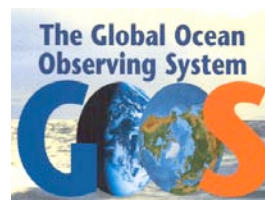


INTERNATIONAL  
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METEOROLOGICAL  
ORGANIZATION

## WORLD CLIMATE RESEARCH PROGRAMME



### Report of the Second CLIVAR/GOOS Indian Ocean Panel Meeting

30 March – 2 April 2005,  
CSIRO, Hobart, Australia

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## Action List

To contribute an Observing System Simulation Experiment (OSSE) section to a BAMS article summarizing the results of the AAMP/IOP Hawaii Workshop on Indian Ocean modelling. **Meyers with assistance from OSSE modellers.**

To summarize the research issues and advances in planning sustained observations for climate in a paper for BAMS. **Meyers, McPhaden and OSSE members.**

To report IOP's recommendations on implementing flux reference sites with justifications to the Ocean Sites Program. **McPhaden, L. Yu.**

To summarize in a letter to IOC and IOGOOS discussions at IOP-2 on the links between basin-scale climate observation and the developing Tsunami warning system. **Erb**

To submit a proposal to the Tsunami planning workshop in Mauritius (April, 2005) on behalf of IOP for developing and implementing an instrumentation package for multi-hazard observations at mooring sites (tsunami, storm surge etc.). **Erb**

To write a paragraph in the Argo section of the Implementation Plan on carbon/biogeochemistry measurements on Argo. **Tilbrook**

Actions for XBT network:

- Communicate to the JCOMM SOT panel, IOP priorities for XBT lines. **Meyers**
- Write to the Director of NIO concerning the western Indian Ocean XBT workshop, NIO/Goa, October 2005, advocating scientists' participation in the workshop (with input from Meyers). **Thurston**
- Summarize the XBT discussions for inclusion in the Implementation Plan. **Vecchi**
- Noting that not all CLIVAR relevant XBT data are submitted to GPS/JCOMM, Masumoto, W. Yu and Murty to work with their national XBT operators to develop a plan for at least annual submissions of data to JCOMM. **Masumoto, W. Yu and Murty**
- Write to Dr Peter Taylor (NOC, UK) for information on Southern IO flux measurements, regarding a suggestion to add a XBT line to help improve knowledge of air-sea fluxes over the Southern Ocean. **L. Yu**

To write to IBPIO outlining the need for improved implementation of drifters in the Indian Ocean. **Meyers**

To proactively collect information and set up a map and a list on CLIVAR's website summarizing research cruises in the IO during 2005-2007, and keep these updated. The cruise information should cover all cruises that collect CTD or XBT data, including repeat hydrography, process studies, regional surveys and routine cruises (e.g. mooring maintenance). **Yan assisted by panel members**

To note that the current draft for the Implementation Plan does not adequately cover research issues relevant to Africa summarize where southern IO data are particularly needed. **C. Reason**

To summarize the advances made so far by IOP into a BAMS paper as soon as possible, while reserving a special issue of CLIVAR Exchanges (June 2006) for more detailed papers. **Meyers / McPhaden assisted by other members.**

To finalize the Implementation Plan for a sustained Indian Ocean observing system. All authors to submit their shortened write-ups to Gary Meyers by 15 April, expecting a complete version via a professional editor by mid June. **Meyers et al.**

To inform D/ICPO (Howard Cattle) of the discussions at the meeting on the future of IOP (**Yan**); and to prepare a short document of the panel's consensus view on its future for the CLIVAR SSG and GOOS SC to consider as soon as possible. (**Meyers**).

To find a local contact / host for IOP3 (Reunion Island, dates to be determined). **Molcard**

## 1. Introductory notes

The 2<sup>nd</sup> Indian Ocean Panel meeting was held at the CSIRO Marine Laboratories, Hobart, Australia. Dr. Tony Haymet (Chief, CSIRO Marine and Atmospheric Research, CMAR) opened the 4-day meeting at 9:00 am, 30 March 2005, by welcoming the delegates. He noted that CMAR is to promote more climate-related studies in future years and appreciated that IOP-2 would help. Dr. Meyers (IOP Chair), Dr. Yan and Mr. Erb, representing the co-sponsors of the panel (IOC and CLIVAR), also welcomed panel members and experts to the meeting. While appreciating the progress the panel had made in developing a sustained observing system for the Indian Ocean, they expressed their wishes that implementation of the array would continue and also, that a more comprehensive science plan would be developed and implemented in coming years.

The aims of IOP-2 were:

- to finalize the Implementation Plan for a sustained, integrated, basin-scale observing system for climate in the Indian Ocean, and
- to discuss/develop a strategy of Indian Ocean oceanographic research relevant to climate, in association with but not limited to study of the Asian-Australian monsoon.

Contact details of the attendees, the meeting agenda and the panel's Terms of Reference are listed in Appendices 1-3. This report is also available online with links to all presentations at the meeting, via the CLIVAR, GOOS and Indian Ocean GOOS websites:

<http://www.clivar.org/organization/indian/>

<http://ioc.unesco.org/goos/>

<http://www.incois.gov.in/Incois/iogoos/home.jsp>

## 2. Science talks

A symposium on Indian Ocean (IO) climate was organized on the 1<sup>st</sup> day, in order to provide a scientific background for panel business. The topics introduced by keynote speakers were as follows.

**Intra-seasonal prediction.** In his talk Prof. Webster argued that conventional prediction of seasonal mean precipitation in conjunction with the Asian monsoon was not only unsuccessful but quite meaningless. He emphasized that intra-seasonal prediction was needed for monsoon regions and illustrated examples of predictions of regional intra-seasonal rainfall variations, resulting from an empirical method filtering the low-frequency variations from other timescale 'noise'. He proposed a generalization of the filtering method for application to coupled, dynamical models. Prof. Webster suggested that CLIVAR should provide direction for promoting useful predictions and applications.

**Mean and variability of air-sea heat fluxes.** Dr. L. Yu showed large uncertainties in global climatology of air-sea fluxes by comparing mapped results from six commonly used flux data sets. While large differences occur at all time scales, the large biases in the annual mean flux between data sets is a major concern. Sustained observations are needed in order to validate air-sea flux climatologies and to study variability in air-sea fluxes in the IO.

**Deep mixing and the surface heat budget.** Dr. Godfrey introduced a fundamental question about the Indian Ocean: Why do all Indian Ocean models published to date demand lower annual mean heat fluxes than those in observed climatologies? He then illustrated why the models produce this result using two runs of a coarse-grid model. Both yield net area-mean, long-term mean heat fluxes and transports, which are similar to one another, despite a large difference in wind forcing. One model was forced by full seasonally varying wind stresses and the other by their twelve-month running mean. Dr Godfrey suggested that the problem in models is in representation of strong currents and vertical mixing processes in the north western part of the basin.

**West Australian Indian Ocean Climate Initiative (IOCI).** Dr. Nicholls introduced IOCI as a program focused on understanding why SW Australia has suffered a 40% decrease in inflow to dams since 1976. He showed the large-scale climate patterns and steady warming trend in the IO associated with the shift. The patterns seemed to be a mix of natural variability and anthropogenic, forced climate change. However, no causal relationship could be found between the IO and climate of SW Australia. More observational and theoretical studies were needed to address the role of the IO in climate of this region.

**Ocean circulation variability and its climate relevance.** Prof. Schott introduced several aspects of the IO circulation, including monsoon circulation means, cross-equatorial cell, variability of the cross-equatorial exchange, and variability of the Indonesian Throughflow, based on ocean re-analysis products. Large differences in interannual to decadal variability were noted between different products and problems in different assimilation models were discussed.

**Ocean modeling and its climate relevance.** Dr. McCreary summarized successes, problems and prospects of current IO modeling. Details of his and others' presentations are available online at CLIVAR's web pages via this IOP-2 report.

The science overview talks were very much appreciated by the largely Australian audience at the symposium. The talks were recorded on video for interested parties. The talks and subsequent discussions provided a base for the panel to obtain a consensus view that IOP may play a more independent role in developing a science plan for the Indian Ocean sector, which is not only in association with CLIVAR's Asian-Australian monsoon study but of a wider scope overlapping other parts of CLIVAR (see Section 5).

### **3. Implementation issues**

After the science symposium, the panel and invited experts discussed the meeting agenda. Dr Meyers emphasized the first aim of IOP-2 is to finalize the Implementation Plan of a sustained observing system for the Indian Ocean. While a comprehensive science plan was unlikely to be developed by this meeting, Dr. Meyers suggested that the panel should discuss the issue and bring it into next meeting's agenda. The IO science strategy was expected to be of a wider scope than just for monsoon studies.

Additional issues on the agenda addressed IOP's role in developing (i) a tsunami and multi-hazard warning system, (ii) a Bulletin of American Meteorological Society (BAMS) paper (iii) a special issue of CLIVAR Exchanges for summarizing recent advances, (iv) data management, and (v) an additional biological/carbon section in the implementation plan. The panel recognized that the agenda was quite ambitious and agreed that the first priority was to finalize the implementation plan, with other issues to be discussed in a more general sense depending on time.

Dr. Meyers reported on IOP contacts and activity during the past year since IOP-1. The Panel reported on the observing system development and/or sent a representative to

- CLIVAR Data Management Meeting, March 2004 SIO La Jolla
- Indian Ocean GOOS, April 2004, Colombo
- OOPC-9, June 2004, Southampton
- GSOP Workshop and Panel, November 2004, Boulder
- Ocean Technology/Oceans '04, November 2004, Kobe

Dr Meyers noted that Global Synthesis and Observations Panel (GSOP) would be the primary CLIVAR link with OOPC and to explore potential for cooperation and collaboration with JCOMM. However, IOP also maintains direct links with these bodies as well. GSOP will also work closely with modelling and basin panels to develop a strategy on how they would interact in the future. IOP also participated in the GSOP email discussion to develop a CLIVAR Data Policy ([http://www.clivar.org/data/data\\_policy.html](http://www.clivar.org/data/data_policy.html)) and the preparation of the CLIVAR SSG Report to WCRP JSC (March 2005 Guayaquil). Several Panel members participated in the CLIVAR 2004 Conference (Baltimore, June 2004). IOP and AAMP organized the Indian Ocean Modeling Workshop (December 2004, Honolulu) and a strong contingent of members and collaborators participated. The PowerPoint talks and a workshop summary are available at:

<http://iprc.soest.hawaii.edu/meetings/workshops/IOM2004/IOM2004talks.html>

#### **3.1. Observing System Simulation Experiments (OSSEs)**

Day 2 started with talks on OSSEs presented by Drs. Vecchi, Lee, and Oke (vice Schiller). OSSEs designed to examine the efficiency of the proposed Indian Ocean Observing System were presented. They assessed a range of time scales from intraseasonal variability to decadal and longer changes. They also used a variety of approaches, from assessing how well the initial planned observing system from IOP-1 performs to

determining what set of observations is ideal, assuming the model is “perfect”. The OSSEs provided valuable insights that led to modification of the initial plan. In particular, the OSSEs

- improved approaches to observing critical regions where upwelling occurs and remote forcing of the thermocline affects SST (e.g. Java/Sumatra upwelling and the SECC ridge); and
- explored what observations are critical for observing change in the cross equatorial heat transport.

The OSSEs also confirmed that our thinking is on track for an initial observing system for the difficult task of observing intraseasonal time scale.

Dr Vecchi began by showing validation of his model against the recent equatorial mooring results from Masumoto et al. (2005). Using a  $1/3^\circ$  resolution ocean general circulation model (OGCM) forced with daily-mean winds, which also include a representation of tidal and internal wave aliasing (Vecchi and Harrison, 2005), he assessed an observing system that includes:

- ARGO profiling floats: one per  $3 \times 3$  degree, sampling 0-2000m every 10 days (compared to 0-1000 every 5 days) and drifting at surface for 8-12 hours to telemeter data;
- XBT lines: 15 times a year (per line), 4 XBTs per day, sampling at 1m down to 1000m; and
- A moored buoy array as designed at IOP-1: similar to ATLAS/TRITON, surface meteorological data and subsurface T/S to 500 m, and equatorial upward-looking ADCP moorings.

Based on his OSSE results, Dr Vecchi concluded that:

- 5-day repeats result in significant thinning out of ARGO as drift-holes form in divergent regions and near topography;
- for sub-seasonal variability, ARGO/XBT are not adequate. The sub-seasonal Indian Ocean temperature variability recovered from sampling at 5-day intervals with ARGO does not represent a significant improvement from 10-day sampling.
- for interannual variability, the planned system is able to map much of Indian Ocean well. High-frequency IX-1 XBT is essential to make up for lack of moorings due to threat of vandalism by fishers; and
- for currents, the western boundary current (WBC) is out of scope and near-surface currents cannot be linearly extrapolated.

The panel recognized that not much is gained by 5-day sampling of Argo, and it has some down sides. The panel felt that 10 day sampling should be retained, but that the efficacy of a system combining Argo floats with the continuous time-series from the mooring array needs to be more thoroughly assessed. Dr. Meyers recalled the decision from IOP-1 that the Java/Sumatra upwelling region cannot be covered by a surface mooring array; however the XBT line IX1 can be covered as frequently as needed, and quickly enough to monitor intra-seasonal variability. It was suggested that the sampling rate be increased to weekly sections, to complement the upward ADCP mooring near the line.

Dr. Lee summarized a study of the sensitivity of annual-mean cross-equatorial heat transport to surface forcing and temperature field, with implications for the OS. His main findings included:

- zonal wind in the eastern equatorial zone off the equator (Ekman pumping) is the most important interannual forcing of variability of cross-equatorial heat transport, which was defined as the cost-function (J);
- sensitivity of J to wind in the current year is opposite in sign to that in the previous year;
- surface heat flux in the subduction zone ( $\sim 100^\circ\text{E}$ ,  $20\text{-}30^\circ\text{S}$ ) is important for longer time scales. Heat flux east of Madagascar did not emerge as a critical region;
- J is not only sensitive to temperature near the equator; off-equatorial data provide a necessary constraint to this model;
- full-depth mooring is not necessary for interannual variability of J; and
- the variability of NCEP heat flux is different from that of ERA40; all flux sites are helpful except the one east of Madagascar.

The panel noted that the eastern near-equatorial region where wind forcing is important is reasonably well covered by the planned mooring array, and a flux reference site is located in the subduction zone. Arguments were raised on the necessity of the flux site in the southwest Indian Ocean. This site is not only for heat

transport, but is intended to reference the regional fluxes associated with tropical cyclone formation, which depends on thermocline depth in this region (Xie et al., 2003).

Dr. Oke presented two model-based assessments of the IO mooring array, aiming at recognizing the best locations to monitor intraseasonal to interannual variability, assuming the model will assimilate data and be used for ocean state estimation. The study showed that the proposed array will:

- resolve seasonal-to-interannual variability of thermocline depth and mixed layer reasonably well,
- not adequately resolve intraseasonal variability, particularly of mixed layer depth, and
- over-sample along the equator, and under-sample south of 8°S.

The study suggested that the best locations to monitor interannual variability are:

- in the southwest tropical IO, south of 8°S;
- off the coast of Indonesia; and
- east of Sri Lanka

and the best locations to monitor intraseasonal variability are:

- along, or just north of the equator in the east IO and
- just south of the equator in the west IO.

The panel noted that the results were generally in agreement with the other assessments; however, concentrating moorings off the equator to observe depth of the thermocline was a result that needs further documentation. Could this be an artifact of monitoring the depth of 20°C in regions where it surfaces as part of the seasonal cycle? Using the vertically integrated temperature was suggested as an alternative. As Dr Oke concluded, the results are qualitatively robust for different methods and for different models.

The panel highly appreciated the OSSE assessments. Considerable advances had been made since the last year's Hawaii meeting. It was recommended that the results be summarized in a paper for BAMS or a high-level journal to highlight what the OSSEs had achieved. The panel noted that the OSSEs are a useful complement to the usual observationalist approach to designing fieldwork.

**Action:** To contribute an Observing System Simulation Experiment (OSSE) section to a BAMS article summarizing the results of the AAMP/IOP Hawaii Workshop on Indian Ocean modelling. Meyers with assistance from OSSE modellers.

**Action:** To summarize the research issues and advances in planning sustained observations for climate in a paper for BAMS. Meyers, McPhaden and OSSE members.

### 3.2. Surface fluxes

Improved observation of surface fluxes and calibration of satellite products is one of the most important goals of the observing system. The panel recognized at IOP-1 that we lacked expertise to adequately address this issue. Dr Lisan Yu joined the panel and attended for the first time at IOP-2. She presented an overview of what are the most challenging issues around estimating Indian Ocean fluxes and what is known about mean and variability from available products. She reviewed six global products:

- Southampton Oceanographic Centre (SOC Climatology)
- NCEP/NCAR reanalysis (NCEP1)
- NCEP/DOE reanalysis (NCEP2)
- ECMWF operational analysis
- ECMWF Re-Analysis 40 (ERA-40)
- OAFlux (Objectively Analyzed air-sea heat Fluxes) WHOI

Dr Yu showed where the air-sea flux products differ the most, where air-sea interaction is the strongest and thus where air-sea fluxes are most useful for modeling and monitoring. The panel expressed concern about the large biases between products throughout the Indian Ocean and very large biases ( $>50\text{W/m}^2$ ) in some regions. Dr Yu suggested possible re-location of some of the flux mooring sites. Discussion focused on two sites, one off Madagascar, SW IO, and another in the SE IO at 25°S (for subduction). There tended to be a consensus view that the 25°S site should be maintained for various reasons (e.g., for carbon-related measurements, aerosols, subduction feeding the cross-equatorial heat transport, interest in the location in



Australia, etc). A very large bias is located NW of the subduction zone. A surface mooring was added to the array near this location (95E, 16S), which permits estimation of fluxes by bulk methods, but lacks high vertical resolution in the ocean measurements. A northward move of the SW IO site off Madagascar seemed more agreeable. The panel noted that some surface mooring sites may be upgraded to flux reference sites in the future depending on new scientific requirements.

The panel discussed a report to the Ocean Sites Program with recommendations for implementing the reference sites, including tentative timelines and justifications for each.

**Action:** To report IOP's recommendations on implementing flux reference sites with justifications to the Ocean Sites Program. McPhaden, L. Yu.

After discussion of the OSSEs, surface fluxes and later agenda items, the panel unanimously supported the final draft of the mooring plan, as in Figure 1. However, the flux reference site in the Bay of Bengal is to be shifted to 12N, 89E as the proposed site (12N, 90E) falls within the EEZ of India (till the IOP/CLIVAR gets the necessary Indian governmental clearances).

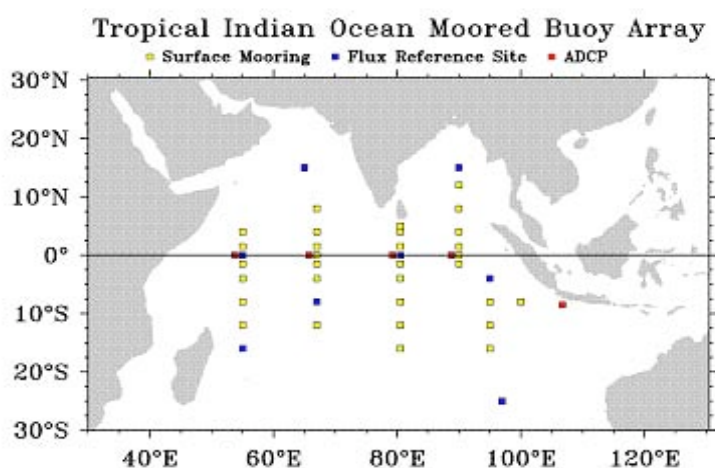


Figure 1. The recommended tropical Indian Ocean moored buoy array.

### 3.3. Basin-scale mooring array

Dr. McPhaden briefed the panel on the status of ongoing and upcoming deployments. Three new ATLAS moorings (like those used in the Pacific) and an upward ADCP were deployed from ORV Sagar Kanya at 80°E by the joint NOAA/NIO initiative planned at IOP-1. A fourth surface mooring was placed at 90°E on the equator. The present status of the array including the Japanese moorings is shown on the map below (Figure 2). A web based mooring data assembly center is under development at PMEL. Data from the combined ATLAS, TRITON and ADCP moorings should be publicly available on the Internet by the end of June 2005. When established, the Indian Ocean Moored Buoy Data Assembly Centre (DAC) will be similar to those for the Pacific and Atlantic moored buoy arrays.

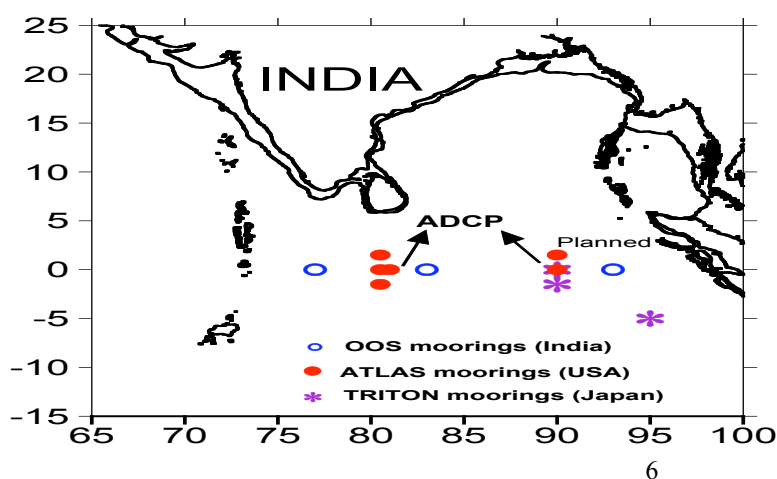


Figure 2. Current tropical Indian Ocean Moored Buoy Array

Dr. McPhaden reviewed the major issues that have to be resolved to fully establish the mooring array:

- Ship time (~180 days per year to service each site semi-annually)
- Fishing vandalism
- Operational funding
- International coordination
- System integration (integration with other observing system components)
- Data management

The surface moored buoys can in principle include bioptical and chemical sensors, which requires interaction with the biogeochemical community.

Dr. W. Yu briefed the panel on the upcoming ASV Xue-Long and R/V Ocean-1 cruises, which offer opportunities to deploy moorings at some of the recommended sites. Discussions are underway on the possibility of using the R/V Ocean-1 cruise to help NOAA deploy three moorings on the southern part of the 80°E line (6°-16°S), during its global survey, late 2005 or early 2006. Dr. McPhaden emphasized the need for sharing information such as cruise timelines as early as possible so that ship time for cooperation could be arranged in time.

Dr. Kuroda presented Japan's present status and future IO mooring plan. The present TRITON mooring sites at 1.5S, 90E and 5S, 95E will be maintained as a pilot study (up to 2008). Present pilot study TRITON data are delivered to meteorological agencies through the GTS and delivered from the TRITON home page. High-resolution hourly data will be available from a presently developing new TRITON data management system from the end of May 2005. Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) has prepared a 5-year competitive fund from year 2005 to promote GEOSS related observational studies. With this fund, JAMSTEC plans to start a new project, under which several moorings are to be deployed mainly in the eastern tropical Indian Ocean (indicated within an ellipse in Figure 3). The project focuses on oceanic variability and air-sea interactions at the time-scale of weeks to years, including the intraseasonal disturbances and the Dipole Mode events. A smaller TRITON buoy, called a mini-TRITON, with a new data processing unit will be developed to achieve sustainable observations. The mini-TRITON buoy can be handled and maintained by relatively small vessels and, thus, provides opportunities for many rim countries to be involved in the mooring array. Planned mini-TRITON buoys are: 2006 (4 sites), 2007 (4 sites), 2008 (6 sites) and 2009 (6 sites). The two pilot study TRITON buoys will be replaced with the mini-TRITON buoys. JAMSTEC will develop data management system and continually improve data quality control methods for the mini-TRITON buoys, and collaborate with PMEL on the Indian Ocean Moored Buoy DAC. Dr Kuroda noted the need for assistance with research vessel time to maintain the deployments. The panel discussed the possibility of adding additional measurements (e.g., for carbon / biogeochemistry) on mini-TRITON. Dr. S. Thurston suggested seeking support from US NOAA for such measurements.

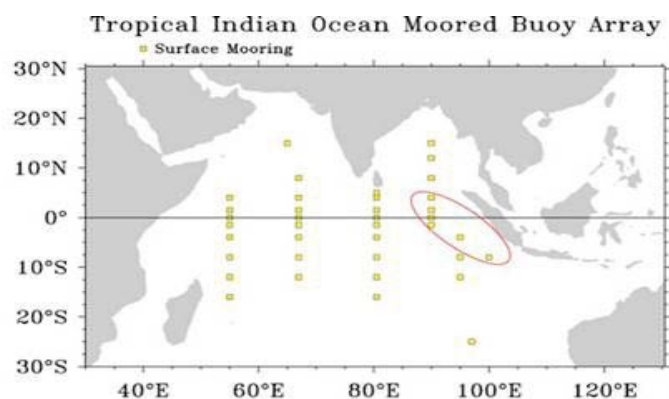


Figure 3. Deployment of JAMSTEC's mini-TRITON buoys are under planning for the Indian Ocean mooring array.

Dr. Murty presented the present status and near-future plan of the Indian Department of Ocean Development Ocean Observing System (DoD-OOS). The program involves current meter moorings along the equator for measurement of deep currents, an extensive moored buoy program in the Bay of Bengal and the Arabian Sea and cruises onboard ORV Sagar Kanya in the equatorial Indian Ocean in 2005. The proposed cruises during

May-December 2005 include hydrographic survey for multi-disciplinary observations (T, S, nutrients, chlorophyll, in situ primary production, dissolved oxygen and pH) and another for servicing the Indian current meter moorings. The later cruise was planned for November 2005, to service the Indian deep equatorial current meter moorings at 77E, 83E and 93E, which have uplooking ADCPs at 100m. During this cruise, in collaboration with NOAA (Figure 4), the TAO moorings at 0, 80.5E; 1.5S, 80.5E and 0, 90E and the ADCP mooring at 0, 81E will also be serviced and redeployed. The TAO mooring at 1.5N, 80.5E, which has disappeared, would be replaced. An additional TAO mooring would be placed at 1.5N, 90E. The dates and ports of embarkation/ disembarkation for this cruise were not yet final. The present DoD OOS program of deep equatorial moorings is funded to 2007. A new proposal will be submitted in 2006, in which the relocation of deep mooring sites to the IOP surface mooring plan will be considered. The Panel discussed pro's and con's of the scientific merit of maintaining the present deep current meter mooring sites for a longer period vs. moving to the surface sites. This issue needs further careful consideration. The figure below shows the sites of the Indian sub-surface current meter mooring array.

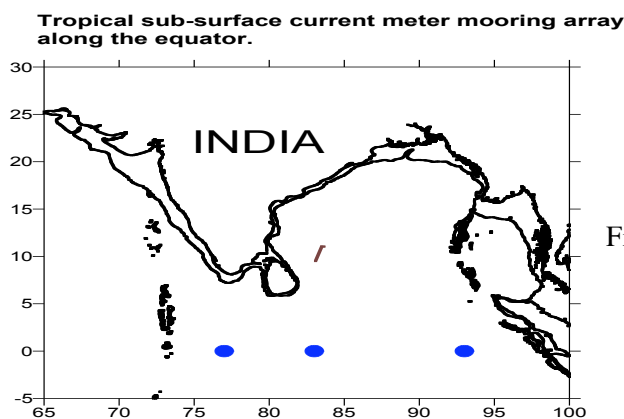


Figure 4. Indian sub-surface current meter moorings.

The panel acknowledged the considerable advances in the IO mooring array. As Dr. Meyers commented, at the SOCIO meeting in 2000, only 3-4 sites were planned because the scientific rationale was not as strong at that time. The scientific progress has been rapid, and currently there are 10 sites in the tropical IO. ~6 additional sites are planned or under consideration. Avenues towards more cooperation, involving more countries need to be developed. US NOAA had been establishing, and would continue to develop, close relationships with JAMSTEC, China, India, Indonesia, France and Australia for sharing information on cruises. Justification for such relationships in addition to research issues and operational oceanography may include providing data to a multi-hazard warning system to mitigate disasters such as tsunami, droughts and sea level rise/coastal flooding. The panel appreciated the national contributions and determined to take the developments into account in the relevant sections of the implementation plan.

### 3.4. Links to the Tsunami Warning System

Mr. Erb introduced recent international activities in response to the last year's tsunami in the IO. Indian Ocean GOOS (IOGOOS, one of IOP's parent bodies) will be involved in relevant activities under the auspices of IOC, towards establishing a warning / mitigation system for tsunami. This would involve capacity building in all Indian Ocean countries. Some countries such as India, Australia, Indonesia and Thailand are planning to build warning systems that will contribute to providing regional warnings. For instance, India is planning to deploy 8 moorings and other devices for the warning system within 6 months (Dr. Ravichandran). All these countries have agreed to cooperate with one another.

The panel discussed what role IOP could play in the tsunami/multi-hazard issue. Real-time data availability was recognized as a major problem. For instance, Bangladesh could not get timely prediction information from India; many countries would not provide daily weather data at all (Prof. Webster). A regional warning center should assure real-time data availability. The panel appreciated that the unfortunate event offered an opportunity to promote sharing of various data in the region. While the panel will not lead this effort it should be a player.

There are obvious synergies between the climate observing network and the need for real time data in a multi-hazard warning system:

- Technology - development of a multi-hazard instrument package for mooring sites;
- Logistics (e.g. ship time) for maintenance of deep-sea stations;
- Tide gauges - expanded, real-time: great news for operational oceanography;
- Commitment to exchange of data as discussed above;
- Integration, providing stability, reliability and regular products and services to the community; and
- Opportunities for joint risk assessment work, e.g. tropical cyclones, intraseasonal prediction.

It was suggested that the panel advise IOC of these synergies, highlighting problems such as tide data unavailability and addressing the necessity of coordination (e.g., for ship time etc) from a point of view of CLIVAR studies. Mr. Erb and the IOP chair, representing the panel, are to prepare a document/letter for IOGOOS/IOC.

**Action:** To summarize in a letter to IOC and IOGOOS discussions at IOP-2 on the links between basin-scale climate observation and the developing Tsunami warning system. Erb

**Action:** To submit a proposal to the Tsunami planning workshop in Mauritius (April, 2005) on behalf of IOP for developing and implementing an instrumentation package for multi-hazard observations at mooring sites (tsunami, storm surge etc.). Erb

### 3.5. Argo floats

At the request of the chairman, a group consisting of F.Schott, M.Ravichandran, Y. Masumoto, G. Vecchi, T. Lee and C. Reason had worked over the draft of the existing Argo section prior to the IOP-2 meeting. Help was also obtained through careful readings of the draft by R. Molinari and J. Gould. The group then prepared a revised draft for the IOP-2 meeting. At IOP-2 the following topics for Argo Implementation were discussed:

- The Panel concurred that Argo is an essential part of the Indian Ocean CLIVAR research objectives. Due to the variability of water mass composition in the Indian Ocean, Argo salinity profiles are a necessity for the interpretation of data provided by other systems such as altimetry, SST or XBTs.
- Argo was also considered important for obtaining improved mixed-layer distributions for air-sea interaction modelling, in particular in regions of barrier layers, and recommendations to users will be made by the Panel as to optimising near-surface sampling.
- Argo in the Indian Ocean is well underway; an updated chart of Argo positions, including planned deployments of the near future, was prepared. Deployment opportunities will be explored and publicized by INCOIS, including R/V opportunities during routine mooring maintenance cruises and process studies as well as contacts to enable air-deployment or deployments from chartered ships in remote regions that are not regularly crossed by commercial shipping.
- Availability of Argo data: the existing status of Argo data submission to centres and availability to the user community was found to be in agreement with the international Argo protocol.
- An important part of the Argo discussion was whether sampling should be carried out frequently enough to resolve the strong intraseasonal variability of the tropical- subtropical Indian Ocean. However, model/observing system experiments presented by G. Vecchi strongly suggest that little is gained by 5-day sampling, and there may be significant downsides to doing so. Instead, the effectiveness of 10-day Argo sampling to observe intraseasonal variability when integrated with data from the planned Indian Ocean mooring array should be assessed
- Since some of the most scientifically challenging and interesting areas in the Indian Ocean are upwelling regimes (such as those off Somalia and Oman, northeast of Madagascar and off Java/Sumatra) where

floats tend to diverge during their surfacing times, reseeded has to be planned to work against voids in Argo coverage.

- Since Indian Ocean water masses are known for their varied temperature-salinity relation, particularly the Red Sea water level of about 800m, the Panel agreed to make a user recommendation that the profiling depths of Argo sampling should reach below 1000m frequently enough to maintain calibration checks on the conductivity sensors.

Dr. Ravichandran presented a survey of present and future deployment of Argo floats. There should be about 450 active floats (currently about 255 floats) in the IO north of 40S. About 140 floats were deployed in 2004. The US plan to start deploying floats in the southern IO in 2006 (John Gould). At present users can access and download data from all active floats (available within 24 hours). INCOIS currently provide real-time quality-control down to 10S, and plan to produce gridded products in delayed mode.

In addition, Dr. Tilbrook discussed carbon and biogeochemistry measurements. Adding such measurements onto Argo could provide useful reference/verification for other products (e.g., satellite measurements), Oxygen sensors are now on many ARGO floats at a cost of about US\$5K extra per float, and bioptical sensors are also available to characterize particulate material. Carbon sensors are being considered, but are unlikely to be available for a number of years.

**Action:** To write a paragraph in the Argo section of the Implementation Plan on carbon/biogeochemistry measurements on Argo. Tilbrook

### 3.6. XBT network

The panel reviewed the JCOMM-recommended XBT lines, led by Dr. Vecchi. The scientific justification, potential impact and feasibility of the currently monitored and previously occupied repeat XBT lines in the Indian Ocean were evaluated. A set of “high priority” XBT lines was identified based on these criteria: high priority lines were those deemed to have significant scientific justification, to complement the other components of the proposed Indian Ocean observing system, and a significant feasibility of either maintaining a currently occupied line or restoring a previously repeated line. The high priority lines were determined to be IX-01, IX-08, IX-09N/IX-10E, IX-12, IX-15/IX-21, IX22 and PX-02 (Figure 5).

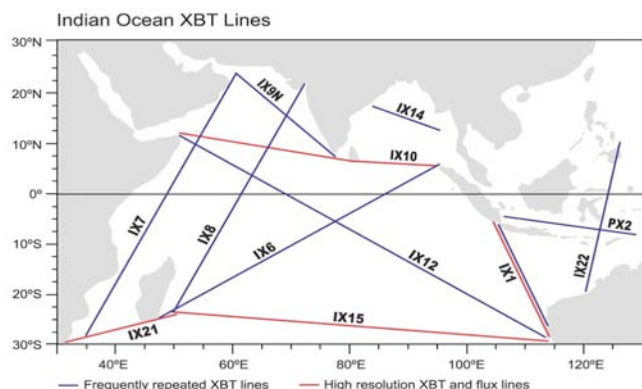


Figure 5. Regularly repeated XBT lines in the Indian Ocean

IX-01 was determined to be essential in monitoring the upwelling zone off the coast of Java/Sumatra, and to monitoring the mass-, freshwater- and heat-transport out of the Indonesian Throughflow region; it was suggested that IX-01 be occupied 52-times per year, with high-resolution lines at least four times a year. The rapid sampling will complement the ADCP located off western Java and resolve intraseasonal variability.

IX-08 monitors the western edge of the SECC thermocline ridge, can describe the zonal current structure in the Arabian Sea, equatorial region and along the western part of the Indian Ocean basin and could be used to constrain estimates of the mass flow into the western boundary current region; it was suggested that it be occupied 18-times per year. Though IX-08 has not been occupied since September 2003, due to lack of funds, it is unique enough to merit its reoccupation.

IX-09N/IX-10E (presently covered in frequently repeated mode) might together act to help constrain the total freshwater, heat and mass transport into the Bay of Bengal and Arabian Sea. The efficacy of IX10 as a high density line to directly measure transports needs to be assessed.

IX-12 samples the central part of the SECC thermocline ridge, and has been occupied consistently for 20 years.

IX-15/IX-21 need to be in high density mode and together close the southern limit of the tropical Indian Ocean. They have been occupied at very-high resolution sampling until recently, when the ship was lost; a search is currently underway for a new ship. Shipping on this route has become sporadic. Nevertheless, the panel recommends that the line be observed when and if it can be, ideally up to the usual four times per year.

PX-02 will help constrain the transport through the Indonesian Throughflow, and should be repeated 18-times per year.

IX22 and PX02 provide the only temperature profiles in the interior Indonesian seas, a region of strong interaction between the thermocline and overlying atmosphere. Until Argo floats can be deployed in this region, IX22 should extend to 7N and continue at 18 times per year.

The panel noted that recommendations of prioritized XBT network should be carefully considered, as national resources and PIs are essential and high density XBT lines need huge funds to maintain. However, it was desirable to add XCDT for salinity measurements whenever/wherever available.

Dr. Thurston informed the panel that the US was keen to support an IO XBT network. Resources had been arranged for recent years, with cooperation with countries such as China and Japan on ship times. A list was summarized by the JCOMM SOT panel at its recent meeting. Dr. Meyers commented that discrepancies between the SOT plan and thoughts of research community ought to be addressed.

#### **Actions for XBT network:**

- Communicate to the JCOMM SOT panel, IOP priorities for XBT lines. Meyers
- Write to the Director of NIO concerning the western Indian Ocean XBT workshop, NIO/Goa, October 2005, advocating scientists' participation in the workshop (with input from Meyers). Thurston
- Summarize the XBT discussions for inclusion in the Implementation Plan. Vecchi
- Noting that not all CLIVAR relevant XBT data are submitted to GPS/JCOMM, Masumoto, W. Yu and Murty to work with their national XBT operators to develop a plan for at least annual submissions of data to JCOMM. Masumoto, W. Yu and Murty
- Write to Dr Peter Taylor (NOC, UK) for information on Southern IO flux measurements, regarding a suggestion to add a XBT line to help improve knowledge of air-sea fluxes over the Southern Ocean. L. Yu

### **3.7. Surface drifters**

At the request of the chairman, a group consisting of R. Molcard, J. McCreary, W. Yu, P. Oke, and M. Jury reviewed the draft of the existing drifter section prior to the IOP-2 meeting. Additional comments were received from P. Niiler (SIO) and R. Lumkin (AOML). Key applications include reduction of the bias error in satellite SST measurements; documentation of large scale surface current patterns and their role in generation of SST anomalies; and validation of surface currents in ocean-models.

Based on data sent by R. Lumkin, the panel noted that the tropical Indian Ocean, particularly north of the equator, is almost not covered and the prospect for any already deployed drifters moving into the area is non-existent. This leaves a huge gap in the integrated observing system because the surface currents of the north Indian Ocean play a crucial role in maintaining the long term heat balance by carrying the upper level of the cross equatorial cell. Coverage of this region needs a re-seeding plan because drifters are pushed out of the region by winds relatively rapidly.

Panel members mentioned a number of additional applications unique to the Indian Ocean: drifters can help to: resolve modeling problems in the Arabian Sea, where current modeling faces difficulty in dealing with

eddies (McCreary); measure small scale upwellings (Schott); get the right wind/current relationship in highly stratified models; etc.

The panel in particular noted that the 5°x5° sampling pattern was established more than 20 years ago for the purpose of calibrating satellite SST measurements. A strategy aimed at monitoring surface currents with drifters has never been determined. This is a gap in observing system design that needs to be reconciled.

The panel strongly supports full implementation of the surface drifter array at least at 5° latitude/longitude spacing for SST-calibration, particularly with regard to the area north of the equator where clouds often interfere with passive measurements and where active re-seeding is required to maintain the array due to strong southward wind drift.

Apparently, the lack of drifter deployments north of the equator may be in part due to difficulty in shipping and importing instruments into India. This difficulty will be discussed with governmental agencies at a workshop to be arranged at NIO in October 2005.

**Action:** To write to IBPIO outlining the need for improved implementation of drifters in the Indian Ocean. Meyers

### **3.8. Data policy**

The panel discussed the CLIVAR Data Policy and agreed that the policy will guide the panel's activities. The panel noted that climate data serve the purpose of operational applications as well as research. For instance, Prof. Webster suggested that IOP should make a statement on real-time accessibility of temperature, salinity and other sustained hydrographic observations for AA monsoon prediction. The panel agreed to encourage this viewpoint, but also recognized that the data are collected by national programs, not CLIVAR per se.

The principle of open and timely sharing of data in the Indian Ocean requires special consideration. The Indian Ocean rim is a region with considerable potential for political instability and conflict. It is also a region where full agreement on the modes of access to exclusive economic zones has not been reached. The political realities have historically had an impact on data sharing. Nevertheless, the threat to countries in the region from natural hazards is recognized now, and this may lead to rapid improvement. The global Argo program and the TAO/TRITON program in the Pacific will serve as examples of data management for development of the Indian Ocean observing system. Countries and research groups participating in Argo and TAO/TRITON have agreed to the open exchange of data. This applies equally to the real-time (GTS and WWW) data stream (over 90% of GTS data are available within 24 hrs) and to delayed mode data. It is recommended that these standards of timeliness and openness set by Argo and TAO/TRITON be applied to all Indian Ocean observations

## **4. Process studies and national or regional research projects**

Participants were asked to briefly report on process studies and national or regional projects that might contribute to the development of a CLIVAR oceanographic activity in the Indian Ocean. Dr. Meyers anticipated that these studies/projects had a scope broader than just for monsoons.

A group of planned and possible oceanographic process studies on the intraseasonal time scale emerged. The panel recognized the opportunity for coordinating and adding value by establishing an exchange of ideas between the investigators. The studies include:

- CIRENE - a project led by Dr. Vialard (LODYC, France) on air-sea interaction in the western Indian Ocean, focused on the SECC thermocline ridge planned for early 2007;
- MISMO - a project led by Dr. Yoneyama (JAMSTEC, Japan) on the onset of convections in the Madden-Julien Oscillation in the eastern Indian Ocean planned for late 2006;
- THORPEX (Indian Ocean) - a suggestion by Prof Webster to develop a process study built on and enhancing the basin-scale observing system and following results from the CIRENE and MISMO projects, probably focussed in the Bay of Bengal but addressing the basin scale intraseasonal time scale;
- ARMEX IIA - a project to observe air-sea interaction over the warm pool in the southern Arabian Sea;



- **INSTANT** - an ongoing (2004-2007) multinational project focussed on Indonesian throughflow and longer time-scales, which never the less provides a unique array of moorings in the Indonesian passages, resolving the intraseasonal time-scale.

Additional details are given below.

**VASCO-CIRENE:** The CIRENE Experiment led by Jérôme Vialard (LODYC, Paris) is aimed at investigating air-sea interaction processes in the western tropical IO at the intra-seasonal timescale. Recent satellite and in situ datasets show large-scale and strong amplitude intraseasonal modulation of the sea surface temperature related to the Madden-Julian Oscillations (MJO) south of the equator (55E-80E, 10S-3S) in boreal winter. The campaign aims at understanding the mechanisms of the SST variability and its influence on the atmospheric evolution, and to understand ocean-atmosphere coupling. During CIRENE, physical oceanographic, air-sea flux and atmospheric measurements will be collected from R/V Atalante following a quasi-lagrangian approach. Special care will be taken in measuring the diurnal cycle (B. Ward's ASIP instrument) since it is believed to play an important role in intraseasonal SST variability. The experiment would include oceanographic observations for 2 or 3 years, using Argo floats (10 Argo floats were deployed in October 2004, and more would be deployed). CIRENE is coordinated with the VASCO experiment, led by J. P. Duvel (LMD, Paris), which would involve the deployment of atmospheric drifting instruments (pressurised balloons and aeroclippers) from the Seychelles.

**MISMO:** The objective is to understand the characteristics of the atmospheric and oceanic variability in the near-equatorial region from 80° to 100°E, during the season of the onset of convection in the MJO. Details with a map are available on CLIVAR's web site

(<http://www.clivar.org/organization/indian/IOOS/IOdata.htm>). The first leg will be deployed from R/V Mirai during October - November 2006, including a stationary observation period at (0, 80E) to observe:

- vertical structure of water vapour, clouds, and divergence field; and
- diurnal cycle of SST and surface flux.

Main measurement systems include:

- Scanning 5.3GHz Doppler radar (1 volume scan = 7.5 min);
- Radiosondes (atmospheric soundings every 3 hours);
- SOAR (Shipboard Oceanographic and Atmospheric Radiation measurement system developed by BNL for downward radiation as well as general surface meteorological parameters);
- Mooring array ATLAS and TRITON;
- Sub-surface ADCP moorings (if possible, tentative deployment at (1.5N,80E), (1.5S,80E), (0,85E), (1.5N,90E), and (1.5S,90E) ).

The experiment will be coordinated with the existing moorings in the region and it will take place within a region that has fair coverage by Argo floats.

**THORPEX** - The panel considered if the present observing system was sufficient for studies such as THORPEX and what suggestions could be made for improvement. Prof. Webster was asked to email panel members and experts to scope their ideas. A short document will be available later.

**ARMEX-Phase IIA:** The project is aimed at collecting time series of temperature, salinity and currents in the upper ocean and surface meteorological observations from a moored surface-buoy during April/May 2005, to address the dynamics and thermodynamics of the warm pool in the SE Arabian Sea. Air-sea interaction in this region is thought to be associated with the onset of monsoon rain in India. While the study is currently in progress, a follow-on to coincide with MISMO and CIRENE is worth considering.

**INSTANT:** As Dr. Molcard reported, INSTANT (International Nusantara STratification ANd Transport) is underway. Details with maps are available on CLIVAR's web site:

(<http://www.clivar.org/organization/indian/IOOS/IOdata.htm>). The first phase of INSTANT deployed current meters, T/C sensors and pressure gauge arrays in the main passages of the ITF starting in September 2003, with the Australian R/V Southern Surveyor, and early 2004 with the Indonesian RV Baruna Jaya VIII. CTD profiles and hull-mounted ADCP surveys were conducted during the cruises. The second phase of INSTANT will begin in June 2005. The arrays will be recovered and redeployed for another 18 months period. The primary objective is to determine the full depth velocity and property structure of the



Throughflow and its associated heat and freshwater flux as well as other long-term characteristics. The arrays will also resolve intraseasonal characteristics of the ITF transport and property flux, permitting a view of the ITF response to, and interaction with, MJO observed by the above experiments.

Routine hydrographic cruises in the Indian Ocean were also reported.

**ORV Sagar Kanya (India)** – Dr. Murty introduced the cruises for servicing of current meter moorings and for hydrographic surveys in the equatorial Indian Ocean in 2005. The deployment of four TAO moorings and one ADCP mooring by the US technicians onboard was highlighted. Regarding the regional experiments in the Indian Ocean organized under the Indian Climate Research Programme (ICRP), Dr. Murty briefed the panel on the recently concluded Bay of Bengal Monsoon Experiment (BOBMEX) and the Arabian Sea Monsoon Experiment (ARMEX-I and II).

**Chinese projects** – As Dr. W. Yu reported, Chinese researchers had paid increasing attention to the Indo-Pacific Warm Pool and been organizing relevant processes studies and in-situ observations. The Chinese Arctic/Antarctic research vessel Xue-Long served as an important platform, via which six Argo floats were deployed in the eastern IO (four were currently active). In 2002/2003, the cruise finished with two high-density XBT sections in the western Pacific and eastern Indian Ocean between 15N and 15S. In 2004/2005, two high-density XBT sections in the eastern tropical IO were carried out. The State Oceanographic Administration (SOA) of China would help US NOAA to deploy three moorings in the tropical Indian Ocean using R/V Ocean-1 during its global survey, approximately in the end of 2005 or early in 2006. In addition, Dr. W. Yu expressed China's willingness to contribute to IOP by:

- maintaining the HD XBT section in the Eastern Indian Ocean and Western Pacific Ocean,
- planning to deploy the mooring off Java through cooperation with Australia and Indonesia,
- providing possible ship time for the implementation of IOOS, and
- maintaining a data-processing center if desired.

The panel discussed possible modifications of the Chinese XBT lines. Dr. W. Yu said that these could be considered in the future planning.

Given all the cruise information and plans discussed at the meeting, the panel felt that it was helpful/necessary to synthesize all into a table/map and to keep it updated. It was suggested that relevant members input (to Drs. Yan/Meyers) necessary information (e.g., ship tracks) to set up a map for years 2005-2007 with a table of additional details (e.g., cruise name, ship name, port/date of departure and at the end, agency, funding situation, PIs, contacts, etc).

**Action:** To proactively collect information and set up a map and a list on CLIVAR's web site summarizing research cruises in the IO during 2005-2007, and keep these updated. The cruise information should cover all cruises that collect CTD or XBT data, including repeat hydrography, process studies, regional surveys and routine cruises (e.g. mooring maintenance). Yan assisted by panel members.

**CLIVAR VACS** – Prof. Reason briefed the panel on Indian Ocean related projects under the auspices of VACS, including SAGRADEX (a proposed regional study for southern Africa), East Africa / Indian Ocean interactions (Fred Semazzi / Laban Ogallo) and Indian Ocean – West African monsoon links. Intraseasonal variations associated with dry-wet spells remained an issue, as farmers and other users would need seasonal forecasts of these rather than seasonal total rainfall. Research had shown that propagation of warm eddies along the Great Horn of Africa (GHA) coast was associated with the evolution of dry & wet spells over the GHA region. Therefore, at the intraseasonal timescale, additional observations particularly over the near coastal regions of GHA would be very useful in clarifying the situation.

To improve model simulation and prediction of African climate, Prof. Reason addressed the need for ocean data (better monitoring of surface fluxes, SST, upper ocean variability) and rainfall and other station observations for model verification (overseas models used in the region should be "customized" to local conditions, e.g., very tight SST, topographic and vegetation gradients that are particularly characteristic over much of southern Africa). He emphasized the impact of both tropical and mid-latitude ocean states on African climate and therefore the need of an observing system that monitors both tropical and mid-latitude southern Indian Ocean areas.

The panel appreciated Prof. Reason's presentation and suggested that he summarize a few items of research issues that need southern IO data.

**Action:** To note that the current draft for the Implementation Plan does not adequately cover research issues relevant to Africa; summarize where southern IO data are particularly needed. C. Reason

## **5. Discussion and agreement on future actions**

The last half-day was spent confirming actions and discussing the future of IOP. Having reviewed quite a full range of IO observing issues, Dr. Meyers suggested leaving further research issues (e.g., those of the Australian project Bluelink) and more application-oriented issues for discussion at the next panel meeting.

It was confirmed that the panel would prepare a BAMS paper summarizing the Implementation Plan of an IO observing system, noting that Julia Slingo was leading another BAMS paper of IO modeling. A special issue of CLIVAR Exchanges was reserved for IOP to cover the implementation issues in more scientific detail.

**Action:** To summarize the advances made so far by IOP into a BAMS paper as soon as possible, while reserving a special issue of CLIVAR Exchanges (June 2006) for more detailed papers. Meyers / McPhaden assisted by other members.

Dr. Meyers mentioned that GSOP was pushing hard to get all hydrographic data (including cruise information) into maps/lists. All panel members/experts were asked to send relevant information to update such maps/lists. It was suggested that IPRC (Hawaii) start with currently available information for the IO to set up a table / maps for 2000 onwards.

For completing the Implementation Plan, Dr. Meyers noted that scientific contents were unbalanced among chapters and should be revised to keep a more consistent structure throughout the document. He anticipated finalizing a version in June. All authors were asked to complete their writings by 15 April, including references etc, expecting no-more-than-4 pages of text plus 2-3 figures for research issues. Most of the sections need to be considerably shortened. By 1<sup>st</sup> May, Dr. Meyers would finalize the implementation sections. With editing help from Drs. McCreary and McPhaden, they will finish the final draft by end May. Mr. Erb suggested that the document should be professionally edited and that his office would cover the charge. A formal version would be available after processing by a professional editor in mid June, and it would be printed shortly after. It should be available for the CLIVAR SSG to review by the middle of 2005.

**Action:** To finalize the Implementation Plan for a sustained Indian Ocean observing system. All authors to submit their shortened write-ups to Gary Meyers by 15 April, expecting a complete version via a professional editor by mid June. Meyers et al.

The panel discussed its role in WCRP/CLIVAR and IOC/IOGOOS. IOP had obvious links to many other groups. For example, Prof. Schott was a member of WCRP/GOOS/GEOS-OOPC. IOP was also well represented for the CLIVAR-OOPC link via GSOP. Some members/experts could directly represent IOP at IOGOOS (Ravichandran), AAMP (Meyers, McCreary and Webster), and VACS (Reason). As described in the Implementation Plan, IOP also addressed scientific problems related to climate change in the past, present global warming / anthropogenic climate changes and impacts, closely related to those of the CLIVAR-CCI ETCCDMI and the CLIVAR-PAGES joint working group. In short, IOP is concerned with the role of Indian Ocean circulation dynamics in a broad range of climate variability and change processes. It also plays a unique role in bridging between CLIVAR's science and IOC's operational activities.

However, the future of IOP was bounded by the CLIVAR SSG decision for IOP to be a sub-panel of AAMP and to have 3 meetings in order to complete the Implementation Plan for a sustained observing system. A consensus view formed during the meeting was that the in-depth discussion of Indian Ocean oceanography as it relates to the climate system, and the coordination and initiation of activities supporting the climate observing system cannot take place anywhere else in CLIVAR at this time. The members felt that IOP should have a longer lifetime (than 3 annual meetings) for a continuous implementation process even if only

for maintaining the observing system, and that it should be a distinct basin-panel, as with the Pacific and Atlantic Oceans.

**Action:** To inform D/ICPO (Howard Cattle) of the discussions at the meeting on the future of IOP (Yan); and to prepare a short document of the panel's consensus view on its future for the CLIVAR SSG and GOOS SC to consider as soon as possible (Meyers).

The panel also discussed the next meeting. It appeared necessary to have the next meeting in less than 12 months because

- the NIO proposal for continuation of equatorial moorings is due in early 2006
- use of R/V's of opportunity to implement new mooring sites in 2006 needs to be arranged
- coordination and enhancement of the process studies is needed in late 2005/early 2006

The time should be therefore around the beginning of 2006. While there were several venues proposed (e.g., in China, Singapore and Japan), a consensus point was at a locality in the IO. Finding a local host would be a key issue.

**Action:** To find a local contact / host for IOP3 (Reunion Island, dates to be determined). Molcard

The panel meeting was closed on 2 April, as a fruitful success in terms of bringing together a wide range of research and operational issues, facilitating in-depth discussions for finalizing the Implementation Plan and resulting in a consensus view on the panel's future. The attendees highly appreciated the CSIRO Marine Laboratories, Hobart and Dr. Meyers for their hosting of this event and looked forward to further collaborations in the near future.

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## **Appendix 2. Meeting agenda**

CLIVAR/GOOS Indian Ocean Panel Second Meeting  
30 March to 2 April 2005  
CSIRO Marine Research, Castray Esplanade, Hobart Australia

### **Day 1 Wednesday 30 March**

0900-0915 Welcome to CSIRO and opening remarks by ICPO and IOC

#### **Indian Ocean Climate Symposium—Auditorium**

0915-1000 Intra-seasonal prediction—Peter Webster  
1000-1045 Mean and variability of air-sea heat fluxes—Lisan Yu  
1045-1115 Morning tea and coffee  
1115-1200 Deep mixing and the surface heat budget—Stuart Godfrey  
1200-1245 West Australian Indian Ocean Climate Initiative—Neville Nicholls  
1245-1415 Lunch  
1415-1500 Ocean circulation variability and its climate relevance—Fritz Schott  
1500-1545 Ocean modeling and its climate relevance—Jay McCreary  
1545-1615 Afternoon tea and coffee

#### **Indian Ocean Panel—Conference Room A/B (members and invited experts)**

1615-1700 Confirmation of the agenda, Chairman's report and discussion of the days talks  
  
1700-1800 Drinks and Nibbles CSIRO Canteen  
1900- Dinner at Ball and Chain, Salamanca Place

### **Day 2 Thursday 31 March**

0900-1030 Observing System Simulation Experiments, Gabe Vecchi, Tony Lee, and Peter Oke (vice Schiller) (~20 min. each), discussion (30 min)  
1030-1100 Morning tea and coffee  
1100-1200 Surface fluxes, Lisan Yu, discussion of flux reference sites (e.g. location, instrumentation); Agree on report to OceanSites Program  
1200-1230 Basin-scale mooring array, discussion leader Peter Hacker w/ Mike McPhaden; Brief reports from Panel on status of ongoing and upcoming deployments  
1230-1400 Lunch  
1400-1530 Mooring array (cont.)  
1530-1600 Afternoon tea and coffee  
1600-1700 Links to the Tsunami Warning System discussion leaders Bill Erb, Neville Smith (mooring array, coordinating ship time, optimizing instrumentation packages for multi purpose environmental warnings, tide gauges, etc.)  
1700-1730 Argo floats, discussion leader Fritz Schott; Brief report on status and future deployments Ravichandran

### **Day 3 Friday 1 April**

0900-1000 Argo floats (cont.)  
1000-1030 XBT network, discussion leader Gabe Vecchi; Brief report on status and review of the JCOMM recommended lines Gary Meyers; W.IO lines Sid Thurston  
1030-1100 Morning tea and coffee  
1100-1130 XBT network (cont.)  
1130-1230 Surface drifters, discussion leader Robert Molcard w/ Gary Meyers  
1230-1400 Lunch  
1400-1530 Process studies and national or regional research projects.

Participants will briefly report on process studies and national or regional projects that might contribute to the development of a CLIVAR oceanographic activity in the Indian Ocean.

Please bring a brief summary (one page max).

Sagar Kanya Murty

Xuelong Weidong Yu

Mirai Kunio Yoneyama

Southern Surveyor Gary Meyers

INSTANT/CIRENE update Robert Molcard

African climate Chris Reason

IOCI Neville Nicholls (reported on Wednesday)

THORPEX Peter Webster (reported on Wednesday?)

BlueLINK Peter Oke

IOTA Gary Meyers

**Additional suggestions** (panel members and invited experts)

1530-1600 Afternoon tea and coffee

1600-1730 Process studies...research projects (cont.)

1900- BBQ CSIRO Marine Lab Terrace

#### **Day 4 Saturday 2 April**

0900-1030 Process studies...research projects (cont.)

Applications of observations and CLIVAR science, discussion leader Peter Webster

XBT Workshop and Monitoring the observing system from JCOMM-HQ discussion leader

Sid Thurston

1030-1100 Morning tea and coffee

1100-1200 Links to other Panels (e.g. GSOP, OOPC), Membership, Next meeting

1200 End of meeting

### **Appendix 3. Terms of reference of IOP**

The need for high-quality ocean observations is shared by research (CLIVAR) and ocean applications and services (GOOS) and there is a shared conviction that, together, the ocean community should endeavour to establish the basis for a comprehensive ocean observation network and oversee the staged implementation of a sustainable ocean observing system for the Indian Ocean. It is therefore agreed that a Panel will be established and supported by CLIVAR and GOOS (through Indian Ocean GOOS and the Perth Office of the IOC) with the following Terms of Reference.

1. 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.
2. 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 modelling 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.
3. 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.
4. Report to the CLIVAR SSG through its AAMP and to GOOS through the IOC Perth Office.



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