WCRP REPORT
World Climate Research Programme

Project Report

Report of the 9th Session of the Asian-Australian Monsoon Panel

Beijing, China 22-25th October 2008

December 2010

WCRP Informal/Series Report No. 31/11
ICPO Informal Report 165/11

CLIVAR is a component of the World Climate Research Programme (WCRP). WCRP is sponsored by the World Meterorological Organisation, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO. The scientific planning and development of CLIVAR is under the guidance of the JSC Scientific Steering Group for CLIVAR assisted by the CLIVAR International Project Office. The Joint Scientific Committee (JSC) is the main body of WMO-ICSU-IOC formulating overall WCRP scientific concepts.

Bibliographic Citation
INTERNATIONAL CLIVAR PROJECT OFFICE, 2010:
Asian Australian Monsoon Panel. International CLIVAR
Publication Series No 165. (not peer reviewed).

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1. Executive Summary

The 9th Session of the CLIVAR's Asian-Australian Monsoon Panel (AMMP9) was held at the China Meteorological Administration (CMA), Beijing, China from 22-25 October 2008. AAMP9 was held jointly with the WMO International Workshop on Monsoons IWM4, the Fifth Asian Monsoon Years (AMY) International Workshop and the 2nd Pan-WCRP Workshop (the first such was a 3-day meeting held in Irvine, California in June 2005). This was a unique opportunity to bring together scientists with a CLIVAR focus and scientists/forecasters with a WWRP focus (operational forecasting and application).

The Panel reviewed the current status of monsoon simulation and prediction, and agreed on the need to develop a Climate-System Historical Forecast Project (CHFP) for prediction of hydrologically relevant fields in the monsoon region. H. Hendon will convey the interest of the monsoon community in developing this activity to the WGSIP (which hosts the CHFP) at their meeting in Miami, January 2009. AAMP also reviewed the new developments in Indian Ocean and Western Pacific observing systems, the ocean's role in the A-A monsoon, and developing initiatives of interest to the panel.

Knowing that the initial 2 yr term of the US CLIVAR MJO working group has now expired, the AAMP agrees on the need of encouraging the creation of a new MJO WG, perhaps as a cross-monsoon activity, with a refined focus to include further development of MJO diagnostics/metrics, especially as pertaining to forecast assessment and verification, development of diagnostics suitable for the poleward propagating intraseasonal variability during the Asian summer monsoon, and development of diagnosis that provide physical insight into shortcomings of convective parameterizations of the representation of the MJO.

The panel has also reviewed the objectives and background of the TRIO ("Thermocline Ridge of the Indian Ocean") project and cruise. AAMP considers that this project, in conjunction with the Vasco-Cirene experiment and other projects mentioned in the science plan focussing on the SCTR, are of direct relevance to CLIVAR in the Indian Ocean and the Asian-Australian monsoon system, and agrees to endorse it and to provide assistance to the TRIO PIs, if required, to help develop a science plan for supporting modelling activities.

The AMMP9 was also an opportunity to receive an update of the activities of both the Indian and Pacific Ocean panels. In particular the panel considered the current status of the field experiment CINDY2011 (Cooperative Indian Ocean experiment on ISV in the Year 2011), a project developed to investigate the initiation process of the MJO-convection and relevant atmospheric and oceanic variability in the Indian Ocean. The panel agrees on the relevance of CINDY science plan to the AAM system, and offered assistance with the modelling/prediction plan (case study prediction for field program). The North-western Pacific Ocean Circulation Experiment (NPOCE) and the Southwest Pacific ocean circulation and Climate Experiment (SPICE) have also been updated. The panel recognised that both observational efforts are relevant to the Asian-Australian monsoon research and will establish linkages for future collaborations. The panel asked that the IOP and PP keep them up to date with the development of these programs via the joint panel members (Vecchi/IOP; Bo/PP).

During the joint session with AMY the panel received an update on the status of the just-finished summer field campaigns and plans for ongoing work in the winter monsoon, after which the panel agrees to continue its involvement in the coordination of the AMY modeling activity. The AAMP and AMY will encourage a joint modeling workshop to be held in later 2009.

The AAMP was actively involved in the 2nd Pan-WCRP Workshop, and participated in the discussion on cross cutting activities and in the development of the proposed joint activities. The panel is particularly interested in the possible development of a WCRP/WWRP Project on Simulation and Prediction of Monsoon Intra Seasonal Oscillation (MISO), which would be complimentary to the historical intraseasonal prediction project that panel members have been advocating. The AAMP agreed to help formulate and refine the PanWCRP project as it evolves.

Further information about the meeting and AAMP activities can be found at:
http://www.clivar.org/organization/aamp/9thmeeting.htm

2. AAMP9 Actions/Statements

Developments in A-A monsoon modelling and prediction

- After receiving the WGSIP report prepared by Ben Kirtman the panel proposed Harry Hendon to represent AAMP panel at the next WGSIP meeting in Jan 2009. He will brief the WG on the AAMP activity, advise them on the AMY modelling plan, on the need to develop an ISV prediction project, and the need to assess CHF for prediction of hydrologically relevant fields in the monsoon region

- The panel received information on the development of a VAMOS Modelling Plan. Carlos Ereno will distribute the plan for the panel to consider the usefulness of revising it for needs of AAM.

Developments in ocean observing systems and the ocean's role in the A-A monsoon

- The panel agrees that Gabe Vecchi and H. Hendon convey to IOP for desire to place a mooring on NW shelf for improved understanding and prediction of Australian monsoon.

Developing Initiatives of interest to AAMP

- The panel received a briefing on the Thermocline Ridge of the Indian Ocean (TRIO) project presented by Gabe Vecchi. At the same time the panel received the request from Jérôme Vialard to formally endorse the TRIO project, see Annex C. Carlos Ereno will distribute the information on the project for feedback from panel members and the CLIVAR project office.

- The panel received a briefing on the accomplishments of the original US CLIVAR MJO WG presented by D. Waliser. The initial 2 yr term of the US CLIVAR MJO working group has now expired and it is time to consider formation of a new working group with a refined focus. Looking forward, the AAMP would like to see a new MJO WG formed that has a similar 2 year term, tight focus, and international participation that might possibly sit across WWRP (THORPEX) and WCRP (CLIVAR). From an AAMP perspective, the focus of the new group should include further development of MJO diagnostics/metrics, especially as pertaining to forecast assessment and verification, development of diagnostics suitable for the poleward propagating intraseasonal variability during the Asian summer monsoon, and development of diagnosis that provide physical insight into shortcomings of convective parameterizations of the representation of the MJO. The AAMP is willing to act as the host of the new MJO WG if that is appropriate. However, the AAMP will strongly urge CLIVAR to push this activity as a cross-cutting activity in WWRP/WCRP. More information has been included as Annex D.

AAMP links to the CLIVAR Pacific Panel

- The panel received a report on the CLIVAR Pacific Panel activities, particularly on the Observational Programs Relevant to the Asian-Australian Monsoon Research, presented by Bo Qiu. The panel takes note of the recent process-oriented obs. programs NPOCE and SPICE, and agrees that Bo will report back to PP on the main interest of AAMP, in particular on the possible contribution to the SPICE science plan, from the modelling and monsoon prediction perspective.

AAMP Links to the Indian Ocean Panel

- Kunio Yoneyama reported on the current Status of the proposed field experiment CINDY2011, see abstract in Annex E. The panel agreed to keep AAMP abreast of the CINDY science plan, and can offer assistance with the modelling/prediction plan (case study prediction for field program). The panel proposed Wheeler to attend the Tokyo workshop, and brief on the AAMP activity. AAMP is willing to assist CINDY in any way possible

The role of AAMP in the Asian Monsoon Year

- The panel agrees to get involved in the coordination of the AMY modelling activity.

The role of AAMP in the Pan-WCRP monsoon activity

- Pariticipation in the WCRP/WWRP Project on Reproduction and Prediction of Monsoon Intra Seasonal Oscillation (MISO)?

AAMP contribution to the WCRP Implementation Plan

- Carlos Ereno briefed the request for input to CLIVAR's contribution to development of an Implementation Plan for WCRP, received from the CLIVAR co-chairs. In particular the panel is asked to address the following three questions:

1. What are the imperatives for the panel over the coming years to 2013 and, perhaps, continuing over the next decade? Imperatives are those activities and/or plans that "must" be continued and/or implemented because they are of the highest scientific importance (e.g., they address the most important science issues) with a high likelihood of success.

2. What are the frontiers the panel envisions for the next decade and beyond? Frontiers are new research areas judged to be of great importance, worthy of seeking funding and developing research efforts/programs around, etc.

3. What key developments to enabling infrastructure do you see as necessary to deliver to the above?

Action: Bin Wang will take lead developing priorities for AAM for the next 5 yrs

Membership

- The panel members discussed the 2008 AMP Panel rotation and agreed to propose the following changes:
    - Bin Wang will rotate off as AAM panel co-chair and will continue as a member of the panel for a new period.
    - Ken Sperber will replace Bin Wang as AAM panel co-chair.
    - Andrew Turner is nominated to become AAM panel member replacing Julia Slingo.
    - Akio Kitoh is nominated to become AAM panel member replacing Takehiko Satomura
    - Tianjun Zhou is nominated to become AAM panel member replacing Congbin Fu
    - Dave Lawrence is nominated to become AAM panel member replacing Peter Webster.

- Action: the proposal will be forwarded to the CLIVAR SSG for approval.

Next panel meeting

- The venue and date of the 10th AAM panel meeting was discussed. AAM Panel members agreed that it makes sense to have the next meeting in a 13 month period, which is around November 2009. The 10th panel meeting will be held jointly with an AMY modelling workshop to stimulate interactions that will help to improve monsoon simulation and prediction. The meeting will also address the TRIO/CINDY field program developments, the proposed Pan-WCRP cross cut ISV simulation-prediction activity, and the coordination of AMY modelling activity.

- The venue of the meeting has not been defined yet, but it is expected to have local support and only limited fund from WCRP will be necessary to support the participation of some panel members.

3 Acknowledgements

The Asian-Australian Monsoon Panel would like to express their gratitude to the China Meteorological Administration (CMA) for their excellent support to the local organization of AAMP9. Everyone agreed that the facilities were excellent and appreciated the attention to details by the CMA.

Annex A – List of attendees

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Annex B – Agenda of AAMP9

Wednesday, October 22, 2008, Afternoon and Evening

14.00 Chair's introduction (Wang and Hendon), Introduce panel members/experts
14.10 CLIVAR/WCRP report (Carlos Ereno)

Develop strategy for AAMP contributions to WCRP seasonal and decadal prediction experiments and collaboration with other panels
14.25 WGSIP perspective – Ben Kirtman (Harry Hendon present)
14.45 Air-sea interaction in the Indian Ocean/AAM region – Gab Vecchi
15.00 Report from the IOP specifically related to the development of the observing system and what activity we should try to spin up – Gabe Vecchi
15.15 Report from PP – Bo Qiu
15.30 Discussion on possible joint (WGSIP/IOP/PP) modelling/prediction activity – Hendon lead
15.50 Current status on the proposed field campaign CINDY2011 (Cooperative Indian Ocean experiment on ISV in the Year 2011) – Kunio Yoneyama
16.10 TRIO – Gabe Vecchi
16:25 Discussion of contribution to developing research proposals for a field program in the Eq IO in 2011 (CINDY) and TRIO, from the perspective of improved monsoon prediction and simulation. – Harry Hendon
16.45 *Break*

Direction for monsoon research:
17.00 *What are the most important common issues for improved monsoon simulation, prediction, and future projection?* - Harry Hendon to introduce
17.05 Uncertainty in future monsoon extreme projections including land surface processes – Andy Turner
17.20 Prospectus on monsoon ISO simulation and prediction – Ken Sperber
17.35 MJO Working Group: Status and plans – Duane Waliser
Session continues Friday afternoon
18.00 *Dinner*

Thursday, October 23, 2008, Morning

08.40 Scientific presentations on IWM4 – Convection
10.20 *Break*

10.35 Scientific presentations on IWM4 – Aerosol and Snow
11.30 *Lunch*

12.40 *Bus to IAP*

Thursday, October 23, 2008, Afternoon

Venue move to Institute for Atmospheric Physics with the IAP 80th anniversary commemoration.

13.30 Seasonal forecast, intraseasonal and subseasonal monsoon forecast lectures at the WMO Training workshop.
14.20 *photo*

14.40 Pan-WCRP monsoon session. Welcome AAMP member to participate
Discussions relevant to the two issues:

(1) monsoon and global climate

- ◃ Role of monsoons on global climate (C.R. Mechoso)
- ◃ Role of land surface processes (T.Yasunari)
- ◃ Role of ocean processes (Tim Li)
- ◃ Monsoon change under global warming (A. Kitoh)

(2) cloud/precipitation systems in monsoons

- ◃ Multi-scale interactions from diurnal to intraseasonal time-scales (Duane Waliser, K. Sperber)
- ◃ Status of NICAM for monsoon cloud/precipitation systems (M. Satoh)
- ◃ Status of RCMs in regional monsoon modeling (Y Q Wang)
- ◃ Observational network for cloud/precipitation systems (Yamanaka)

18.00 *IAP Reception*
Bus to Hotels

Friday, October 24, 2008, Morning (10:30-12:00)

08.40 Scientific presentations on IWM4 – Land and Ocean Processes
10.10 *Break*

Joint AAMP-9, AMY-5, and Pan-WCRP IMS Session

10.25 CLIVAR Asian/Australian Monsoon Panel – B.Wang
10.45 CLIVAR VAMOS – H. Berbery
11.05 GEWEX/CEOP Monsoon Study – J. Matsumoto
11.25 GEWEX aerosol/monsoon study – K.M. Lau
11.45 WMP/WGCM monsoon modeling – J. Shukla
12.05 WMO monsoon/tropical climatology – CP Chang
12.25 *Lunch*

Friday, October 24, 2008, Afternoon

Direction for monsoon research, continued:
14.00 *What are the most important common issues for improved monsoon simulation, prediction, and future projection?* - Harry Hendon
14.00 Status and issues of prediction in AAM region – In-Sik Kang
14.15 Austral/Indonesian region: research activities and issues - Holger Meinke
14.30 Discussion of summary report to WCRP on current status/direction of monsoon simulation and prediction including MJO WG advice; – Bin Wang
15.30 *Break*

Joint AAMP-9, AMY-5 Session

15:45 Status/Plans Briefing: Jun Matsumoto

Discussion of development of AMY coordinated modelling tasks including coordinated hindcast experiments for Monsoon intraseasonal prediction and its impact on seasonal forecast. Led by Bin Wang, Harry Hendon, Akio Kitoh, In-Sik Kan, Ken Sperber.
Relationship of AAMP with GEWEX monsoon activities (MAHASRI) – Jun Matsumoto
End the Joint Session
17.45 *Break*

Friday, October 24, 2008, Evening

18.00 What can we do to promote improved uptake of monsoon predictions? (intraseasonal-seasonal-decadal-climate change) – Holger Meinke
18.20 AAMP business: membership, co-chairs, panel functionality, next meeting
18.45 Actions items (Carlos) including summary of AAMP activities in IWM4 – Co-chairs
19.00 *AAMP9 ends*

Saturday, October 25, 2008, Morning

08.30 Pan-WCRP Plenary discussion & future plan - Chairs: G.X.Wu and T.Yasunari
10.30 *Break*

10.40 Plenary discussion & future plan (cont.) - Chairs: G.X.Wu and T.Yasunari
12.10 Close

Annex C

AAMP Endorsement of the TRIO Proposal

November 2008

Prepared by H. Hendon (AAMP co-chair) and C. Ereno (ICPO representative for AAMP), with contribution from Gabriel Vecchi (AAMP and IOP member)

The 5°S-10°S band in the Indian Ocean is a region where several phenomena of significant climatic influence build up. It is a genesis region for tropical cyclones striking inhabited islands of the Indian Ocean and the African coast. It was recently shown that it is one of the regions of the globe where atmospheric intraseasonal variability (e.g. Madden Julian Oscillation, MJO) is associated with the strongest oceanic response. Finally, there is an important interannual variability over this region (e.g. Indian Ocean Dipole, IOD), which has significant implications on the rainfall over India during the following monsoon.

The study of the air-sea processes in this region (e.g. in relation with cyclones and intraseasonal perturbations) and the origin of the interannual variations of the ocean structure are still hindered by a lack of data. The Cirene experiment and the first buoys of the RAMA network (the Indian ocean counterpart of TAO and PIRATA) provided some first quantitative process studies in this region, but many questions remain unanswered.

The TRIO (Thermocline Ridge of the Indian Ocean) project aims at analysing the role of coupled processes in phenomena at different time and space scales (i.e. cyclones, MJO, IOD), on the scale interactions between these processes and on their predictability. TRIO is an integrated project that continues and expands the Vasco-Cirene programme. TRIO will combine modelling, analysis of past observations and a new field experiment. The field experiment is mostly based on a cruise in the 5°S-10°S band and will be coordinated with SWICE (South West Indian Ocean cyclone experiment), with three new satellite programs (Altika, SMOS and Megha-tropiques) and with the development of a mooring Array in the Indian Ocean (the RAMA array). The TRIO cruise and SWICE are scheduled for late 2010 / early 2011. This takes opportunity of the Atalante presence in the western Pacific in late 2010. The TRIO cruise will cover the 5°S-10°S band in the Indian Ocean and the northwestern Australian basin. These two regions have recently been identified as having the strongest surface temperature signals associated with the MJO

In terms of relevance to CLIVAR, The TRIO project will investigate the role of air-sea interactions on the initiation and the evolution of MJO events in a region where the associated intraseasonal SST perturbations are the strongest. A better understanding and simulation of these processes might also improve extended and seasonal forecasts for other phenomenon such as the Australian monsoon or ENSO. The cruise track will also follow WOCE IO2 line at least for part of the way across the Indian Ocean which is good. Also as the authors state in the article that has been accepted for publication in BAMS "The Indian Ocean Panel from the CLIVAR project of the World Research Climate Program has stressed that the “Seychelles-Chagos Thermocline Ridge”-SCTR should be a major emphasis of the Indian Ocean Observing System (CLIVAR IOP - Meyers and Boscolo, 2006)".

Given the temporal and spatial variability of processes in the SCTR region the AAM panel considers that this project is of direct relevance to CLIVAR issues in the Indian Ocean and Asian-Australian monsoon system.

The TRIO field experiment and its contribution to the development of the RAMA array are timely. Indeed, a strong agreement that a future field program should be developed in the Indian Ocean emerged at the Trieste WCRP/THORPEX workshop on tropical convection/MJO.
In view of these facts, the AAMP fully supports the TRIO project.

Annex D

Recent accomplishments of the US CLIVAR MJO Working Group (MJOWG)

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CLIVAR AAMP Meeting, Bejing China, October 2008

In spring 2006, US CLIVAR established the Madden-Julian Oscillation (MJO) Working Group (MJOWG; http://www.usclivar.org/mjo.php). The formation of this roughly 2-year limited lifetime WG was motivated by: 1) the wide range of weather and climate phenomena that the MJO interacts with and influences, 2) the fact that the MJO represents an important, and as yet unexploited, source of predictability at the subseasonal time scale, 3) the considerable shortcomings in our global climate and forecast models in representing the MJO, and 4) the need for coordinating the multiple threads of programmatic and investigator level research on the MJO. MJOWG tasks have involved the development of diagnostics for assessing model performance in both climate simulation and extended-range/subseasonal forecast settings as well as the development of a consistent and coordinated approach to subseasonal, specifically MJO, forecasting. The purpose of this newsletter item is to make the readers aware of these activities. The items below highlight the main activities of this working group.

MJO Simulation Diagnostics

The Madden-Julian Oscillation (MJO) interacts with, and influences, a wide range of weather and climate phenomena (e.g., monsoons, ENSO, tropical storms, mid-latitude weather), and represents an important, and as yet unexploited, source of predictability at the subseasonal time scale. Despite the important role of the MJO in our climate and weather systems, current global circulation models (GCMs) exhibit considerable shortcomings in representing it. These shortcomings have been documented in a number of multi-model comparison studies over the last decade. However, diagnosis of model performance has been challenging, and model progress has been difficult to track, due to the lack of a coherent and standardized set of MJO diagnostics. A chief objective of the US CLIVAR MJO Working Group is the development of diagnostics for objectively evaluating global model simulations of the MJO. Motivation for this activity is reviewed, and the intent and justification for a set of diagnostics is provided, along with specification for their calculation, and illustrations of their application. The diagnostics range from relatively simple analyses of variance and correlation diagnostics, to more sophisticated space-time spectral analyses and computation of empirical orthogonal functions. These diagnostic techniques are used to construct composite life-cycles, to identify associations of MJO activity with the mean state, and to describe interannual variability of the MJO. A link to the diagnostics are posted on the MJOWG web site (or see direct link at: http://climate.snu.ac.kr/mjo_diagnostics/index.htm) and a journal article has been submitted that describes this effort. See US CLIVAR Madden-Julian Oscillation Working Group, 2008: MJO Simulation Diagnostics, *J. Clim.*, Submitted.

Application of MJO Simulation Diagnostics to Climate Models

The ability of 8 climate models to simulate the Madden-Julian Oscillation (MJO) has been examined using recently developed diagnostics for MJO simulation. This study focuses on the boreal wintertime (November-April). The mean state, variance map and equatorial space-time spectra of 850hPa zonal wind and precipitation are compared with observations. Although many of participating model have stronger sub-seasonal variability of precipitation, only one model produces dominant spectral peak in the MJO space-time scale as in observation. It is revealed that the MJO signal from large-scale circulation (850hPa zonal wind) is better than that of latent heating (rainfall) in most of the models. Multivariate empirical orthogonal function (EOF) method is suggested as useful tool to extract model's own MJO-like phenomenon and it is compared with single variable EOF analysis. By compositing on the phase and amplitude of the two leading principal components, the decay time scale of canonical strong MJO events is assessed for different initial phases of the in the MJO life-cycle. The MJO decay (e-folding) time scale depends on initial phase and all models have shorter period (~23-29days) compared to observation (~31days). The important features - surface latent heat flux, boundary layer (925hPa) moisture convergence and vertical structure of moisture - associated with the model's MJO are investigated. Frictional moisture convergence ahead (east) of convection seems to be a mechanism of eastward propagation in most of the models, supporting to current paradigm. Some models are able to reproduce the observed geographical difference in vertical structure of moisture associated with the MJO. Also examined in this effort are the characteristics of the models' precipitation dependence on lower tropospheric relative humidity and fraction of stratiform rainfall, and the implications on the fidelity of the MJO simulation. A journal article is being prepared that describes this effort (contact: kim@climate.snu.ac.kr; Kim et al., 2008: Application of MJO Simulation Diagnostics to Climate Models, *J. Clim.*, In Preparation)

MJO Workshop: New Approaches to Understanding, Simulating, and Forecasting the Madden-Julian Oscillation

Through the sponsorship of US CLIVAR and International CLIVAR, the MJOWG hosted an invitation-only workshop that gathered researchers and forecasters of the Madden-Julian Oscillation to discuss new approaches to understanding, simulating, and forecasting the MJO in the context of weather-climate connections. The workshop was held November 5-7, 2007, in Irvine, CA. The workshop was attended by members of both the MJO research and forecasting communities. Its objectives included: (1) Introducing new diagnostics designed to systematically evaluate model simulations and forecasts of the MJO; (2) Identifying key limits to our understanding of the MJO as well as to the processes that might be crucial for modeling the MJO; and (3) Developing integrative approaches to tackle the problems associated with understanding, simulating, and forecasting the MJO. The workshop was organized into six half-day sessions over three days. The first day emphasized diagnostics and models, and forecast metrics. The second day focused on vertical and multi-scale structures, as well as theory and modeling. The theme of the third day was integrative modeling approaches with sessions on existing and planned efforts, and new initiatives and next steps. Each session included three invited talks, a poster session, and a one-hour discussion. Most of the oral and poster presentations can be found at: http://www.joss.ucar.edu/joss_psg/meetings/Meetings_2007/MJO/index.html, and a meeting summary is in press with the Bulletin of the Meteorological Society (BAMS), with an Early Online Release version available at: http://ams.allenpress.com/archive/1520-0477/preprint/2008/pdf/10.1175_2008BAMS2700.1.pdf.

Operational Forecasting of the MJO

The development and operational implementation of an MJO forecast metric is a key goal of the MJOWG. We have developed a version of the Wheeler & Hendon combined EOF that is being applied operationally, in a coordinated manner, to a number of forecast centers' extended-range forecasts and their ensembles. Participation in this activity, through its development phase, has been from ECMWF, UKMO, CMA, BMRC, and NCEP. We recently received endorsement for this activity from the Working Group on Numerical Experimentation (WGNE), and through collaboration with WGNE, are formally establishing this methodology and inviting wider participation from other international forecast centers. Based on this invitation, JMA and CPTEC have also become participants. At this time, the centers are sending their MJO forecast metric data to CPC/NOAA for uniform, real-time web presentation and potential use and development of a multi-model ensemble prediction of the MJO (contact Jon.Gottschalck@noaa.gov for details). More information on this effort can be found in an article in the next CLIVAR Exchanges (October 2008;

http://www.clivar.org/publications/exchanges/exchanges.php), and a journal article is being prepared for BAMS.

To more formally assess the MJO skill of the operational forecasting effort, we are considering the development of hindcast experiments. These experiments would provide valuable information with respect to MJO predictability from different phases of the MJO life-cycle, as well as the MJO's associated impacts on other weather/climate phenomena. Additionally, it is possible that select MJO hindcast periods could be adopted as benchmark tests for model development by the numerical weather prediction community. Also under consideration is the development of a forecast metric that is more specific to the boreal summer Asian monsoon domain, so as to better capture the northward propagating intraseasonal convective signal that affects India and southeast Asia.

Annex E

The proposed field experiment CINDY2011

Kunio Yoneyama (JAMSTEC)

1. Introduction

The Madden-Julian Oscillation (MJO; Madden and Julian 1994) is the dominant intraseasonal variation in the tropics. It is characterized by eastward propagating disturbances in the atmosphere, with deep atmospheric convection primarily evident over the warm pool region from the central Indian Ocean to the western Pacific Ocean in the boreal winter-spring season. In addition to its important role in regulating the tropical climate, the MJO has a strong impact on higher latitudes through interaction with monsoons (e.g., Yasunari 1979; Hendon and Liebmann 1990), El Niño (e.g., McPhaden 1999), tropical cyclones (e.g., Maloney and Hartmann 2001), and others. The MJO also has substantial impact on weather along the west coast of the U. S. (Bond and Vecchi 2003). Furthermore, because of its prominence, the MJO is often used as a testbed to evaluate the performance of the general circulation models (GCMs) (Slingo et al. 1996; Lin et al. 2006). Therefore, accurate knowledge on the MJO is important not only for understanding the current climate but also for improving weather and climate prediction.

The MJO has been extensively studied over the past three decades from observations, numerical modeling, and theories. Recent progress and current understanding of the MJO are summarized in several articles (e.g., Wang 2005; Zhang 2005). Explaining the initiation process of MJO-convection has been a major concern of MJO studies since its discovery. Although many hypotheses have been proposed (e.g., Hsu et al. 1990; Wang and Li 1994; Hu and Radall 1994; Kemball-Cook and Weare 2001; Sperber 2003), there has been no definitive explanation so far. Insufficient in-situ data in the Indian Ocean makes difficult to address the features and mechanisms of the initiation process.

As a first step to overcome this problem, Japan Agency for Marine-Earth Science and Technology (JAMSTEC) had conducted a field experiment MISMO (Mirai Indian Ocean cruise for the Study of the MJO-convection Onset) in the central equatorial Indian Ocean from October to December 2006 (Yoneyama et al. 2008). As the extensive analyses using MISMO data have progressed, several key questions have been raised and we recognize the necessity of another field experiment in the Indian Ocean as a multi-national effort. Thus, we propose a new field experiment CINDY2011 (Cooperative Indian Ocean experiment on isv in the Year 2011) to collect data for the study of MJO-convection onset as well as intraseasonal atmospheric and oceanic features in the tropical Indian Ocean. In this document, we will briefly mention about the overview of MISMO project and then several key components which should be discussed and determined by the international scientific communities to accomplish CINDY2011.

2. What was MISMO?

MISMO was the first ever field experiment which targeted the MJO-convection in the Indian Ocean. The aim of MISMO was to capture the atmospheric and oceanic features when convection in the MJO was initiated. For this purpose, we constructed an observational network with the R/V Mirai, a moored buoy array, and land-based sites at the Maldives Islands from October to December 2006 (Fig. 1). The Mirai was the major component of this campaign and stayed within the buoy array area centered at 0°, 80.5°E from October 24 through November 25. On board the Mirai, we conducted atmospheric observations using C-band Doppler radar, radiosonde (8 times/day), and surface meteorological measurement systems and oceanic observations using CTD and shipboard ADCP systems. In addition, many researchers from various institutes and universities joined the cruise and conducted their observations including wind profiler, lidar, cloud profiling radar, video-sonde, and so on. Around the Mirai, we deployed two m-TRITON (mini-Triangle Trans Ocean Buoy Network) buoys and four ADCP sub-surface mooring systems for about one month to detect the oceanic response from/to the MJO. Along the 80.5°E line, ATLAS (Autonomous Temperature Line Acquisition System) buoys had already been deployed as a part of RAMA (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction) buoy array (McPhaden et al. 2008) using the Indian oceanographic research vessel Sagar Kanya by National Institute of Oceanography (NIO), India and the U.S. Pacific Marine Environmental Laboratory (PMEL) / National Oceanic and Atmospheric Administration (NOAA). Before arriving at the stationary observation site, we deployed ten Argo-floats along 80°E line whose ascent was set at every day from 500 m depth. Furthermore, we also conducted observations at Maldives Islands with the aid of Maldives Meteorological Office to construct the radiosonde sounding array with the Mirai. Surface meteorological measurement systems and GPS receivers were deployed on Hulhule, Kadhdhoo, and Gan islands, while radiosonde soundings were carried out at Hulhule and Gan islands 6- or 12-hourly during the intensive observation period. We also deployed Doppler radar on the site at Gan under the collaborative work with the Hokkaido University. All information on this field campaign including the details of measurement systems deployed during MISMO is summarized in Yoneyama et al. (2008) and MISMO web site http://www.jamstec.go.jp/iorgc/mismo/), from which the data collected during MISMO have already been available.

3. Key questions raised from MISMO

The intensive observation period of MISMO corresponded to the mature and decaying phases of an Indian Ocean Dipole event (Horii et al. 2008; Masumoto et al. 2008). While convective activity was suppressed from late October to early November, convection started to develop in mid-November, and finally much deep convection developed in the central Indian Ocean in late November. After that, eastward movement of large-scale cloud systems was observed in early December. By applying the wavenumber-frequency filtering to the satellite-based outgoing longwave radiation (OLR) data following the work of Wheeler and Weickmann (2001), we could confirm that cloud systems developed in late November was associated with the MJO, although their signal was weak and dissipated before arriving over the maritime continent region (Fig. 2). Therefore, we can say that MISMO campaign could capture the onset of large-scale cloud system associated with the weak MJO in mid-November 2006. (Note that there might be a controversy whether this event can be regarded as an MJO-convection or not due to its weakness. However, hereafter we refer it as MJO-convection for simplicity.) We also find that large-scale cloud systems drastically developed when the equatorial Rossby wave arrived over the observational area. Thus, it is possible to speculate that the equatorial Rossby wave might play a role for the onset of the MJO-convection, as recently Masunaga et al. (2006) pointed out.

Atmospheric sounding array with the Mirai and two Maldives Islands clearly captured the feature of the MJO-convection onset. Figure 3 depicts the time-height cross section of mass divergence calculated over three sounding sites. It illustrates low-level convergence throughout the IOP and the strongest low-level convergence and upper-level divergence occurs in November 15 - 18, when the drastic development of large-scale cloud system was observed as indicated by vertical arrow with mark “C”. In particular, two significant features can be found. First, the gradual deepening of the strongest convergence layer from early November to mid-November is obvious, suggesting development of convection over the MISMO area as indicated by a dashed line. Second feature is that this gradual deepening was followed by a pair of strong low-level convergence and upper-level divergence as indicated by vertical arrows with marks “A”, “B”, and “C”. Their appearance corresponded to the passage of eastward propagating meso-scale convective systems (not shown).

Currently, the relationship between these eastward propagating cloud systems and large-scale equatorial Kelvin wave has been analyzed (Katsumata et al. 2008 in preparation).

From these analyses, several important questions have been raised.
1) Although gradual moistening in the middle and upper troposphere was observed and it might act as a preconditioning for deep convection developed in late November, it seems that several meso-scale convective systems which appeared with 5 to 7 day periods might play a key role for this moistening. If so, how did such meso-scale systems develop and what was their exact role during the preconditioning period? What is the relationship between the meso-scale and the large-scale convection?

2) Did the equatorial Rossby wave excite the deep large-scale convection in late November? If yes, how did they interact?

3) Although large-scale intraseasonal convective systems developed over the central Indian Ocean and moved eastward during the MISMO IOP, they dissipated just before arriving at the maritime continent region. Instead, after the MISMO IOP, another large-scale system, which developed in late December and was clearly identified as an MJO from the filtered OLR data, reached to the tropical western Pacific Ocean. McPhaden (2008) suggested that warming of the eastern Indian Ocean in the wake of the 2006 IOD event preconditioned the onset of the December MJO-convection. The relationship between the MJO and IOD requires further studies to verify this speculation and for example, whether the IOD prevented convection in the November 2006 from developing into an eastward-propagating.

Questions 1) and 2) indicate the important role of large-scale equatorial waves, whose features are usually captured by satellite data. However, the relationship between meso-scale convective systems observed by in-situ Doppler radar and the large-scale features observed by satellite data should be carefully interpreted, because they do not always show the consistent features. For example, when the *Mirai* cruised eastward in early December 2006, westward propagating cloud system passed over the *Mirai* as shown by satellite-based infrared data (black dot-dashed arrow in the left panel of Fig. 4). However, shipboard Doppler radar observed eastward propagating precipitating system as shown by red dashed arrow. As illustrated in the vertical cross section of precipitating systems (right panels of Fig. 4), this cloud system moved eastward with developing, but this feature could not be obtained from satellite data only. Namely, in-situ observation surely provides important information on the developing cloud systems which are usually hard to be detected by satellite observations. On the other hand, question 3) suggests that large-scale oceanic observation system is also needed to reveal the behavior of the MJO-convection.

4. Observational plan: What will be CINDY2011?

While MISMO has proved that in-situ observations can provide very useful information on the study of MJO-convection, key questions listed in the previous section cannot be solved only from one-time limited field campaign. In addition, key questions suggest that the long-time and large-scale observation network is essential to capture the relationship between meso-scale convective systems and large-scale equatorial waves. Actually, since ship and land-based sites are limited, large-scale features will be studied mainly using satellite data or numerical studies. However, it is possible to construct the observation network which is suitable for the comparison between in-situ data and satellite data so that we can interpret the large-scale features revealed by satellite data using in-situ data by considering the typical scale of large-scale disturbances. Furthermore, since the MISMO was one-month campaign, much longer time-series data is strongly desired. Thus, the aim of CINDY2011 is to collect long enough intraseasonal in-situ atmospheric and oceanic observation data with appropriate spatial observation sites. Therefore, it is impossible to accomplish this campaign by one or a few institutes, and it should be done as a multi-national effort. Currently, many researchers from various countries are discussing the possibility of collaborative work in accomplishing CINDY2011 at several international meetings such as CLIVAR Indian Ocean Panel.

Here, we describe the possible observation facilities. It should be noted that all items listed here are not decided yet in terms of funding and configuration of the network shown in Fig. 5 is just one idea for further discussion.

4.1 Research vessels
a. R/V Mirai

JAMSTEC has a plan to send the *Mirai* to the Indian Ocean to conduct the observation as a part of CINDY. The *Mirai* will have about 50-days ship-time in the Indian Ocean to conduct the stationary observation near 0°, 67°E or 0°, 80.5°E, where RAMA buoys are deployed. The exact location will be decided based on the configuration of other vessels and the status of RAMA buoy array at that time. In any cases, observational site west of Maldives Islands should be deployed, because most of shallow convections developed over the western Indian Ocean (cf. Fig. 2) while well-organized deep convection develop over the central Indian Ocean as observed in MISMO IOP. Since at present it is scheduled that the Mirai will leave Japan in early October, we will conduct the observation in the Indian Ocean from late October to late December, when convection in the MJO often developed over the equator (e.g., Zhang and Dong 2004; Masunaga 2007). During this cruise, various atmospheric measurements using Doppler radar, radiosonde, surface meteorological measurement system, ceilometer, lidar, cloud profiling radar, etc. and oceanic measurements using CTD with water sampler, shipboard ADCP, surface sea water monitoring system etc. will be carried out. Since the diurnal cycle is one of the key components to study the development of cumulus convection (Slingo et al. 2003), radiosonde sounding should be carried out every 3 hours during the IOP. In addition, precise skin-sea surface temperature will be measured by floating thermistor and infrared radiometer.

After the CINDY cruise, another cruise by JAMSTEC biogeochemical researchers will start from Seychelles, which across the Indian Ocean from late December to February (Fig. 6). The purposes of this cruise are to evaluate heat and material transports such as carbon, nutrients, etc. in the Indian Ocean and to detect their long-term changes and basin-scale biogeochemical changes since the 1990s. This cruise is a reoccupation of the hydrographic section called WHP-02 (8°S) and WHP-I10 (110°E), which were previously occupied by a U.S. group in 1995/1996 as a part of World Ocean Circulation Experiment (WOCE). For this, they will measure the physical and biogeochemical properties such as water temperature, salinity, dissolved oxygen, nutrients, total dissolved inorganic carbon, total alkalinity, pH, CFCs, ^{14}C, ^{13}C, and so on.

b. Other possible research vessels

Several research vessels are expected to join the campaign. Below are candidates which are now discussed about their participation in CINDY2011.

India; NIO will have one-month biogeochemical cruise in 2011 using the ORV *Sagar Kanya* and this will be done as a part of CINDY2011. One month stationary observation at appropriate site on the equator is planned. Possibility of atmospheric observations including radiosonde sounding is now discussed. In addition, another cruise for maintaining their deep sea current-meter mooring array along the equator as well as several RAMA buoys along 80°E line is also expected prior to the campaign.

Australia; The science group from the Bureau of Meteorology Research Center (BMRC) and Commonwealth Scientific and Industrial Research Organization (CSIRO) is searching the possibility to join the campaign with their R/V *Southern Surveyor*. It is expected to have 25 days cruise in the eastern equatorial Indian Ocean.

U.S.; Researchers of NOAA, University of Miami, Colorado State University are seeking the possibility of their participation in the campaign using the R/V *Ronald H. Brown* (*RHB*). As the RHB has a C-band Doppler radar and many state-of-the-art measurement systems on-board, it is anticipated to play a key platform of the campaign.

France; A new field experiment TRIO (Thermocline Ridge in the Indian Ocean) is proposed to be taken in January-February 2011 as a follow-up project of Cirene (Vialard et al. 2008). The main target of the TRIO is to observe atmospheric and oceanic features along 8°S related to Seyshelles-Chagos thermocline ridge. During the cruise, continuous sea surface measurement, radiosonde sounding, CTD casting as well as maintenance of RAMA buoys will be carried out. Since the cruise line and measured parameters are very similar with that of *Mirai*'s biogeochemical cruise in January-February 2012, collaborative work including data exchange is being discussed.

4.2 Land-based sites

In order to construct the atmospheric sounding array, sounding stations at several Islands are very important component. Possible candidates for this are Maldives Islands as we did in MISMO campaign (ex. Gan at 0.7°S, 73.2°E, and Hulhule at 4.2°N, 73.5°E). In addition, Islands in the southern hemisphere especially located off-equatorial region in 5°S - 10°S is strongly required. Seychelles and Diego Garcia might be candidates for that. Further investigation is needed. Furthermore, HARIMAU (Hydrometeorological Array for ISV-Monsoon Automonitoring) project funded by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) has been conducted in Indonesia (Yamanaka et al. 2008). Extension of the project period is strongly desired as data can be used not only for the study of local convection developed over the maritime continent but also for the study of modulation of MJO-convection. Currently, data can be obtained from HARIMAU web site at http://www.jamstec.go.jp/iorgc/harimau/.

4.3 Moored buoy array

RAMA buoy array is essential to provide basic and long-term information on the surface ocean conditions. Therefore, contribution to maintain (or newly deploy) the buoys is highly required. The coordination of ship-time for the RAMA buoy array is extensively discussed at the CLIVAR Indian Ocean panel. Currently, PMEL/NOAA and NIO are planning to deploy sub-surface ADCP moorings along 80.5°E line for the process study of oceanic intraseasonal and interannual variations. The *Mirai* cruise may have an opportunity to contribute this activity.

4.4 Satellites

Needless to say, satellite data will provide basic large-scale atmospheric and ocean surface features and they are inevitable factors for the study of MJO-convection and any intraseasonal variation. We expect the following satellite data are available during CINDY2011 campaign; MTSAT and EUMETSAT (brightness temperature), TRMM (precipitation), DMSP-SSM/I (water vapor), QuikSCAT (surface wind), Aqua (3-d temperature and humidity), CloudSat (3-d clouds), CALIPSO (aerosol), AIRS (humidity), and many.

4.5 Numerical studies

In order to interpret the physical processes of observed features, numerical study is essential for that. In particular, recently Miura et al. (2007) could success to simulate the MJO event by using the global cloud resolving model called NICAM (Nonhydrostatic icosahedral atmospheric model; Satoh et al. 2008). NICAM research group has also simulated the event observed during MISMO and they are now analyzing the mechanism. They will also join the scientific unit which discuss about the utility of CINDY data sets. In addition, it is planned that the impact of assimilation of observation data taken during CINDY will be studied (cf. Moteki et al. 2007). Any comments from numerical researchers will enhance the observation plan effectively.

5. Remarks

MISMO workshop will be held at JAMSTEC Yokohama Institute of Environmental Studies on November 25 – 26, 2008. At that time, while the progress of MISMO data analyses will be presented, future observational plan for CINDY2011 based on MISMO results will be discussed. Details on that workshop will be uploaded at MISMO web site at http://www.jamstec.go.jp/iorgc/mismo/.

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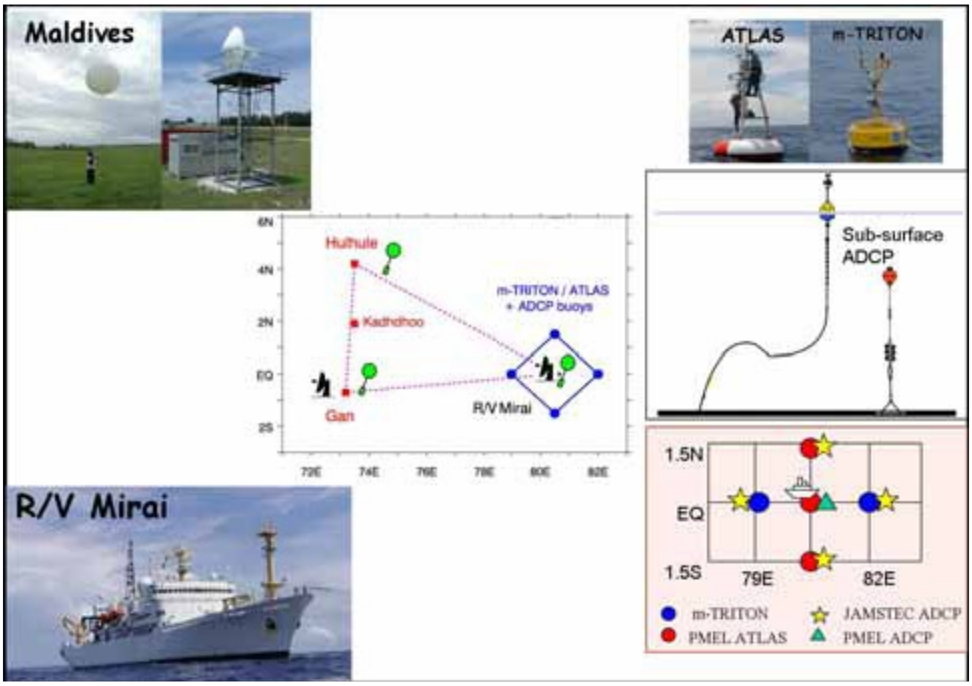

Fig. 1. MISMO observational network.

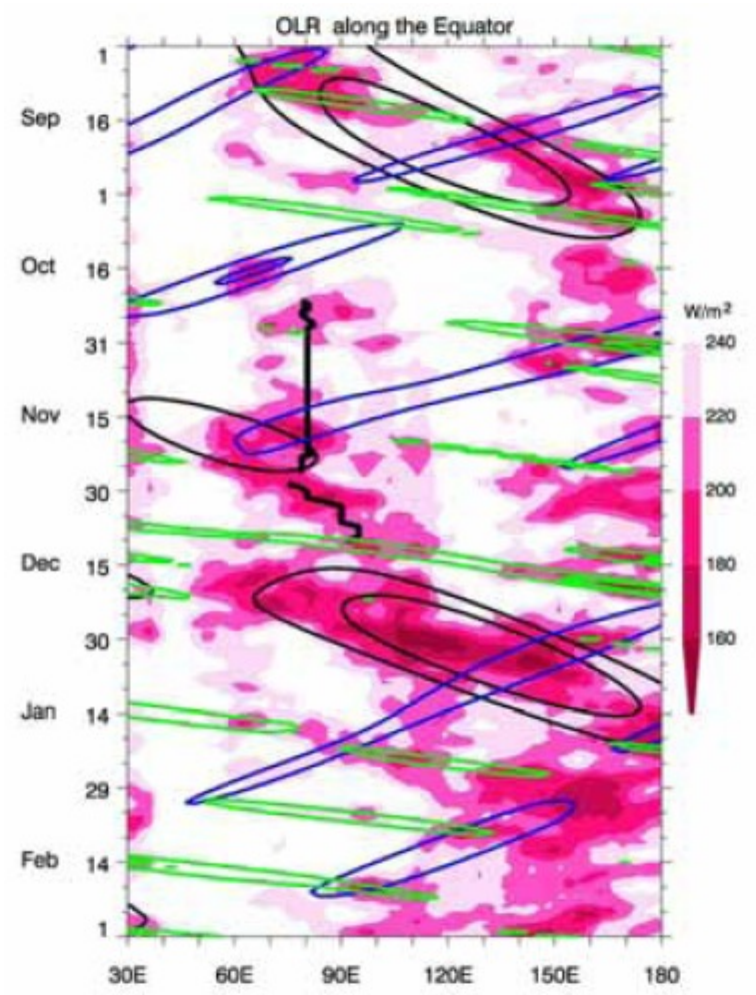

Fig. 2. Time-longitude cross section of OLR along the equator averaged over 7.5°S-7.5°N (shading). Contours are the wavenumber-frequency filtered OLR anomalies indicating the signals identified as MJO (black), Kelvin wave (green), and equatorial Rossby wave (blue). Contours indicate the negative anomalies and contour interval is 7.5 W m^{-2}. The position of the *Mirai* is superimposed as black thick line. From Yoneyama et al. (2008).

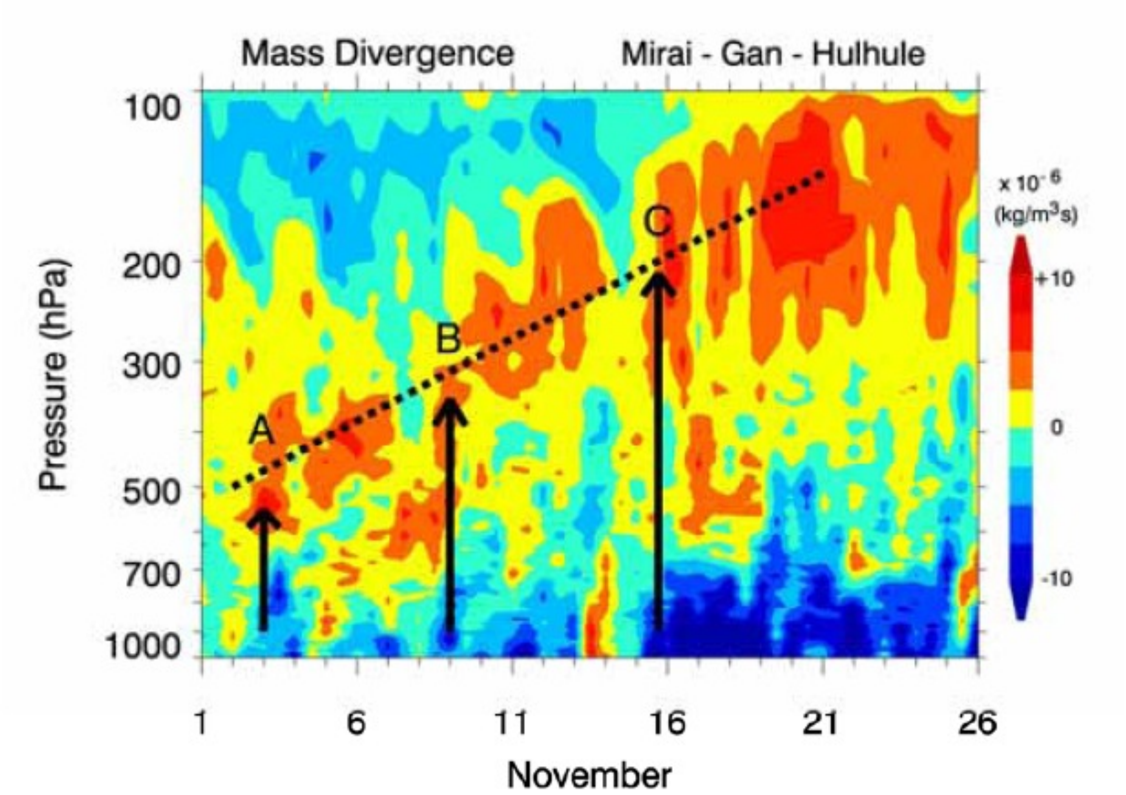

Fig. 3. Time-height cross section of mass divergence calculated over the three sounding sites. From Yoneyama et al. (2008).

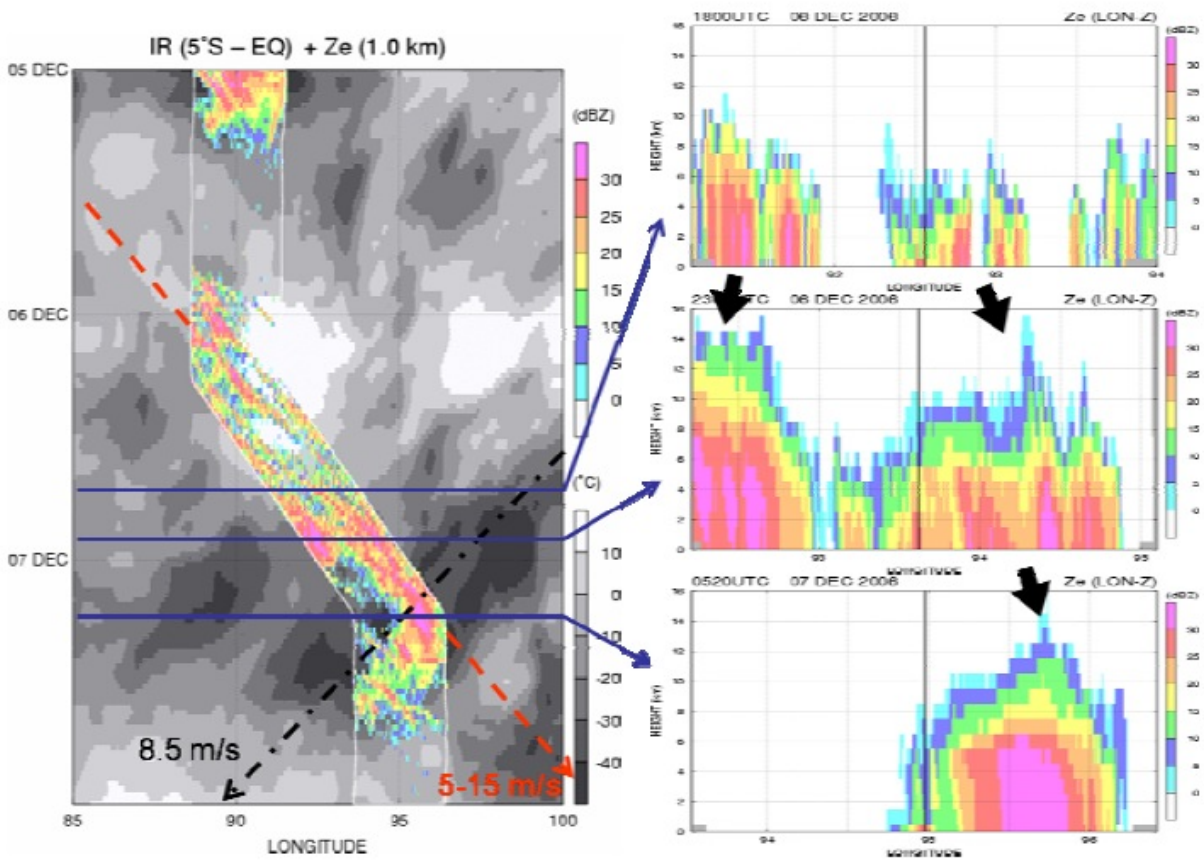

Fig. 4. (left) Time-longitude cross section of IR averaged over 5°S – equator (monochrome) and echo intensity at 1-km height obtained by *Mirai*'s Doppler radar (color). (right) Vertical cross-sections of echo intensity for three different times.

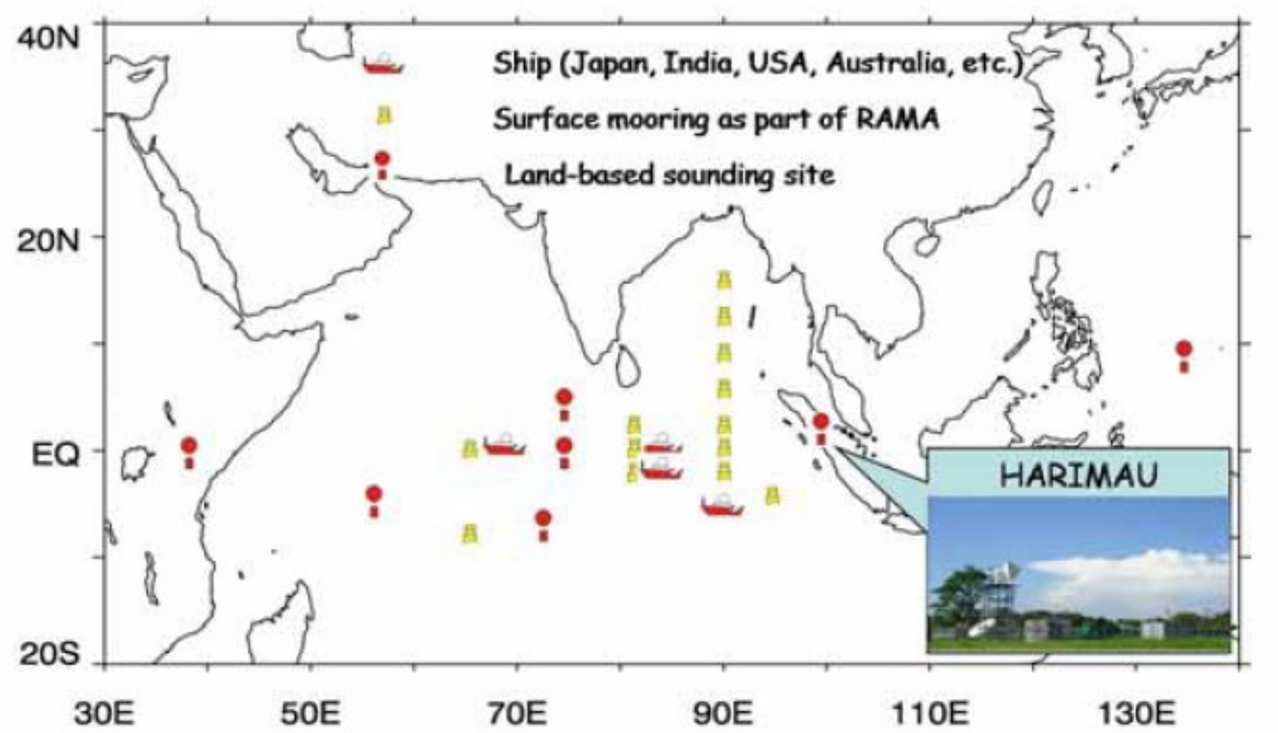

Fig. 5. A proposed observational network for CINDY2011. Observation facilities and their exact location will be determined later.

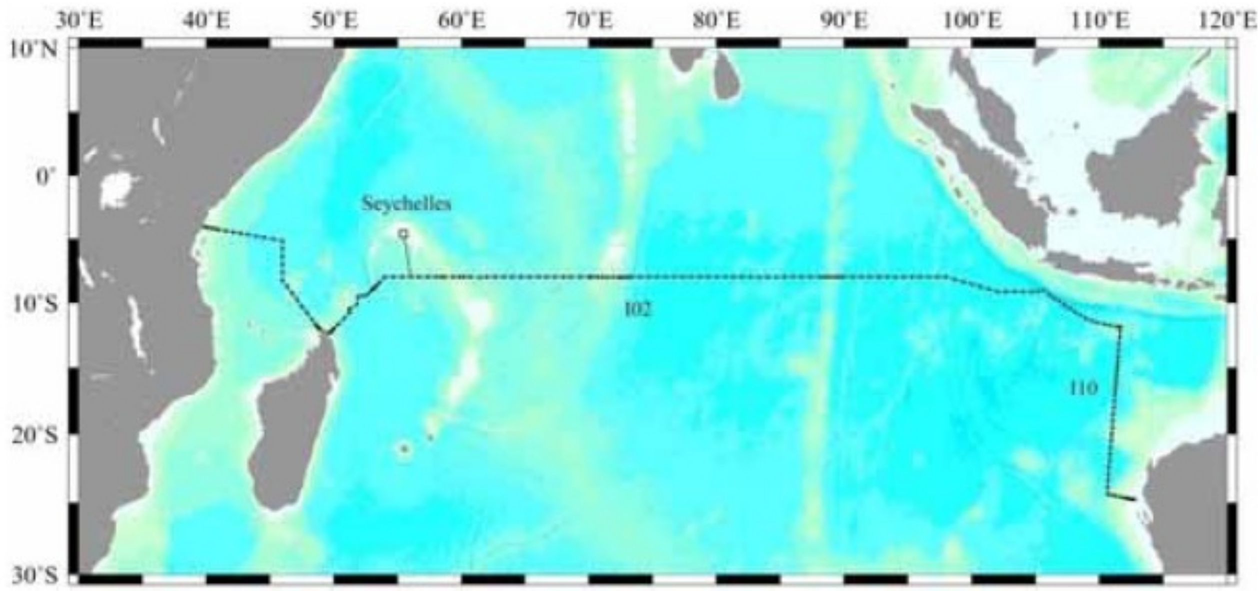

Fig. 6. Planned cruise track of the *Mirai* biogeochemical cruise after CINDY2011 cruise.

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