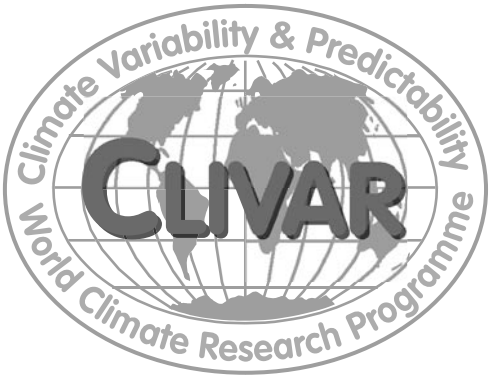
INTERNATIONAL COUNCIL FOR SCIENCE

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

WORLD METEORLOGICAL ORGANIZATION

WORLD CLIMATE RESEARCH PROGRAMME



Report of the Third Session of the CLIVAR Pacific Panel

Honolulu, Hawaii, USA
15-17 February 2006

October 2006

ICPO Publication Series No. 095

WCRP Informal Report No. 18/2006

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, 2006: Report of the Third Session of the CLIVAR Pacific Panel. October International CLIVAR Project Office, CLIVAR Publication Series No. 95 (not peer reviewed).

Contents

Action Items

ACTION: Circulate South Pacific Workshop report to panel members (K. Richards)

ACTION: Follow up South Pacific workshop recommendations and actions and identify leaders for those items (A. Timmerman)

RECOMMENDATION: Use of Jin's index as a standard for CGCM evaluations

RECOMMENDATION: Use of different datasets for initialization or validation of model outputs

ACTION: Initiate a discussion group about indices to assess what has been done and propose new indices (S. Power, A. Clement, A. Timmermann, W. Cai and M. Balmaseda)

ACTION: Initiate a joint effort between WGCM and Pacific panel in defining metrics for good coupled models. Contact WGCM with a list of processes and indices (M. Balmaseda and A. Timmermann)

ACTION: Increase linkages among Indian, Pacific and Asian-Australian Monsoon panels for discussion of common scientific interest (Indian, Pacific and AAM Panel chairs)

ACTION: Initiate a group discussion about error growth vs. predictability in multiplicative noise (M. Balmaseda and Fei-Fei Jin)

ACTION: Define list of possible applications of decadal prediction (B. Crawford, T. Suga and R. Martinez]

ACTION: Circulate SPICE draft science plan to panel and request feedback (A. Ganachaud, W. Cai and B. Qiu)

ACTION: Panel to discuss by email co-sponsorship of VOCALS and write decision to VOCALS chair (A. Timmermann to lead discussion and write decision letter)

ACTION: Provide scientific input to VOCALS group, and keep them informed of Panel activities (A. Timmermann, D. Neelin and ICPO]

ACTION: Support the recommendations of the International Repeat Hydrography Workshop, Shonan Village, Japan, Nov 2005 (http://ioc.unesco.org/ioccp/RepeatHydrog2005.htm) and take it to GSOP (A. Timmermann)

ACTION: Encourage the community to commit the P19 transect at 85W, going through the heart of the Antarctic Intermediate Water, and take this recommendation to GSOP and OOPC (A. Timmermann, T. Suga and D. Wang)

ACTION: Set up a questionnaire directed to experts about ENSO prediction (A. Timmermann to talk to APDRC)

ACTION: Update observing systems section of Panel webpage, with current available data and planned data acquisition (all panel members and ICPO)

ACTION: Provide scientific input from Panel to GLOBEC (A. Clement)

ACTION: Establish links and provide input to CliC/CLIVAR Arctic Panel (B. Crawford)

ACTION: Re-establish links with PICES (B. Crawford)

ACTION: Post KEY SCIENTIFIC questions in the panel webpage (ICPO)

ACTION: Check the possibility of organising the ENSO workshop in Australia and take the proposal to CLIVAR SSG (S. Power, W. Cai and ICPO)

1. Introduction

The CLIVAR Pacific Implementation Panel is one of the regional panels part of the CLIVAR programme, which is regionally oriented by Principal Research Areas (PRA's) within its global framework. The PRA's of specific relevance to the panel are:

G1- ENSO – extending and improving predictions of ENSO by advancing our understanding and observation of climate variability associated with ENSO and related global teleconnections.

D4 – Pacific and Indian Ocean Decadal Variability – improving the description and understanding of the decadal variability and its predictability in the Pacific and Indian Ocean basins (and its relationship with ENSO)

The Panel's Terms of Reference are:

1 To oversee and facilitate the implementation of CLIVAR in the Pacific sector in order to meet the objectives outlined in the Science and Initial Implementation Plans particularly with respect to:

- Expanding and Improving ENSO predictions
- Variability and predictability of the Asian-Australian Monsoon system
- Indo-Pacific Decadal Variability

And also on Pacific impacts on:

- Variability and predictability of the American Monsoon system
- Southern Ocean Climate variability
- Climate change prediction/detection and attribution

2 To develop broadscale atmospheric sampling plans and processes studies to complement the oceanic observations planned for the Pacific and as an integral component of the strategy to improve atmospheric and coupled models. To work with agencies and nations to sustain broadscale atmospheric sampling in the Pacific.

3 To coordinate the activities of the Pacific nations, facilitating cooperative efforts and coordinating work within the boundaries of the various nations as well as outside those boundaries. To provide a forum for exchange and discussion of national plans in the Pacific.

4 To organize and conduct workshops that will entrain oceanographers, atmospheric scientists, and other investigators from the Pacific nations, that will lead to formulation of plans for broadscale sampling and for sampling locations of high interest (such as boundary currents), and will coordinate not only the field activities but also the modeling, empirical, and paleo studies in the Pacific.

5 To collaborate with WCRP JSC/CLIVAR Working Group (WG) on Coupled Modeling, the CLIVAR WG on Seasonal-Interannual Prediction and the WG on Ocean Model Development in order to design appropriate numerical experiments. To be aware of the requirements of these groups for data sets needed to validate models.

6 To liaise with the Ocean Observation Panel for Climate (OOPC), with the Joint Commission for Oceanography and Marine Meteorology (JCOMM), with the Atmospheric Observations Panel for Climate (AOPC), and other relevant groups to ensure that CLIVAR benefits from and contributes to observations in GOOS and GCOS

7 To advise the CLIVAR SSG of progress and obstacles toward successful implementation of CLIVAR in the Pacific.

2. Opening Session

The third meeting of the CLIVAR Pacific Implementation panel was held at the Waioili Tea Room, in Honolulu, Hawaii (USA) on 15-17 February 2006. The meeting agenda can be seen in Appendix A. The panel chair, Axel Timmermann opened the meeting welcoming panel members and guests (Appendix B). Apologies were received from David Neelin and Alexandre Ganachaud. Axel Timmermann expressed his appreciation for the financial support received from WCRP and US CLIVAR, and for the logistical support provided by Jill Reisdorf (UCAR). Nico Caltabiano, ICPO staffer, provided logistical information and local arrangements.

Tony Busalacchi, co-chair of the CLIVAR SSG, gave an overview of the CLIVAR programme and its mission, emphasizing the aspect that CLIVAR needs to bring into focus a transfer of its science to applications. He also highlighted the success of the CLIVAR Conference in 2004 and the major achievements of the programme

to date. Tony Busalacchi charged the Panel to identify the scientific challenges of the role of the Pacific in a coupled climate context with respect to the four CLIVAR science foci, to meet which processes studies, sustained observations, and model improvements all provide necessary inputs. The panel should strengthen collaboration with CLIVAR's Working Group on Seasonal to Interannual Prediction (WGSIP), Working Group on Coupled Modelling (WGCM), Working Group on Ocean Model Development (WGOMD), Global Synthsies and Observations Panel (GSOP), and Expert Team on Climate Change Detection and Indices (ETCCDI) in providing metrics and indices for monitoring, prediction and evaluation of Pacific variability. It also should identify scientific application demands from the Pacific sector through cross-panel interactions with the Indian Ocean Panel, Variability of the American Monsoon Systems (VAMOS) and Asian-Australian Monsoon Panel (AAMP).

Axel Timmermann reviewed the panel membership (Appendix C) and introduced the goals of this meeting. He then highlighted the need for the panel to identify new scientific thrusts, with targeted questions, and work with new ideas. There are clear challenges for the panel in some subjects, and the panel should seek answers/ ideas to enable them to be met. The challenge areas are: mean state, ENSO, multidecadal variability, models and observations, and Axel presented a list of specific scientific questions that should be addressed. Although the panel agreed with the questions, some members felt that the questions should be narrowed down in order to focus the panel. There were some divergences regarding which aspects should be taken in consideration in order to narrow down the questions. It was proposed that the discussion on this matter should be done at the end of the meeting, after the scientific talks had taken place.

3. Session I: Overarching Key Questions

3.1 Pacific climate change: past, present and future

In her presentation Amy Clement summarized the recent efforts to simulate the climate of the last glacial maximum as well as the mid-Holocene optimum using coupled general circulation models as well as intermediate ENSO models. The sensitivity of the zonal equatorial temperature gradient to external forcing is still a matter of large modeling uncertainty. This indicates that the heat budget in the equatorial Pacific is represented differently in different CGCMs and intermediate models. While some of the intermediate ENSO models, such as the Zebiak-Cane model show a pronounced thermocline feedback, other models favor the zonal advective feedbacks. This behavior depends also on the simulated background state, which under present-day conditions is known to exhibit large biases. Amy Clement also reviewed some of the paleo-reconstructions. Apparently these reconstructions are also plagued with large uncertainties – in particular in the eastern equatorial Pacific. Some reconstructions suggest that the eastern equatorial Pacific was almost as warm under glacial maximum conditions as under present-day conditions, whereas other reconstructions show a cooling of up to 4K in the upwelling regions. Reconciling both the paleo-data as well as the modeling uncertainties seems an important challenge and requires a close collaboration between modelers and paleo-proxy experts. Amy Clement also pointed out that large uncertainties exist for the observed SST trends of the 20th century. Not surprisingly the evolution of the east-west temperature gradient in the future greenhouse warming scenarios conducted as part of CMIP-2 and IPCC 4AR is also quite uncertain. The most likely scenario (p=.59) in a model-skill-weighted histogram of CMIP models is for no trend towards either mean El Nino-like or La Nina-like conditions. However, there remains a small probability (p=0.16) to a change to El Nino-like conditions of the order of one standard El Nino per century in the 1%/year CO_2 increase scenario." The Pacific panel proposed to conduct a more in depth analysis of the greenhouse warming simulations with respect to the questions of zonal and meridional gradient changes, changes of the annual cycle and ENSO.

3.2 Review of midlatitude Pacific decadal variability

Bo Qiu went through the current knowledge of the decadal variability in midlatitude regions of the Pacific, and he showed three possible scenarios:

- A climate noise scenario where interannual-to-decadal variability in the midlatitide Pacific simply reflects year-to-year or decade-to-decade changes of the short-term statistics. Also, this scenario portrays the ocean as a passive integrator which does not exert any feedback to the overlying atmosphere;
- A fully-coupled system involving unstable air-sea interaction as shown by Latif and Barnett (1994; 1996); and,
- A weakly coupled system with the ocean providing the memory and enhancing variance in certain frequency bands.

There are disparities in the spatial and temporal scales between the oceanic and atmospheric variability. The latter has, by nature, basin scales, with its spectrum largely "white" on the monthly and longer timescales. The oceanic variability is spatially confined to the western boundary current outflow region (the Kuroshio Extension in the N Pacific) and the spectrum is commonly "red". However, the atmospheric variables that have oceanic "imprints" (e.g., air-sea heat fluxes, storm-tracks), have, in fact, oceanic length scales. The implication of this is that to the extent that, for instance the air-sea flux or stormtrack variability affects the basin-scale atmospheric circulation, the ocean variability must play a role in the midlatitude climate system. And this leads to the challenging questions: how much of the variance in the observed signals is of a coupled nature? And to what extent are they predictable?

The observational data (albeit short in length) supports the presence of a midlatitude air-sea coupled mode in the North Pacific involving the Kuroshio Extension system. Although the variance of this mode is modest, it can have a large impact upon the predictability of the North Pacific climate system. Coupled modes have been detected in CGCMs but there is still a need to improve the Western Boundary Current dynamics in such models.

3.3 Report of the South Pacific Workshop

In October 2005, the University of Concepión, Chile hosted a Workshop on the South Pacific, jointly sponsored by CLIVAR/OOPC/Argo/GOOS/CPPS. Kelvin Richards, chair of the workshop's organizing committee reported the key outcomes of the meeting. The workshop had a very good attendance with 59 participants from 13 different countries, and was structured around four sessions on Climate, Regional Impacts, Prediction and Predictability, and the Observing System. There was also a special session dedicated to the Argo Programme, and the impact it has had on monitoring the South Pacific.

One of the issues discussed relates to the air-sea interaction in the South Pacific, and the need in examining this issue and its importance in underpinning statistical forecast systems. This is an interesting area to pursue, and a possible area where strong collaboration among the Pacific Panel, VAMOS and WGSIP would be necessary. Based on the potential importance of air-sea coupling in the South Pacific to climate variability over South America, it was suggested a series of numerical experiments be conducted that would address the effect of Central South Pacific (CSP) SSTs in driving atmospheric changes over South America.

Argo was discussed at considerable length. It was noted that there are considerable gaps in the South Pacific but those areas are being targeted for future deployments by the US Argo program. Other deployment strategies were discussed and offers were made by representatives of Peru, Chile Ecuador and Colombia to assist with deployments for the completion of the global array. All the other components of the observing system in the South Pacific were reviewed, with some important contributions on the efforts of the Pacific Island GCOS, and on data mining and data management.

It was also noted that the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS), which is presently in the planning stages of its field mission, will certainly provide a better understanding of the southeastern Pacific (SEP) coupled ocean-atmosphere-land system, on diurnal to interannual timescales. However, it was felt that VOCALS is very much focused on the marine boundary layer and clouds, therefore there is a strong need for a more sustained and coordinated effort to improve the monitoring of the eastern boundary current in the Southeastern Pacific. It has been recommended that a small group could lead the task in gathering information on all the existent oceanographic observations along this region, and evaluating if there is a need for any additional sustained program that would enable a long term study of the eastern boundary current's impact on the South American continent.

ACTION: Circulate South Pacific Workshop report to panel members [Kelvin Richards]

ACTION: Follow up South Pacific workshop recommendations and actions and identify leaders for those items [Panel chair]

3.4 Understanding of ENSO

Despite of many years of research many fundamental questions on ENSO dynamics still remain unresolved. Fei-Fei Jin gave an overview presentation on ENSO dynamics and provided some new insights in the characterization of ENSO stability.

It is well known and accepted that ENSO can be characterized as an irregular, seasonally modulated, skewed interannual coupled air-sea mode which originates from the tropical Pacific ocean-atmosphere system with

various global impacts. The present generation of coupled models can predict ENSO with skills at about 6-9 months lead.

Fei-Fei Jin discussed the following items:

a. How stable is ENSO?

ENSO stability has several implications for the amplitude and predictability of ENSO, its sensitivity to climate changes, the mechanisms for phase-locking and the understanding of paleo-ENSO. For years it has been a major challenge to estimate the stability from observations and models. Fei-Fei Jin introduced a new methodology to estimate an ENSO instability from CGCM data as well as from observations. The feasibility of this method was tested using an intermediate ENSO model. The panel recognized the importance of this finding and recommended using the BJ (Bjerknes-Jin) index for extensive future CGCM intercomparison projects. Roberto Mechoso highlighted that the instability of ENSO derives from the instability of basic state. Some CGCMs show that simulations of ENSO are dominated by instabilities like MJO. However, the dominant factor of ENSO stability is the basic state.

b. Coupled modes?

The questions here are: how many coupled modes does ENSO have? And if more than one, which one dominates and under what conditions? Theoretical work by Fei-Fei Jin suggests that at each point in space, ENSO is not just a single mode but rather consists of a combination of two modes: a biennial and a 4-year mode (in addition to the known SST modes). This new perspective may help to explain the diversity of ENSO behaviour in the observed record.

c. How does noise influence ENSO?

Westerly wind bursts (WWBs), regarded often as the noise source for ENSO, are modulated by the SSTs in the central Pacific. This means that WWBs are a state-dependent (multiplicative) noise source for ENSO. This crucially changes the characteristics of ENSO dynamics and predictability substantially. A new paper on this effect has been submitted to GRL and will be distributed widely in the months to come.

RECOMMENDATION: Use of Fei-Fei Jin's index as a standard for CGCM evaluations

Magdalena Balmaseda enquired if it would be possible to use the BJ index for reanalysis products since it would be easier than applying it to observations. The panel agreed that this would certainly be the case and its use should be encouraged.

4. Session 2: Modelling Issues

4.1 Ocean model development

Stephen Griffies, chair of WGOMD, presented new directions for the next-generation of ocean models. Ocean climate models are presently in a middle adolescent stage. Their maturation in the next 10-20 years will come as developers merge some previously disparate efforts (e.g., MITgcm, HIM, and mom4p1) to greatly facilitate scientific interactions and controlled experimental design and analysis. This merger does not imply homogenization of methods, but instead allows for scientific resolution and assessment of various algorithmic and parameterization methods. As much as "new and improved models" remain a key element for the success of climate science, there are unfortunately few who can develop and support cutting-edge community codes for use in both academics and operations. This situation is a result largely of scarce intellectual resources and few funding opportunities.

Physical parameterization research is ongoing to resolve many of the outstanding problems with global climate models. In particular, Ocean Climate Process Teams (CPTs) are an important activity to facilitate these studies and to move advances into the models. As model resolution is refined, it is expected that sensitivities to physical parameterizations become less important, as previously parameterized (or missing) processes are explicitly represented. Conversely, numerical methods become more important as resolution is refined, because more ocean processes are explicitly represented (or partially done so) rather than parameterized.

One specific issue on coupled models is the representation of Tropical Instability Waves (TIWs). They are thought to be important for equatorial heat transport, but unfortunately they are inadequately represented in most IPCC AR4 climate models. This is mainly due to inadequate resolution. Also, many modeling groups are starting to consider ocean biology in climate models. However, the latest AR4 models do not incorporate seasonally varying ocean color. It would be highly desirable if the next generation of models for AR5 will employ

interactive ocean biology and spatio-temporally varying attenuation depth.

One area where WGOMD hopes to contribute to tropical modes of variability is in the CORE (Coordinated Ocean Reference Experiment) experiments. It is nontrivial to perform scientifically controlled comparisons between global ocean-ice simulations run at different climate centers. CORE runs will provide simulated data for analysis by collaborating members of the research community on the performance of ocean models in response to the timescales of tropical variability. The CORE framework is set in three experiments:

- CORE-I experiments provide an opportunity to study the behaviour of ocean simulations under repeating annual cycle run for multiple hundreds of years. The models indeed show large variations depending on the strength of the salinity forcing.
- CORE-II reference experiments provide some opportunity for community analysis of ocean model response to decadal timescale variability in the forcing of the ocean.
- CORE-III freshwater experiment runs (see below) allow investigation of the initial dynamic and thermodynamic response of the ocean-ice system to an imposed freshwater anomaly around Greenland.

Given the present status of coupled climate models (i.e., most are now stable without flux adjustments), it appears that ocean+ice models are more difficult to run stably than fully coupled climate models. The most pressing issue is the salinity/water forcing, in particular the missing feedbacks at the ocean-ice edge, where assuming a fixed atmospheric state can lead to runaway situations that cause either artificial oscillations, or unstable and/or weak Atlantic MOC.

The panel raised the question regarding the evolution of data assimilation schemes. Stephen Griffies said that techniques are being developed but the biases of the forward models are the main problem for the assimilation schemes. He also highlighted that global ocean datasets are needed for ocean model development, either for initialization or validation of the model output. Reliable global heat flux datasets are not available, although urgently needed.

RECOMMENDATION: Use of reference datasets for initialization or validation of model outputs

ACTION: Take recommendations for reference datasets to GSOP

4.2 Coupled Global Models in the Pacific

Akio Kitoh gave a detailed description of the climate projection uncertainties in the Pacific as simulated by the multi-model ensemble of greenhouse warming simulations conducted for the 4AR of IPCC. The presentation showed that many of the state-of-the art coupled general circulation models (CGCMs) exhibit severe biases in the tropical mean state, the annual cycle and ENSO variability. In particular, most coupled GCMs fail to capture the zonal and meridional extent of the anomalies in the eastern Pacific and tend to produce anomalies that extend too far into the western tropical Pacific. Many models also reproduce ENSO variability that occurs on time scales considerably shorter than observed, although there has been some notable progress over the last decade.

AOGCMs used for the IPCC show large uncertainties in simulating the mean annual precipitation in the southeastern Pacific. One of the key systematic biases in the tropical eastern Pacific is the equatorial cold bias, as well as the southeastern tropical Pacific warm bias and the north Pacifc cold bias. Models also fail to adequately capture the zonal temperature gradient. Different hypotheses were discussed for the origin of these biases. While the cold bias might be due to a lack of resolved tropical instability waves in CGCMs or an unrealistic representation of light attenuation in the water column, warm biases in the southeastern Pacific might be due to a under-represented stratus cloud-SST feedbacks, lack of ocean eddies, or problems in simulating the strength of oceanic Tsuchiya jets that upwell near the Peruvian coast. The atmospheric resolution may impact representation of ENSO variability since the atmospheric model has a dominant role on setting ENSO characteristics. When the atmospheric resolution is increased, an improvement of ENSO spectra is observed, with a shift towards lower frequencies.

Model representation of sea surface salinity also presents large biases when compared with observations. The most striking features are the very large positive bias in the Arctic Ocean and in the north Pacific. Model outputs present a fresher Atlantic Ocean, subtropical South Pacific and Indian Ocean.

Akio Kitoh pointed out that climate modelling uncertainties for future climate change projections are still very large and exacerbate regional assessments of future climate change in the Pacific. Models disagree on present-day ENSO magnitude and in a scenario of warmer climate, some models show a likelihood of increased ENSO

amplitude, though there is considerable spread among the models, as previously mentioned. No unequivocal indication of an ENSO frequency change was observed in the latest AR4 simulation. An intense debate started on the question whether all CGCM greenhouse warming simulations shall be treated equally by the IPCC or whether metrics can be introduced which lead to a weighting within the multi-model ensemble of CGCMs. "Metrics" here is referred to as a general measure of compatibility, whereas the notion "index" signifies a physical process based-quantity which allows for a quantitative intercomparison of model data. The panel did not reach any conclusion and further discussion will continue post-meeting. However, it was agreed that some model intercomparison is necessary, and this should be done against some simple ocean and atmosphere indices.

ACTION: Initiate a discussion group about indices to assess what has been done and propose new indices (Power, Clement, Timmermann, Cai, Balmaseda)

ACTION: Initiate a joint effort between WGCM and Pacific panel in defining metrics that would be used to asses global coupled models. Contact WGCM with a list of processes and indices (Balmaseda, Timmermann)

5. Session 3: Indo-pacific Connections

5.1 Asian-Australian monsoon and Indo-Pacific warm pool interaction

The co-chair of the CLIVAR Asian-Australian Monsoon Panel (AAMP), Bin Wang, started his presentation by introducing some recommendations for the Pacific Ocean that AAMP made at its last panel meeting held in Irvine, CA, USA in June 2005. David Neelin attended the meeting representing the Pacific Panel. AAMP identified ENSO-monsoon connections, including decadal variability, and studies of ISOs as key areas for future interaction between AAMP and the CLIVAR Pacific Panel. Also, AAMP encourages assessment of coupled model simulations of the Western North Pacific monsoon, with an initial attack on model systematic errors. This would also be one of the areas for collaboration with the Pacific Panel.

Addressing a broader range of issues of the Asian-Australian Monsoon system requires integration of the diagnostic and modeling efforts in both the Indian Ocean and Western Pacific sectors. Clarifying the interconnections between the monsoon variability in the two regions should be one of the priorities of research coordinated by AAMP. The Western North Pacific (WNP) plays a critical role in driving the Eastern Asia (EA) monsoon as well as the broad scale south Asian monsoon. Enhancement of the activity in the EA-WNP monsoon region facilitates collaboration with the Pacific Panel and the GEWEX efforts in Asia.

The enhancement of the study of the role of WNP will benefit from a more complete understanding of many important A-AM science issues such as the varying ENSO-monsoon relation, the biennial tendency of the A-AM system, the Indonesian through flow, the Indian Ocean zonal mode, and the monsoon intraseasonal oscillations. In the EA-WNP monsoon region, there have been strong interests and a number of ongoing national and international monsoon programs including field experiments and numerical modeling studies. It is critical to connect the key researchers involved in those programs and form an integrated activity. In addition, key science issues need to be better identified in a unified framework of atmosphere-ocean-land interaction in this region. The atmosphere-ocean interaction over the WNP is one of the major sources of the variability and predictability of EA monsoon. In this context, the AAMP's connection to the Pacific Ocean panel should be reinforced.

5.2 Indo-Pacific oceanic connection

The issue of pan-oceanic connection between the Indian and Pacific Oceans was highlighted by Wenju Cai. He showed the two existent pathways for an oceanic connection: the tropical pathway, through the Indonesian Throughflow, and the subtropical pathway through the supergyre circulation in the Southern Ocean.

With regard to the connection through the tropical pathway, some of the ENSO signals in the context of the recharge-oscillator paradigm will be transmitted into the Indian Ocean. Cai showed that those signals will follow a subtropical North Pacific (NP) pathway. They will arrive at the central Western Australian coast after being displaced from the NP along the Kelvin-Munk ray-path proposed by Godfrey, and will move poleward along the northern western Australian (WA) coast as coastally trapped waves, radiating Rossby waves into the south Indian Ocean. In this way, up to 60% of the total interannual variance present in the WA is due to the subtropical NP pathway. Although the ENSO discharge-recharge signal was strong during the 97-98 El-Niño, the subtropical NP pathway signal did not fully develop and it did not arrive at the WA coast. The reason behind

this lack of correlation in 97-98 needs to be further investigated.

The influence of the radiative forcing of aerosols has been estimated by Wenju Cai. Most interestingly, the aerosol forcing can account for 0.6-0.8 K cooling in the central equatorial Pacific whereas the subpolar North Pacific was subject to more than 1K cooling due to direct aerosol forcing. This may have compensated for some of the greenhouse warming signal in the Pacific Ocean and its polar amplification. Recent climate trends over the Southern Hemisphere (SH) summer feature a strengthening of the southern circumpolar winds. Much of the change is attributable to Antarctic ozone depletion. The changes in circulation occur by the advection of warm water southward and a corresponding strengthening of the East Australian Current (EAC) flow passing through the Tasman Sea. The southward shift may be responsible for the observed unusually large warming in the SH midlatitude ocean and may contribute to the reported extension in range to the south of many marine species in the southwest Pacific.

5.3 The sustained Indian Ocean observing system

Gary Meyers, chair of the CLIVAR/GOOS Indian Ocean Panel presented the current status of the implementation of the sustained Indian Ocean observing system (IOOS). The backbone of the IOOS is a basin-scale moorring array, which has an emphasis on the ocean, but will provide surface meteorological data as well. However, the whole observing system has an integrated approach that includes Argo floats, XBT lines and drifters. Alternative observational strategies have been assessed by observing system simulations (OSSEs). Further details can be found on the CLIVAR report "The role of the Indian Ocean in the climate system—implementation plan for sustained observations" (http://eprints.soton.ac.uk/19645/).

Some process studies being planned for the Indian Ocean basin are MISMO (Japan) scheduled to run from October to December 2006, and CIRENE (France), scheduled to happen in January 2007. These process studies aim to address air-sea interaction/mixed layer dynamics, in particular MJO variability, as they are key to understanding and predicting intraseasonal variations. However, they are country led and the region clearly needs a more global study. One of the scientific issues of common interest to both Indian and Pacific panel is the poor prediction skill in the IO and southwest Pacific, and this could be addressed jointly by the panels. Another particular challenge for the panel is the continuity of what has been achieved by INSTANT in the Indonesian Throughflow region. There are several ideas, from proposing extensive arrays in the region to other sustained observations using proxies. The Indian Ocean Panel would welcome comments and suggestions on its plans by the Pacific Panel members.

ACTION: Increase linkages among Indian, Pacific and Asian-Australian Monsoon panels for discussion of common scientific interest [Indian, Pacific and AAM Panel chairs]

6. Session 4: Pacific Seasonal & Decadal Prediction

6.1 Seasonal Prediction

Magdalena Balmaseda showed the current status and future prospects of ENSO forecasting. The most common practice in such forecasting systems is the use of uncoupled initialization of ocean and atmosphere. Atmosphere initialization is not so important for seasonal forecast, and the potential for seasonal prediction is thought to reside in the ocean initial conditions. These are generated by assimilating data into an ocean model forced by atmospheric fluxes. The data assimilated consists of altimeter derived sea level anomalies and in situ observations, mainly from Argo floats, moored buoys and XBTs.

Atmospheric fluxes are still a large source of systematic error in the ocean state, and the data assimilation scheme has large problems in correcting this systematic error. The initialization of seasonal forecasts requires not only a real time ocean analysis, but also a historical ocean reanalysis for forecast calibration. These reanalysis are an important source of information for climate variability. Within the European ENACT Project, a set of multi-reanalysis experiments were conducted for the period 1959-2002, with different models and different assimilation methods. Results show that while the different reanalysis agree in the variability of temperature, the uncertainties for salinity are larger than the interannual variability. Therefore, Argo data, and potentially SMOS surface salinity data, are very important for improving our knowledge of salinity variability.

Operational ENSO prediction with the multi-model approach now produces reliable seasonal forecasts, but it is usually at the expense of large ensemble spread. Increasing the forecast resolution can only be achieved by improving the quality of the individual forecasting systems. Crucial problems common to many forecasting systems are initialization shocks, weak MJO-ENSO interactions and errors in the simulated ENSO statistic. Some of these problems can be alleviated by short-term practical fixes such as flux correction or anomaly

assimilation, but a fundamental long-term solution is still needed. Better coupled models and more balanced ocean-atmosphere initialization procedures are required. Ensemble strategies other than the multi-model, such as stochastic physics, should be explored.

Improving coupled models and their initialization is even more important for a seamless prediction system. For instance, at monthly time scales, the vertical resolution of the mixed layer is very important for predicting MJO. The calibration of model output and the combination of multi-model forecasts is essential for the generation of reliable forecasts products. Bayesean calibration and combination can help in reducing the error and making the spread more consistent.

ACTION: Initiate a group discussion about error growth vs. predictability in multiplicative noise [Balmaseda, Fei-Fei Jin]

6.2 The predictability of interdecadal changes in ENSO teleconnections

Scott Power's presentation focused on the predictability of decadal and interdecadal ENSO teleconnections, and the origin of ENSO-like decadal patterns like the IPO/PDO. He addressed four key questions: (i) Are interdecadal changes in ENSO teleconnections predictable? (ii) Why do decadal "El Nino-like" patterns appear to modulate ENSO teleconnections? (iii) What causes decadal ENSO-like patterns? and (iv) Why are decadal ENSO-like patterns broader than their interannual counterparts?

The predictability of interdecadal changes in the impact that ENSO has on Australia was found to be low in a BMRC CGCM. Scott Power showed that, in theory, the statistical relationship between IPO/PDO variability and the impact of ENSO on Australia can arise without the need for predictability beyond interannual timescales because (a) ENSO statistics can change randomly from decade to decade and (b) the recent discovery that the impact of ENSO on Australia is non-linear: In Australia the magnitude of a La Nina SOI or NINO4 anomaly is strongly related to the magnitude of the Australian rainfall increase, whereas the magnitude of an El Nino SOI or NINO4 anomaly is not. Australian rainfall tends to decrease during El Nino, but the degree of drying is not closely linked to ENSO indices. This means, for example, that the size of the ENSO event measured using traditional ENSO indices is not strongly linked to the size of the average response in a particular location (and this needs to be considered in the provision of climate services). Therefore decades dominated by La Nina years (even if by chance) will tend to be decades in which ENSO's impact on Australia will appear "strong", and for which decadal SST anomalies will be La Nina-like (again by chance). Similarly decades dominated by El Nino years (again, even if by chance) will tend to be decades in which ENSO's impact will appear "weak" and for which decadal SST anomalies will be El Nino-like.

Power also pointed out that while this simple stochastic model has the potential to explain a large part of the observed and modelled inter-relationships between ENSO, ENSO impacts and decadal "modes", it cannot explain robust differences evident between ENSO and decadal ENSO patterns. He showed that ENSO drives variability off the equator that is actually more predictable than ENSO itself. This arises because ocean thermodynamics and dynamics in the region act as a low pass filter on the ENSO forcing. He then showed that the same processes explain why decadal ENSO-like patterns have a broader meridional structure than their interannual counterparts.

He also described additional studies suggesting that a small part of the multi-year/decadal component of ENSO indices might be partially predictable. If this is true then the non-linearity described above provides a mechanism via which modulation of ENSO statistics can occur in a partially predictable fashion.

6.3 Climate and society

Linking scientific achievements and societal needs is not an easy task. This was the main focus of the presentation of Rodney Martinez during the meeting, together with an overview of how climate information percolates down to decision makers, particularly in South America. There is a clear need for the application of scientific excellence and understanding to the existing and emerging problems of concern to society, and it is possible to identify some activities that have been addressing the issue of providing information to society according to its needs. The CIIFEN (Ecuador) and AGRITEMPO (Brazil) online bulletins are example of these activities.

Climate variability uncertainty leads to a gradual mistrust of indigenous or traditional climate knowledge, and users demand more accurate and time-extended predictions. On the other hand, decision makers realize that climate knowledge is advantageous, and governments are increasingly demanding climate information for planning. One example is that in Latin America, there is a steady progress to apply risk management in all development sectors, mainly agriculture, health (impact of disease vectors), water resources, energy, fisheries and

infrastructure. In particular for fisheries management, there is a current need for ocean modeling in SE Pacific that could provide surface and subsurface information to be applied on a regional sustainability perspective.

With this in mind, there are three important steps needed to create climate knowledge:

- To understand climate variability (physical measure of variability);
- To understand production variability (bio-physical measure of climate impact); and,
- To understand vulnerability (eg. income variability, an economic measure of vulnerability)

Rodney Martinez highlighted that there is a strong need to improve climate products to contribute to society, including the level of uncertainty, which will provide the necessary confidence and a realistic vision to the users. One example was the 2002-03 El-Niño forecast which was biased and impacted on the confidence of users in the system. A new strategy is not to mention the phenomena (e.g., El-Niño) but the conditions that it will lead to (e.g., more/less rainfall). Issues that are particularly important to address:

- MJO prediction, which could be paramount for most vulnerable countries at the time when traditional local forecasts not take them in consideration.
- ENSO long term forecasts could be extremely useful, but also could be extremely dangerous if not clearly explained in terms of local impacts.
- PDO understanding could be extremely useful for national planning processes if is adequately explained and translated to decision makers.
- Extreme events forecasts are a current need that must be faced in a lot of places on the Pacific coasts.

The panel discussed how CLIVAR is addressing the processes and its impacts, and how much scientists show the limitations of forecasts. CLIVAR, as a programme, is not explicitly addressing applications of basic research, therefore groups like CIIFEN or IRI are needed to propagate forecast products. It was also clear during the discussion that it is necessary for scientists to state the limitations of forecast systems limitations limitations so policy makers can make use of it accordingly to its significance.

Magdalena Balmaseda enquired what would be the most useful timing for predictions and what would be the choice between a very good 3-month forecast or a not so reliable 12- month forecast. Rodney Martinez felt that based on his experience in South America, it is crucial to have a very good prediction fro the first month and therefore it would be preferable to have a very good 3-month forecast.

ACTION: Define list of possible applications of decadal prediction [Crawford, Suga, Martinez]

7. Session 5: Pacific Processes

7.1 Mode water and eddies

Toshio Suga reviewed several recent studies addressing the role of eddies and mode water in the North Pacific climate variability. It has been estimated that the eddy induced heat transport across the high-resolution XBT transect at an average latitude of 22^{o}N, analyzed together with TOPEX/Poseidon altimetric data amounts to about 0.086 PW (about 15% of the total). It was also estimated that the southward eddy transport of the thermocline water is 3.9Sv. It was suggested that the eddy heat transport is a major contributor to time variability of the northward heat transport and that eddies may cause interannual-to-decadal fluctuation in thermocline water supply to the tropical ocean.

Other studies extended the above analysis to the whole North Pacific by using Argo float data combined with satellite SSH and SST data and showed the large northward eddy heat transport associated with the Kuroshio Extension and the subtropical front. Since it has been proposed that the latter front is caused by the southward spreading Subtropical Mode Water (STMW), the variability in the eddy heat transport is possibly related to the STMW variability.

The decadal variability of STMW was related to the eddy variability, and it has been suggested that the decadal eddy variability controls STMW through changes in preconditioned stratification, that is, the higher eddy variability in the Kuroshio Extension region causes the stronger stratification, reducing the STMW formation. STMW variability may then control the heat content in the recirculation region of the Kuroshio and eventually the air-sea heat flux there.

7.2 Tsuchiya jets and their climate relevance

Jay McCreary gave a presentation on the dynamics and potential climate relevance of the Tsuchiya jets (TJs). TJs can be found on both sides of the equatorial undercurrent system. They also appear to be connected to the subsurface equatorial thermostad waters, which are characterized by temperatures between 10-15C. In a

suite of theoretical studies and modeling experiments Jay McCreary and his group were able to disentangle some of the main dynamical ingredients of TJs. TJs can be interpreted as arrested fronts in a mean flow field. Meridional flow bends the characteristics of Rossby waves and leads to the generation of sharp jets. These jets are sucked up by southeastern tropical Pacific coastal upwelling and the Costa Rica Dome upwelling in the northern tropical Pacific. Ocean models can simulate TJs only in a very low vertical diffusion limit. In general vertical diffusion leads to an erosion of the thermostad waters. Jay McCreary argued that the representation of TJs in CGCMs may play an essential role for the simulation of the temperature of upwelled waters in the eastern tropical Pacific upwelling zones. Not representing TJs, as in most CGCMs, might lead to severe warm biases in the southeastern tropical Pacific. The panel also discussed the importance of TJs for the VOCALS process study.

7.3 CLIVAR Process Studies

7.3.1 SPICE

The Southwest Pacific is a region of complex ocean circulation. Thermocline waters, carried by the broad westward flowing South Equatorial Current, split into strong zonal jets upon encountering the different island archipelagos. Those jets cross the Coral Sea to feed the western boundary current system east of Australia and eventually the East Australian Current and the Equatorial Undercurrent. This circulation, and its influence on remote and regional climate, is poorly understood due to the lack of appropriate measurements.

Lionel Gourdeau gave an overview of SPICE (Southwest PacIfic Circulation and Climate Experiment), a planned process study in the Southwest PacIfic. On 19 -21 August 2005, a kick-off workshop gathered twenty-seven scientists from Australia, France, New Zealand and the United States in Cairns, Australia to review current knowledge and define the open questions concerning the southwest Pacific ocean circulation, its direct and indirect influence on the climate and environment, and to initiate an international research project under the auspices of CLIVAR. The outlines of a feasible, regionally-coordinated experiment to measure, study and monitor the ocean circulation, and to improve and validate numerical models of the region have been drawn. SPICE reflects a strong sense that progress can only be made through collaboration among South Pacific national research groups, and should be fully coordinated with the broader South Pacific projects. The Pacific panel will play an important role in the development of SPICE, by recognising its importance and providing feedback to the project principal investigators.

The Pacific panel discussed some issues that could be addressed by SPICE. It is clear that SPICE, which is focused in the Southwestern Pacific circulation, does not have climate-oriented aims, as other process studies in the region, e.g. KESS and VOCALS. However, some objectives are climate-relevant since some coupled models will be used to map precipitation in the region. Ocean models will certainly be validated by the data collected in the field campaigns. One aspect in particular likely to be addressed by SPICE is the circulation of the Indonesian Throughlfow, and the BlueLink initiative (CSIRO and Bureau of Meteorology, Australia) is planning to do run tests regarding to the observations. Another issue that could be interesting is the systematic atmospheric measurements planned by SPICE, which should be very useful in the analysis of decadal variability in the South Pacific.

ACTION: Circulate SPICE's draft science plan to panel and request feedback [Ganachaud, Cai, Qiu]

7.3.2 PUMP

William Kessler gave an overview of the PUMP (Pacific Upwelling and Mixing Physics) experiment. PUMP is a process study to observe and model the complex of mechanisms that connect the thermocline to the surface in the equatorial Pacific cold tongue. Its premise is that climate-scale ocean models are ready to exploit realistic vertical exchange processes, but need adequate observational guidance. The surface fluxes, upwelling and mixing that determines equatorial SST have previously been measured only in isolation, and the results have not yielded an understanding of the mechanisms of vertical exchange that can be distilled into model parameterizations.

Further, existing observations have not been able to provide a description of the meridional circulation that would let us evaluate the realism of these structures in modern OGCMs, whose development has focused primarily on the equatorial zonal currents. PUMP will observe the transition from the Ekman-geostrophic regime at +/-5 degrees to the equator, and provide a quantitative model and observational diagnosis of the meridional circulation. The proposed surface flux, turbulence and velocity measurements are complementary checks on one another, and will serve as a testable challenge to the models.

7.3.3 VOCALS

The Southeast Pacific Climate system is a region characterized by cold sea surface temperatures originated by the coastal upwelling, and cloud-topped Atmospheric Boundary Layer. This region has strong teleconnections with other climate systems but unfortunately are poorly simulated by ocean-atmosphere GCMs. There are also in this region important links between aerosol and clouds. Roberto Mechoso's talk focused on these issues and what are the scientific issues that VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study) aim to address.

The overall goal of VOCALS is to develop and promote scientific activities leading to improved understanding, model simulations, and predictions of the southeastern Pacific (SEP) coupled ocean-atmosphere-land system, on diurnal to interannual timescales. VOCALS science objectives include:

- Improving the understanding and simulation of aerosol-cloud-drizzle interactions in the marine PBL.
- Improving the understanding and simulating of the ocean budgets of heat, salinity, and nutrients in the SEP.
- Characterizing, determining, and alleviating the systematic biases of atmosphere-ocean GCMs in the SEP.
- Elucidating and understanding interactions between the SEP climate and remote climates.

The VOCALS Program has a regional experiment (VOCALS-REX) component and a modeling component. The former is scheduled to begin in October 2007 but the actual planned field work could be re-designed with input from experts. The scientific strategy for the modeling component uses data gathered in VOCALS-REX to establish eddy and frontal structures and assess model verisimilitude, and then uses the models to establish the eddy heat flux consequences. The aim is to provide the appropriate framework for understanding regional, small-scale processes and heat budgets. There are real issues in models but VOCALS will not do any model intercomparison. VOCALS will have a modelling workshop, and panels should agree in the science approach.

Roberto Mechoso would encourage any comments from the Pacific Panel regarding the scientific issues to be addressed by VOCALS. Also, there is a need for coordination with other modeling programs and field campaigns in the South Eastern Pacific and/or with complementary scientific objectives, e.g. PUMP. Formally, Mechoso requested co-sponsorship from the Pacific Panel, with VAMOS, of VOCALS activities in a WCRP framework. This would also encourage formation of stronger of links with other CLIVAR ocean panels, e.g. Atlantic Panel. Also, VOCALS would appreciate being kept informed of Pacific Panel meetings and workshops

ACTION: Panel to discuss by email co-sponsorship of VOCALS and write decision to VOCALS chair [Timmermann to lead discussion and write decision letter]

The panel discussed some scientific issues that could be used as input to the VOCALS program. One key question is the issue of stratus deck and double ITCZ. It is also not clear if the heat transport by mesoscale eddies in this area is a crucial component of the total heat budget. It is a big challenge in understanding since there are no observations for this. In the CGCMs, the stratus deck created biases since led to warmer SST It seems that some models can simulate the stratus deck a little better but the double ITCZ is still a problem. Part of the reason the models show the double ITCZ is possibly due to the fact that they do not solve the stratus problem well. However this probably is not the whole issue. SSTs are colder but displaced north, so the eddies do not appear to transport the cold water to the equator. Tsuchiya jets and a possible relation with the stratus deck would also be an interesting issue to investigate and explore in modeling and theory. It would be interesting to have moorings capable of measuring pCO_2, which would help in understanding the marine carbon cycle's response to climate variability in this area. Technology is available, and Dick Feely offered to provide more information on that if contacted by VOCALS.

ACTION: Provide scientific input to VOCALS group, and keep them informed of Panel activities [Timmermann, Neelin, ICPO]

8. Session 6: Pacific Observational Systems

8.1 Anthropogenic carbon dioxide

Richard Feely gave an overview of the CLIVAR/CO_2 Repeat Hydrography Program, focusing on the Pacific basin, and showed the latest preliminary results on the decadal changes of CO_2 concentration in the oceans.

The CLIVAR/CO_2 Repeat Hydrography Program aims to conduct ongoing observations in which ocean sections spanning the global ocean are reoccupied every 10 years. The program is very important since it is necessary to understand the temporal and spatial changes of the global ocean carbon system and the feedbacks to the climate system. The main objectives of the program are:

- Data for Model Calibration and Validation
- Carbon system studies
- Heat and freshwater storage and flux studies
- Deep and shallow water mass and ventilation studies
- Calibration of autonomous sensors

To date, the program has completed one half of the decadal survey, and the completed cruises have met 100% of their objectives. Some of the data have been submitted to data centers, making it possible to have some very exciting preliminary results. Air-sea exchange, ventilation, and circulation processes are the primary control of the Dissolved Inorganic Carbon increases in the surface and intermediate waters of the Atlantic and Pacific Oceans. They also suggest that North Atlantic accumulation rate over the last decade may have been about half of the North Pacific accumulation rate. However, continued support for funding and ship-time is needed in order to complete the first global decadal survey by 2012 as planned. There is a strong need to continue to foster collaborations with national and international partners to coordinate the modeling and synthesize of these results with the growing international data set.

The CLIVAR/CO_2 Repeat Hydrography Program and the Argo Program have been collaborating with each other. The hydrographic survey measurements are key for Argo sensor calibration and the Argo Program is looking into the possibilities to recommend the addition of oxygen sensors as part of the standard float suite. Adding oxygen to the global Argo database will make these data much more relevant for biogeochemical studies.

The technology is ready and being implemented by a handful of investigators, but needs large-scale implementation to be most effective.

ACTION: Support the recommendations of the International Repeat Hydrography Workshop, Shonan Village, Japan, Nov 2005 (http://ioc.unesco.org/ioccp/RepeatHydrog2005.htm) and take it to GSOP [Timmermann]

Nico Caltabiano reminded the panel that one of the recommendations from the South Pacific Workshop was that the P19 transect at 85W has not been commited by any country for repeat. Given the importance of the area as likely sources of the Antarctic Intermediate Water, it should be considered high priority, and the Pacific Panel agreed to endorse the recommendation and take it to GSOP and OOPC.

ACTION: Encourage the community to commit the P19 transect at 85W, going through the heart of the Antarctic Intermediate Water, and take this recommendation to GSOP and OOPC [Timmermann, Suga, D. Wang]

8.2 Observational programs in the Northeast Pacific

Satellite as well as hydrographic data have shed some light on the complex interactions between flow fields and temperature anomalies in the North Pacific as highlighted by Bill Crawford's presentation. In the Northern Gulf of Alaska, many features (now labelled Haida and Sitka Eddies) determine chlorophyll distribution in the region. It has been determined that Haida Eddies carry seaward between 35% and 60% of the winter supply of heat to the continental shelf from the south. Sitka Eddies likely carry a similar amount. These eddies remove heat from the shelf, cooling Alaska in winter. These eddies account for most of chlorophyll seaward of the 500 m contour in the northern gulf, as seen from space by SeaWiFS.

The seasonal variation in phytoplankton concentration shows that there is a drop in July with a following increase in September and October. The mentioned eddies can impact many of the phytoplankton distribution patterns in October. The region north of 40N and east of 160W seems to have no impact on global or even Pacific-wide atmosphere or ocean variability. It is a relatively simple system, but very vulnerable to ENSO teleconnections and Pacific Decadal Variability. An example is that coastal eddies generally start near the eastern shore in winter and drift westward. Eddies formed during the major El Niño winter of 1997/98 drifted instead to the south, with impact on the phytoplankton distribution.

This regional sea has experienced extreme variability in temperature and salinity, which in turn seemed to have affected the western Canadian marine biota. Details of those impacts in 2005 can be seen at the "Ocean Status Reports", prepared by the Pacific Scientific Advice Review Committee – PSARC (http://www.pac.dfompo.

gc.ca/sci/psarc/OSRs/Ocean_SSR_e.htm). Some of the latest impacts show a surprisingly consistent response across a wide range of species:

- Cold species in decline along continental shelf, e.g. herring and salmon
- Warm species are appearing in greater numbers: hake, sardine, Humboldt Squid
- Hake not gaining weight and fewer Humpback whales appearing.

8.3 Update on TAO Transition and related activities

Michael McPhaden gave an overview of the present conditions at the tropical Pacific, as well as an update on the transfer of responsibility of the TAO (and PIRATA) arrays from PMEL to the National Data Buoy Center (NDBC). The state (at the time of the workshop in Feb. 2006) of the tropical Pacific was officially recognised as La Niña. However, the event was not well predicted in November 2005 by any of the model forecasts used for ENSO prediction. There was a large scatter in forecasts, with NINO3.4 SST anomaly ranging from -0.7oC to 1oC. Similarly, the current forecast made in February 2006 also shows a larger scatter of the NINO3.4 SST anomaly ranging from -1.4°C to 1.3°C. This clearly emphasizes the need for better forecasting models.

The TAO transition to NBDC will take place over the period of three years (2005-2007), and aims to make operations more cost effective and ensure continuity of the data streams. As of 1 Jan 2006, NDBC maintains the official TAO web site for data display and distribution, and from beginning of 2007, NDBC will be responsible for all fieldwork. There has been no break in continuity of the data stream and the process so far has been transparent to TAO data users.

The TAO array has been funded to expand its activities to the Indian Ocean. Other activities covered by the funding are:

- Addition of salinity sensors to the TAO array to improve seasonal-interannual forecasting.
- Upgrades for 4 TAO and 3 PIRATA moorings to ocean reference station quality.
- Provide 4 additional buoys for the PIRATA array in the hurricane-genesis region of the Atlantic Ocean for improved understanding of ocean-atmosphere interactions on hurricane development.
- Support the technological development of the next generation of moored buoys

The panel discussed how the problems of ENSO prediction, which could be seen by earlier presentations in the meeting. Rodney Martinez emphasized how critical it is for several countries to get a good prediction. In some places, based on knowledge accumulated along the years, farmers can give a very good prediction of the impact ENSO will have on the country, e.g., more or less precipitation. Based on this experience, the panel suggested that a questionnaire directed to experts should be done, and see how good ENSO prediction would be based only on experts opinion.

ACTION: Set up a questionnaire directed to experts about ENSO prediction [Timmermann to talk to APDRC]

8.4 Observational techniques for the ocean

An overview of the current observations made in the Pacific basin, with a focus on the South China Sea measurement, was given by Dongxiao Wang. The presentation also showed some of the latest technology available for ocean measurements. Between 1984 and 2004, Chinese oceanographic institutions have conducted 22 cruises in the southern South China, and the datasets indicate that the upper 1000m layer in the region has become cooler and saltier. Dongxiao also reviewed the NOAA observation network in the Pacific, as well as the current status of the Argo and Global Drifter Program, hydrographic transects, moored current observations and VOS lines. The usefulness of satellite altimetry was also highlighted, in particular for mapping mesoscale eddies.

On the latest technologies available, some results using underway CTD casts showed an incredible high-definition compared with common practice of CTD stations. The examples shown were done in the South China Sea during the Asian Seas International Acoustics Experiment (ASIAEX) program (http://www.apl.washington.edu/programs/ASIAEX/index.html). Another example of technology in development is acoustic tomography. Although deep-sea acoustic tomography has a two-decade history as a three-dimensional mapping tool of mesoscale sound speed (temperature) and current velocity structures, it has been only recently used with success in coastal areas by the Hiroshima University in Japan. Several hydrophone systems were deployed to Uwajima Bay of the Seto Inland Sea, and in Tokyo Bay in order to map the circulation in those areas.

To conclude his presentation, Dongxiao reported on the latest activities of North-East Asian Regional GOOS

(NEAR-GOOS) and Southeast Asian GOOS (SEA-GOOS). A very important issue for SEAS-GOOS is the existence of the South China Sea Throughflow and its possible connection with the Indonesian Throughflow. In order to address this issue, there is a strong need for more observations in the region.

The panel was reminded that there is a webpage on the CLIVAR website that lists all the process studies in the Pacific basin, with current available data and some planned field campaigns. However, to keep the webpage up-to-date, panel members should regularly check it and advise of known datasets of interests and planned field campaigns. New information should be then directed to the ICPO staffer responsible for the panel.

ACTION: Update observing systems section of Panel webpage, with current available data and planned data acquisition [all panel members, ICPO]

8.5. APDRC and data archiving

Jim Potemra gave an overview of the activities of the Asia-Pacific Data Research Center (APDRC). The APDRC was established within the IPRC to be a climate data and web-based product serving facility. and has an informal relation to other CLIVAR DACs. APDRC mission is to increase understanding of climate variability in the Asia-Pacific region by:

- developing the computational, data-management, and networking infrastructure necessary to make data resources readily accessible and usable by researchers and other users;
- undertaking data-intensive research activities that will both advance knowledge and lead to improvements in data collection and preparation.

In today's fast-changing world, there are several challenges for distribution of climate data, and more importantly, with the view that users needs are widely varying:

a) disparate data types: data can be archived and distributed by station data, or in a gridded format data, ocean-only data, atmospheric-only data, levels, time-series, etc.

b) disparate data formats: several "standard" are being used- netcdf, grib, flat binary, etc.

c) datasets can be large: coupled model outputs, long integrations, high resolution (time/space), etc.

APDRC project supports archiving and distribution of several programs and initiatives:

- Global Ocean Data Assimilation Experiment (GODAE)
- ARGO
- Pacific Regional Integrated Data Enterprise (PRIDE)
- Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- JAMSTEC Earth Simulator Group (ESG)
- Quality control of historical profiles of temperature and salinity for the global oceans (HydroBase2, WHOI) and the Indian Ocean (CSIRO), GTSPP

This datasets are distributed using several interfaces:

a) EPIC: was developed at NOAA's Pacific Marine Environmental Laboratory to manage the large numbers of hydrographic and time series oceanographic in-situ data sets. The EPIC system provides data archival, retrieval, display and analysis procedures for oceanographic time series and hydrographic data. Users select data by specifying data type, latitude, longitude and time range or other identifying characteristics. There is a complete suite of routines for graphical display and data analysis. It is used for non-gridded data.

b) LAS (Live Access Server): is a highly configurable Web server designed to provide flexible access to geo-referenced scientific data. It can present distributed data sets as a unified virtual database through the use of DODS networking. LAS enables the Web user to:

- visualize data with on-the-fly graphics
- request custom subsets of variables in a choice of file formats
- access background reference material about the data (metadata)
- compare (difference) variables from distributed locations

c) OPeNDAP (Open-source Project for a Network Data Access Protocol): is a framework that simplifies all aspects of scientific data networking. OPeNDAP provides software which makes local data accessible to remote locations regardless of local storage format. OPeNDAP also provides tools for transforming existing applications into OPeNDAP clients (i.e., enabling them to remotely access OPeNDAP served data).

The panel discussed several issues related to data archiving and distributing, in particular the possibility of APDRC to integrate ocean datasets from South America to its databases, and host model output for intercomparison projects. In principle, it is possible for APDRC to host those datasets, although for the latter it can be a very demanding task.

9. Session 7: Organisational Programs

9.1 GCOS in the Pacific Islands

The U.S. in partnership with Australia, New Zealand, and the nations of the South Pacific Regional Environment Program have taken the lead in working towards establishing a robust and sustainable Pacific Islands Global Climate Observing System (PI-GCOS) that meets the climate change and variability observations, and application needs of the PI nations and meets the associated regional and international requirements for climate observing in this data sparse area. Howard Diamond gave a general overview of the PI-GCOS program and on the program's activities in the region. The PI-GCOS Action Plan developed in 2002 has identified the high priority actions, many of which can be implemented as stand alone modules that will assist in restoring and improving observing systems in the region to a level necessary to effectively monitor the climate of the region and systematically detect trends and changes in climate primarily via support from the GCOS Surface Network and GCOS Upper Air Network sites across the region.

The U.S. GCOS Program Office, based at NOAA's National Climatic Data Center (NCDC), has been a primary supporter of the PI-GCOS effort since the first regional GCOS workshop in Apia, Samoa, in August 2000, and has contributed resources towards that effort. The U.S. GCOS Program Office plans to continue contributing in-kind support and facilitation of furthering the goals of PI-GCOS as it has undertaken the role as the Secretariat of the region's PI-GCOS Science and Technology (S&T) Panel. The S&T Panel is a subsidiary body established to provide advice and guidance to the PI-GCOS Steering Committee. In addition to supporting GCOS regional efforts in the Pacific, the U.S. GCOS Program Office has also provided resources to help stage workshops, as well as in providing presenters on various topics.

In support of the PI-GCOS effort, the Global Observing System Information Center (GOSIC), a data management facility supported by NOAA/NCDC has developed, in concert with the regional PI-GCOS Program Officer, a new Pacific Islands GCOS portal in order to facilitate the access to Pacific Islands GCOS datasets that may be held in a diverse group of data centers. This portal, located at http://pi-gcos.org, has become a key tool to aid in the management of the Pacific Islands Regional GCOS Program, as well as providing an administrative tool for use by the regional PI-GCOS program officer based at the Secretariat of the Pacific Regional Environment Program (SPREP) in Apia.

9.2 US CLIVAR reorganisation

David Legler presented to the panel the new organisational structure of US CLIVAR, and highlighted possible ways of interaction between the US CLIVAR panels and the International CLIVAR Pacific Panel. David started his presentation by introducing the former organisational structure of the US CLIVAR, and the motivations for change which are based in the US Climate Change Science Program (CCSP) Strategic Plan. It also responded to the assessment made by the International CLIVAR in 2004 and to the official start of the WCRP COPES (Coordinated Observation and Prediction of the Earth System) framework. As there is more competition and tighter resources, it became clear that it was necessary to focus on the scientific advances, e.g, where are the new frontiers, and gaps in climate research?

The vision of US CLIVAR is based on a overarching issue, which is the need to improve the ability to predict responses of the climate system, and see that improvement in place at major applications centers, e.g. NCEP, IRI, NCAR-CCM, GFDL. The US CLIVAR challenge is in helping to facilitate this. Research priorities should be informed according to the needs of the applications community, and in addition to the needs of prediction research led by centres involved in climate risk management (CRM).

This vision had led to the development of a new structure to US CLIVAR, where the building blocks are neither regional panels nor model development groups focused on a specific time scales. The new groups recognize the global nature of climate research and facilitate the incorporation of improvements to prediction in applications. Further details on the new structure can be found at http://www.usclivar.org/Organization/US_organization.html. The new US CLIVAR structure also encompasses the creation of limited lifetime Working Groups (WGs), which will be on the front lines of coordinating and implementing focused components of the climate variability/predictability research enterprise. At the present, two WGs have been set up: Salinity Working

Group and Subseasonal Variability: MJO Working Group. With suitable arrangements, WGs can be formed jointly with other national and international programs.

Links between US and International CLIVAR are vital for both programs, and this linkage can be done by several mechanisms, e.g., US membership on international panels, regular updates on US planning and solicitation of input from international panels. Also, International CLIVAR panels could be represented at te annual US CLIVAR Summit Meetings. US CLIVAR would like to encourage comments and reactions on its reorganization and initial goals/foci.

At the end of his presentation, David Legler posed some questions to the panel that he would like to see discussed and fed back to US CLIVAR:

- What (focused) scientific challenges are the most critical, tractable, and affordable for CLIVAR to pursue?
- What new approaches and ideas does the panel recommend for addressing these challenges?
- Which Pacific panel plans and activities map onto US Panels/WGs?

The panel enquired about what would be the best way to send recommendations to funding agencies in US. According to David Legler, recommendations from International CLIVAR panels could be submitted through the US CLIVAR panels, with unusual ones being submitted through the US CLIVAR office. Creation of US CLIVAR WGs would be possible for attractive subjects with focused ideas but the panel can be more efficient if engaging in activities already being pursued, in particular due to tight funding opportunities.

9.3 Links to other programs

The panel discussed how to increase linkages with other research programs, in particular with GLOBEC, PICES and the newly created CliC/CLIVAR Arctic Panel.

GLOBEC (Global Ocean Ecosystem Dynamics) was initiated by SCOR and the IOC of UNESCO in 1991, to understand how global change will affect the abundance, diversity and productivity of marine populations comprising a major component of oceanic ecosystems. It is also now co-sponsored by IGBP. The aim of GLOBEC is to advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing so that a capability can be developed to forecast the responses of the marine ecosystem to global change. See http://www.pml.ac.uk/globec/ for more details. During the last CLIVAR Atlantic Panel meeting, GLOBEC presented a short document containing a set of questions, and requested consideration on those from all CLIVAR panels and working groups. The panel delegated to Amy Clement the task to provide a draft input and circulate to the panel before sending to GLOBEC.

ACTION: Provide scientific input from Panel to GLOBEC [Clement]

Prior to the panel meeting, Rebecca Woodgate, member of the now CliC/CLIVAR Arctic Panel, circulated a slide presentation to the panel in order to initiate linkages with other appropriate CLIVAR basin panels. The Pacific Panel welcomed the recent CLIVAR co-sponsorship of this group and recognized its importance and delegated to William Crawford the task to establish the links and provide input to the CliC/CLIVAR Arctic Panel.

ACTION: Establish links and provide input to Clic/CLIVAR Arctic Panel [Crawford)]

PICES (North Pacific Marine Science Organization) has always had a link with the Pacific Panel, which was made through the former panel chair, Kelvin Richards. The panel agreed that is important to keep these strong linkages and delegated to William Crawford the task to re-establish links with PICES.

ACTION: Re-establish links with PICES [Crawford)]

10 Panel Business

10.1 Working Groups

Axel Timmermann introduced to the panel his ideas on how the panel could advance discussions if working groups on some subjects are setup. These working groups would work by email and provide input for the panel in order to encourage open discussion. The proposed working groups and membership (leaders in bold) are:

- Advanced numerical and observational techniques (Qiu, Neelin, Crawford, Suga)
- Warm pool climate and its sensitivity (Clement, Neelin, Qiu, D. Wang)
- Use of ocean data assimilation (Balmaseda, Ganachaud, Cai)

- Pan-oceanic connections (Timmermann, Cai)
- Improving seasonal predictions (Power, Balmaseda, Martinez)
- Falsifying hypothesis (Cai, Qiu, Power, Suga, Feely)

The panel also identified some key scientific challenges that need to be addressed and that will focus the discussion made by the working groups and by the panel as a whole group.

Mean state: Why do CGCMs do a poor job in simulating the cold tongue? Why do CGCMs do a poor job in simulating southeastern Pacific upwelling? What is the origin of coupled model biases and what is their effect on the simulated annual to decadal variability? How much of the model biases in the tropical Pacific originate from model biases elsewhere (e.g. tropical Atlantic)?

ENSO: What determines the variations of ENSO? What is the role of MJO-SST interactions for ENSO? How does the annual cycle interact with ENSO? What determines the long-term behaviour (decadal to centennial) of ENSO? How can predictability limits of ENSO be extended? What is the optimal way for initializing ENSO forecasts?

Observations:

Short-term: Is the Pacific observing system adequate and what are its vulnerabilities?

Long-term: What are the future needs for the Pacific? What key observations do we need in order to address the key scientific questions identified by CLIVAR? Is there a technical possibility to attach small mass spectrometers to ARGO floats?

ACTION: Post KEY SCIENTIFIC questions in the panel webpage [ICPO]

10.2 Coordinated model experiment

Based on the discussions during the meeting, the panel agreed with the following recommendations for coordinated model experiments, with names in brackets being tasked to take the recommendations forward to other appropriate groups

- Contact modeling centers and check/ synchronize their activities about light attenuation experiments (Griffies, Timmermann)
- CMIP2 THC collapse and influence on ENSO, annual cycle, mean state (Timmermann)
- IPCC: annual cycle/ENSO interactions (Timmermann)
- Multidecadal variability intercomparison in 4AR control runs (Timmermann, Cai)
- Contact Eli Tziperman on Westerly Wind Bursts (WWB)-ENSO interaction (Balmaseda, Power)
- Check BFJ index and Boer diagnostics in 4AR simulations, and contact Achuta Rao, Guilyardi, Geert Jan van Oldenborgh and Mat Collins on these simulations (Power, Timmermann)

10.3 Proposed meeting and workshops

The Pacific Panel is co-sponsoring the "Global Multidecadal Climate Variability Workshop" to be held in Honolulu, November 2006. The workshop is being organised by Henk Dijkstra, Fei-Fei Jin, Axel Timmermann and Francois Primeau. The objective of this workshop is to synthesize knowledge on the physics of three main phenomena of multidecadal-to-centennial climate variability: the Atlantic Multidecadal Oscillation, the Pacific Decadal Oscillation and

Pan-oceanic connections. Invited presentations will provide overviews of observational, modelling as well as theoretical aspects of this variability. This provides an evaluation of which theories have been suggested based on idealized models, GCMs and observations.

Based on the discussions during the meeting, the panel proposed the organisation of a ENSO workshop, co-sponsored by the Pacific Panel and other CLIVAR panels and working groups. The suggestion is that the workshop would take place in 2007/2008. Scott Power and Wenju Cai offered to take the idea forward and investigate the possibility of organise such workshop in Australia.

ACTION: Check the possibility of organising the ENSO workshop in Australia and take the proposal to CLIVAR SSG [Power, Cai, ICPO]

Two other suggestions were to organise a workshop on Low Latitude Western Boundary Currents (2008) and a workshop on Pacific Climate dynamics: what have we learned from IPCC models? (2009). These suggestions would be further considered by the panel and discussions will continue post-meeting.

10.4 Date of next meeting

With the suggestion too organise a workshop on ENSO in 2007/2008, the panel agreed to hold the next panel meeting in association with this workshop. Details of dates and venues will be advised at the appropriate time.

Appendix A

Meeting Agenda

February 15th, 2006

9.00 – 9.15 Welcome and Opening remarks (Axel Timmermann), Logistics (Nico Caltabiano)

9.15 – 9.35 International CLIVAR (Tony Busalacchi)

9.35 – 10.20 Goals of this workshop (Axel Timmermann)

Break 10.20 – 10.40

Session 1 Overarching key questions

10.40 – 11.10 Pacific climate change: past, present and future (Amy Clement)

11.10 – 11.40 Midlatitude Pacific decadal variability: A review and some thoughts (Bo Qiu)

11.40 – 12.10 Unresolved questions in the South Pacific (Kelvin Richards)

12.10 – 12.40 Do we really understand ENSO? (Fei-Fei Jin)

Lunch 12.40 – 13.40

13.40 – 14.10 Discussion Session 1

Session 2 Modelling issues

14.10 – 14.40 Ocean model deficiencies and what needs to be done to resolve them (Stephen Griffies)

14.40 – 15.10 How good are CGCMs in the Pacific (Akio Kitoh)

15.10 – 15.40 Discussion Session 2

Break 15.40 – 16.00

Session 3 Indo-Pacific connections

16.00 – 16.30 Evidence and issues on monsoon and Indo-Pacific warm pool interaction (Bin Wang)

16.30 – 17.00 Indo-Pacific transmission: tropical and extra-tropical pathways (Wenju Cai)

17.00 – 17.30 Research issues to be addressed by the sustained Indian Ocean observing system (Gary Meyers)

17.30 – 18.00 Discussion Session 3

End of day 18.00

February 16th, 2006

Session 4 Pacific seasonal & decadal prediction

09.00 – 9.30 Seasonal prediction: quo vadis? (Magdalena Balmaseda)

9.30 – 10.00 The predictability of interdecadal changes in ENSO teleconnections, (Scott Power)

10.00 – 10.30 What climate information does society need? (Rodney Martinez)

Break 10.30 – 10.50

10.50 – 11.20 Discussion Session 4

Session 5 Pacific processes

11.20 – 11.50 Mode water and eddies: their role in North Pacific climate variability (Toshio Suga)

11.50 – 12.20 Tsuchiya jets and their climate relevance (Jay McCreary)

Lunch 12.20 – 13.20

13.20 – 13.50 SPICE (Lionel Gordeau)

13.50 – 14.20 PUMP (Billy Kessler)

14.20 – 14.50 VOCALS (Roberto Mechoso)

14.50 – 15.20 Discussion Session 5

Break 15.20 – 15.40

Session 6 - Pacific observational systems

15.40 – 16.10 Antropogenic carbon dioxide increases in the Pacific Ocean (Dick Feely)

16.10 – 16.40 Observational programs in the Northeast Pacific – what have they contributed to understanding climate variability (Bill Crawford)

16.40 – 17.10 Update on TAO Transition and related activities (Mike McPhaden)

17.10 – 17.40 Observational techniques (Dongxiao Wang)

17.40 – 18.00 Discussion Session 6

End of day 18.00

February 17th, 2006

9.00 - 9.20 The APDRC: where to archive your data? (Jim Potemra)

9.20 – 9.50 GCOS in the Pacific Islands (Howard Diamond)

9.50 – 10.20 The reorganized US CLIVAR (David Legler)

Break 10.20 – 10.40

10.40 – 12.20 Working groups

- Advanced numerical and observational techniques
- Warm pool climate and its sensitivity
- Use of ocean data assimilation
- Pan-oceanic connections
- Advancing seasonal predictability
- Falsifying hypothesis

Lunch 12.20-13.20

13.20-14.20 Major issues for working groups

14.20-14.50 Consolidate observational programs and develop new thrusts

14.50-15.10 Panel input for JSC XXVII (Pune, India) and CLIVAR SSG-14 (Buenos Aires, Argentina)

Break 15.10-15.30

15.30-16.00 Reaching out to other programs (PICES, CliC Arctic panel, GEWEX, GLOBEC etc.)

16.00-17.00 Final discussion, writing assignments

End of day 17.00

Appendix B:

List of Attendees

BALMASEDA, Magdalena
ECMWF
Shinfield Park
Reading RG2 9AX , UK
Magdalena.Balmaseda@ecmwf.int

BUSALACCHI, Antonio
Earth System Science Interdisciplinary Center
224 Computer and Space Science Building,
Room 2207, University of Maryland
College Park, MD 20742-2425 USA
tonyb@essic.umd.edu

CAI, Wenju
CSIRO Atmospheric Research,
107 Station Street
Aspendale 3195 Australia
wenju.cai@csiro.au

CALTABIANO, Antonio
International CLIVAR Project Office
National Oceanography Centre, Southampton
European Way, Southampton, UK, SO14 3ZH
caetano@noc.soton.ac.uk

CLEMENT, Amy
RSMAS, University of Miami MPO, MSC 362
4600 Rickenbacker Causeway
Miami, FL 33149 USA
aclement@rsmas.miami.edu

CRAWFORD, William
Ocean Sciences Division
Institute of Ocean Sciences, Fisheries and Oceans Canada,
P.O. Box 6000, 9860 West Saanich Road, Sidney, B.C., Canada, V8L 4B2
CrawfordB@pac.dfo-mpo.gc.ca

FEELY, Richard
NOAA/PMEL
7600 Sand Point Way NE
Seattle, WA 98115-6349
Richard.A.Feely@noaa.gov

GOURDEAU, Lionel
UMR 65
IRD, BPA5, 98848 Nouméa
New Caledonia
gourdeau@noumea.ird.nc

GRIFFIES, Stephen
Geophysical Fluid Dynamics Laboratory
Princeton Forrestal Campus Rte. 1
201 Forrestal Road
Princeton, NJ 08542-0308 USA
stephen.griffies@noaa.gov

JIN, Fei-Fei
Florida State University
404 Love Building/Meteorology - 4520
Tallahassee, FL 32306-4520 USA
jff@met.fsu.edu

KESSLER, William
NOAA/PMEL,
7600 Sand Point Way NE
Seattle WA 98115 USA
william.s.kessler@hoaa.gov

KITOH, Akio
Climate Research Department
Meteorological Research Institute
1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan
kitoh@mri-jma.go.jp

LEGLER, David
1717 Pennsylvania Avenue NW, Suite 250
Washington, DC 20006 USA
legler@usclivar.org

MARTINEZ, Rodney
CIIFEN
P.O Box Escobedo y 9 de Octubre 1204
Guayaquil - Ecuador
r.martinez@ciifen-int.org

MCCREARY, Jay
IPRC/SOEST
University of Hawaii, POST Bldg. 401
1680 East West Road
Honolulu, Hawaii 96822 USA
jay@hawaii.edu

MCPHADEN, Michael
NOAA/PMEL
7600 Sand Point Way N.E.
Seattle, WA 98115-6349 USA
Michael.J.Mcphaden@noaa.gov

MECHOSO, Roberto
University of California, Los Angeles
Department of Atmospheric Sciences
7127 Math Sciences Building
405 Hilgard Avenue
Los Angeles, California 90095-1565 USA
mechoso@atmos.ucla.edu

MEYERS, Gary
CSIRO Marine Research
P. O. Box 1538, Hobart TAS 7001
Australia
Gary.Meyers@csiro.au

POWER, Scott
Bureau of Meteorology Research Centre
GPO Box 1289, Melbourne, VIC 3001, AUSTRALIA
s.power@bom.gov.au

QIU, Bo
Department of Oceanography
University of Hawaii at Manoa
1000 Pope Road, Honolulu, HI 96822, USA
bo@soest.hawaii.edu

RICHARDS, Kelvin
IPRC/SOEST
University of Hawaii, POST Bldg. 409
1680 East West Road
Honolulu, Hawaii 96822, USA
rkelvin@hawaii.edu

SUGA, Toshio
Department of Geophysics
Graduate School of Science
Tohoku University
Aoba-ku, Sendai Japan 980-8578
suga@pol.geophys.tohoku.ac.jp

TIMMERMANN, Axel
IPRC/SOEST
University of Hawaii
Honolulu, Hawaii 96822
axel@hawaii.edu

WANG, Bin
IPRC/SOEST
University of Hawaii
Honolulu, Hawaii 96822
wangbin@hawaii.edu

WANG, Dongxiao
LED, South China Sea Inst. of Oceanology, Chinese Academy of Sciences
164 West Xingang Road, Guangzhou 510301, China
dxwang@scsio.ac.cn

Appendix C: Panel Membership

Axel Timmermann (Chair)	IPRC, U. Hawaii, Honolulu, USA
Magdalena Balmaseda	ECMWF, Reading, UK.
Wenju Cai (Data Liaison)	CSIRO, Division of Atmospheric Research, Aspendale, Australia
Amy Clement	Univ. of Miami, USA
Bill Crawford	IOS, Canada
Alexandre Ganachaud	Legos/IRD, New Caledonia, France
Rodney Martinez	CIIFEN, Ecuador
David Neelin	Univ. California, USA
Scott Power	BoM, Melbourne, Australia
Bo Qiu	Univ. Hawaii, Honolulu, USA
Toshio Suga	Tohoku University, Japan
Dong-Xiao Wang	South China Sea Institute, China
Richard Feely (carbon representative)	NOAA/PMEL Seattle, USA

Ex-officio

Michael McPhaden, NOAA/PMEL, Seattle, USA (Tropical Moored Buoy Implementation Panel)

National Oceanography Centre, Southampton
University of Southampton Waterfront Campus
European Way, Southampton SO14 3ZH
United Kingdom
Tel: +44 (0) 23 8059 6777
Fax: +44 (0) 23 8059 6204
Email: icpo@noc.soton.ac.uk