hendon, Schiller) will organize an Indian Ocean Modeling Workshop preliminarily planned for November/December 2004. They will work with relevant experts to decide dates, venue, funds and foci of the workshop.
Action 2: The IOP (McPhaden assisted by members) will design a tropical mooring array including measurements of Indonesian Through-flow and western boundary currents and including surface flux sites for calibration of basin scale products.
Action 3: The IOP/AAMP (Meyers/Schiller) will promote and help plan further OSSE's to set sampling guidelines for an integrated observing system that will include Argo floats, the tropical mooring array and other measurement platforms. Initial results will be reported at the Indian Ocean Modelling Workshop mentioned above.
Action 4: The IOP (Chair) will write OOPC recommending the review of global XBT sampling, and participate in the review if required.
Action 5: The IOP chair will contact IBPIO to discuss how the IOP can help find resources to complete the drifter array.
Action 6: The AAMP will communicate to Vasco/Cirene to promote the case for a detailed field experiment on the suppressed MJO phase. (At the time of publishing this meeting report, communication to the Vasco/Sirene group had been initiated through the ICPO. Jean Philippe

Duvel, one of the leading scientists of the project, confirmed that the group planned to carry out 30-day cruises, which will therefore hopefully cover both active and suppressed phases of MJO.)
Action 7: AAMP (Kumar Kolli) will be represented in SASCOM and to contribute to long term planning of MAIRS. There is a need to develop formal programme linkages between AAMP and MAIRS, to be initiated by a formal letter from the panel co-hairs to the coordinator MAIRS and the START Deputy Director.
Action 8: Kolli and Yan will investigate the possibility of a joint meeting between MAIRS and AAMP, by contacting the coordinator MAIRS and the START Deputy Director.
Action 9: Register strong concern about lack of dialogue with GEWEX CIMS project. Ask JSC to provide guidance (co-chairs, ICPO)
IOP Implementation Plan writing assignments: Details are in Section 3.4

Background

A. The Asian-Australian Monsoon Panel (AAMP) is a part of the CLIVAR organization. It plays a primary role in the development of CLIVAR's research programme for monsoons in the Asian-Australian sector extending from the western Pacific Ocean to Africa. The programme includes investigations of the annual monsoon cycle, and intraseasonal through interannual to longer-term variability of the entire monsoon system. Its terms of reference are to:

� Evolve a strategy to assess climate variability and predictability of the coupled ocean-atmosphere-land system in the Asian-Australia-Africa monsoon region;

� Design and implement a programme to investigate the mechanisms of ENSO-monsoon interactions;

� Determine a monitoring strategy for the Indian Ocean, Western Pacific and surrounding marginal seas and land regions necessary for investigating the structure and variability of the monsoon;

� Co-ordinate and promote interactions among meteorologists, oceanographers and hydrologists from interested nations;

� Develop an implementation plan for monsoon research in the region, that recognizes the need for a well coordinated and optimized set of process studies; and

� Work in co-operation with other existing and planned regional and multinational programs directed at improving our understanding of the monsoon system, which include investigations on regional weather forecasting, seasonal climate prediction and impacts on human activities.

The history of the panel and its activities are recorded in previous meeting reports (http://www.clivar.org/organization/aamon/index.htm).
The AAMP membership at the time of the meeting was:

J. Slingo	Co-Chair, University of Reading, Reading, UK
P. Webster	Co-Chair, Georgia Institute of Technology, Atlanta, USA
H. Hendon	BMRC, Melbourne, Australia
I.-S. Kang	Seoul National University, Seoul, Korea
R. Kumar Kolli	Indian Institute of Tropical Meteorology, Pune, India
W. K.-M. Lau	NASA/GSFC, Greenbelt, USA
J. McCreary	IPRC, Honolulu, USA
G. Meyers (IOP chair)	CSIRO, Hobart, Australia
A. Schiller	CSIRO, Hobart, Australia
H.-J. Wang	Institute of Atmospheric Physics, Beijing, China

B. The Indian Ocean Panel (IOP) was recently established by CLIVAR and GOOS (through Indian Ocean GOOS and the Perth Office of IOC). Both programmes require a strategy for observing the Indian Ocean and recognize the need for high-quality ocean observations for research and ocean applications. Therefore the IOP was established to:

� Provide scientific and technical oversight for a sustained ocean observing system for the

Indian Ocean and Indonesian Throughflow in order to provide ocean observations needed for climate variability research and to underpin operational ocean applications and services relevant to the region, particularly with regard to ocean-state estimation and climate prediction.

� Develop, coordinate and implement a plan for a sustained ocean observing system for the Indian Ocean to (a) meet the common requirement of CLIVAR research themes and regional initiatives, particularly those identified by AAMP and VACS and the CLIVAR modeling panels, (b) satisfy the common requirements of GOOS and its modules, and (c) coordinate implementation activities in collaboration with relevant regional and global bodies and IOGOOS and JCOMM in particular.

� Liaise with relevant research Panels of CLIVAR and implementation Panels of GOOS and JCOMM and provide a focal point for coordination of ocean observing networks in the region.

� Report to the CLIVAR SSG through its AAMP and to GOOS through the IOC Perth Office.

The current IOP members are

G. Meyers (chair)	CSIRO, Hobart, Australia
S. Burhanuddin	Ministry of Marine Affairs and Fisheries, Jakarta, Indonesia
P. Hacker	University of Hawaii, Honolulu, USA
Y. Kuroda	JAMSTEC, Yokosuka, Japan
Y. Masumoto	FORSGC, JAMSTEC, Tokyo, Japan
J. McCreary (AAMP)	University of Hawaii, Honolulu, USA
M. McPhaden	NOAA, PMEL, Seattle, USA
R. Molcard	Laboratoire d'Oceanographie Dynamique et Climat, Paris, France
L. Ogallo (VACS)	University of Nairobi, Nairobi, Kenya
M. Ravichandran	Indian National Centre for Ocean Information Services, India
F. Schott	Institute for Marine Research, University of Kiel, Germany
S. Shetye	National Institute of Oceanography, Pune, India
B. Tilbrook (IOCCP)	CSIRO, Hobart, Australia
P. Webster (AAMP)	Georgia Institute of Technology, Atlanta, USA

As indicated in the member list, the IOP includes representatives from the AAMP, VACS and IOCCP. Web links for details of these organizations can be found through http://www.clivar.org/organization/indian/. Appendix 5 expands all the acronyms used in this report.

The ICPO contact for the AAMP and IOP is Zhongwei Yan (c/o Southampton Oceanography Centre, Southampton, UK, zxy@soc.soton.ac.uk). The contact for IOC Perth Office is Bill Erb (c/o Bureau of Meteorology, Perth, Australia, W.Erb@bom.gov.au).

C. The aims of the joint panel meeting

� To develop a joint vision for the two panels for the promotion of IOP activities. Specifically, to develop and implement a working plan for IOP for the near term (2-3-years) taking into account the implementation time lines of AAMP and CLIVAR (up to 2013) and IOC/GOOS.

� To review/update the implementation process of AAMP, specifically to summarize current status and the near-term development in monsoon modeling (in order to develop a working plan for a monsoon modeling workshop in collaboration with GEWEX building on the CIMS and COPE initiatives), monsoon prediction and applications.

1. Introductory Remarks

The 1st Indian Ocean Panel and 6th Asian-Australian Monsoon Panel joint meeting was held at the Indian Institute of Tropical Meteorology, Pune, India. Dr. G. B. Pant (Director of the host institute) opened the 3-day meeting at 9:00 am, 25 February 2003 by welcoming the delegates. Profs. J. Slingo, P. Webster and Dr. G. Meyers, as the panel chairs, thanked Dr Pant and welcomed new panel members and all experts to the meeting. The chairs reiterated the importance of the Indian Ocean observing system and the relevance of this to the AAMP. Prof. Webster made special mention of the importance of the winter as well as the summer monsoons.

Contact details of the 26 attendees are listed in Appendix 1. The meeting agenda is at Appendix 2 and it is also available online at CLIVAR�s web site with links to presentations (http://www.clivar.org/organization/aamon/aamp6/aamp6iop1_agenda.htm).

2. Joint Sessions

2.1. IOC/GOOS and CLIVAR Activities

IOC/GOOS perspective of the IOP - Bill Erb, Head of the IOC Perth Regional Programme Office, stated that the IOC was very pleased to be co-sponsoring the IOP with CLIVAR. The idea for a planning panel for an Indian Ocean observing system originated at the SOCIO meeting in Perth in 2000 and was discussed/promoted at the 4th and 5th AAMP meetings. This was later reinforced at the first meeting of Indian Ocean GOOS (IOGOOS) in Mauritius in 2002. IOGOOS is a GOOS Regional Alliance (GRA) based at Indian Center for Ocean and Information Systems (INCOIS) in Hyderabad. It is in fact one of the sponsors of the IOP and one of their primary goals, as stated in their organization strategy, is the establishment of an observing array. IOGOOS recognizes that the coupling of research and operational requirements is necessary for the array�s design. The IOP intends that their plan will be closely coordinated with the work of JCOMM and that both JCOMM and CLIVAR oversight and input will sought. The IOC is very pleased at the mix and expertise of the people named to the panel and will do its utmost to ensure they are funded to carry out the work expected.

WCRP/CLIVAR Activities - Dr. Mike Sparrow forwarded apologies from Drs. Zhongwei Yan and Howard Cattle, who co-authored the presentation but could not attend the meeting. As the presentation showed, the establishment of the IOP filled an organizational gap in CLIVAR, which had previously set up ocean basin panels for the Atlantic, Pacific and Southern Oceans. The panels were briefed on a few important activities as follows:

The **COPE**, Climate Observation and Prediction Experiment, was recently initiated (JSC 2003, Reading), to regulate the future direction of the WCRP (by the time of writing this report, the concept evolved to **COPES**, Coordinated Observation and Prediction of the Earth System). It aims to provide society with a tangible result on what is, and what is not, predictable at weekly, seasonal, interannual and decadal time scales; and to provide the research community with a central theme for building climate observation systems, developing climate system models and climate data assimilation techniques, and computing and data processing systems. Its specific objectives that are relevant to the AAMP/IOP include:

� determining the extent to which seasonal prediction is possible with current data/models;
� determining the extent to which the various monsoons are predictable;
� assessing the extent to which ISOs are predictable in coupled models; and
� determining how, why and where modes of climate variability change in response to anthropogenic forcing.

The COPES is still under development and contributions from the panels are appreciated.

The **CLIVAR Data and Information System** is being developed. The ICPO will synthesize information and develop tools, but it is essential that panels, especially the data liaisons (currently I-S Kang for the AAMP and M Ravichandran for the IOP), provide input. An example is that the ICPO developed a facility at CLIVAR�s web for scientists to add/update information of new/ongoing carbon-measuring and hydrographic cruises, simply by clicking on the link http://www.clivar.org/carbon_hydro/hydro_table.php. The system will be very useful for summarizing / highlighting advances in the field, but only if there is sufficient input from experts.

The **CLIVAR mid-term assessment** was underway, aimed at measuring the achievements to date against the CLIVAR objectives and providing the SSG with the input to determine what steps might be necessary to ensure future progress. Reports from all panels would be reviewed at the next SSG meeting, immediately after the First International CLIVAR Science Conference (Baltimore, June 2004). The assessment, together with other relevant documents developed by the panels (e.g., **the AAMP Prospectus and the CLIVAR folder with flyers**, to be discussed in a later section), will be used to regulate the future activities of the panels.

Other monsoon studies with WMO sponsorship were noted. The AAMP has close links to the GEWEX monsoon studies. A link was to be developed with the START Integrated Regional Study of Monsoon Asia (IRS-MA), which is aimed mainly at long-term and anthropogenic climate changes, impacts and applications (more detailed discussion in section 4.2 resulting in Action 7). There are some activities that could perhaps do with more coordination, e.g., the International Workshop Series on Monsoons sponsored by the Committee of Atmospheric Science/Working group on Tropical Meteorology Research (WGTMR).

2.2. Joint Issues

The second-day joint panel session started with a summary of items discussed in the parallel sessions (details in later sections) the previous day. The meeting then continued with several talks addressing issues concerned by both panels.

Ocean Carbon Project and AAMP/IOP - In his talk titled 'Carbon and CLIVAR interactions in the Indian Ocean', Dr. Bronte Tilbrook pointed out that the JGOFS/WOCE CO_2 survey of the oceans during the 1990s had dramatically improved understanding of the ocean storage of anthropogenic CO_2 and the air-sea exchange of CO_2. The results show that between 1800 and 1994 the anthropogenic CO_2 storage in the Indian Ocean, north of 50S, is about 20 PgC of 118 +/- 19 PgC of the total ocean storage. Most of the storage in the Indian Ocean is in the mode and intermediate waters, with the storage pattern being strongly influenced by the shallow overturning circulation. Surface underway measurements of CO_2 have also provided the first patterns of the air-sea fluxes of CO_2 in all the major ocean basins. Carbon cycle researchers are building on these results to develop a program aimed at documenting and understanding how the air-sea exchange and storage of CO_2 is evolving in the ocean. The work is coordinated through the International Ocean Carbon Coordination Project (IOCCP), which is jointly sponsored by IOC, SCOR, and the Global Carbon Project. The IOCCP assists in the design and implementation of the carbon research and in building links to IGBP and WCRP programs. The research has two key observational themes; repeat hydrographic sections and surface observations (time series and ship of opportunity).

Repeat hydrographic section work aims to determine changes in CO_2 storage and associated transports on decadal scales. The work is closely integrated with CLIVAR activities and is aligned with the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) program of IGBP and SCOR. Understanding the role of the overturning circulation in controlling the storage pattern and how it might change will benefit from interaction between CLIVAR and IOCCP. Information on Indian Ocean sections planned or recently completed is available at: http://ioc.unesco.org/ioccp/hydglobal.htm. Three sections with CO_2 measurements have been completed since 2000 in the subtropical Indian Ocean. The USA proposes to complete meridional sections along WOCE I9N and I7N in 2009 (Table 1). Chokepoint sections in the Indian sector of the Southern Ocean are also planned by Australia (I9S, 2005) and the USA (I6S, 2008). The distribution of the sections is designed to allow the storage to be calculated for the Indian basin and most follow WOCE sections. Extra coverage in the tropical Indian Ocean would be useful including a section across the Indonesian throughflow.

Section	Country	Status
Indian Ocean DOTSS	Australia, CSIRO	completed 2000
I5	UK, SOC	completed 2002
I3/I4	Japan, JAMSTEC	completed 2003
I7N	USA, NOAA	planned 2009
I9N	USA, NOAA	planned 2009

The surface observation network aims to resolve seasonal to interannual changes in the air-sea flux of CO_2 on a basin scale to 0.2 PgC/yr. The work is aligned with the Surface Ocean - Lower Atmosphere Study (SOLAS), and the coverage in the Indian Ocean needs to be developed. The French OISO program (Metzl, LBCM) has a winter-summer sampling program in the central Indian Ocean between Reunion Island, Amsterdam Island and Kerguelen Island. India carries out a program of time series and underway measurements in the Arabian Sea and Bay of Bengal (Kumar, NIO). With the exception of measurements on one Japanese cruise each austral summer down the east Indian Ocean (Hashida, NIPR) there is no other routine coverage of surface carbon in the Indian Ocean. Integration of the CO_2 measurements with XBT lines and new time series moorings in the region are two ways to substantially improve coverage.

Based on Dr. Tilbrook's report, the IOP agreed to develop the carbon programme as a part of its evolving implementation plan. The carbon measurements will form a part of the integrated observing system for the Indian Ocean.

Argo sampling to support monsoon research - As Dr. Andreas Schiller reported, Argo floats are a core element of the ocean observing system in the Indian Ocean, which will ultimately improve predictability of the monsoons. Open questions remain as to where and how often to sample the upper ocean. Or, as John Gould, Argo Project Director, put it: can the AAMP and IOP '*identify crucial areas that are presently blank that should have high priority for infilling to meet the needs of those trying to understand monsoon dynamics?'* (2002). The task is to aid the design for an Argo float array in the Indian Ocean by inferring information from Observing System Simulation Experiments (OSSEs).

Some preliminary results from activities undertaken in India, the U.S. and Australia suggest that capturing variability on intraseasonal-to-seasonal scales in the Indian Ocean requires a spatial sampling with approximately $x < 500$km and $y < 100$km (less in the equatorial Indian Ocean and Western Boundary Currents, larger elsewhere). Intraseasonal variability requires a temporal sampling of 5 days or less (current sampling period is typically 10 days). An enhancedan> temporal and spatial sampling by Argo floats might attract higher costs. For example, shorter lifetimes of the Argo system might be a consequence of running the batteries down by more frequent sampling. Such additional costs need to be taken into account when drawing conclusions about the feasibility of higher sampling rates. Consequently, amendments to the current sampling strategy might require joint international efforts to accommodate additional costs.

Current research activities are virtually uncoordinated and without any specific funding, well-defined research goals or timelines. To make progress with the design of an Argo float array in the Indian Ocean, the AAMP/IOPs were requested to

� support the formal evaluation of individual data sets and their role in improving our understanding of the ocean. A full observing system design requires state-of-the-art models and estimation methods.

� provide a platform for assessment of an Indian Ocean observing system and of the utility of new ocean data sets, and, ultimately, aid the acquisition of the most useful data through adaptive sampling.

To facilitate progress with a sustained, integrated ocean-observing system, the AAMP and IOP were requested to support and encourage the following research efforts in OSSEs through evaluation of:
� existing observational data from moorings and Argo floats,
� different models (eddy/non-eddy resolving) and
� methods (forward models, adjoint models, Kalman Filter techniques etc.)

Special emphasis should be given to state-of-the-art eddy resolving models such as those being used by the international GODAE community. The Argo Science Team, AAMP, IOP and GODAE might want to consider a joint activity supporting the design and evaluation of an integrated observing system using a combination of observing platforms (e.g. moorings, Argo floats and XBT lines).

The panels acknowledged Dr. Schiller's suggestions and agreed to write to relevant organizations to promote the suggested studies (see Action from AAMP5 below and more discussions and Action 3 in Section 3.2).

Action from AAMP5: Webster/Schiller write a letter to the Argo Science Team with a copy to the GODAE Steering Team to summarizing the Panel's ongoing effort to develop recommendations of how to deploy the floats in order to efficiently monitor intra-seasonal oscillation in the tropical oceans.

Modeling Indian Ocean Circulation - Dr. Jay McCreary started the discussion with a talk entitled 'Modeling Indian Ocean (IO) circulation: Successes and Limitations'. The talk focused on three questions: What IO phenomena remain to be explored with existing models? What specific improvements are needed for IO models? In what way can an IO modeling effort link with the other CLIVAR modeling groups?

He began with a brief summary of accomplishments in the field of Indian-Ocean modeling. Much has been accomplished since the first Indian Ocean numerical modeling paper: probably O'Brien and Hurlburt's (1974) simulation of the Wyrtki Jets. Progress in IO dynamics has recently been reviewed by Schott and McCreary (2001). Dr. McCreary highlighted progress in understanding the dynamics of the Wyrtki Jets, Somali Current, Indian coastal currents, Indonesian Throughflow, the Cross-Equatorial and Subtropical Cells, and mixed-layer processes (primarily in the Arabian Sea). He also noted progress in understanding the influences of ENSO and the Indian Ocean Dipole (or Zonal Mode, IODZM) on Indian-Ocean circulations.

Dr. McCreary proceeded to outline limitations of our current knowledge, asking: What phenomena can still (or should still) be studied with existing models? What are existing models not able to do? Regarding the mean and seasonal cycle, McCreary noted that the dynamics of the Eastern Gyral Current are still not understood, and that, although there are many ideas about the origin and maintenance of the Leeuwin Current, its basic dynamics are still a matter of debate. Regarding interannual variability, much work needs to be done on Indonesian Throughflow and Sumatra/Java upwelling, the latter a key component in the IODZM. Modeling of intraseasonal variability in the ocean needs attention. Among other things, recent work suggests that this variability is associated with SST anomalies that feedback significantly to the atmosphere. Dr. McCreary focused attention on inability to adequately simulate thin salinity layers in the eastern equatorial Indian Ocean and Bay of Bengal in models. It is doubtful that existing GCMs can simulate them, without improvements to their mixed-layer parameterizations. Progress in modeling salinity will be limited unless much better rainfall and river runoff data sets become available.

Dr. McCreary summarized the e-mail exchanges he had with the leaders of three CLIVAR modeling panels, namely John Mitchell (WGCM), Ben Kirtman (WGSIP), and Claus Boening (WGOMD) to find out if the Panels are addressing the needs of the Indian Ocean (the edited versions of those messages handed out at the meeting are in Appendix 3). Tony Busalacchi (CLIVAR SSG co-chair) had expressed the fear that IO issues might be overlooked in the Panels without IO representation. Ben Kirtman noted that WGSIP is becoming aware of the importance of IO climate, and in particular its potential impact on the Pacific sector. Claus Boening wrote that WGOMD is interested in low-frequency ocean variability, but at periods longer than seasonal-to-interannual. Based on these messages and discussion at the meeting, it seemed that the best link of the IO modeling community was to WGSIP. A link to WGOMD was less clear but possible; for example, questions concerning the interaction of Pacific Decadal Variation with the IO would seem to be of interest to both groups.

One solution for the AAMP/IOP was to establish their own (informal) modeling activity for the Indian Ocean to identify key issues from both an IOP and AAMP perspective. Dr. Harry Hendon suggested that the panels could provide advice with e.g. hindcasts, and determine the key issues required for model improvement, which could be communicated to the global modeling groups. The general feeling was that the AAMP should work on modeling issues of relevance to the Indian Ocean and surrounding area. It was generally felt that a workshop should be held to tackle these problems.

In a later talk Prof. Julia Slingo noted that one reason why coupled models have problems with ISOs is the lack of sufficient vertical resolution in the upper few meters of the ocean. OGCMs with ~10m vertical resolution simply do not adequately capture the diurnal cycle. After the meeting Dr. Andreas Schiller pointed out that many of the problems mentioned by Dr. McCreary are likely to be related to this problem and the key might be a combination of both better mixed-layer models as well as higher vertical resolution in the uppermost ocean.

Action 1: AAMP and IOP (McCreary, Slingo, Hendon, Schiller) will organize an Indian Ocean Modeling Workshop preliminarily planned for November/December 2004. They will work with relevant experts to decide dates, venue, funds and foci of the workshop.

The Workshop will review Indian Ocean simulations within coupled models and forced ocean model hindcasts, identify key strengths and weaknesses and knowledge gaps, and design experiments to quantify the predictability of, and the predictability arising from, the Indian Ocean. It may also address OSSE's to assist setting sampling guidelines for development of the sustained, integrated observing system for the Indian Ocean. Potential areas of study include:

- mean seasonal cycle and basic ocean structure
- upper ocean/mixed layer processes
- equatorial and coastal K-waves and R-waves
- intraseasonal variability
- response to El Ni�o forcing
- IOD(ZM) - see Appendix 5
- role of ITF
- Arabian Sea and Bay of Bengal salinities.

Joint issues with VACS - Prof. Laban Ogallo discussed issues of common interest to IOP and VACS. The key research issues identified by VACS are:

- Variability / changes in the African climate system and their effects on the global climate system

- Global climate variability impacts on the African climate
- Understanding the nature and Predictability of the African climate system

Compared with other continents we know relatively little about the African climate system. In part this is due to lack of adequate capacity to address some of the required research challenges - observations (ocean observations in particular); data exchange and management; computing, modelling, skilled human resources; etc. Nevertheless, it is known that the continent has very high seasonal and interannual climate variability, including extreme events such as droughts and floods and that they have far reaching socio-economic implications. Some of the climate extremes have been linked to anomalies in the wider global / regional climate system such as ENSO and Indian Ocean variability. VACS has identified SST patterns in the tropical and subtropical Indian Ocean that have significant correlation with African rainfall patterns. The role of ocean dynamics in the formation of these patterns is however not known. The issues of common interest to IOP and VACS are:

- Observations around Africa
- Data management and exchange
- Process Studies
- Climate modeling and prediction
- Climate change activities
- Capacity building
- Applications
- Outreach

2.3. Monsoon Monitoring and Process Studies

These presentations during the joint panel session were intended to provide input to the detailed panel discussions later in the meeting.

Vasco/Cirene Experiment - Dr. Robert Molcard introduced the Vasco/Cirene experiment to be carried out by Principal Investigators Drs. J�r�me Vialard and Jean-Philippe Duvel. The Vasco-Cirene experiment investigates various oceanic and atmospheric processes in the tropical Indian Ocean, but its main focus is on ocean-atmosphere interactions at intraseasonal timescale. Recent satellite and observational datasets have shown large-scale large amplitude intraseasonal modulation of the sea surface temperature south of the equator in winter, which need to be understood better.

Vasco/Cirene includes long term oceanographic observations for two or three years, using Argo floats (deployed in 2004 and 2005) and an equatorial subsurface mooring with an ADCP and T/C sensors. There will be an intensive observing period in early 2006, involving an oceanographic campaign in the western and central Indian Ocean on board the RV Atalante. This campaign will be coordinated with the launching of Aeroclippers and pressurized balloons from the Seychelles and possibly with an Indian campaign in the East. Aeroclipper - Dr. Molcard went on to introduce the International Nusantara STratification ANd Transport programme (INSTANT). Several groups from various nations have been trying for some years to understand the dynamics of the fluxes between the Pacific and the Indian Ocean through the Indonesia Archipelago. Theoretical and experimental studies are now widely published but simultaneous measurements distributed over the whole archipelago from the entrance of the ITF on the Pacific side to the exit on the Indian side are still required. Previous measurements were unfortunately much scattered in time and in space and often of too short duration. The INSTANT was established to

- determine the full depth velocity and property structure of the Throughflow and its associated heat and freshwater flux;
- resolve the annual, seasonal and intraseasonal characteristics of the ITF transport and

property flux;
� investigate the storage and modification of the ITF waters within the internal Indonesian seas, from their Pacific source characteristics to the Indonesian Throughflow water exported into the Indian Ocean;
� contribute to the design of a cost-effective, long term monitoring strategy for the ITF; and
� facilitate training of Indonesian scientific and technical personnel in the acquisition, processing and analysis of state-of-the-art oceanographic data.
The countries and individuals involved are: Indonesia (Indroyono Soesilo), United States (Arnold Gordon, Janet Sprintall, Dwi Susanto, Amy Ffield), Australia (Susan Wijffels), France (Robert Molcard) and the Netherlands (Hendrik van Aken). Dr. Molcard provided maps with details of the planned mooring positions (available at http://www.clivar.org/science/indian.htm).

The first phase of INSTANT was completed with 11 current meters and T/C sensors in place in the main passages of the ITF. Many Indonesian scientists joined the cruises and the measurements and would process and analyze the data as part of, and in collaboration with the INSTANT scientific team. The first current meter and tide gauges data set will be available by spring 2005, when the moorings are to be recovered, and re-instrumented to be finally recovered at the end of 2006. Three-year time series of simultaneous measurements are therefore expected from this experiment.

Climatic variation over Indonesia - Dr. Paulus Agus Winarso noted that the Maritime Continent lies in the tropical region between two oceans (the Indian and Pacific) and two continents (Asia and Australia). Humid air prevailed and adequately supported the national agricultural activities before the 1990s, but the situation has changed since then, partly in association with prevailing El Ni�o-like conditions. Since 1991 various El Ni�o episodes have tended to cause longer dry than wet/rainy season. The monsoonal wind system changed around 1991. Generally, the dry season is associated with the easterly winds and the wet season with westerly winds. A decreasing trend occurred in annual rainfall from 1997 onwards, related to enhancement of the easterly wind system, which itself causes development of an inversion layer over the region. Consequently, fires, smoke and haze more easily develop in the dry season during recent years than before. This phenomenon has no relation with the Asian Brown Cloud (ABC) (active in winter monsoon), because the time of occurrence is different (the haze episode in Indonesia is mainly during summer monsoon in Asia).

Dr. Winarso also briefed the group on the current conditions in January 2004, including the lack of tropical cyclone generation and prevailing easterly wind over Indonesia. The features were almost the same as in January 2003. He predicted that long dry and short wet seasons would still feature in 2004.

Influence of the Southern Hemisphere circulation on the East Asian summer monsoon - Dr. Huijun Wang introduced a recent study of interannual variability of the Mascarene High (MH) and Australian High (AH) and their influences on the East Asian Summer Monsoon, based on the reanalysis data from NCEP/NCAR and other observational data for the boreal summers of 1970-1999. Interannual variability of the MH is dominated by the Antarctic Oscillation (AAO) in a way that the MH is intensified with the development of the circumpolar lows in the high southern latitudes. On the other hand, the AH is correlated with the El Ni�o - Southern Oscillation (ENSO) as well as AAO, and tends to be intensified when El Ni�o occurs. With the intensification of the MH, the Somali jet and Indian monsoon westerlies tend to be strengthened. Concurrently, the AH and the associated cross-equatorial current become stronger whereas the trade wind over the tropical western and central Pacific become weaker. In association with the above changes, convective activities near the Philippine Sea are suppressed, as a consequence, exciting a negative convection anomaly and a Rossby wave train from East Asia via North Pacific to the western coast of North America (a negative Pacific-Japan pattern). Corresponding to the negative Pacific-Japan pattern, there is more rainfall from the middle and lower valley of the Yangtze River to Japan. The case study of 1980 indicates that, the MH, AH and the associated cross-equatorial currents exhibit a quasi-biweekly oscillation. Moreover, the position and intensity of the western Pacific subtropical high (WPSH) on the intraseasonal timescale is largely modulated by the oscillation of the two highs. On interannual timescale, however, the MH plays a major role in the WPSH and the related summer rainfall over East Asia.

Based on the above observational analysis, two sets of numerical experiments were carried out using a nine-level AGCM developed at the Institute of Atmospheric Physics, Beijing. The result shows that with the intensification of MH, the Somali low-level jet is significantly enhanced together with the summer monsoon circulation in the tropical Asia and western Pacific region. The weakened convection in the tropical western Pacific to the east of Philippines may induce a negative Pacific-Japan teleconnection pattern. In the meantime, geopotential height is enhanced in the tropics while reduced over most regions of mid-high latitudes, thus the northwestern Pacific subtropical high at 500 hPa extends southwestward, resulting in more rainfall in southern China and less rainfall in northern China. A similar but weaker anomaly pattern of the atmospheric circulation systems is found in the experiment of the intensification of AH. Comparison between the two sets of experiments indicates that, the MH plays a major role in the interactions of the general atmospheric circulation between the two hemispheres. This study implies that, as a strong signal, AAO plays an important role in interannual variability of the East Asian summer monsoon. Due to the seasonal persistence of AAO during boreal spring through summer, the strength of MH in boreal spring may provide some valuable information for summer monsoon forecast over East Asia.

Future Process Studies - Dr. Peter Hacker pointed out that process/pilot studies are needed for building a sustained observation system. Every new measurement constitutes a process/pilot study in that region and there is a need to identify science and benefits from new observations. Dr. Hacker suggested that the IOP/AAMP provide guidance/prioritization input for new efforts. It may take 1-2 years to identify, track and make a statement of value for sustained observations, but planning workshops are needed soon. Having noted some ongoing / proposed efforts, including INSTANT, Vasco/Cirene, moorings (India, Japan, Europe, USA, etc) and on shallow water overturning, Dr. Hacker listed some targets for future efforts suggested by his colleagues at the University of Hawaii:

- ISO as coupled process, especially ocean processes and effect on SST
- 60-100E, 5-10S, ISV with stationary SST, cloudiness and wind speed
- Bay of Bengal heat and freshwater budget experiment
- Freshwater flux through secondary straits in the ITF
- Sumatra process study, maybe one mooring
- 15S eastern Gyral current feeding the Leuwin current
- Sumatra study of role of ocean dynamics and barrier layer on SST
- Biogeochemical data for global change studies

2.4. Science Talks

The talks in this joint session address major scientific challenges of concern to both panels.

Shallow overturning circulation and variability of the Indian Ocean - Prof. Fritz Schott gave a full scientific presentation on this topic. The Indian Ocean equatorial zone is characterized by downwelling, not upwelling as in the other oceans. Therefore, the Indian Ocean�s shallow overturning circulation is marked by a cross-equatorial cell (CEC) that relates upwelling in the northern hemisphere and subduction in the southern hemisphere subtropics. The northward flow is carried by the thermocline Somali Current at 50-300m depth and the southward return flow by the annual-mean southward Ekman transports. A unique feature of the near-equatorial mean zonal wind stress is that it changes approximately linearly with latitude, resulting in near-equivalency of meridional Sverdrup and Ekman transports (Godfrey et al., 2001; Miyama et al., 2003). The CEC transports 6 Sv and approximate agreement was found between (model) net northern upwelling, Somali Current and interior Ekman/Sverdrup transport (Schott et al., 2002). Northern upwelling occurs in large wedges with the offshore flows off Somalia and in smaller filaments off Oman, while models also suggest open-ocean upwelling in domes both sides of India / Sri Lanka (Miyama et al., 2003). There are, however, open questions about the contributions of the different northern upwelling sites to the total.

There is now overall observation-model agreement on a fairly large southward mean transport through the Mozambique Channel, which appears to be mostly supplied by the Indonesian Throughflow (ITF), but the ITF also contributes to the CEC. A second shallow overturning cell is the hemispheric Subtropical Cell (STC) of the Indian Ocean. It relates open ocean upwelling in a longitudinally extended band northeast of Madagascar, at about 3-12S, to southern subduction, ITF and recirculation from the south (Miyama et al., 2003).

The northern upwelling variability is largely related to the 'Great Whirl' (GW). It has recently been concluded from model studies (Wirth et al., 2002) that the observed significant interannual variability in intensity and location of the GW is largely caused by internal variability, not external interannual wind forcing. The northern Somali Current also displays intraseasonal variability at 40-60 days period. The cause was also found to be instability of the GW, leading to forced Rossby waves in the summer monsoon that gradually approach the dispersion relation of free waves during the subsequent winter (Brandt et al., 2003). The wedges and filaments of the Arabian Sea exert a meso-scale imprint on the large-scale airflow above, leading to meso-scale patterns of stability and air-sea exchange that need to be considered when making large-scale budget calculations for the northern Arabian Sea (Vecchi et al., 2004). Arabian Sea SST is highly correlated with West Indian rainfall (Vecchi and Cane, 2004) and the interesting question is to what degree the import/export across the equator by the CEC is a driver of upwelling and SST anomalies (Loschnigg and Webster, 2000).

The variability of the STC and upwelling northeast of Madagascar is related to the Indian Ocean Zonal Mode (IOZM; Feng and Meyers, 2003) and the associated SST variability is highly correlated with east African rainfall (Latif et al., 1999; Xie et al., 2002). Rossby wave propagation from the east modulates that doming regime, providing hopes of predictability. The ongoing debate on whether the IOZM is an independent mode akin to the Indian Ocean or whether it needs triggering by the Pacific ENSO may be resolved by including the role of the Pacific Decadal variability (PDV) and ITF (Annamalai et al., 2004; Murtugudde and Annamalai, 2004; Webster 2004). By advecting thick or thin mixed layers from the Pacific, the ITF may thus cause Sumatra SST become insensitive to the onset of ENSO in one PDV phase and sensitive in the other.

Role of the salinity field in SST evolution in the region of the Monsoon onset - Dr. S. Shetye introduced the results from ARMEX on the subject. The region off the southwest coast of India is of interest from the point of view of both ocean and atmospheric processes. It is in this region that the onset vortex of the Indian Summer Monsoon forms. The region has been shown to have a distinct annual cycle of sea level variability. The region receives low salinity waters from the Bay of Bengal after withdrawal of the southwest monsoon (approximately October). These waters are believed to play an important role in formation of high SSTs here during late May or early June. The SSTs in turn may be influencing formation of the onset vortex. An experiment - Arabian Sea Monsoon Experiment (ARMEX) - was carried out during 2002-2003 to study these issues. The oceanic component of the experiment was primarily based on XBT surveys, in-situ measurements on board ORV Sagar Kanya, and numerical model studies. First results from the experiment conclude the following:

� A barrier layer exists in the region of interest during approximately November-April. It supports formation of temperature inversions during Winter Monsoon (November-May). The inversions propagate westward together with the low-salinity waters from the Bay of Bengal (Shankar et al., 2004, GRL, in press)

� The inversions heat the surface layer above, leading to a net increase of 1�C in SST during November-May; at this time the air-sea fluxes lower SST by 0.3�C (Durand et al., 2004, GRL)

� The barrier layer in the region of interest is almost annihilated by remotely forced upwelling in early April. The relic that survives is annihilated by the inflow of high-salinity waters from the north, which too is primarily remotely forced. [Shenoi et al., 2004, GRL, in press]

The coupled nature of monsoon intraseasonal variability and implications for prediction - Prof. P. Webster introduced the coupled nature of the annual cycle and interannual variability of the monsoon, the similarity between the interannual and intraseasonal variability and the coupled nature of intraseasonal variability, and then focused on monsoon prediction. He stressed that even if one can forecast perfectly that the All-India-Rainfall-Index will be + or - 10%, it does not tell when an active or break period will occur or which parts of the country will be above or below average. In a climate where the intraseasonal variability is far larger than the interannual variability forecasting of year-to-year variability is secondary. From practical point of view, the 20-25-day prediction is the most useful for applications.

Prof. Webster summarized that intraseasonal variability of monsoon is slow and large-scale, with easily identifiable major features and a strongly coupled nature. Although it is very difficult to simulate the monsoon intraseasonal oscillations (MISO) with current dynamical models, it is possible to utilize the robust structure for empirical modeling. Theoretically, instability modes like MISO/MJO are chaotic and inherently unpredictable. However, once instability has occurred, we can follow the life-cycle of that instability (or families thereof) through to completion, albeit though the initiation of the next instability is unpredictable. In fact, the group of Prof. Webster had developed a physics-based empirical model using wavelet analysis and Bayesian statistical technique, which produced encouraging results of multi-weekly forecasts of monsoon rainfall in the region. More details can be found at http://cfab.eas.gatech.edu/forecasts/predictors.html.

3. IOP Sessions

3.1 Terms of Reference, short and long term goals

Meeting for the first time, the Panel reviewed and accepted the TOR as written. The Panel expressed a lot of enthusiasm for its first major task--writing an implementation plan for sustained, basin-scale ocean-observations relevant to climate variability.

The Panel agreed the time was right in a political sense to identify and push forward a plan that provides all of the necessary observations for both research and operational prediction of climate and ocean-state in the Indian Ocean region. The optimism is based on several factors indicating international support, including:

� Ministerial level agreement at the First Earth Observation Summit in July 2003 to prepare a conceptual framework to be reviewed in April 2004

� Publication of the GCOS Second Adequacy Report to COP9/UNFCCC, noting the lack of global coverage of the oceans, and identifying consensus on the essential surface and subsurface ocean-variables that have to be measured

� Preparation of a draft GCOS Implementation Plan, that takes a global perspective and needs to be backed up with a regional perspective providing technical detail.

The scientific rationale for enhancing sustained observations now is based on progress and ongoing research on key phenomena of the Indian Ocean�s role in the climate system, including:

- Intraseasonal oscillation
- Seasonal monsoon variability
- Indian Ocean Dipole (or Zonal Mode)
- Decadal warming trends
- Shallow overturning cells
- Deep meridional overturning
- Indonesian throughflow
- Global ocean linkages
- Carbon and Biogeochemistry

COPES (see Section 2.1) was recently initiated by WCRP and will focus on identifying what is predictable at a broad range of time-scales - weekly, seasonal, interannual and decadal - taking a unified approach. It will require the sustained observing system in addition to a synthesis of the above Indian Ocean research themes. The Panel welcomed the TOR giving it scientific oversight of observational oceanography and its liaison-role to climate modelling.

3.2 Elements of the observing system and forward plans

3.2.1 Tropical pilot-mooring arrays

Ongoing mooring activities include the following:

- agencies in India (INCOIS, NIOT) have established 22 oceanographic and/or meteorological moorings in the Bay of Bengal and Arabian Sea.
- Indian National Institute of Oceanography (NIO) has maintained three subsurface current meter moorings on the equator.
- Japan (JAMSTEC, FORSGC) has maintained three Triton moorings and one ADCP mooring near the equator.
- The INSTANT Project has established moorings in the major passages of Indonesia to measure full depth mass, heat and salt transports of the Indonesian Throughflow.
- France (LODYC) will contribute additional moorings to the central, equatorial region starting in 2004
- An international group led by South Africa is preparing a proposal for moorings in the western region.

A map of the locations of on-going and planned pilot-moorings at the time of the First Indian Ocean GOOS Conference in November 2002 is available at http://www.clivar.org/science/indian.htm.

Some of the ongoing pilot mooring sites now have a record extending up to four years. Preliminary results reviewed at the meeting show strong intraseasonal variability of currents, as well as longer term seasonal and interannual signals.

After considerable discussion, the Panel agreed on a rational, coherent, sustained array for the tropical Indian Ocean, in particular to address ocean physics in intra-seasonal variability and the multi-scale interactions between the intra-seasonal time scale and longer term modes of climate variability and change. The Panel recognized that in addition to the broadscale array, elements to observe the Indonesian throughflow and western boundary currents will have to be designed out of session and included in the Implementation Plan.

Action 2: The IOP (McPhaden assisted by members) will design an appropriate mooring array including measurements of Indonesian Through-flow and western boundary currents and including surface flux sites for calibration of basin scale products, as an ongoing action of the IOP.

3.2.2 Argo floats

Implementation of Argo has progressed rapidly in the past year and was about 40% complete by late April 2004. The Panel recognized that the Argo data are a critical new resource for climate research and that it needs to play a role in defining what research should result from the data. Additional time must be devoted to this topic at the second IOP meeting. IOP expressed concern that the fast, energetic variability at intra-seasonal time scale and internal tides is an important source of noise due to aliasing the 10-day Argo sampling. IOP will liase with the Argo International Science Team in addressing both of the above issues (see Action 3 below and also refer to the talk of Dr. Schiller, in Section 2.2).

Action 3: The IOP/AAMP (Meyers/Schiller) will promote and help plan further OSSE's to set sampling guidelines for an integrated observing system that will include Argo floats, the tropical mooring array and other measurement platforms. Initial results will be reported at the Indian Ocean Modelling Workshop mentioned earlier.

3.2.3 XBT network

The XBT network established by TOGA and WOCE has been taken over as a global, operational activity by JCOMM and is implemented by SOOPIP. The excellent work of several people in JCOMM and SOOPIP (including Rick Bailey and Steve Cook, the former and present SOOPIP Chairmen, and Etienne Charpentier of JCOMM OPS) needs to be recognized. They have established a tracking system for XBT lines that continuously assesses implementation of the GOOS XBT strategy. In reviewing present day sampling IOP noted:
� The Upper Ocean Thermal Expert-Panel Report (Melbourne, 1999; Observing the Oceans in the 21st Century edited by N. Smith and C. Koblinsky) recommended a transition of the global XBT network to "line sampling" (so called frequently repeated and high density lines) as Argo becomes fully implemented. The scientific rationale for line sampling is given in the above reference.
� The strategy in the Indian Ocean is only partially implemented, and a number of other lines are being routinely sampled. According to the assessment for Jan-Jun 2003:

- FRX lines IX1, IX9(north of 5N) and IX10(east of 78E) are well sampled
- FRX lines IX10(west of 78E), IX12, IX22 and PX2 are sampled but not well
- HDX line IX28 is well sampled
- HDX line IX2 began to be sampled in 2004
- The remaining FRX and HDX lines (IX2, 6, 7, 8) are not sampled according to this review.

� Some regularly sampled Indian Ocean lines are not reporting on GTS or only sending data in delayed mode with one year delay.
� Resources for Indian Ocean XBT sampling have to be about doubled to get full implementation of the "line sampling" strategy (figure).
IOP recommended a new mini-review of global XBT sampling by OOPC to obtain an overview of how well the "line sampling" strategy is being implemented and to reconsider the selection of lines to be sure that all of the necessary lines are included (see Action 4).

Action 4: The IOP (Chair) will write OOPC recommending the review of global XBT sampling, and participate in the review if required.

3.2.4 Tide gauge network

More than 50 Indian Ocean tide gauges have a record of monthly values in the GLOSS sea level archive. A relatively small number of the stations are useful for research. Historical hourly data are not available from most stations and near real-time, hourly data are available from only about 10 sites. After the panel meeting, the IOP Chair participated in the CLIVAR Data Management Meeting at Scripps Institute of Oceanography (SIO) in April 2004 and made contact with the University of Hawaii Sea Level Centre and the Sea Level Data Assembly Centre at BODC. The IOP will correspond with these centres to get a better understanding of the potential uses of the historical archive for climate research, and make this information known to the CLIVAR community.

A paper on the need for near real time hourly tide gauge data (see Appendix 4) was briefly considered at the meeting. The AAMP was very supportive of the idea because of its relationship to prediction of the coastal impacts of extreme events; storm surge and coastal flooding in particular. The meeting noted the potential relationship of real time tide gauges to the IOC�MILAC project being organized by Drs. Johannes Guddal and K Radhakrishnan. Following encouragement from Dr. S K Srivastav, the Director General of Meteorology, in his address to the INDOCLIM workshop held immediately following the panel meeting, Dr. Y.E.A. Raj and the IOP Chair continued a discussion of the real time issue with a view toward submitting a proposal to establish some stations in India.

3.2.5 Surface drifters

Typically about 80-100 drifters are active in the Indian Ocean at any one time, about half of them with temperature and pressure sensors and half with temperature only. This gives about 50% of desired coverage of the Indian Ocean north of 40 S. The Panel noted that surface drifters indicate the combined effect of directly wind driven (Ekman) and geostrophic currents and as such are an important component of the integrated observing system.

Action 5: The IOP chair will contact IBPIO to discuss how the IOP can help find resources to enhance/complete the drifter array.

3.3 Data management

The Panel noted that under the auspices of IOGOOS a workshop on data and information management and capacity building was held in Hyderabad during December 8-10, 2003. The workshop agreed to undertake a number of activities to improve data management in the Indian Ocean region. The initial task is to undertake surveys of the region to assess capability and to identify data centers and contact personnel. It was also agreed that a data manager would be assigned by INCOIS to serve as the IOGOOS data coordinator. This should contribute to improving the region's capability and provide a focal point for IOP and others. Various capacity building activities will be undertaken by IOGOOS. The Panel should take advantage of this initiative by linking with it and ascertaining how elements of the planned Indian Ocean observing system can utilize IOGOOS related data mechanisms. It was agreed that Dr. Ravichandran should serve as the liaison person for this work.

After the joint panel meeting, the IOP Chair participated in the Workshop on CLIVAR Data Management and Global Synthesis of the Oceans at SIO on 24-26 March because Dr Ravichandran was not available. The SIO Workshop identified the need for the IOP (and other CLIVAR ocean-basin panels) to work more closely with the ongoing and re-established WOCE DACs. The SIO workshop welcomed news that the INCOIS/IOGOOS Secretariat office may be able to help meet some of CLIVAR's data needs.

3.4 Outline of the Implementation Plan and writing assignments

The IOP placed highest priority on establishing the sustained Indian Ocean mooring array and made considerable progress in defining the broad scale component. The Panel noted that observations of the Western Boundary Currents remain to be designed. The IOP Chair will invite regional experts to help design these arrays out of session. Observation of the mass, heat and salt transports of Indonesian throughflow will be designed in collaboration with the INSTANT community. The Panel developed the initial plan for an integrated observing system (a figure is available at http://www.clivar.org/science/indian.htm).

In preparation for writing the Implementation Plan out of session, the Panel agreed on the following outline and writing assignments, with a complete rough draft due by June 2004 and a document ready for circulation outside the Panel by September 2004.

Outline:

- Unique geography and physics: Satish Shetye
- Research issues:
  - --Seasonal Monsoon Variability: Peter Webster
  - --Intraseasonal oscillations: Peter Hacker
  - --Indian Ocean Dipole: Jay McCreary
  - --Decadal warming trends: Gary Meyers
  - --Cross Equatorial overturning cells: Fritz Schott
  - --Deep Meridional overturning: Fritz Schott
  - --Carbon and Biogeochemistry: Bronte Tilbrook
  - --Indonesian Throughflow: Robert Molcard
  - --Links to Global Circulation: To be decided later
- Operational issues: Gary Meyers with assistance from Neville Smith
- Unique political and economic situation: Bill Erb
- The concept of an integrated OS (to be decided later)
- Mooring Array: Mike McPhaden
- Existing elements
  - --Argo: Ravichandran
  - --XBT, SL, Drifters: Gary Meyers
- Biogeochemistry and Repeat hydrography: Bronte Tilbrook
- Data management (To be decided later)
- Modeling need for sustained observations: Jay McCreary
- Process studies and need for sustained observations (To be decided later).

4. AAMP Sessions

4.1. Simulating and Predicting the AA Monsoon: Daily, Intraseasonal, Interannual and Decadal Timescales

Issues in modeling monsoon climates: variability and the basic state - Prof. Julia Slingo illustrated a number of problems in simulating monsoon climate with currently models. She emphasized the following points.

- There is evidence that basic state errors affect variability in a non-linear fashion.
- The Maritime Continent is a key area requiring research.
- The importance of organised convection (in space and time).
- The importance of representing atmosphere/upper ocean coupling on all timescales.
- The vertical resolution in the atmosphere and upper ocean is important.

� Land surface processes are important (in particular for regions such as China). Representation of (i) the seasonal cycle in vegetation and (ii) soil hydrology need attention. Strong links with GEWEX are obviously required.

It was noted that ocean-atmosphere interaction is extremely important. Accurate modeling of the top 1 m or so of the ocean is required - a problem since many models have only 10 m or so vertical resolution.

Role of warm pool SST anomalies on the interannual variability of monsoons - Dr. Hanna Annamalai introduced the diagnostics from observed precipitation and reanalysis products, which revealed that after the 1976-77 Pacific Climate shift, the Indian summer monsoon (ISM) was stronger than normal during the developing phase of El Ni�o, particularly during July-August of 1977-2001 (POST76). During PRE76 (1950-75), the ISM was weaker than normal over the entire monsoon period (June-September). The major difference between the two epochs was the presence of cold SST anomalies over the tropical Indo-Pacific warm pool region. Sensitivity experiments with an AGCM reveal that the cold SST anomalies and associated condensation anomalies over the warm pool force an anticyclone in the lower atmosphere over the northern Indian Ocean, which increases the modeled low-level monsoon westerlies during July-August of POST76. Further AGCM experiments reveal that a near-absence of such cold SST anomalies over the warm pool resulted in a severe drought over India during the developing phase of the El Ni�o in 2002.

Prof. Webster made the point that a major problem is that we still cannot correctly predict ENSO. Dr. Hendon noted that the western Pacific SST anomaly is also important for Australian climate.

Real-time monitoring and prediction of the MJO at BMRC - Dr. Hendon introduced a technique to define and identify the MJO in real-time. Because band pass filtering cannot be applied in real-time, a technique has been developed which depends only on spatially filtered data. The MJO can be effectively isolated by projection onto equatorially averaged EOFs of upper and lower tropospoheric zonal wind and OLR. This definition, while having benefits for real-time prediction and monitoring, also allows objective determination of intraseasonal (poleward propagating) variability in the Indian monsoon that is independent of the MJO. It also allows objective identification of the relationship of monsoon onset with the phase of the MJO (onset tends not to occur in the suppressed phase but can occur anywhere within the broad active phase). Extreme rainfall events during Australian summer were also shown to be 3 times more likely in the active phase of the MJO than in the suppressed phase. A simple linear prediction scheme was also developed based on these EOFs, and it shows skill similar to other empirical schemes for intraseasonal prediction.

Modeling studies of the predictability of the Asian Summer Monsoon - Dr. Molteni focused on three issues regarding the predictability of monsoon variability in GCM simulations:
(1) Are GCMs able to reproduce the patterns and the variance distribution among different modes of monsoon variability?
(2) Can we identify which patterns are mainly driven by SST forcing at the seasonal time-scale, and how well can we reproduce their interannual variability in observed-SST experiments?
(3) Is there evidence of regime-like behavior in the monsoon variability simulated by GCMs, and how is it related to tropical SST anomalies (e.g. ENSO phase)?

Results from a set of AGCM ensemble simulations, referred to as the PRISM (Predictability experiments for the Asian summer monsoon) ensembles, were presented. These experiments were run with the T63 ECMWF AGCM, using observed SST from nine years in the 1980�s and 1990�s with large ENSO variability. Each 10-member ensemble covered a one-year period from

November to October of the following year, and EOF and SVD analysis of interannual and intraseasonal variability were performed to assess the predictability of different variability modes.

With regard to question (1), it was found that the ECMWF model overestimated the variance associated with the leading mode of 850-hPa wind and rainfall, which was associated with a meridional shift of the TCZ in the Indian Ocean. A second mode of variability detected by SVD analyses, and associated with regional circulation features in the region of the Indian subcontinent, was simulated with a somewhat reduced variance. However, when the time series of the time coefficients associated with the two modes were correlated with SST anomalies and compared to observations, the second mode was found to have a much stronger association with the ENSO cycle than the first mode. As the consequence, the correlation between ensemble-mean and re-analysis anomalies onto the second SVD mode was found to be very high (up to 96% for the rainfall component of this mode), thus providing a positive answer to question (2).

With regard to question (3), results from a principal component (PC) analysis of 5-day-mean rainfall were presented. Probability density functions for the joint distribution of the leading two PCs suggested a regime-like behavior during the cold ENSO phase (i.e. La Ni�a events), but not during the warm phase. It was noted that, while other studies suggested that the main effect of ENSO on monsoon regimes was to affect the frequency (but not the spatial structure) of flow regimes, the ECMWF model results showed a more complex behavior, reminiscent of the existence of a bifurcation point in a non-linear dynamical system.

Monsoon modeling studies at the Hadley Centre - Dr. Gill Martin reported that previous versions of the Hadley Centre climate model have produced a reasonably good simulation of the Asian summer monsoon. A new semi-Lagrangian, non-hydrostatic version of the Met Office climate model called HadGEM1 is currently under development. This model incorporates numerous changes to the physical parameterizations in both the atmosphere and ocean components, as well as to the model grid and vertical resolution, and includes additional processes such as the sulphur cycle and cloud aerosol effects. Thus, both the coupled model and its atmosphere-only version, HadGAM1, are very different from the previous versions, HadCM3 and HadAM3.

The monsoon climatology in HadGAM improves on HadAM3. The monsoon in HadCM3 is rather different from that in HadAM3. The monsoon circulation is weaker and there is far less precipitation over and around the Indian peninsula, while precipitation over Indonesia is increased. These changes are associated with errors in SST of the coupled model, where the northern hemisphere temperatures are colder and the SSTs around Indonesia warmer than observed. Similar errors are seen in HadGEM, although they are significantly smaller than those in HadCM3. However, an equatorial cold bias remains as a result of continuing problems with near-surface winds in the tropics.

Both atmosphere-only models have a dominant mode of interannual variability which explains around 40% of the variance. The coupled models, HadCM3 and HadGEM1, have similar dominant modes, although they explain slightly less of the variance. In the case of the coupled models there is an additional contribution from the eastern equatorial Indian Ocean. These dominant modes resemble those calculated from NCEP/NCAR and ECMWF reanalyses, Molteni et al. (2002) and Annamalai et al. (1999) respectively. Both of the first two modes from the reanalyses also showed the presence of anomalies over the equatorial Indian Ocean. The presence of such anomalies in only the coupled versions of the models may suggest an improved representation of the Indian Ocean SST dipole mode when the atmosphere and ocean are allowed to interact.

Analysis of the intraseasonal variability in the models shows a strong similarity between the dominant modes from all four models, which describe around 13% of the variance in all cases. This mode is in good agreement with that calculated from NCEP reanalyses (Sperber et al, 2000). Of the first four modes of intraseasonal variability in the NCEP reanalyses, three represented different stages of the northward propagation of the Tropical Convergence Zone (TCZ). Several of the first few EOFs from the models do appear to represent slightly different positions of the TCZ, and spectral analyses of the principal component (PC) time series show preferred timescales which are all in the range 10-50 days, again in agreement with Sperber et al (2000). The dominant intraseasonal mode resembles that of the interannual variability, a feature which is common to other GCMs and also present in observations. In spite of this, the intraseasonal variations within this mode appear to be stochastically-forced in HadAM3/CM3, whereas there is significant forcing of this mode on the interannual timescale in these models.

Ultimately, the impact on the monsoon simulation of the many changes made to the model between HadAM3/CM3 and HadGAM1/GEM1 is perhaps surprisingly small, and errors still remain. Past experience of model development has shown that the tropical performance is very robust and difficult to improve. However, the improvements made to HadGAM1/GEM1 over HadAM3/CM3 provide a more solid framework for developing the next generation of climate models.

Monsoon modeling at IITM - Dr. Rupa Kumar Kolli gave an overview of modeling work in monsoon studies being carried out at the Indian Institute of Tropical Meteorology (IITM). COLA and HadAM2 GCMs are being used at the institute to study global/regional climate variability and change, with focus over the Indian-Pacific regions, and also for experimental seasonal prediction of the Indian summer monsoon. The institute also uses a variety of diagnostic models for the study of regional energetics, instability mechanisms in the formation and growth of monsoon disturbances and linear/non-linear interactions among different spatial and temporal scales of monsoon flow. Mesoscale models are used to study the typical synoptic-scale systems during the monsoon season, IITM has recently taken a major initiative to develop high-resolution climate change scenarios and seasonal prediction products by dynamical downscaling of GCM simulations using regional climate models like PRECIS, MM5, RSM, etc. Ocean models/coupled models are being used to study the role of Indian Ocean in monsoon variability. Dr. Kolli briefed the panel on the recent work done by different groups of IITM on the above aspects. IITM was one of the participants in the AAMP-endorsed model intercomparison programme of the effects of 1997/98 El Ni�o.

Dr. Kolli highlighted the use of GCMs in studying the role of Indian Ocean SST boundary forcing in the monsoon interannual variability. In particular, modeling experiments have indicated that the role of Indian Ocean SSTs in modulating the out-of-phase variability of convection between the land and oceanic regions have important implications for the intraseasonal variability of the monsoon. This aspect was also seen in the model experiments of the 2002 drought. Model experiments with the HadAM2 with observed SSTs of 1997 produced near-normal summer monsoon rainfall over India, indicating that the model is able to represent the non-ENSO influences on the monsoon. Dr. Kolli mentioned that IITM has been making experimental seasonal forecasts in real-time using persistent SSTs, but the general experience has been that the skills are very limited.

Dr. Kolli presented some results of climate change studies using dynamical downscaling of GCM projections, which the IITM has been doing as part of a Joint Indo-UK collaborative programme on climate change impacts in India. It was shown that the regional climate model PRECIS was able to reproduce realistic spatial patterns of monsoon rainfall, indicating the potential of downscaling strategies to provide useful monsoon prediction products for local applications.

Modeling Discussion - After the talks a general modeling discussion was held. The key issues arising were:

� The climate of the Maritime Continent is an important issue, involving, e.g., dry season rainfall over Indonesia. In the longer time the panel should consider the case for a focused workshop on the climate of the Maritime continent.

� ISO/MJO simulation - There is a failure to capture dominant modes (structure and partitioning) in northern summer. The simulation is improved with coupling. There is a need to understand suppressed phase processes. The panel recommends the use of DERF approach for investigating growth of errors in different phases of the MJO in collaboration with MJO prediction activities of Waliser et al.

� Influence of land surface processes - Eurasian snow is important. There is a need for more observations of snow depth. Land-use change is particularly considerable for China. There is a need to study soil hydrology.

� Indian Ocean - There is much to be studied, e.g., SW Indian Ocean thermocline dome, IO coupled variability, equatorial wave dynamics.

� ENSO-monsoon relationship - There is a need to study how the Indo-Pacific warm pool vs. ENSO is influential for interannual variability. Seasonal phase locking remains a problem.

� Upper ocean-atmosphere interactions - Is flux correction an option in seasonal prediction or as a research tool? What are air-sea interaction modes?

� There are general difficulties in modeling, e.g., diurnal cycle in SSTs in light wind conditions, Asian summer monsoon, and errors in mean state, which may compromise variability.

Recommendations:
(a) In longer term, consider case for a focused workshop on the climate of the Maritime Continent.
(b) Use DERF approach for investigating growth of errors in different phases of the MJO in collaboration with MJO prediction activities of Waliser et al.
(c) Encourage cataloguing of routine snow depth measurements for Eurasia. Liaise with CliC.

Action 6: The AAMP will communicate to VASCO/CIRENE to promote the case for a detailed field experiment on the suppressed MJO phase. (At the time of publishing this meeting report, communication to the Vasco/Sirene group had been initiated through the ICPO. Jean Philippe Duvel, one of the leading scientists of the project, confirmed that the group planned 30-day cruises, which will therefore hopefully cover both active and suppressed phases of MJO.)

4.2. Applications / Impacts of Monsoon Predictability, Variability and Change

The AAMP has been increasingly interested in developing its application aspects. The talks at this session highlight recent advances in applications of monsoon studies and possible future directions.

Flood forecasting for Bangladesh - Prof. Webster briefed the panel on recent advances within the Climate Forecasting Applications in Bangladesh (CFAB) project, which is funded by USAID and NSF. A 3-tier overlapping forecast system has been developed, providing seasonal outlook, 20-25-day and 1-10-day forecasts. Prof. Webster emphasized again that the multi-week scale is one on which water resource and agricultural arrangements can benefit. CFAB had recently started producing multi-week forecasts of 5-day rainfall and river discharge in the region.

Prof. Webster hoped the method could be developed for applications in other monsoon regions. An immediate future plan is aimed at the upper, middle and lower reaches of the Mekong River system, where economical development has been tremendously speeded up in recent years. He discussed how to communicate the forecasts to a user community, and emphasized again the importance of multi-week forecasts by quoting A. R. Subbiah in discussion of the July 2002 drought in India: 'The minimum length of time of a forecast that will allow a farming community to respond and take meaningful remedial actions ...about 10 days, although 3 weeks would be optimal...Assuming (such) were available by the third week of June 2002... farmers could have been motivated to postpone agricultural operations saving investments worth billions of dollars...water resource managers could have introduced water budgeting measures'

Predicting annual crop yields in current and future climates - Prof. Slingo briefed the panel on the development of an integrated weather/crop forecasting system at the University of Reading, which combines the benefits of more empirical approaches (low input data requirements, validity over large spatial scales) with the benefits of the process-based approach (potential to capture intra-seasonal variability, and so cope with changing climates). The results suggest that process-based approach can produce accurate results over large areas where there is a climate signal. Further research would need to deal with

� What to do where climate signal is less evident (Pests and diseases are often dependent on climate)

� Use of probabilistic information

� Quantifying uncertainty in climate change assessments

� Plenty of fundamental biophysical modelling and analysis to be done.

Interannual variability of the Indonesian-Australian Monsoon - Dr. Hendon noted that Indonesia experiences a distinct monsoon, with a wet season running from December through March and a dry season running June through August. Counter to other continental monsoons, however, rainfall in the �maritime continent� does not go to zero in the dry season. Furthermore, dry season rainfall, which is highly variable year to year, is vitally important for agriculture and forest fires. Hence, prediction of dry season rainfall will have wide societal benefits. A coupled feedback between windspeed and sea surface temperature in the eastern Indian Ocean and seas to the north of Australia was described which accounts for the strong local correlation of SST and rainfall in the dry season and the lack of correlation in the wet season. This feedback also helps to explain the strong negative correlation of rainfall with El Ni�o in the dry season and lack of correlation during the wet season. An implication of this feedback is that rainfall and local SST anomalies, while highly predictable in the dry season, are unpredictable through the wet season.

The question was raised as to whether using coupled models helps the prediction of the MJO. Dr. Hendon said that it does not seem to, although Dr. Martin said it did in their model. There is something that requires further investigation.

Climate impact studies in India - Dr. Kolli emphasized that regional-global linkages in the earth system must be understood in order to develop appropriate predictive capabilities at various spatio-temporal scales. Such knowledge can be used in support of policy development consistent with sustainable development pathways. In this context, he mentioned about the regional networking established by START and the South Asian START Committee (SASCOM) which is active in India. START has initiated integrated regional studies of global change (IRS) in Monsoon Asia, co-sponsored by IGBP, WCRP and IHDP and with its regional networks in East Asia, South Asia, and Southeast Asia. The studies will cut across the natural and social sciences, and address relevant aspects of marine, terrestrial, atmospheric and social components of the earth system. Monsoon variability has significant consequences for water resources, agriculture and health outcomes. Dr. Kolli brought special focus on the new Monsoon Asia Integrated Regional Studies (MAIRS) programme spearheaded by START, and strongly recommended that AAMP should establish formal linkages with this programme. He mentioned that he is actively associated with SASCOM, and offered to contribute to the development of AAMP-START linkages on MAIRS. The South Asia component of MAIRS has a focus on the summer monsoon and regional perturbations of the monsoon system by aerosols, land-use / land cover change, etc. and consequences of monsoon variability (interseasonal, intraseasonal) for key elements. The emphasis is on process understanding, specifically socio-economic processes and natural processes. Dr. Kolli suggested that AAMP could make significant contributions to this programme by way of model development and applications to derive advance information (e.g., seasonal/ intraseasonal prediction, climate scenarios) on monsoon variability. Climate model evaluation, downscaling of monsoon prediction products, development of application-specific products and providing handles on uncertainty issues are some of the aspects that can be easily integrated into AAMP�s involvement in MAIRS.

The panel recognized the importance of developing the application aspects of the AA monsoon studies and recommended developing formal programme linkages to START/MAIRS (see Actions 7 and 8).

Dynamics of pre-monsoon heat waves - Dr. Annamalai noted that during the premonsoon months of April and May following a weak monsoon in the previous year, anomalous surface temperature (2-3C above normal) persist for more than two-three weeks over continental India. The anomalous temperature signal is observed over the entire troposphere. The persistence in conjunction with warming over the entire atmospheric column results in the loss of the order of 1500-2000 human lives.

During the period when heat waves prevail over India, an increase in convective anomalies is observed over the tropical west Pacific and equatorial Indian Ocean. Diagnostics from simple model experiments reveal that the anomalous heating over west Pacific force descending long Rossby waves over India. On the other hand, the local Hadley circulation forced by equatorial Indian Ocean convective anomalies force descending motion over India. These two dynamical effects warm the entire troposphere due to adiabatic processes resulting in the formation and persistence of heat waves during premonsoon months.

Recommendation: Promote investigation of causal factors in pre-monsoon heat waves and winter cold spells leading to improved prediction.

The panel felt the promotion of the applications of AAMP research through development of links with START was an important issue. A joint meeting is desirable. Also, as Dr. Molteni reported, a summer school on 'The Water Cycle of S.E. Asia' in summer 2005 was recently proposed, combining training activities and an international conference. AAMP endorses the activity, will contribute to the planning and seek support from relevant organizations.

Action 7: AAMP (Kumar Kolli) will be represented in SASCOM and to contribute to long term planning of MAIRS. There is a need to develop formal programme linkages between AAMP and MAIRS, to be initiated by a formal letter from the AAMP co-chairs to the coordinator MAIRS and the START Deputy Director.

Action 8: Kolli and Yan will investigate the possibility of a joint meeting between MAIRS and AAMP, by contacting the coordinator MAIRS and the START Deputy Director.

4.3. Coordination with GEWEX and other monsoon studies/issues

Update on CIMS - Dr. Jun Matsumoto updated the panel on the current status of CEOP (Coordinated Enhanced Observing Period), CIMS (CEOP Inter-monsoon Modeling Study) and the planned post-GAME (GEWEX Asian Monsoon Experiment). CEOP is now in the final EOP (Enhanced Observing Period) year, EOP-4. At present, the data archiving of the EOP-1 has been almost successfully finished and preliminary comparisons of the in-situ reference site data with numerical weather prediction output and/or satellite remote sensing data mainly on the land surface characteristics have been made. In CIMS, it is planned to compare the reference sites' data and satellite data with monsoon modeling output to improve the model physics. Since CEOP EOP data will be fully obtained soon, CIMS modeling will start its organized experiments within 1-2 years. Since the GAME project under the framework of GEWEX will be terminated in March 2005, the group has begun to plan the post-GAME monsoon program in Asia. More intimate collaboration with the CLIVAR AAMP community is needed for performing both CEOP/CIMS and post-GAME programs. However, communication between GEWEX monsoon related researches and CLIVAR AAMP has not, to date, been very good. This situation should be overcome in the future and would be raised in the next WCRP-JSC (March 2004). The panel felt somewhat concerned by the seeming change of focus of GEWEX to encompass AAMP TORs. There also seemed to be a lack of communication between the two panels which should be addressed as a matter of urgency.

Action 9: Register strong concern about lack of dialogue with GEWEX CIMS project. Ask the JSC to provide guidance (co-chairs, ICPO)

AAMP Prospectus - Dr. Sparrow presented a presentation prepared by Dr. Yan on the proposed AAMP prospectus (last meeting's action item 3). Finding funding to pay for the printing is still a major issue, but the panel felt it would be worth producing a web-based version even if such funding was not forthcoming. Panel members were identified to revise each page.

Membership - Prof. Slingo was standing down as co-chair after this meeting, but would remain on the panel. Dr. Kolli was proposed as the new co-chair. Prof. Webster would likely stand down at the next meeting. A replacement was nominated. Several members were stepping down from the panel, causing loss of some links (e.g., with WGSIP and GEWEX). New members should be considered in ways that they will activate panel activities and keep the necessary inter-panel links for implementing the TORs. A nominee list would be needed shortly after the meeting.

Future Meeting - It was encouraged that AAMP7 be attached to a relevant international conference. To encourage applications of monsoon research and prediction, the panel suggested AAMP7 be joined, if possible, to a START MAIRS planning meeting.

Appendix 1: Attendee List

Dr. Hanna Annamalai (expert)
IPRC, University of Hawaii
2525 Correa Rd., Honolulu
Hawaii 96822, USA
Email: hanna@soest.hawaii.edu

Dr. Safri Burhanuddin (IOP)
Director of Research Center for Maritime Territory and Non Living Resources
Agency for Marine and Fisheries Research
Ministry of Marine Affairs and Fisheries
Republic of Indonesia
Jalan M.T. Haryono Kav.52-53, Jakarta Selatan 12770
Email: safribur@yahoo.com

Dr. William Erb (IOC)
Head, Intergovernmental Oceanographic Commission Perth Regional Programme Office
c/o Bureau of Meteorology
P.O. Box 1370, West Perth
WA 6872 Australia
Email: W.Erb@bom.gov.au

Dr. Peter Hacker (IOP)
University of Hawaii
JIMAR, 1000 Pope Road, MSB 312
Honolulu, HI 96822 USA
Email: hacker@soest.hawaii.edu

Dr. Harry Hendon (AAMP)
Bureau of Meteorology
P O Box 1289k, Melbourne, Victoria 3001 Australia
Email: h.hendon@bom.gov.au

Dr. Rupa Kumar Kolli (AAMP)
Climatology & Hydrometeorology Division
Indian Institute of Tropical Meteorology
Pune 411 008, India
Email: kolli@tropmet.res.in

Dr. Gill Martin (expert)
Met Office, Hadley Centre
Fitzroy Rd, Exeter, Devon EX1 3PB UK
Email: gill.martin@metoffice.com

Dr. Yukio Masumoto (IOP)
FORSGC, JAMSTEC
2-15, Natsushima-cho, Yokosuka
Kanagawa 237-0061, JAPAN
E-mail: masumoto@jamstec.go.jp

Dr. Jun Matsumoto (expert)
Dept Earth & Planetary Science (Bld. No. 5), University of Tokyo
7-3-1, Hongo, Bunkyo-ku
Tokyo, 113-0033 Japan
E-mail: jun@eps.s.u-tokyo.ac.jp

Dr. Jay McCreary (AAMP)
IPRC/SOEST, University of Hawaii
2525 Correa Rd., Honolulu, Hawaii 96822, USA
E-mail: jay@soest.hawaii.edu;

Dr. Michael McPhaden (IOP)
NOAA/Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE
Seattle, Washington 98115
Email: Michael.J.Mcphaden@noaa.gov

Dr. Gary Meyers (IOP chair)
CSIRO Marine Research
GPO Box 1538
Hobart Tas 7001, Australia
E-mail: Gary.Meyers@marine.csiro.au

Dr. Robert Molcard (IOP)
LODYC - UMR 7617 CNRS / IRD /UPMC
Institut Pierre et Simon Laplace (IPSL)
UPMC, Tour 15, 4 place Jussieu, 75252 Paris Cedex 05
E-mail Robert.Molcard@lodyc.jussieu.fr

Dr. Molteni (expert)
Physics of Weather and Climate Group
The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11
Miramare (Trieste) I-34014, ITALY
E-mail: moltenif@ictp.trieste.it

Prof. Laban Ogallo (VACS)
Co-ordinator
Drought Monitoring Centre Nairobi
P.O.Box 10304, 00100-Nairobi
Nairobi, Kenya
Email: laban.ogallo@meteo.go.ke

Dr. G. B. Pant (local host)
Director, Indian Institute of Tropical Meteorology, Homi Bhabha Road
Pune 411008, India

Dr. M. Ravichandran (IOP)
Dept Ocean Development
Indian National Centre for Ocean Information Services
Plot 3 Nandagiri Hills Layout, Jubilee Hills, Hyderabad 500 033 India
Email: ravi@incois.gov.in

Dr. Andreas Schiller (AAMP)
CSIRO Marine Research

GPO Box 1538, Hobart Tas 7001, Australia
Email: Andreas.Schiller@csiro.au

Prof. Fritz Schott (IOP)
Institut f�r Meereskunde
Physikalische Ozeanographie I
Duesternbrooker Weg 20
24105 Kiel, Germany
Email: fschott@ifm.uni-kiel.de

Dr. Mike Sparrow (ICPO)
International CLIVAR Project Office
Southampton Oceanography Centre
Southampton, UK
Email: mdsp@soc.soton.ac.uk

Dr. S. Shetye (IOP)
Physical Oceanography Division
National Institute of Oceanography
Dona Paula, Goa 403004 India
shetye@darya.nio.org

Prof. Julia Slingo (Co-Chair)
NERC Centre for Global Atmospheric Modelling, Department of Meteorology, University of Reading
Reading RG6 6BB, UK
E-mail: j.m.slingo@reading.ac.uk

Dr. Bronte Tilbrook (GOCCP)
CSIRO Marine Research
PO Box 1538, Hobart TAS 7001, Australia
Email: Bronte.Tilbrook@csiro.au

Prof. Peter Webster (co-chair)
School of Earth and Atmospheric Sciences
Georgia Institute of Technology
Atlanta, GA, 30332-0355
Email: pjw@eas.gatech.edu

Dr. Huijun Wang (AAMP)
Director, Institute of Atmospheric Physics
Beijing 100029 China
Email: wanghj@mail.iap.ac.cn

Dr. P. A. Winarso (expert)
Kompleks Meteorologi
Jl. Pemancar 8/37, Pd. Betung - Pd. Aren, Tangerang 15221 � Indonesia
Email: paulusaguswinarso@yahoo.com

Appendix 2: Agenda of the 6th CLIVAR Asian-Australian Monsoon Panel and the 1st CLIVAR/IOC Indian Ocean Panel Joint Meeting, 18-20 February 2004, Indian Institute of Tropical Meteorology, Pune, India (http://www.clivar.org/organization/aamon/aamp6/aamp6iop1_agenda.htm)

Appendix 3. IO modeling and the CLIVAR modeling panels

Jay McCreary
I am writing to you (John, Ben, Tim, and Claus) as chairs of the WGSIP, WGCM, and WGOMD modeling panels. Next month (February 18-20), there will be a joint meeting of the CLIVAR Asian-Australian Monsoon (AAMP) and newly formed Indian Ocean (IOP) panels. Gary Meyers is the IOP chair, and he has asked me to lead a discussion about issues relevant to Indian-Ocean modeling, as well as their relevance to the modeling interests of other CLIVAR panels. Specifically, he wrote (a version of) the following:

In writing the Terms of Reference for the IOP, the linkage of the IOP to CLIVAR and the other WCRP modeling panels was an issue that received considerable attention. From the CLIVAR side, a modeling effort was seen as essential for research planning. From the GOOS side, there was concern that the IOP already had too much to do in preparing an implementation plan for the observing system, so that having the IOP also delve deeply into research planning would be a distraction. In the end, modeling was not given a prominent place in the Terms of Reference. Nevertheless, I assured the committee that modeling was an activity that would not fall off the IOP agenda.
I would appreciate your leading a discussion on how the IOP can develop links to the modeling panels. As a beginning, it would be useful to have an initial viewpoint on what will be of interest to them.

Issues of air-sea interaction that are important to IO modeling include: *i)* thin mixed layers (due to fresh-water flux) in the Bay of Bengal and eastern IO; *ii)* upwelling of cold water off Sumatra/Java, which is important for the development of the IO Dipole Mode (Zonal Mode) of climate variability; *iii)* upwelling in the 5��10�S band where the thermocline rises close to the surface, among other things generating SSTAs that influence hurricane activity; *iv)* the role of Rossby waves in all of the above; *v)* air-sea fluxes; and *vi)* equatorial jets.
Clearly, many of these issues are of direct relevance to your individual panels. Conversely, a key issue that the IOP needs to address is what general IO modeling issues are *not* currently being addressed in the existing modeling panels, and to what extent new modeling activities initiatives need to be initiated.
As a start in developing an appropriate IOP modeling agenda, could you provide a brief overview of the existing panels and their main activities, particularly highlighting any gaps that you perceive with respect to IO modeling. I would appreciate any other thoughts you have regarding IO modeling in general.

Tony Busalacchi
Regarding the modeling panels, the appropriate ones would be WGSIP (Chairs Ben Kirtman and Tim Stockdale) for S-I (including intraseasonal to decadal time scales), WGCM (Chair John Mitchell) for global change and GHG forced runs, and WGOMD (Chair Claus Boening) for OGCM efforts/improvements as part of coupled global change scenarios. In each of these panels, if left to their own agendas, the IO will likely get low priority. However, the chairs have been encouraged to work with the ocean sector and monsoon panels, and to rely on them as sources of expertise to broaden the interaction, use, and analyses of the ongoing studies being done at many of the major modeling studies. For example, for a long time WGCM was primarily interested in the various IPCC scenarios and 2×CO_2 runs within the context of global mean temperature. Now, they are beginning to consider how the various modes of natural variability are modulated in response to such forcing. The most specific tangible example has been the collaboration between WGCM and the Atlantic panel on some coordinated experiments for freshwater forcing of the Atlantic THC. Across WGSIP, WGCM, and WGOMD one could imagine potential joint activities regarding the ISOs, IOD, ITF, and the role of the IO in the THC and monsoon circulation.

John Mitchell
Probably the best way to link with WGCM is to contact Claus Boening, who is chairman of the Working Group on Ocean Model Development, which reports to WGCM. WGOMD deals specifically with ocean models. For coupled phenomena, the best contacts are probably Tom Delworth (GFDL) and Mojib Latif (Kiel), who have particular interests in climate variability. Claus, Tom, and Mojib are all members of

WGCM. Some of what you mention will also be of interest to WGSIP (e.g., anything relevant to ENSO). WGSIP is also beginning to look at longer timescales (annual up to decadal).

Ben Kirtman
WGSIP past involvement with the Indian Ocean sector has been limited. We are very interested in global prediction and the monsoon in particular, but little specific attention in the past has been given to the Indian Ocean sector. WGSIP is enthusiastic about the newly formed IOP and its joint meeting with AAMP.
WGSIP was charged by the JSC (in 2000, I think) to comment on the need for an ocean observing program in the Indian Ocean. At that time, the WGSIP position can be summarized with the following bullet - �More Observations Required for Better Understanding, Need for Routine Observations Likely, But More Study Required.� In the past, we have also tried to keep abreast of ongoing observations, such as the XBT network under the direction of the JAFOOS. We have also been briefed on some of the work that Godfrey and colleagues have been doing regarding the dynamics and thermodynamics of the Indian Ocean.
In terms of future collaboration, WGSIP is very interested in a number of issues in the Indian Ocean sector. For example, there are several recent studies that indicate coupled air-sea interactions are essential in terms of accurately simulating, and perhaps even predicting, monsoon variability and ENSO-monsoon interactions. We are interested in how tropical Indian Ocean variability relates to atmospheric predictability, especially in central Africa. We are also interested in how much Indian Ocean variability is due to stochastic forcing and air-sea interaction (either damped or unstable), which ultimately determines our ability to predict the variability. How much India Ocean variability is remotely forced versus internally generated? Are India Ocean SSTs predictable, and if so for what lead times?

Claus Boening
WGOMD, as a sub-group of WGCM, was established to �stimulate the development of ocean models for research in climate and related fields, with a focus on decadal and longer timescales at mid- and high-latitudes,� the reason for the focus being to avoid overlap with WGSIP. Accordingly, the group's activities so far centered on issues of model formulation (e.g., effects of resolution, mixing parameterizations etc.), and on the performance of global models, particularly those that are part of coupled models for IPCC-type climate runs.
Part of that activity was the initiation of a coordinated assessment of ocean model performance, by formulation of a standard protocol for an �ocean model intercomparison project� (OMIP). Because the comparison mainly aims at model development and testing, the forcing protocol defined for that is based on a climatological (repeating annual cycle).
Since WGOMD is also a CLIVAR panel, however, there has been a growing interest to engage in modeling activities of more immediate relevance to the various basin panels. In discussions with the Atlantic and Pacific panels (e.g., through cross-representation at the meetings), a plan is emerging to engage in coordinated modeling activities addressing the characteristics and mechanisms of low-frequency ocean variability. For WGOMD, it would seem most natural to build such activities (e.g., a hindcast of the past, say, 50-year variability) on the current (pilot) phase of the OMIP.
While this type of modeling program would naturally embrace Indian Ocean variability, and perhaps allow a rather systematic investigation into effects of model formulation on basin- to global-scales, it is not clear to me whether it would be the best framework for addressing all the issues pertinent to the IO you mentioned in your mail.

Appendix 4. Discussion paper on Tide Gauge Data and Storm Surge Prediction

Follow-up to First Indian Ocean Panel Meeting and INDOCLIM Workshop Held in Pune, India, 18-27 Feb 04

The Issue: The availability of continuing, routine observations of the ocean is giving us a capability to address a number of scientific questions which are of importance to society, in particular the problem of storm surge and flood prediction. If we wish the systems providing these observations to continue over the long term, it is imperative that we demonstrate that the data are useful for addressing societal impacts. We need rapid and positive feedback to help justify sustained funding for the observing systems.

Several types of data from Indian Ocean sources are available in near-real time and can be used in prediction systems, including:

� Continuing observations for more than a decade of open-ocean sea surface height from TOPEX/Poseidon and Jason-1 altimetry

� Observations of surface vector winds from QuikSCAT for almost five years

� Growing coverage of the Indian Ocean by Argo profiling floats and the resulting observations of broad-scale upper-ocean temperature, salinity and dynamic height structure.

� Continuing observations from surface drifting buoys and Volunteer Observing Ship XBT lines.

Sea level is missing!

� Monthly averaged observations of sea level measured at tide gauges are accessible within several months to years of collection. The data are used for research and applications on climate variability and change.

� But timely access to hourly observations is possible for only a few tide gauges in the Indian Ocean region. Timely access to hourly tide gauge data is needed for:

- Warning systems and research for storm surge and floods in coastal low lands
- Smooth operation of the Indian Ocean Observing System, including: calibrating the satellite altimeters, monitoring the performance of the sea level network � e.g. knowing exactly when a tide gauge becomes inoperative, quality controlling the data � having hourly data to help assess the quality of monthly averages and the performance of the gauge.

What are possible factors standing in the way of making hourly tide gauge data available in near real time?

Contributing factors and possible solutions are:

� Access to technology and the need for capacity building at the locality of the tide gauges (Developed countries would most likely be willing to work this issue to mutual satisfaction, including the provision of funds; this is not a big expense item)

� Perceived threat to national security (To overcome, need to counterbalance with potential societal benefits and national well being derived from prediction of storm surge, coastal floods, and extreme events, e.g. precipitation and wind, associated with intra-seasonal variability)

Integrated with the other data mentioned above, what are the important questions in the Indian Ocean that these observations can help us address?

� Cyclone growth/movement and the associated storm surge, an issue of particular importance in the Bay of Bengal

� Intra-seasonal variability, eg influence of the Indian Ocean on seasonal precipitation patterns associated with the SW monsoon over India

� How changes in the upper-ocean temperature and salinity fields contribute to long-term sea level rise in the Indian Ocean

� Decadal variability like the Indian Ocean Dipole (IOD) and its correlation with seasonal precipitation patterns in SE Asia and E and S Africa

� ENSO in the Indian Ocean and how it modulates the effects of IOD
� In general, to advance our understanding of how the ocean is coupled with and influences the coastal zone � especially given the observational coverage of the deep ocean

Ongoing related activities in the Indian Ocean include:
� The CLIVAR Asian-Australian Monsoon Panel (co-chaired by Peter Webster and Julia Slingo) coordinating research on the influence of the Indian Ocean on seasonal/intra-seasonal precipitation patterns associated with the SW monsoon over India
� The IOC/CLIVAR Indian Ocean Panel (chaired by Gary Meyers) preparing an implementation plan for broad scale Indian Ocean monitoring
� Indian Ocean - Global Ocean Observing System (IOGOOS) (chaired by K. Radhakrishnan) is working to coordinate the collection of sustained, systematic ocean observations in the Indian Ocean, in particular concerned with the coastal observing system and on-shore/off-shore interaction including climate impact.
� A proposed JCOMM capacity-building effort in storm surge forecasting in the Bay of Bengal entitled Marine Impacts on Lowlands Agriculture and Coastal Resources (led by Johannes Guddal) and endorsed by the WMO
� An earlier (~2000) Project Proposal for Storm Surge Disaster Reduction in the Northern Indian Ocean lacked focus, was too ambitious, and never got off the ground

Ongoing activities outside the Indian Ocean region are developing related predictive capability:
� The Coastal Ocean Observations Panel (chaired by Tom Malone) wants to understand the impact of open-ocean processes on the coastal regime; this be a prototype for linking the two domains
� Keith Thompson�s work has shown significant coastal signatures in tide gauge observations (along the E coast of N America) which reflect the North Atlantic circulation

What might be Next Steps?
- In general, identify specific locations of tide gauges around the Rim of the Indian Ocean for which access to timely, hourly data are desired
- In particular, begin with gauges in the Bay of Bengal as part of a cyclone/storm surge demonstration project
- Assess what is needed to bring these initial demonstration gauges on line
- The University of Hawaii Sea Level Center (UHSLC) (Directed by Mark Merrifield) is available to assist with training, installation, maintenance, data management, and communications issues
- The UHSLC would serve as one archive for resulting data; INCOIS in Hyderabad could serve well as the responsible regional agency for a Bay of Bengal pilot study
- Develop scientific consensus for this plan among those groups working under the auspices of the IOC and WMO, CLIVAR, IOGOOS.
- Make commitments to carry out these steps at the upcoming Second IOGOOS Conference to be held at Colombo, Sri Lanka, April 26-29 2004.

Closing Comment
� Enhancing the tide gauge network in the way proposed here is technologically feasible without resorting to high technology or expensive instrumentation. It is something that can be achieved relatively easily and quickly. It would give all Bay of Bengal nations and potentially all Indian Ocean Rim nations an opportunity to participate in the development of IOGOOS, and in so doing, would demonstrate a significant commitment by all of these nations to the ideals of GOOS.

Gary Meyers, CSIRO Marine Research
Gary.Meyers@csiro.au

Stan Wilson, NOAA
Stan.Wilson@noaa.gov

Appendix 5. Acronyms

Most of the acronyms used in this report are listed here. More can be found at http://www.clivar.org/publications/other_pubs/iplan/iip/appendix_6_acro.htm.

AMIP	Atmospheric Model Intercomparison Project
BMRC	Bureau of Meteorology Research Centre (Australia)
BODC	British Oceanographic Data Centre
CEOP	Coordinated Enhanced Observing Period
CGCM	Coupled General Circulation Model
CIMS	CEOP Inter-monsoon Model Study
CLIVAR	Climate Variability and Predictability (WCRP component)
COPE	Climate Observation and Prediction Experiment
CSIRO	Commonwealth Scientific and Industrial Research Organization
ECMWF	European Centre for Medium Range Weather Forecasts
ENSO	El Ni�o Southern Oscillation
GCOS	Global Climate Observing System (IOC/WMO/ICSU/UNEP)
GCM	General Circulation Model
GEWEX	Global surface Energy and Water cycle Experiment
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System (IOC)
GTS	Global Telecommunication System
HadCM	Hadley Centre Coupled Model (UK)
IBPIO	International Buoy Programme for the Indian Ocean
ICPO	International CLIVAR Project Office
ICSU	International Council of Scientific Unions
IOD(ZM)	Indian Ocean Dipole (or Zonal Mode)
IGBP	International Geosphere Biosphere Programme
IRS	START Integrated Regional Study
MAIRS	Monsoon Asia IRS
IHDP	International Human Dimensions of global change Programme
IOC	Intergovernmental Oceanographic Commission
IOCCP	International Ocean Carbon Coordination Project
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
ITF	Indonesian Through-Flow
JCOMM	Joint Commission for Oceanography and Marine Meteorology
JSC	Joint Scientific Committee for the World Climate Research Programme
NCAR	National Center of Atmospheric Research (US)
NCDC	National Climate Data Center (US)
NCEP	National Center for Environmental Prediction (US)
OOPC	Ocean Observation Panel for Climate (GCOS/GOOS/WCRP)
OSSEs	Observing System Simulation Experiments
PDV	Pacific Decadal variability
START	Global Change SysTem for Analysis, Research & Training
UNEP	United Nations Environment Programme
VACS	CLIVAR Panel for Variability of the African Climate System
WCRP	World Climate Research Programme
WGCM	Working Group on Coupled Modelling (JSC/CLIVAR)
WGOMD	Working Group for Ocean Model Development
WGSIP	Working Group for Seasonal and Interannual Prediction
WMO	World Meteorological Organization

WOCE	World Ocean Circulation Experiment (WCRP component)

[GM1]Summary of Jay�s talk in his own words inserted here.
[GM2]