Proposal for an Indian Ocean Panel

AAMP5 Action 20: To write a detailed proposal for establishing a joint CLIVAR/IOC (or GOOS?) Indian Ocean Panel, including rationale, functions, structure and possible membership and funding issues, available for discussion at the CLIVAR SSG meeting (May 2003). – Meyers, Webster, Thorncroft

Rationale

The rationale for establishing an Indian Ocean Panel at this time is based, firstly on the large increase in resources available for sustained observations and the need to coordinate implementation; secondly, on a broad range of research-themes that require basin-wide and regional observations; and thirdly, on a need for sustained observations to support operational oceanography and marine products for applications.

Resources identified at the Mauritius Conference and Workshops

The present status, future plans and available resources for sustained observations in the Indian Ocean were reviewed at the First Indian Ocean GOOS Conference in Mauritius in November 2002. The Conference identified substantial progress toward implementation since the Workshop on Sustained Observations of Climate in the Indian Ocean (SOCIO) in November 2000, and a high level of new resources that will be available for observations in the near future.

Briefly summarized, the Conference was held in Mauritius on 1-9 November 2002. 158 participants from 22 nations and 5 intergovernmental agencies attended. The highlight of the conference was signing of the Indian Ocean GOOS Memorandum of Understanding by 19 organizations from 10 countries affirming interest in creating a regional alliance to develop GOOS. The Conference included six overview presentations on the need, scientific rationale and status of Indian Ocean GOOS, as well as Workshops on Ocean Dynamics and Climate, Coastal Ocean Observations, Data Management and Satellite Applications. The Conference Report can be obtained from Intergovernmental Oceanographic Commission Regional Program Office-Perth, PO Box 1370, Perth WA 6872, Australia; or can be viewed at: http://210.212.212.83/iogoos/Indian_Ocean_Conference_Report_Draft.pdf .
Extended abstracts of the presentations can be downloaded from: ftp://ftp.marine.csiro.au/pub/meyers/ .

While the vision of the Indian Ocean observing system involves integration and assimilation of a broad range of satellite and in situ observations, real progress was reported on pilot moorings and Argo floats. Moorings to monitor high frequency (e.g. intraseasonal) upper ocean variability are essential for the Indian Ocean. Japan and India have established six, multiyear, near-equatorial moorings for measurement of upper ocean currents and/or temperature/salinity; and India has planned an ambitious future mooring program for the Bay of Bengal and the Arabian Sea. These are pilot projects that might be sustained by demonstrating the usefulness of the data and by enhancements from other countries. The initial data from the pilot moorings are providing new insights on the role of oceanic processes in the Intraseasonal Oscillation (ISO). The Asian Australian Monsoon Panel identifies the ISO as “the building block of the Monsoons” and interannual variability, and views it as an opportunity to enhance the skill of seasonal climate prediction.

The Argo float program also has progressed in the Indian Ocean, with >70 floats sending temperature/salinity profiles every 10 days at the present time. Resources have been committed to bring the deployment up to 170 in 2003 and 450 in 2005. This will provide full coverage of the north Indian Ocean at the standard Argo sampling density (~1 float in each 300 km square) and substantial coverage in the subtropical and subantarctic zones. Development of the global Argo program will progress under auspices of the International Argo Science Team. However, oceanographers with regional interests will have to design a sampling strategy based on regional uses of the data, which takes account of the fast variability in the Indian Ocean.

The Conference identified a number of future actions to continue development of the observing system. An ad-hoc panel of mooring experts was formed and needs to meet to coordinate and enhance a multinational pilot mooring array. An ad hoc group in Mauritius started Observing System Simulation Experiments using models and pilot mooring data and they will develop guidelines for regional Argo-sampling. An implementation plan agreed by the contributing organizations is needed to guide the effective use of resources coming from several countries.

Research themes

The boundary of the Indian Ocean is unique in comparison to the Atlantic and Pacific, and it sets constraints on basin-wide circulation and heat-transport, giving the Indian Ocean a unique role in variability of the global climate system. Closure in the north by the Asian subcontinent, opening to the Pacific through Indonesia, and a broad connection to the Southern Ocean result in a large, highly variable heat-gain by the tropical Indian Ocean. Surface-fluxes, import of heat by Indonesian Throughflow and three-dimensional, cross-equatorial export to higher latitude control the heat gain in the north.

The resultant Indian Ocean heat pool is highly variable as a consequence of strongly interacting processes with time scales ranging from the intra-seasonal to the multi-decadal. At the seasonal time scale, cross-equatorial heat transport occurs in both the ocean and the atmosphere during the Asian Summer Monsoon. Ekman currents driven by south-easterlies south of the equator and south-westerlies north of the equator shift heat in the ocean-surface layer southward, while northward flow in the thermocline feeds regional upwelling zones that cool the surface in the northern hemisphere. In the atmosphere northward propagating, seasonal to intraseasonal variations carry latent heat northward into the zones of Monsoon rainfall. At the interannual time scale currents, Kelvin Waves and Rossby Waves shift the heat pool eastward and westward, changing the location of the sources of heat to the atmosphere. At the multidecadal time scale the tropical Indian Ocean has warmed. ISO events are thought to play a role in interannual to multidecadal variations.

The spatial scale of Indian Ocean circulation that affects the tropical heat pool spans the width and breadth of the basin from Australia to Africa and from the Asian subcontinent to the Southern Ocean. Within this domain, key large scale processes are:

- **Intraseasonal Oscillation and Madden Julien Oscillation[1]:** a weather-mode known for a long time in the atmosphere, which has a strong impact on seasonal climate in Monsoon regions. The ocean response was recently documented, but the feedback from ocean to atmosphere is still not understood, although it seems to be important in coupled models. The intraseasonal time scale has been observed throughout the Indian Ocean basin at a range of frequencies from 15 days to 60 days.
- **Indian Ocean “Dipole Mode” or “Zonal Mode”[2]:** a coupled ocean-atmosphere mode that develops like a “Bjerknes (1969)” feedback, during years when the seasonal Java-Sumatra upwelling is particularly strong. Oceanic, dynamical processes are clearly involved, but their role in formation of the zonal, basin-wide sea surface temperature pattern has not been adequately observed. The role of intraseasonal events in generating the mode needs study.
- **Multi-decadal warming[3]:** Much of the Indian Ocean surface layer has warmed during the past 30 years, with a strong signal in the tropics. Activity at the intraseasonal time scale has become stronger during the warmer period. Historical oceanographic data is not adequate to track the trend in possibly related, subsurface, ocean dynamical properties. The ocean-atmosphere feedbacks and interactions at different time scales are not known.
- **Shallow cross-equatorial exchange and upwelling[4]:** subtropical/tropical overturning cells associated with upwelling off Somalia, India, Arabia and Sri Lanka during the Asian Summer Monsoon. The overturning cell connects northern hemisphere upwelling to subduction in the southern subtropics. A reverse cell develops during Asian Winter Monsoon with upwelling (or a doming thermocline)

along a broad zonal band in 5-10S. The role of these cells in the generation and maintenance of decadal to multidecadal sea surface temperature patterns is not known.

- **Deep meridional overturning[5]:** circulation in the deep and abyssal ocean below 1000m extending into the tropics. The overturning cell connects subduction and mixing processes in the Southern Ocean to the deep thermocline in the tropics. A change in thermal structure may affect variability with shorter time-scales. While the heat transport of deep overturning is small, the cell is important in the estimation of future global warming because of the uptake of anthropogenic carbon in the deep and abyssal waters. Climate models predict large changes in the southern Indian Ocean in response to global warming.

The above large scale processes are all relevant in one way or another to maintenance, variability and change in the tropical heat pool of the Indian Ocean at a range of time scales. Progress in understanding this system is critically dependent on development of the sustained observing system. In addition to basin-scale processes, regional ocean-processes affect regional SST and, hence, probably affect regional climate.

The Indonesian Throughflow[6] (ITF) is a major choke point in heat transport of the global climate system. It is highly variable at a range of time-scales from intraseasonal to decadal, in response to both local and remote forcing. Its variability is associated with large changes in the depth of the thermocline, mixed layer depth and SST. Located in the midst of the “maritime continent”—the most convectively active region in the world—the ITF is likely to have a profound influence on both local and global climate. The INSTANT (International Nusantrara Stratification and Transport) Experiment is a multinational process study to directly measure the ITF and understand its dynamics. The study will identify proxy-measures of ITF that can be sustained in the long term, and that will eventually become part of the Indian Ocean Observing System.

The Arabian Sea[7] has been a focal point for regional oceanographic studies for decades because of its intrinsic oceanographic interest—strong Monsoon forcing, a strong and variable western boundary current, an upwelling zone with distinctive variability (e.g. the Great Whirl and cold water-wedges), a monsoonal equatorial current system, and circulation at intermediate depths naturally tagged by the Red Sea outlfow. These features were the object of intensive observational studies and advances in dynamical understanding during WOCE. The Arabian Sea is also a region of high evaporation and is a source of latent heat and moisture to the atmosphere. The challenge for CLIVAR is to incorporate the WOCE legacy into ongoing climate research, even if the specific oceanographic phenomena are not known to be part of Monsoons. In contrast to the Arabian Sea the importance of the Bay of Bengal[8] for Monsoon research has been recognized and has been the focus of process studies to understand regional air-sea interaction.

The south-western Indian Ocean[9] is the primary outflow region where export of cooler waters can balance heat intake in the tropics and the mass transport of ITF. The Agulhas Current and southward flow in Mozambique Channel are the western boundary currents. Regional sea surface temperature has a statistical impact on African climate but the mechanisms of temperature variability in this region are not known.

The south-eastern Indian Ocean[10] is unique because of the poleward flowing Leeuwin Current, which is another effect of the open boundary to the Pacific Ocean north of Australia. Heat and freshwater transports have an impact on regional climate in Australia.

The above basin-scale and regional processes are research-themes all relevant to understanding how the Indian Ocean gets rid of its excess heat gain in the tropics through variability with a broad range of time scales. A sustained observing system in the Indian Ocean is needed to address this issue. Further development of the system requires a multinationally coordinated deployment of the resources identified at the Mauritius Conference. A lesson learned in WOCE is that we don’t have enough resources to close the basin-scale heat budget in the face of strong variability and a complex set of basin-scale and regional processes. The challenge for developing the future observing system is to monitor a carefully selected subset of the properties of the Indian Ocean with time series long enough to see the full range of climate variability, and in sufficient detail to know if Indian Ocean models adequately represent the key processes and phenomena that affect the heat budget. Selecting the properties to be measured will be an important task for Indian Ocean oceanographers. An implementation plan agreed by all parties will be required to achieve the measurements.

Operational oceanography

Ocean state estimation is the cross-linking theme that provides integration of the different types of ocean-measurements and products for initial interpretation. Climate prediction models will use the products as an ocean-initial condition. However the application of products has the potential to be much broader. The Global Ocean Data Assimilation Experiment (GODAE) has taken on the challenge of demonstrating the feasibility of operational oceanography and the usefulness of products. Indian Ocean GOOS will play a role in this effort.

Participants at the Mauritius Conference identified a long list of potential applications of GOOS products including coastal erosion and flooding, loss of habitat and biodiversity, nutrient pollution, sustainable fisheries, chemical contamination, invasive species, aquaculture practices, harmful algal blooms and safety of life at sea. Consensus was reached on setting up three working groups to address the highest priority issues:

- Coastal erosion and flooding
- Habitat/biodiversity
- Sustainable fisheries

The Western Indian Ocean Marine Applications Project (WIOMAP) involves nine countries aiming to provide marine and meteorological services, improved marine communication and capacity building, an enhanced observational network and marine applications centres. Intergovernmental coordination is maintained through the WMO/IOC Joint Committee for Oceanography and Marine Meteorology (JCOMM).

Organizations in Australia, UK, France and USA have undertaken the development of ocean modelling and analysis systems as part of GODAE, including nested components for downscaling to address marine applications. Implementation of Indian Ocean GOOS will require coordination with the GODAE community, as well as WIOMAP and the community of product-users who are addressing the priority applications.

Functions

The primary function of the Panel will initially be to coordinate implementation of the Indian Ocean observing system and to monitor management of the data and derived products. The Panel has to recognize that resources for implementation will come from national organizations for their own purpose. The Panel will have access to these organizations and will be in a position to provide an overview and to make recommendations intended to achieve the maximum benefit for all. It will also have access to the climate-research community and will plan an implementation that is consistent with research goals. The Panel's overview of data management and products will assist the people who will use the products for applications. The initial phase of the Panel's work will take two to three years.

The Panel will be an expert sub-panel of AAMP. Two or three AAMP members should be on the Panel. The first meeting will be held in conjunction with AAMP6 and further meetings will be co-located with AAMP meetings at least every other year. This recognizes the importance of some aspects of tropical oceanography for Monsoon research, and it recognizes the current focus of AAMP on seasonal predictability and intraseasonal time scales. By focussing initially on implementation of the observing system, the Panel is taking on a task that AAMP simply does not have time to address now. The Panel will also try to ensure that implementation of the observing system addresses oceanographic issues other than Monsoons, particularly the South Indian Ocean, and longer time scales.

Possible terms of reference for the Panel are:

- Provide advice to organizations that are implementing Indian Ocean observations to coordinate their planning processes
- Develop a mutually agreed implementation plan that serves the purpose of planned Indian Ocean research, and periodically review progress and revise the plan as appropriate
- Promote and review applications of data and products
- Review and identify new areas of Indian Ocean research

Structure

The resources currently available for developing the Indian Ocean observing system come from a mixture of research projects and operational oceanography. The observing system will serve the research purposes of a number of CLIVAR Panels, including AAMP, the Southern Ocean Panel and modeling panels. It will also serve the purpose of a broader range of Indian Ocean research, as well as a variety of applications identified by Indian Ocean GOOS. The structure of parent-bodies for the Panel has to reflect this mixed heritage. We propose that one parent body be CLIVAR. A second parent body for operational oceanography could be IOC (or an affiliate such as GOOS, or Ocean Observation Panel for Climate (OOPC)). Within CLIVAR the Panel will be an expert sub-panel of AAMP.

Membership

The Panel membership should be about 10 to cover all the areas of expertise and the organizations that contribute to the observing system. Possible members and their contributions are:

Indian Ocean countries

Australia
Dr Gary Meyers CSIRO—AAMP, Observing system development
Dr Susan Wijffels CSIRO—Argo contact; INSTANT contact
India
Dr Ehrlich Desa NIO (or delegation to Dr Satish Shetye or Dr VSN Murty)—Eq. moorings
Dr K. Radhakrishnan INCOIS (or delegation to Dr M. Ravichandran)—Argo, NH moorings
Mauritius
Prof Ranadhir Mukhopadhyay MOI—Regional applications
Mr Sachooda Ragoonaden--WIOMAP
South Africa
Prof Johann Lutjeharms U Cape Town—South Indian Ocean oceanography
Prof Mark Jury U Zululand—SH and Eq. moorings, WIOMAP

Indian Ocean interests

Europe
Prof Fritz Schott U Kiel—Indian Ocean oceanography
Prof Robert Molcard LODYC (or delegation to Dr Jerome Vialard)—Equatorial moorings
Japan
Dr Yoshifumi Kuroda JAMSTEC—Equatorial moorings
Prof Toshio Yamagata U Tokyo (or delegation to Dr Yukio Masumoto)—Modelling
USA
Dr Michael McPhaden PMEL—Equatorial moorings
Dr Peter Hacker U Hawaii—Equatorial moorings
Dr Bob Molinari, PMEL—Argo, Indian Ocean oceanography
Prof Jay McCreary, IPRC—AAMP, Modelling
Prof Peter Webster, GIT—AAMP, Monsoons

Funding—Joint funding by CLIVAR and IOC is proposed. Countries with more than one Panel member should provide funding from national sources for at least one member. CLIVAR support for reporting and secretariat is proposed.

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[4] **Ocean circulation:** Schott, F. A and J.P. McCreary (2001) The monsoon circulation of the Indian Ocean. Progr. Oceanogr. 51, 1-123. Schott, F.A., M. Dengler and R. Schoenefeldt (2002) The shallow overturning circulation of the Indian Ocean. Progr. Oceanogr. 53, 57-103. **Upwelling:** Miyama et al. 2002 Deep Sea Res. II (submitted); **Subduction:** Karstensen, J. and D. Quadfasel (2002) Water subducted into the Indian Ocean subtropical gyre. Deep Sea Res. II 49, 1441-1458.

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[6] **Indonesian Throughflow:** Gordon, A.L., R.D. Susanto and A. Field (1999) Throughflow within Makassar Strait. Geophys. Res. Lett. 26, 3325-3328. Wijffels, S. and G. Meyers (2003) An intersection of oceanic wave-guides—variability of Indonesian Throughflow. J. Phys. Oceanogr. (submitted)

[7] **Arabian Sea:** Stramma, L., P. Brandt, F. Schott, D. Quadfasel, J. Fischer (2002) Winter and summer monsoon water mass, heat and freshwater transport changes in the Arabian Sea near 8N. Deep Sea Res. II 49, 1173-1195.

[8] **Bay of Bengal:** See process studies in footnote 1.

[9] **SW Indian Ocean:** Beal, L.M. and H.L. Bryden (1999) The velocity and vorticity structure of the Agulhas Current at 32S. J.Geophys. Res. 104, 5151-5176. De Ruijter, W.P.M., H. Ridderinkhof, J.R.E. Lutjeharms, M.W. Schouten and C. Veth (2002) Direct observations of flow in the Mozambique Channel. Geophys. Res. Lett. 29. .DiMarco, S.F. and Coauthors (2002) Volume transport and property distributions of the Mozambique Channel. Deep Sea Res. II 49, 1481-1511.

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