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Introduction

The 4th meeting of the CLIVAR Pacific Panel (PP) was held at the Guangzhou Sanyu Hotel, Guangzhou (CHINA) on 29-30 November 2007. The meeting followed the successful CLIVAR workshop on "Western Tropical Pacific: Hatchery for ENSO and Global Teleconnections" (http://www.clivar.org/organization/pacific/meetings/pacific_workshop.php).

Axel Timmermann. Pacific Panel (PP) chair, opened the meeting by welcoming the panel members and guests (see Appendix A) and thanking the local host, DongXiao Wang from the South China Institute of Oceanography, for the impeccable organizational support. Apologies were accepted from David Neelin and Amy Clement for their absence.

D. Wang welcomed Adee Zai, science and innovation officer of the UK Foreign & Commonwealth Office in Guangzhou. Miss Zai leases with the Chinese Government on issues related to regional climate change impacts and was invited to attend the meeting as an observer.

Finally A. Timmermann reviewed the meeting agenda (see Appendix B) and proposed to start the meeting with the discussion on SPICE-NPOCE-PACSWIN international coordination given the early-scheduled departure of Prof. Dunxin Hu.

NPOCE and International Coordination

Prof. D. Hu reported on the NPOCE activities and plans. The western North Pacific low-latitude area, encompassed by NPOCE (see figure 1), is highly relevant to climate. The oceanic variability of the NPOCE is large. After mutual visits and discussions over the last 10 years, scientists from various countries are showing a strong desire to study the western Pacific again. As a result, an NPOCE workshop was held on 17-18 May 2007 in Qingdao, China. The discussions focused on two areas. The first is what could be accomplished in the coming 2 years (2007-2008) to potentially enhance the proposed NPOCE observations centred along 18N. This latitude has been chosen because it is a relevant place to monitor the Kuroshio as it approaches the downstream marginal seas (*i.e.*, the South China Sea and the East China Sea) and because the flow there determines the northward heat transport in the region. Secondly, It what might be pursued scientifically over the period of the next 5 years was discussed.

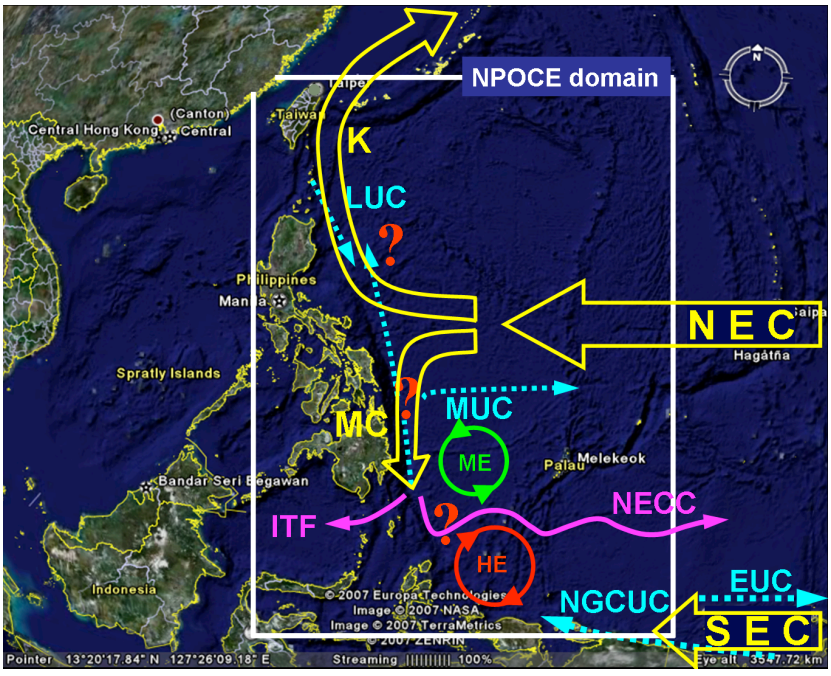

Figure 1

Regarding the short-term goal (2007-2008), two Chinese projects have been funded (a 2007 fall cruise to deploy an initial subsurface mooring and some hydrographic surveys), a third proposal, under revision, consists of additional subsurface moorings along 18N. The present Argo coverage in the NPOCE area is below the Argo requirement. However the US Argo program has made about 30 Argo profiling floats available, to be deployed in the area, probably during the NPOCE cruise in 2008. Additional ship time may also be available from another related Chinese project.

Regarding the long-term goal (of the next 5 years), the NPOCE program will focus on the southern part of the western boundary current systems (from the North Equatorial Countercurrent bifurcation to the equator). This will facilitate collaborations with the SPICE and PACSWIN programs. Much of the equatorward transport of the subtropical cells (STCs) is carried by the low-latitude western boundary currents. In-situ measurements across the Mindanao Current and New Guinea Coastal Undercurrent are crucial to close the heat/mass transport budget for the equatorial Pacific Ocean. The circulation structures of the region are still poorly understood. These include the Mindanao Current and Undercurrent, the Equatorial Undercurrent, the New Guinea Coastal Current and Undercurrent (NGCUC), the North Equatorial Countercurrent (NEC) and the South China Sea Throughflow (SCSTW).

In the light of the climate significance of interannual-to-decadal variability of the STCs, long-term monitoring of the low-latitude WBCs will be essential. It is the goal of NPOCE to leave a sustainable monitoring network for this system.

One cost-effective way to monitor the long-term variability in the region is to reactivate some of the tide gauge stations along the Philippine coast and combine the tide gauge data with satellite altimetry and Argo profiling data to adequately monitor the offshore signals. There is also a need to deploy subsurface moorings in selected locations (especially along 8N) to study vertical T/S and flow structures. The MC/NGCUC provide the source water for the Indonesian Throughflow (ITF). As such, their variability can impact not only the regional western Pacific variability, but also the oceanic signals and, for example, water masses in the eastern Indian Ocean. NPOCE observations in the western equatorial Pacific can bridge to PACSWIN and SPICE.

Prof. D. Hu proposed an international workshop/conference be held in 2008 with a focus on the variability of the regional climate and ocean circulation in the NPOCE area.

PACSWIN Initiative

PACSWIN (PACific Source Water INvestigation) is one of the major international ocean climate programs for the next 10 years or so in the Indo-Pacific region. Strategically, it aims to establish a long-term and cost-effective ocean climate monitoring program using, for example, moorings, submarine cables and modified floats enabling the Indonesian seas to be included in the Argo array. PACSWIN will study the various source waters entering the Indonesian seas, especially those originating in the Pacific, their pathways and transformations.

PACSWIN will consist of about 20 components covering ocean climate monitoring (hydrography surveys, lagrangian floats, moorings, submarine cables, etc…), broad scientific themes (tides and tidal mixing, biogeochemical tracers, LLWBCs (Low-Latitude Western Boundary Current), marginal sea effects, water mass and mixing, etc…) and modeling aspects (ocean-only, ocean-atmosphere coupled models, etc…). Each component is lead by scientists from participating countries. Phase 1 of PACSWIN will focus on the Indonesian seas, the adjacent Pacific entrance, Indian outflow and marginal seas.

A Scientific Advisory Committee has been established and, with the guidelines from the co-chair and other top scientists, is helping to shape the program. Chairs/co-chairs for the PACSWIN components have been nominated - the most advanced components will organize workshops soon.

The PACSWIN scientific program description and implementation plan are under preparation; the presentation at the PP meeting and the one scheduled at the CLIVAR IOP meeting in May 2008 is meant to initialize the process of gaining CLIVAR endorsement.

Scientists with interest to this program should contact John Y. You: you@geosci.usyd.edu.au

> **ACTION 1.** In collaboration with IOP, promote an active interaction between the Pacific Panel and the PIs of PACSWIN for providing feedbacks on the PACSWIN Science Plan (J. You and PP members)

A 1st PACSWIN submarine cable workshop is scheduled for April 2009 in Korea. Submarine cable is cost-effective ocean current observing tool: except for the calibration costs, about US$3000 for a voltage recorder and a computer to make it work for monitoring net current transport of a particular strait. It is most practical for satisfying the present urgent need for implementing a long-term ocean climate monitoring network. Submarine cable has been applied since the 1980s for monitoring the Florida Current transport and has also been used in other parts of the world oceans such as for measuring the Kuroshio between Taiwan, Luzon and Okinawa and the Tsushima Current in the Korea Strait. The western Pacific contains most of the marginal seas and straits of the world's ocean and so submarine cable is potentially useful for monitoring this region.

The proposed workshop will review and promote the technique, allow updates and exchanges among the users and enable experiences to be shared with non-users. Meaningful current transport measurement with cable depends upon accurate determination of parameters such as tides, sediment condition, local magnetic field and intercomparisons with real current measurements, and the workshop will seek to standardize the methodology and intercomparison technology. The workshop will set out a road map for building a global network and open-access data banking.
The international organizing committee will be composed of John You (University of Sydney), Christopher Meinen (NOAA AMEL), Momoki Koga (University of the Ryukyus), Kuh Kim (Seoul National University), Cho-Teng Liu (National Taiwan University) and CLIVAR representatives.

John You will request CLIVAR endorsement of the workshop by sending all the appropriate information to the director of the International CLIVAR Project Office.

SPICE Science and Implementation plans

The scientific background of SPICE (South Pacific Ocean Circulation and Climate Experiment) was been published in May 2007 and is available at:
http://www.pmel.noaa.gov/people/ganachaud/spice/SPICEscienceplan_bkgnd.pdf
This coordinated study of the circulation of the southwest Pacific will follow a collaborative and cost-effective approach based on existing human and technical resources. SPICE is regionally focused, but designed within the basin-scale ocean-atmosphere system. The large-scale context, including the basin-scale South Pacific circulation and its connection with equatorial processes and climate variability, are addressed within other CLIVAR experiments. The main objectives and timetable are set out in Table 1.

Objectives	**2004-2007**	**2008-2010**
1. Role of the southwest Pacific in CGCMS		-Modeling experiments -Major SPCZ experiment?
2. Air-sea fluxes and currents	-SEC inflow (cruise and glider) -Gyre dynamics and jets	-SEC inflow monitoring -Solomon Sea exploration (model, cruise, moorings, gliders)? - EAC monitoring? - VOS with AWS Hull SST?
3. Monitoring key	-Experimental monitoring	-Experimental monitoring SEC and

quantities	Solomon Sea	Solomon Straits
4. Local impacts	-Model downscaling (ROMS-type) -Operational prototypes -SSS-based analysis	-Regionally oriented applications and training

Table 1

SPICE has been built to contribute to the CLIVAR objectives, with a large-scale approach targeted toward:

- Identifying key regional features and their impact on climate simulation on seasonal to decadal timescales
- Understanding pertinent air-sea fluxes and oceanic currents (especially LLWBCs) to improve climate modeling and prediction

There is a particular focus on western boundary currents, which are recognized as a key issue by CLIVAR because they accomplish a large and rapid meridional transport of mass and heat. Throughout the southwest Pacific boundary currents are less studied than in other parts of the world. They are of special interest for climate because they provide an efficient communication from the subtropical gyre to the equator. The SPICE relevance to CLIVAR can be summarized in 4 themes:

1. Decadal Influence: a) thermocline water connection between the subduction zone of the South East Pacific and the equator; b) decadal gyre spin-up and Tasman Outflow linkage to the "supergyre"
2. South Pacific Convergence Zone (SPCZ): high convective activity, precipitation and wind convergence
3. Seasonal Prediction: improve knowledge of oceanic conditions and ocean atmosphere fluxes
4. Seasonal/Interannual prediction: local impacts

SPICE is taking the first steps toward implementing the observations necessary to interpret the southwest Pacific circulation and its effects on local and remote climate, and to build a regional observing system that will allow ongoing monitoring of its variability.

An informal meeting was organized at the AGU in S. Francisco, December 2007, to discuss the overarching issues and necessary future research in relation with the SPICE experiment (http://www.clivar.org/organization/pacific/SPCZ_SWPac_AGU2007.pdf)

ACTION 2. Distribute the SPICE Science plans to CLIVAR Modelling WGs, AAMP and IOP, as well as to relevant monsoon projects within the Asian Monsoon Years (MAHASRI, AIPO, IMS). (A. Ganachaud and D. Wang)

ACTION 3. Collect the feedbacks on SPICE science plan and write the case for CLIVAR endorsement (A. Timmermann)

SPICE, NPOCE & PACSWIN Coordination

Alex Ganachaud, John You and D. Hu proposed the monitoring of the Low-Latitude Western Boundary Current (LLWBC) alimentation of Pacific Equatorial Under Current (EUC) and Indonesian ThroughFlow (ITF) as the overarching theme for the coordination of the three projects. Figure 2 shows the positions of the planned moorings and the proposed new moorings where NPOCE and SPICE meet with PACSWIN. A. Timmermann also proposed the use of high-resolution models to guide the positioning of the moorings. Which line is best to monitor the local circulation and how many moorings? What is the optimal design?
Fei-Fei Jin added that this area is a very important buffer to the recharging and discharging of the warm pool, which is a key element of the global climate.

It was proposed to set up an *ad hoc* working group (WG) to guide the international coordination of the observations in the western tropical Pacific. The WG would act as a forum for exchanging plans and ideas, identifying gaps and overlaps, learning from each other's experiences and to share data and model results.

> **ACTION 4.** Form a Task Team in charge of co-ordinating observations of SPICE, NPOCE and PACSWIN in order to address the recharging and discharging of the warm pool in the western Pacific (A. Ganachaud, D. Hu, J. You, M. McPhaden, K. Ando, D. Wang, K. Richards, M. Balmaseda and B. Qiu)

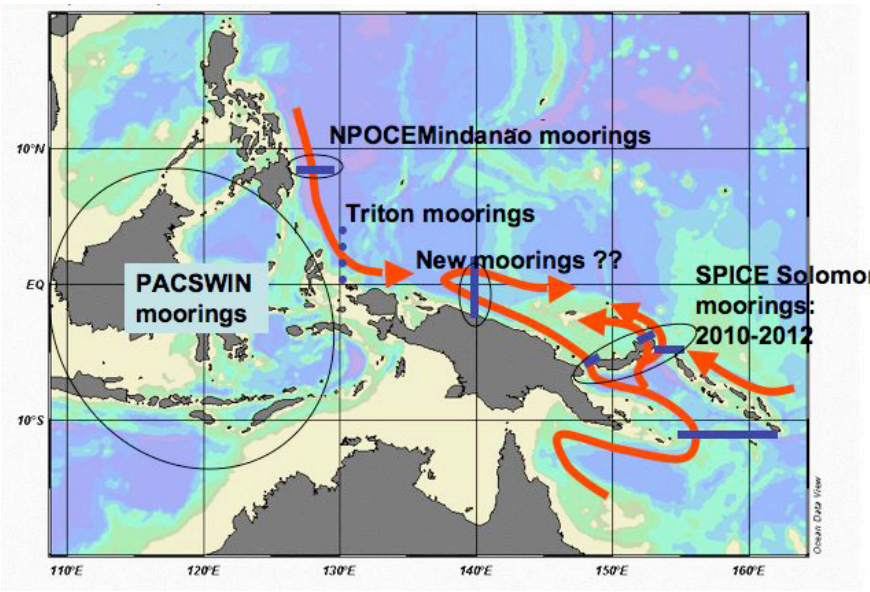

Figure 2

Understanding SPCZ: SPICE-VOCALS interaction

The SPCZ marks one of the world's largest rainfall regions and is a dominant feature of southern hemisphere climate. It is characterized by a band of low-level convergence, cloudiness and precipitation in the western Pacific extending south eastwards towards French Polynesia. Its location varies in relation to both the Interdecadal Pacific Oscillation (IPO) and El Niño Southern Oscillation (ENSO). The SPCZ is a broad feature, and is associated with maxima in sea surface temperatures (SST), precipitation, cloudiness, low level convergence and a minimum in out-going long-wave radiation (OLR). The SPCZ is linked to the Inter-Tropical Convergence Zone (ITCZ) in the west over the Pacific warm pool and it is maintained by the interaction of the trade winds and disturbances in the mid-latitude westerlies in the east. The SPCZ tends to be most active during the southern hemisphere summer months (November-April). It has been shown that the location of the SPCZ varies systematically with ENSO-related expansion and contraction of the western Pacific warm pool, moving northeast during El Niño events and southwest during La Niña events. The SPCZ also changes its mean locations with the polarity of the IPO, a ~15-30 year time scale fluctuation in SST and circulation across the whole of Pacific basin. Variations in the mean location of the SPCZ are important to the climate of many developing south-west Pacific island nations, as precipitation can vary strongly with the movement. Greater focus on SPCZ research e.g. through SPICE, could lead to major CLIVAR legacy

The South Pacific Convergence Zone (SPCZ) is poorly represented in most of the CGCMs. The mechanism by which trade winds bring cool and dry air into the SPCZ from the stratocumulus region in the Southeastern Pacific is not well understood. Wind curl variations associated with the SPCZ have a large effect on the ocean by changing the thermocline gradient across the South Equatorial Current (SEC). This signal is a principal feature of both annual and interannual variability of the subtropical gyre circulation. The Rossby waves produced by the

SPCZ wind stress curl radiate these signals to the western boundary, resulting in variability of the strength of the gyre (SEC transport) and western boundary transport.

Although lower in resolution compared to several others, the Meteorological Research Institute GCM captures the SPCZ better than many. Most GCMs fail to reduce the wind speed of easterlies and to resolve the east-west zonal gradient in SSTs of the corresponding convergence zone in the Atlantic. The problem perhaps needs to be tackled for the whole Southern Hemisphere, including the South Atlantic Convergence Zone (SACZ). A better understanding of the physical processes that determine the margins of deep convection is also needed. Simple models suggest that the edge of the convective zone is sensitive to vertical motion.

Analyses of existing remote and in situ data would be of great value in understanding the factors controlling the evolution of the SPCZ. Currently there are sparse in situ observations and satellite data lack the vertical structure. Southwest Pacific soundings are made from islands; they are biased by the island effect on local convection, therefore potentially misrepresenting large-scale conditions. Ship-based soundings could help in calibrating island data.

> **ACTION 5.** Check where the radiosonde measurements are based in the area of SPCZ for operational forecasts (M. Balmaseda)

It was suggested to promote an observational program between SPICE (southwest) and VOCALS (southeast) regions consisting of aircraft measurements from 170E to 135W near 10/15°S. In addition to ship-of-opportunity, SPICE contributors will be conducting field experiments between 2008 and 2012, west of 170°E, near the western edge of the SPCZ. Development of atmospheric modeling components in collaboration with SPICE is also very welcome. In terms of in situ observations, improved air-sea fluxes are part of SPICE objectives, and their extension to the west to cross the SPCZ zone can be justifiable. Measurements of opportunity such as soundings may be done during SPICE cruises.

> **ACTION 6.** Check whether there is a ship of opportunity crossing the SPCZ area (Australia-Solomon Islands) and highlight gaps of observation in the PP webpage (T. Suga and R. Boscolo)

ENSO stochasticity: proposal for a review paper

Following the presentations and discussion on MJO-ENSO interactions that took place during the workshop held in GuangZhou (see http://www.clivar.org/organization/pacific/meetings/pacific_workshop.php), A. Timmermann proposed to write a review paper on ENSO stochasticity.

The proposed outline and involved authors are as follow:

1. Introduction: A. Timmermann, M. Lengaigne, F.-F. Jin
2. MJO/WWB-ENSO coupling in observations: C. Zhang, M. McPhaden, H. Hendon, G. Vecchi and M. Balmaseda
3. Theoretical background: F.-F. Jin, C. Zhang, A. Timmermann and E. Tziperman
4. Modeling ENSO-MJO/WWB coupling: M. Lengaigne, E. Tziperman, G. Vecchi
5. Effects on ENSO prediction: H. Hendon, M. Lengaigne, M. Balmaseda, S. Power and M. McPhaden

Mike McPhaden noted that during the workshop session "MJO-ENSO interactions" several Chinese colleagues mentioned a few articles on the subject that are published in Chinese journals. F.–F. Jin proposed to get hold of copies and to give them a first quick read.

ACTION 7. Look for Chinese relevant papers on MJO-ENSO interactions, translate them and make them available to the community, after getting copyright clearance (F.-F. Jin, D. Wang and R. Boscolo)

A. Timmermann suggested using the CLIVAR wiki webpage to exchange information and post relevant material

ACTION 8. Make use of the CLIVAR wiki webpage to post relevant papers on MJO-ENSO (R. Boscolo)

The panel agreed on the following actions and deadlines:

1. Contact editor of J. Climate or Reviews in Geophysics
2. Send an outline to everyone by end of January
3. Exchange sections for feedback, July 2008
4. Final version: September 08

ACTION 9. Write a review paper on stochastic ENSO and contact the editors of journals to submit the paper (A. Timmermann)

AAMP-PP interactions

H. Hendon reported on the CLIVAR AAMP research foci that can benefit from a close interaction with the PP. Active and break episodes of the monsoons are dominated by intraseasonal variations. In particular the Intraseasonal Oscillation or MJO is viewed as being an elementary component of the monsoon system. Hence, monsoon simulation and prediction hinges on the ability to simulate the MJO.
ENSO also affects the AA monsoon through perturbations to the Walker circulation. The importance of air-sea interaction for modulating intraseasonal variability and for capturing the monsoon-ENSO teleconnection suggests that use of coupled ocean-atmosphere models is a key requirement for monsoon prediction.

ACTION 10. Explore the possibility to promote concerted experimentation on WWB (Westerly Wind Burst)-effects on ENSO prediction (M. Balmaseda and C. Zhang)

ACTION 11. Assess outputs from the planned TFSP/WGSIP seasonal prediction experiment and reanalyses in order to diagnose the MJO-WWB processes. Make the case for a formal diagnostic sub-project looking at 1997 event (H. Hendon, C. Zhang, M. Langaigne, S. Power, G. Vecchi)

New Insights from KESS

The Kuroshio Extension System Study (KESS, http://uskess.org/) is a collaborative effort between the Woods Hole Oceanographic Institution, the University of Rhode Island, and the University of Hawaii. The purpose of KESS is to understand the processes that govern the variability of, and the interaction between, the Kuroshio Extension and its recirculation gyre. The Kuroshio Extension is also one of the most intense air sea heat exchange regions on the globe, where the warm Kuroshio waters encounter the cold dry air masses coming from the Asian continent. The Kuroshio Extension system exhibits variations, which strongly affect North American climate.

KESS Objectives are:

- Understand SST variability on weekly-to-interannual timescales (atmospheric forcing, re-emergence, advection, eddy fluxes…)
- Provide a midlatitude reference site of surface heat fluxes.
- Clarify the formation/transformation of Subtropical Mode Water
- Clarify the formation processes of WBC recirculation gyre (anticyclogenesis vs. eddy-driven)

- Identify cross-frontal processes of mass, heat, salt, and potential vorticity (PV)
- Clarify vertical coupling (barotropitization) processes intrinsic to baroclinic instability
- Assess the influence SST's upon the overlying PBL

A moored array was designed to measure the time-varying density and velocity fields with the 4-D mesoscale resolution required to determine dynamical balances and cross-frontal exchanges of heat, salt, momentum, and PV. The array was comprised of inverted echo sounders equipped with bottom pressure gauges and current meters (CPIES), and McClean moored profilers (MMPs) equipped with upward looking Doppler current meters (ADCPs) and deep current meters (CMs). CTD/shipboard acoustic Doppler profiler (SADCP) surveys measured the broad-scale density and velocity structure and conducted highly resolved feature-studies (intense synoptic surveys) to examine the ultimate mixing processes of water parcels that cross the front.

Satellite observations of SSH and SST provided large-scale context for KESS. Profiling T, S floats (Argo profiling floats) deployed within the recirculation gyre monitored the temporal evolution of the temperature and salinity in the near-surface mixed layer, the Sub Tropical Mode Water (STMW), and the intermediate waters. Surface flux measurements from the Kuroshio Extension Observatory (KEO) buoy contributed to climate studies of the role of the Kuroshio jet and its recirculation gyre. The KEO buoy was near the southern most MMP mooring site. To help understand the connection of the Kuroshio Extension and the Recirculation Gyre to the atmosphere and climate, surface air-sea flux measurements were conducted (atmospheric soundings).

GCM Modeling (http://uskess.org/modeling.html) was used to provide the broad-scale context for KESS and the *in situ* measurements were used to improve model parameterizations.

By combining the float temperature—salinity measurements with satellite altimetry data, the KE region was found to have exhibited a transition from a 3-yr period of low eddy activity (2002-04) to a high eddy kinetic energy state in 2005. This transition is the result of delayed oceanic response to the 2002 shift in the basin-scale surface wind forcing in connection with the Pacific decadal oscillation. The eddies' influence upon STMW is observed to be both significant in magnitude and efficient in time. Relative to 2004, the PV signal in the core of STMW was reduced by one-half in 2005, and this weakening of STMW's intensity occurred within a period of less than 7 months. This result supports recent findings based on historical temperature data that the variability in STMW formation depends more sensitively on the dynamic state of the KE than on the overlying atmospheric conditions.

NOAA deployed the Kuroshio Extension Observatory (KEO) in the recirculation gyre south of the Kuroshio Extension at 144.6°E, 32.4°N in June 2004. In February 2007, JAMSTEC deployed a second KEO buoy (JKEO) north of the Kuroshio Extension at 37.9°N, 146.6°E. Both KEO moorings carry a suite of meteorological sensors to measure winds, air temperature, relative humidity, rainfall, and solar and longwave radiation. With measurements of sea surface temperature and these surface meteorological measurements, the net air-sea heat, moisture and momentum fluxes can be computed. Surface and subsurface instrumentation includes temperature and salinity at 1 m to 500 m. Daily-averaged data are available in near-real time. In addition, both moorings carry a pCO_2 sensor for computation of the air-sea CO_2 flux. In the future, additional sensors may be added to the moorings.

A Kuroshio Implementation Panel (KIP) has been formed by those involved in KEO, JKEO and WBC groups in order to identify shortcomings in atmosphere, ocean, and coupled models that need to be addressed to accurately model WBC atmosphere-ocean coupling.

VOCALS: improving our understanding for the eastern tropical Pacific

The overall goal of VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study, http://www.eol.ucar.edu/projects/vocals/) is to develop and promote scientific activities leading to improved understanding of the:

- Formation and maintenance of oceanic stratocumulus clouds and their interactions with the global climate system
- Role of local meteorology and ocean eddies in determining the distribution of clouds, and the heat and momentum budgets in the South East Pacific Ocean

and to:

- Identify key shortcomings in coupled GCMs, and to explore the potential for higher skill in ENSO predictions and of improved simulation of the South-eastern Pacific climate

Specifically PreVOCA (VOCALS Model Assessment) will critically assess the ability of global and regional atmospheric, oceanic, and chemical transport models to simulate and predict synoptically-varying clouds, meteorology, ocean circulation and aerosols in the southeast Pacific (SEP) subtropical stratocumulus regime for a month in the southern spring season. All participating models will be run in some form of weather forecast mode.

The SEP contains the world's most persistent subtropical stratocumulus region. The meteorology is simpler than the more-studied northeast Pacific due to the low latitudes and the flow channeling by the high Andes. There is a persistent aerosol contrast between the coasts of Northern Chile and Peru, polluted by sulfate from copper smelters and other industrial activity, and the pristine flow offshore where biogenic and salt aerosol may dominate. In the clean offshore air large POCS (patches of open cells) regularly form within the solid stratocumulus sheet and last for days, possibly maintained by feedbacks between drizzle and aerosol scavenging. New satellite instruments and algorithms are giving a much more integrated view of oceanic clouds that we have had before, turning the SEP from a data void into a region with a feast of new observations. These are supplemented in the SEP by research-grade buoy measurements and limited research cruise data. Lastly, the VOCALS-REx field experiment in Oct.-Nov. 2008 will take many detailed in-situ measurements in the SEP.

The simulated period is October 2006. This is the SEP stratocumulus maximum, has POCs and includes a week of in-situ data (soundings, ship remote sensing and aerosols) from a buoy maintenance cruise. Model outputs will be archived at the University of Washington and will be analyzed by Wood, Bretherton and Mechoso. The UW and UCLA groups will each share the procurement and assembly of the various satellite datasets.

The VOCALS-Rex (Regional Experiment) will collect datasets required to address a set of issues that are organized into two broad themes: (1) aerosol-cloud-precipitation interactions in the marine boundary layer (MBL) and the physicochemical and spatiotemporal properties of aerosols; (2) chemical and physical couplings between the upper ocean, the land, and the atmosphere. The climate of the SEP region is a tightly coupled system involving poorly understood interactions between the ocean, the atmosphere, and the land. To achieve its goals, the VOCALS-REx field campaign, which is designed to complement a suite of enhanced long-term observations, aims at providing detailed and targeted observations to improve model simulations, leading to benefits for climate and regional forecasting agencies

Climate Change Projections (2010-2030) for the Pacific

In the last IPCC WG1 report (2007) the multi-model averages trends show a weak shift towards average background conditions, which may be described as an El Nino-like state. With SST in the central and eastern equatorial Pacific warming more than in the west, weakened tropical circulations result and an eastward shift in modelled mean precipitation. Models also exhibit an increasing precipitation over the eastern equatorial Pacific through the Walker circulation and local Hadley circulation changes. In terms of magnitude of naturally occurring

variability, the multi-model ensemble predicts a global sea-level increase of 18-59 cm by 2100.

The global warming projections are made for 2100 with different IPCC emission scenarios however the PP suggested that a Pacific-centric catalogue of projections for 2010-2030 would be more interesting/useful. The short-term projections for the Pacific have the advantage that CO_2 concentrations are less divergent over 2008-2020 than later in 21st century in IPCC/SRES scenarios and one can use 2030 (and maybe even 2070) projections as inflated proxies for the 2008-2010 climate change signal (if spatial structure of signal is not markedly transient). The catalogue can start by including mean changes in sea level, P-E, soil moisture, wind, etc. The information can be used as a contribution to a paper and/or posted in the CLIVAR PP webpage. The information would also be useful to decision/policy makers, socio-economic sectors groups etc. The sea level trend is especially important for the small Pacific islands.

In the last past decade we have observed several features of variations/trends:

- Flattening of the equatorial thermocline
- Shallowing of the southern tropical Indian Ocean thermocline, despite a large surface warming, and a heat loss from the ocean to the atmosphere
- More westerlies in the equatorial Pacific and more easterlies over the equatorial Indian Ocean.

Do AR4 models simulate these variations? If not, is this due to poor model performance, or are these features a consequence of climate variability rather than change? How do these processes relate to the overall heat sequestration by the ocean in a warming climate? For example the Indo-Pacific oceanic teleconnection is required to attribute the observed temperature trend of the Indian Ocean. The Indian Ocean subsurface temperature exhibits a cooling trend around the 20C isotherm as a consequence of a shallowing of the thermocline due to a weakening of the Walker circulation. Such feature is reproduced by only half of the IPCC models

> **ACTION 12**. Assess decadal variability and change from AR4 model runs in the Pacific area and put the information on the web (S. Power, A. Timmermann, W. Cai, G. Vecchi, M. Collins, B. Qiu, E. Guilyardi and R. Boscolo)

Applications of decadal predictions

The decadal time period falls between and overlaps with interannual variability and long-term climate change. ENSO, an acronym for El Niño-Southern Oscillation, can be considered a type of interannual variability, and climate warming is a factor in long-term climate change. Many of the applications of decadal prediction rely on this overlap. Changes in the nature and impact of ENSO over decadal periods are part of decadal variability. Many of the applications below discuss how understanding of decadal changes in ENSO will help humanity. For example, when, if ever, will we see ENSO events as strong as those of 1982/83 and 1997/98?

Decadal variability merges into long-term climate change at longer periods. Scientists now realize the near certainty of long-term climate warming, but are not as certain how this warming will differ from present decadal climate variability. Scientists are often asked questions such as "Is this warm summer part of climate warming?" or "Can we expect stronger monsoons and typhoons in this warming climate?" Imagine how it would be if scientists had the answer! If warmer or wetter weather in a region is part of a climate-change trend, societies and individuals will be able to plan their lives.

- **Climate-related diseases.** Decadal variability is closely related to health, mainly applied to the possible changes in temperature and rainfall, and the estimation of the spread of disease. Diseases carried by insects expand in geographical range as temperatures rise and fall. Warmer weather enables tropical insects to carry diseases toward higher latitudes. Wetter weather allows malaria to spread to new regions and increase in severity in already-infected areas. Reliable decadal predictions will enable

populations and agencies to enhance disease treatments and mitigation, and will even determine how populations move.

- **Agricultural planning**. The influence of decadal variability in the change of the spatial and temporal rainfall patterns in many regions of the world is a big issue for long term agricultural planning, mainly related with contingency measures and policies to mitigate and to get an effective adaptation of communities to these new scenarios, reducing economic losses and protecting investments in this sector. We list a few examples below. The differing impacts of large and minor ENSO events are well known. If improved decadal predictions can forecast the returns of major events like the 1997/98 ENSO, entire continents will be able to plan for floods, forest fires, food storage and crop changes:
  - Most south Asian farming relies on monsoon rainfall, and this will suffer or expand if this rainfall changes in amount or timing.
  - Reliable decadal predictions will allow governments and farmers to plan for continuing changes in monsoon-region farming. For example, water reservoirs can be built in less than a decade, and can redirect rainfall to regions newly hit by reduced monsoons.
  - In regions where irrigation is already the main water supply, accurate decadal predictions will lead to better planning of water uses.
- **Forest planning.** Decadal predictions can permit foresters to determine the type of trees to plant in cultivated forests. Many of the commercially harvested forests now are replanted manually with trees selected for the local climate. Knowledge of decadal variability will permit planters to select appropriate types of trees that will best survive their vulnerable first few years. An example from Canada is devastation by the mountain pine beetle. It is normally killed by cold winters, but absence of warm winters in the past decade has allowed this beetle to spread over most pine forests in western Canada. Will cold winters return? Improved decadal predictions would answer this question and help local foresters determine what trees to replant, and how to manage this disaster.
- **Fisheries.** Fisheries operations require several years of lead-time to build and maintain fleets, to set up or shut down shore processing plants, and to change marketing. Expected fisheries variability due to temperature changes of a few degrees Celsius can be anticipated in many ocean regions at lead times of months; however, decadal predictions of temperatures will assist fisherman and fishing industries in planning catches and marketing, and in building or moving processing plants. It will assist fisheries managers in assigning quotas.
- **Hurricane and typhoon predictions.** The link between ocean temperatures in the tropics and strength of tropical cyclones is appreciated in the North Atlantic, and also in other hurricane and typhoon regions. The role of temperature of the upper troposphere and lower stratosphere is also a factor. Reliable decadal predictions in this atmospheric layer and in the surface ocean will enable predictions of the strength of hurricanes, enabling the deployment of resources to prevent damage. Decadal predictions will determine insurance rates, the amount of construction near the ocean, and even the long-term movement of populations toward or away from the coast.
- **Arctic navigation.** Higher temperatures might open up navigation through the Arctic in summer. Research suggests the northeast passage (north of Russia) might open up before the northwest Passage (through the Canadian Archipelago). Both routes will enable fast transit between North Pacific and North Atlantic Oceans. Decadal predictions of continued Arctic warming will allow planning of routes and ship construction, building and deployments of ice breakers, and management of safe, clean transits through these passages.
- **Arctic hydrocarbon exploration.** As Arctic sea-ice melts it opens up more regions for hydrocarbon exploration. But this same warming creates problems in exploration and extraction of hydrocarbons on land in regions where permafrost was formerly present. Decadal predictions of continuing warming will be applied by both the shipping and hydrocarbon exploration industries. Ironically, it is the burning of hydrocarbons that is leading to this climate warming.

- **Electrical power generation.** This industry requires accurate seasonal predictions of precipitation and temperatures to determine the levels to maintain in reservoirs. Decadal predictions will speed or slow plans for construction of new electrical stations, and will be a factor in negotiating sales of power between states. Decadal predictions of storm tracks are essential in regions where wind energy can be harnessed to generate electricity, especially over the ocean where construction costs and electrical output depend greatly on wind intensity. The use of air conditioning is expanding, especially in the tropics. Electrical utilities try to maintain peak capacity to supply power on the hottest days when usage is greatest. Decadal predictions of hottest summers will enable these utilities to build capacity to meet these demands, or plan for mitigation on the hottest days.
- **Shipping and offshore construction.** These industries are vulnerable to intense storms with strong winds. With accurate decadal predictions of storm tracks and intensity, these industries will be able to change their construction methods to adapt. Better interannual variability will not help as much, because all these projects require many years to plan and build, with the resulting infrastructure lasting for decades.

In summary improved planning is the main impact of improved decadal predictions. All humanity wants to plan for the future, usually considered in terms of decades. If the future depends on the weather, then these predictions will allow better planning. Any future decadal predictions should be accompanied by reasonable analyses of reliability. Few to no decadal predictions have been issued in the past, so the public have no past experience against which to assess them. Future decadal predictions may be accepted as 100 percent reliable, or not reliable at all, depending on the user. It is far better for the predictor to issue an assessment of reliability.

Improving seasonal and decadal predictions: Ocean Initialization

For seasonal forecasts, the ocean initialization is a boundary condition problem from the atmospheric point of view and an initial value problem from an oceanic point of view. The optimal initial conditions (OIC) are those that produce the best forecast and theoretically should represent accurately the state of the real world.

The most common ocean initialization strategy is the uncoupled approach: ocean observations are assimilated into an ocean model forced by atmospheric fluxes. In general, this strategy improves the forecast skill in the prediction of SST however if there are serious model errors this strategy can lead to large degradation of the predictive skill (as in the equatorial Atlantic). The skill of seasonal forecasts of SST is steadily improving due to the improved quality of coupled models, atmospheric reanalysis, the ocean observing system and ocean assimilation systems themselves. In ECMWF-S3, ocean data assimilation improves forecast skill in the equatorial Pacific, especially in the western part. The observations used in the ECMWF ocean reanalysis (ORA-S3) are from: moored arrays (TOGA/TAO/TRITON, PIRATA and RAMA), Argo floats and altimetry. The altimeter data have a larger effect on Atlantic and Eastern Pacific analyses, Argo has larger effect on Indian Ocean and Western Pacific analyses and anomalies from moorings have a large impact on Pacific Ocean analyses. The impact of data assimilation on forecast skill depends on the region:

- in the central/eastern Pacific, assimilating data improves the seasonal forecast skill by correcting the mean state and anomalies (NINO4)
- in the eastern Pacific (NINO1/2, NINO3) the impact of better initialization of the anomalies is hampered by the degradation of the mean state. The assimilation of data results in warmer bias, which is detrimental for ENSO prediction.

The forecasts of SST are still not reliable. In the equatorial Pacific there is an interaction between the mean state and the variability: warm bias produces weaker interannual variability while cold bias make it stronger. In the subtropics, the seasonal cycle is underestimated and delayed. The coupled models cannot predict the rapid shallowing of the mixed layer from

spring to summer. The bias-correction a posteriori may not be adequate and better calibration methods and correction terms during the forecasts are needed.

Prediction of precipitation is still quite deficient mainly due to atmosphere model error. Multi-model ensemble, perturbed and stochastic physics methodologies are used to make better predictions; however a better representation of soil/land components is also needed.

CLIVAR/GSOP and IOC/OOPC are jointly organizing the OceanObs09 symposium (http://www.oceanobs09.net/) in order to celebrate a decade of progress in the ocean observing system and make a major contribution to chart the way forward for the coming decade. The main goals are to:

- Document the importance and benefits of the existing ocean observing system.
- Demonstrate its scientific, societal and economic impacts.
- Revisit the current status, and update plans for the physical and carbon ocean observing systems.
- Advance capabilities for marine biogeochemistry and ecosystems.

ACTION 13. Propose a specific Pacific session at the OceanObs09 on ocean observing systems and their impact on climate hindcasts and forecasts (M. Balmaseda and O. Alves)

How Seasonal Predictions are used

Examples were shown from the International Centre for the Study of El Nino (CIIFEN, www.ciifen-int.org) of regional climate early warning system inputs to climate risk management. One was a project on climate information applied to agricultural risk management in the Andean countries which is based on three components:

1) regional climate data base and information system
2) dissemination information system
3) institutional strengthening and capacity building

Another example was the use of climate forecasts to facilitate short term water management in Ceara'. Seasonal to interannual probabilistic forecasts of reservoir inflows, existing reservoir storage and macroeconomic models help to establish the marginal value of water in each economic sector. Policy constraints on sectoral allocation are then used for determining the total amount of water available for allocation.

Seasonal Predictions are being used and applied successfully in different parts of the world, providing visible evidence of the societal benefits to be derived from the climate community. However whilst decision makers should not omit seasonal forecast information form their considerations, we must also be aware that our products are not the only factor they consider. To communicate the uncertainty and limitations of seasonal forecasts is definitely a powerful method to ensure that our information is applied in an approariate fashion. The seasonal forecast time scale is consistent with planning, prevention and preparedness stages for a range of economic activities and risk management, therefore the implications of their application are measurable in social and economic terms. The most transparent way to contribute on climate applications is the public dissmination of the information without any distinction.

The CLIVAR PP can contribute by:

- Assessing existing climate applications in the region.
- Assessing the prediction and applications needs in the region.
- Implementing a section of the web site on methodologies, learnt lessons and reference material on climate applications in the region.

- preparing a document that matches forecast capabilities for the Pacific against needs and gaps in climate applications.
- organizing an International Workshop where an exchange of experiences could take place and an Action Plan could be established.

ACTION 14. Make an assessment of current applications of ENSO and seasonal forecast in the Pacific Rim and make them available on the PP webpage (R. Martinez and R. Boscolo)

Report from the GSOP ocean reanalysis comparison

The first CLIVAR/GSOP meeting on ocean reanalysis intercomparison took place in September 2006 (http://www.clivar.org/organization/gsop/synthesis/synthesis.php), focused on a collaborative intercomparison assessment of the existing global analysis/synthesis products (http://www.clivar.org/data/synthesis/directory.php). For the equatorial Pacific the averaged temperature in the upper 300m shows a relatively robust interannual variability while the North Pacific shows a warming trend and a rapid shift in the early 90s.

Such a shift has been detected in the properties of the North Pacific Central Mode Water (CMW) that changed abruptly from 1988 to 1989 as reported by Toshio Suga. In his paper published in 2003 he attributed the changes to the climate shift characterized by a weakening of the Aleutian Low and the westerlies and an increase in the SST in the subartic-subtropical transition region. Bill Crawford suggested that such a shift should be documented in fisheries an ecosystem changes. In particular he referred to a PICES report on "Fisheries and ecosystem responses to recent regime shifts" published in 2005 (http://www.pices.int/publications/scientific_reports/Report28/Rep_28_default.aspx).
Empirical evidence of a climate shift in 1989 is given by observing the dynamics of species (salmon, hake, sardines etc…) and large marine ecosystems of the North Pacific and Bering Sea.

ACTION 15. Evaluate synthesis products (GSOP) and study the 1989 regime shift in the North Pacific (W. Cai, T. Suga, B. Crawford, A. Timmerman, M. Balmaseda, B. Qiu, R. Mechoso and D. Wang)

Ocean Acidification and Links to IMBER

Rates and amounts of CO_2 now being emitted exceed those inferred for at least the past 50 million years, and possibly much longer. Much of this CO_2 is being absorbed by the ocean, where it is causing changes in the carbonate chemistry of seawater. Today, the surface ocean is saturated with respect to calcium carbonate (including its several mineral forms, i.e., high-magnesium calcite, aragonite, and calcite), meaning that under present surface conditions these minerals have no tendency to dissolve and that there is still enough calcium and carbonate ions available for marine organisms to build their shells or skeletons. Colder and deeper waters are naturally undersaturated with respect to calcium carbonate, where the water is corrosive enough to dissolve these minerals. The transition between saturated surface waters and undersaturated deep waters is called the saturation horizon. Because of the increase in CO_2 entering into the ocean from the atmosphere, the saturation horizons for calcium carbonate have shifted towards the surface by 50-200 meters compared with their positions before the industrial revolution. This means that the zone occupied by undersaturated deep waters is growing larger and the zone occupied by the saturated surface waters is growing smaller. By 2050, this saturated surface zone will begin to completely disappear in some areas of the ocean. High-latitude surface waters, already naturally low in calcium and carbonate ion concentration, will be the first to have undersaturated surface waters with respect to aragonite, with undersaturations for the calcite phase of calcium carbonate expected to follow 50-100 years later. At 550 ppm, about half of the Southern Ocean will be undersaturated, this would impact pteropods and other aragonitic organisms that live in those regions with unknown consequences up the food chain. Coral calcification rate and

aragonite saturation state are linearly related with each other. What is the spatio-temporal variability of pH on decadal timescales? Is this variability represented by climate-ocean-geochemical models? Can calibrated models be used to predict the future hotspots of ocean acidification?

> **ACTION 16.** Explore the effects of climate on ocean acidification in the Pacific Ocean and make links with IMBER (B. Crawford, D. Feely and W. Hazeleger)
>
> **ACTION 17.** Propose to add a pH sensor in the ARGO floats at the next OOPC meeting. Prepare a scoping document assessing costs etc… (T. Suga)

Understanding El Nino in coupled GCMs: progress and challenges

Clear progress has been made in IPCC-class models. However major errors are still present for El Nino simulations, which lead to unresolved issues in El Nino understanding, seasonal forecasting, global climate and climate projections. In summary, El Nino in coupled GCMs presents the following behaviour:

- **Amplitude**: model's diversity much larger than observed diversity
- **Frequency:** too frequent, singled-peaked, SST-type events - progress towards low frequency/wider spectra but still errors
- **Structure:** westward extension, too narrow around equator
- **Seasonal Phase Lock**: very few models have the spring relaxation and the winter variability maximum
- **Modes**: very few models exhibit the diversity of observed ENSO modes; most are locked into a SST-mode (coherent with too strong trade winds)
- **Teleconnections**: ENSO much too dominant over local modes
-

The analysis suggests that the atmosphere GCM has a dominant role, mean and annual cycle of wind stress are too strong (SST-mode), there is no clear relation between mean state and ENSO amplitude (linear regime) and the amplitude is easier than frequency to relate to model errors. CMIP3 (IPCC AR4) models show clear improvement over CMP2 models and a number of new approaches (multi-model, theory-GCM bridges) are promising. The modelling community is ready to integrate them.

In order to assess ENSO simulations it is important to go beyond the NINO3 SST statistics and adopt metrics that can bridge GCMs, observations and theory. In order to improve model formulation, focused fields experiments are very helpful (VOCALS, SPICE…). Multi-decadal global-scale observations of upper ocean/lower atmosphere are today the limiting factors to understand model diversity.

The community is proposing a set of well-observed metrics (easy to compute) and a set of more sophisticated, mechanism-based, metrics to be used as standard "ENSO assessment". This represents a promising path both to understand modelled ENSO errors and to help GCM developers to get it right for the right reasons.

The structure of the ENSO metrics should be:

- A tree of recommended metrics/diagnostics, with clear paths bridging the simple and the sophisticated.
- Concise, physically informative, societally relevant, and easy to understand, compute, and compare.

As an example, the information tree for NINO3 SST (in order of increasing sophistication) might grow like this:

  - climatological annual mean (a single scalar)

- climatological annual cycle (12 months) leading to the climatological standard deviation
- time series statistics: anomaly standard deviation, skewness, phase locking, autocorrelation
- wavelet decomposition leading to time-mean spectrum, ENSO modulation
- correlation with other time series (e.g. NINO4 zonal wind stress).

A small group will be in charge of defining a first list of metrics and applying them to a set of observations. A white paper will be distributed to the community and PP members' feedbacks are sought.

ACTION 18. Provide feedbacks on list of ENSO indices. Help distribute the information through the PP webpage (E. Guilyardi, M. Balmaseda, D. Neelin, A. Clement, A. Timmermann and B. Boscolo)

ACTION 19. Establish interactions with the ENSO metrics project (E. Guilyardi, W. Cai, S. Power and C. Zhang)

Kon-Tiki: Pacific Modelling experiment proposal

CLIVAR/WGOMD is about to discuss an experimental setup to assess ocean model performance in the representation of inter-annual variability. GCMs have large errors in the Pacific basin and ENSO, and large uncertainty about the causes. In the last WGOMD meeting in Bergen, it was suggested to conduct, in addition to the WGOMD Core II main experiment, a series of sensitivity ocean-only experiments should be carried out that could give guidance on which elements are key for improvement of Pacific Ocean climate simulations. There are known model deficiencies in the representation of the Pacific Ocean climate:

- Upwelling off the South American Coast (winds, resolution…?)
- Cold tongue penetrating too far west (winds? momentum mixing…?)
- Too weak/too strong east-west slope of the thermocline
- Equatorial heat content (IT/meridional transport, vertical mixing

Is it possible to say which are the dominant sources of error: forcing fields, model parameterizations/configuration, model resolution, parameterization of air-sea interaction? WGOMD have suggested conducting a long ocean model simulation (20-40 years) with a variety of models, using inter-annually varying atmospheric forcing. This will be the main set of Core II integration. This set of long integrations can be used as:

- a reference experiment to diagnose and answer some of the above questions (see later)
- and potentially as initial conditions for concerted seasonal forecast experiments

Additional integrations, with each model if possible (not compulsory), should be done to test sensitivities. The sensitivity experiments can be done and diagnosed within each group without need of large "data" transfer volumes. It would be interesting to measure the sensitivities both in the mean state and in the interannual variability. It is suggested that each basin panel could perform such experiments:
- Kon-Tiki for the Pacific
- Ra for the Atlantic
- Trigris for the Indian

Some groups have already done some sensitivity experiments; for them it will be a matter of further exploitation of results and addition of new sensitivities. There is the hope that other modelling groups will follow. To aid this, the PP panel is willing to provide a list of relevant aspects to explore and measures for validation.

ACTION 20. Promote Kon-Tiki, i.e. sensitivity experiments with ocean models, in collaboration with WGOMD (M. Balmaseda and R. Boscolo)

Reports from PICES and from Arctic decadal climate research

(a) PICES

The North Pacific Marine Science Organization (PICES, http://www.pices.int/), an intergovernmental scientific organization, was established in 1992 to promote and coordinate marine research in the northern North Pacific and adjacent seas. Its present members are Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation, and the United States of America.

PICES is starting a new science program: Forecasting and Understanding Trends, Uncertainty and Response of North Pacific Marine Ecosystem (FUTURE). The vision is to understand and forecast responses of North Pacific marine ecosystems to climate change and human activities at basin-wide and regional scales, and to broadly communicate this scientific information to countries members, governments, resource managers, stakeholders and the public. How does ecosystem structure and function determine an ecosystem's response to natural and anthropogenic forcing?

How do physical and chemical processes respond to natural and anthropogenic forcing and how are ecosystems likely to respond to these changes in abiotic processes? How do human activities impact coastal marine ecosystems and their interactions with offshore and terrestrial systems?

The deliverables are regional-scale atmospheric and oceanic physical models to develop climate change scenarios at spatial and temporal scales that are relevant to both ecosystem process research and to marine resource policy development. Mathematical simulation experiments will use eddy-resolving models to understand the role of mesoscale eddies in transporting heat, water, chemicals and organisms. Fine-scale models will be developed, especially for coastal or limited areas of open oceans. Ecosystem models with multiple trophic levels will be used to evaluate management strategies. Individual based model (IBM) approaches will be linked to eddy-resolving ocean circulation models to understand the mechanisms of species dynamics and to forecast the consequences of anthropogenic forcing. Regional atmospheric and oceanic models will be downscaled from global model output using numerical and/or statistical techniques. Forecasts of marine ecosystems on multi-decadal or century timescales will be developed using global climate model projections or regional climate/ocean model outputs.

PICES needs strong connections to atmospheric and oceanic scientists who study larger regions, either the entire Pacific or global climate scientists. It also needs ongoing insight on how the North Pacific responds to global climate change and variability, and on how it might drive climate change and variability. It is important, therefore that CLIVAR Pacific scientists participate in PICES annual meetings to provide large scale climate insight. It was suggested the CLIVAR PP propose a session on Tropical Pacific teleconnections to PICES Region at the PICES Annual Meeting in 2009 (in Rep. Korea). This could be done at the next PICES Annual Meeting in Dalian, China, October 23 to November 2, 2008.

(b) Arctic decadal climate research

The International Polar Year (www.ipy.org) is a large scientific programme focused on the Arctic and the Antarctic from March 2007 to March 2009. IPY, organized through the International Council for Science (ICSU) and the World Meteorological Organization (WMO), is actually the fourth polar year, following those in 1882-3, 1932-3, and 1957-8. In order to have full and equal coverage of both the Arctic and the Antarctic, IPY 2007-8 covers two full annual cycles from March 2007 to March 2009 and involves over 200 projects, with thousands of scientists from over 60 nations examining a wide range of physical, biological and social research topics.

As of September 1, analyses by Environment Canada indicated a major reduction of the sea ice cover over the Northern Hemisphere extending from Eurasia into the central part of the Arctic Ocean. Sea ice cover has reached the lowest level in more than 50 years (since reliable sea ice records have been available) and is still decreasing. This major decline in sea ice extent is consistent with the general consensus in the sea ice community that the loss of sea ice is accelerating and anthropogenic climate warming is one of the main causes. The scientists observed less perennial ice cover in March 2007 than ever before, with the thick ice confined to the Arctic Ocean north of Canada. Consequently, the Arctic Ocean was dominated by thinner seasonal ice that melts faster. This ice is more easily compressed and responds more quickly to being pushed out of the Arctic by winds. Those conditions facilitated the ice loss, leading to this year's record low amount of total Arctic sea ice. Key questions are whether atmosphere-ocean models can simulate such changes over the decadal timescale including, relevant to PP interest, the teleconnections between the tropics and the Arctic (and Antarctic) and any changes in the throughflow of Pacific waters to the Arctic via the Bering Strait.

Recommendations and Actions from the South Pacific workshop

A workshop on the South Pacific was held at the University of Concepción, Chile, from 11 to 14 October 2005. The workshop was solicited by the CLIVAR Pacific panel, approved by the CLIVAR SSG and arranged in coordination with OOPC and the Argo Programme. The main objectives of the workshop were:

- To review our present understanding of the role of the South Pacific in seasonal to decadal variability of the climate system.
- To assess the adequacy of present day climate models to capture the essential physics and observational networks to monitor climate variability and change, and propose the needs of future numerical experimentation
- To assess the influence of South Pacific on the South American and Australasian climate
- To support and help coordinate existing and beginning climate observing efforts, and build associated partnerships
- To identify deployment opportunities for the observing network, e.g. Argo floats
- To identify where the existing observing network spanning the South Pacific needs to be supplemented (such as the location of GLOSS tide gauges)
- To look for coordination of CLIVAR activities with other programmes in the South Pacific, such as Carbon, SOLAS and IMBER.

The report of the workshop is available at:
http://eprints.soton.ac.uk/47496/01/116_S_Pacific_Wshop.pdf

A few of the formulated recommendations were revisited:

1) Review literature describing decadal variability in the South Pacific, its cause and predictability. Although a literature review article has not been written, a lot of progress has been made in terms of linking the South Pacific circulation with (i) subtropical circulations in other oceans (see Rommich 2007, Nature http://www.nature.com/nature/journal/v449/n7158/pdf/449034a.pdf, and Ridgeway and Dunn 2007, GRL doi:10.1029/2007GL030392) and (ii) the North Atlantic overturning circulation (Speich et al. 2007, The Atlantic Meridional Overturning and the Southern Hemisphere Supergyre, GRL, in press). A rather comprehensive review is also provided in the SPICE science plan.

2) Explore possible collaboration between the Pacific Panel, CLIVAR's Variability of the American Monsoon System Panel (VAMOS) and WGSIP to jointly develop a strategy to address the influence of air sea interactions on the predictability of the South Pacific climate, making use of numerical experiments already made by WGSIP and by other modelling groups. Possible contact with WGCM should be also

considered. The suggestion was made at the Chile meeting to test assumptions made in operational statistical forecast systems used to predict South American seasonal climate anomalies by examining inter-relationships between SST patterns and South American climate in AGCMs (SST forced and coupled to mixed layers). Carolina Vera was going to examine feasibility, possibly try and get funding to pursue, and discuss the possibility of tapping in to experiments that had been done already with Ben Kirtman. Progress with this is unknown and seemed to be dependent on securing new funds.

3) Report on the recommendation of repeat of transect at 85W to participants of the International Repeat Hydrography Workshop. Nico Caltabiano took this matter to the International Repeat Hydrography Workshop but it seems that there is no commitment from any country to re- occupy this line. An International Hydrography Advisory Group has been formed with CLIVAR and IOCCP participants (Bernadette Sloyan and Masao Fukasawa are CLIVAR representatives). Nico Caltabiano will raise this issue again at their next meeting

Review of CLIVAR roadmap: modes of climate variability

Building on the outcome of the 1st International CLIVAR Science conference and the assessment of progress carried out at the CLIVAR SSG-13, the SSG-14 sought the development of a CLIVAR Forward Look against the key cross cutting themes:

- ENSO and other modes of tropical variability (TAV)
- Monsoon
- Decadal Variability and the thermohaline circulation
- Anthropogenic climate change

Special attention was given to initial thoughts on the CLIVAR legacy.

The immediate (2007) priority paths for ENSO & TAV are:

- Enhanced Monitoring arrays (Indian basin-wide array, ITF, PIRATA enhancement; 4 TAO flux reference sites; TAO surface salinity array). Encourage GOOS, GCOS, GEOSS to sustain ocean observations.
- Coordinate experiments to address causes/robustness of model biases (cold/warm biases; extent of SST anomalies; double ITCZ; zonal gradient of Atlantic SST; ENSO)
- Evaluate AR4 and 20th century runs of coupled models against observations (indices, metrics, synthesis products)
- Establish connections between modes (MJO <-> IOZDM & ENSO; IOZDM -> **WWB -> ENSO** -> IOZDM) in AR4 models

The identified targets for 2010 are:

- Sustain ocean observing system
- Reduced model biases: identification of key indices/metrics for model evaluation; evaluation of models (those in AR4 as well as operational forecast models); robustness of mechanisms and global teleconnections in models; comparisons with observations
- Evaluation of predictability of TAV, Indian Ocean modes and both weak and strong events in the Pacific
- Evaluation of tropical Atlantic heat budget and subsurface heat content
- Evaluation of mechanisms of tropical mode variability and global connections of patterns of variability (ENSO, SAM, TAV, AMO, IOZDM).
- Improved coupled initialization for subseasonal and seasonal forecast systems
- Evaluation of feasibility of (requirements for) OSEs and OSSEs for coupled prediction systems
- Development of experimental decadal prediction systems (our charge is the Pacific)

The overall aims by 2013 are:

- Sustain observing system
- Improved ENSO and other tropical mode variability and their global teleconnections in AR5 models
- Improved understanding of intraseasonal variability and predictability leading to improved representation in coupled models
- Improved seasonal predictions of TAV
- Operational decadal thermocline anomaly predictions
- Experimental decadal predictions with comprehensive Earth system models in a multi-model framework
- Involvement in follow-up program of CLIVAR

How do we ensure progress and accountability on the Roadmap? A. Timmermann put forward the concept of "Legacy Managers". He identified 4 themes for the Pacific legacy and the associated leaders:

- **Decadal Predictions**. Experimental predictions 10-year AR4 forecasts for the Pacific (B. Qiu, W. Cai, S, Power)
- **ENSO dynamics and prediction**. Better initialization, interactions (WWBs, DCV, climate change, Atlantic, annual cycle…) and reduction of model biases (A. Timmermann, M. Balmaseda, S. Power, A. Clement)
- **South-Pacific (SP) climate, variability and predictability**. Better understanding of SP, SPCZ, boundary currents, decadal predictability (A. Ganachaud, S. Power, W. Cai)
- **Enhanced observing system for seasonal and decadal prediction** (T. Suga)

ACTION 21. Form subgroups to work on CLIVAR Pacific Ocean legacy (A. Timmermann, S. Power, W. Cai and A. Ganachaud)

Several activities promoted by the PP are towards the achievement of the CLIVAR legacy:

- Report on ENSO metrics being prepared to provide guidance on diagnosing ENSO characteristics in CGCMs
- Advance planning with AAMP, TFSP, WGSIP to examine role of MJO in onset of 1997 El Nino
- A major coordinated observational effort to improve understanding of SPCZ…. (long-term perspectives)
- Jointly with WGOMD propose Kon-Tiki Pacific Ocean modelling experiment as part of CORE-II to assess ocean model biases
- Finalise simple decadal prediction system for Pacific thermocline, timeline by 2010
- Examine decadal variability and predictability in CGCMs, completion by mid 2010
- Examine decadal projections in CMIP3/IPCC AR4 models
- Discuss with WGCM and WGOMD experiments and their coordination to identify and reduce CM errors in tropical and South Pacific

CLIVAR Pacific Panel Initiatives on ENSO

The CLIVAR Pacific panel has developed an ENSO expert prediction site (http://apdrc.soest.hawaii.edu/ENSO/). This website is designed to assess the current knowledge (and its uncertainty) on the evolution of ENSO several seasons in advance. ENSO experts are invited to submit their 3, 6, 9, and 12 month forecasts for the Niño3.4 sea surface temperature anomaly (SSTA). Some of the forecasts submitted will be based on dynamical or statistical modeling results, whereas others will reflect the physical understanding, experience and intuition of the ENSO experts. It is this blend of information that we hope will help to improve the forecasting horizon of ENSO. The goals of this experimental website are:

1. to provide probabilistic seasonal ENSO forecasts from the ENSO community;
2. to assess whether a multi-expert-ensemble forecast can help to improve ENSO forecasting skill compared to conventional forecasting approaches;

3. to assess how well we understand the processes leading to the evolution of El Niño or La Niña events.

This website will be operated for two years in an experimental mode, without public access. Every year a statistical analysis and evaluation of the skill and performance will be made. The forecasting data will be released in the second year and the website will be made accessible to the general public.

An ENSO summer school is planned for June 2008 in Puna, Big Island Hawaii. The school will address key scientific questions on ENSO dynamics and predictability and aims at training the next generation of scientists that will continue to do ENSO-relevant research.
The Summer School Objectives are:

- to train the next generation of climate scientists in ENSO dynamics and forecasting
- to establish a new network of outstanding young scientists to tackle the unresolved questions of ENSO dynamics
- to provide high quality supervision for international PhD students in the field of climate dynamics

Leading ENSO experts will offer hands-on classes on ENSO research, the topics covered will include:

- ENSO theory (*Lecturers:* Fei-Fei Jin and Axel Timmermann, UH, USA)
- ENSO phenomenology: from observations to predictions (*Lecturer:* Mike McPhaden, PMEL, USA)
- Predictability theory (*Lecturer:* Richard Kleeman, NYU, USA)
- Operational ENSO forecasting (*Lecturer:* Magdalena Balmaseda, ECWMF, UK)
- Decadal variability and longer term changes in ENSO and the tropical Pacific (*Lecturer:* Scott Power, BMRC)

WCRP, IPRC, NOAA and EU/LOCEAN have confirmed their support to the school however further funding is sought. Institutions in Latin America, Australia, USA and UK plan to support 1 or 2 students to attend the school

ACTION 22. Put the information on the ENSO summer school in 2008 on the webpage and approach potential funders (A. Timmermann, S. Power, B. Qiu and R. Boscolo)

Reports from WCRP JSC-28, CLIVAR SSG-15 and the next Pacific Panel meeting

The 28th session of the WCRP Joint Scientific Committee, held in March 2007, reviewed progress in implementing its Strategic Framework 2005-2015 (see report at http://wcrp.wmo.int/documents/jsc28report.pdf). Implementation of the WCRP Strategic Framework focuses in part on cross-cutting issues aimed at meeting society's and stakeholder's needs, specifically:

- Anthropogenic Climate Change
- Atmospheric Chemistry and Climate
- Monsoons and the Year of Tropical Convection
- Decadal Prediction
- Extreme Climate Events
- International Polar Year
- Sea-level Rise
- Seasonal Prediction

These cross-cutting themes are intended to provide integration between the projects and key areas across WCRP. CLIVAR will take the lead for Seasonal and Decadal predictions and shares responsibilities on Monsoon and Extreme Events. As a result of introducing cross-cutting activities within WCRP and a further cut in sponsor support, the total budget allocated to

CLIVAR activities will be reduced considerably (to about 1/4) for the period 2008-9. In this financial framework the CLIVAR SSG co-chairs urged the ICPO and the Panels/WGs to introduce a new modus operandi. At the last CLIVAR SSG meeting (SSG-15, September 2007) it was suggested to hold meetings at margins of workshops/conference, to attract national support and to supplement per diem with other funds. It was also proposed to continue with the present structure (13 panels/WGs in total) till 2010 and then to restructure the organization in order to address the final analysis and assessment phase.

The SSG-15 recommended holding the 2nd CLIVAR Science conference in 2011 and organizing a farewell-symposium in 2013. All the Panels and WGs should provide an assessment of their achievements and identification of major outstanding questions at the 2nd science conference.

The Pacific Panel expressed concerns on the lack of guidance and feedback on the panel issues that Scott Power presented at the SSG-15 meeting. In particular on the need of a co-chair to complement A. Timmerman's expertises and on SPICE endorsement.

> **ACTION 23.** Solicit more feedbacks on the discussions/decisions that took place at last SSG meeting (A. Timmermann and S. Power)

For the next meeting of the Pacific Panel it was suggested to explore a venue in Australia and to follow the successful organization in Guangzhou.

> **ACTION 24.** Explore the possibility to hold next Panel Meeting in Australia in October 2009 together with a workshop (W. Cai and R. Boscolo)

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APPENDIX B. Agenda

Day 1: Thursday 29th November 2007

8:30 - 8:50	Welcoming and local arrangements (*A. Timmermann and D. Wang*)
8:50 - 9:20	International Coordination SPICE-NPOCE-PACSWIN (*A. Ganachaud, D. Hu and J. You)*
9:20 – 9:40	NPOCE and Chinese Observational Programs *(D. Hu*)
9:40 – 10:00	PACSWIN initiative *(J. You)*
10:00 - 10:45	SPICE Science and Implementation plans (*A. Ganachaud*)
10:45 - 11:15	Tea Break
11:15 - 11:40	Western and eastern Pacific control on SPCZ (*R. Mechoso*)
11:30 – 11:50	The role of the SPCZ on the south Pacific climate (*S. Power*)
11:50 – 12:15	ENSO Stocasticity: Proposal on Review Paper (*A. Timmermann*)
12:15 – 12:30	AAMP-PP interactions (*H. Hendon*)
12:30 - 14:00	Lunch
14:00 – 14:45	KESS science highlights (*B. Qiu*)
14:45-15:30	VOCALS: improving our understanding for the eastern tropical Pacific (*R. Mechoso*)
15:30 - 16:00	Tea Break
16:00 - 16:45	Climate Change Projections, 2010-2030, for the Pacific *(S. Power and W. Cai)*
16:45 – 17:30	Applications for decadal predictions (*R. Martinez and B. Crawford*)
17:30	Adjourn

Day 2: Friday 30th November 2007

9:00 – 9:45	Improving seasonal and decadal predictions**:** Ocean Initialization: (*T. Suga and M. Balmaseda*)
9:45 – 10:10	How seasonal predictions are used (*R. Martinez*)
10:10 - 10:30	Ocean model intercomparison for the Pacific: what are the key model deficiencies? (*M. Balmaseda*)
10:30 - 11:00	Tea Break
11:00 – 11:30	Report from the CLIVAR/GSOP assimilation comparison workshop (*M. Balmaseda*)
11:30 – 12:00	Ocean Acidification and links to IMBER (A. Timmermann)
12:00 – 12: 30	ENSO metrics (*E. Guilyardi*)
12:30 - 14:00	Lunch
14:00 – 14:20	KON-TIKI Project and links to WGOMD *(M. Balmaseda)*
14:20 - 14:40	Reports from PICES and from Arctic decadal climate research (*B. Crawford*)
14:40 - 15:00	Follow up South Pacific workshop recommendations and actions (*W. Cai and A. Ganachaud*)
15:00 – 15:30	CLIVAR roadmap: modes of climate variability (*A. Timmermann*)
15:30 - 16:00	Tea Break
16:00 - 16:20	CLIVAR Pacific Panel ENSO Initiatives (*A. Timmermann*)

16:20 – 17:30	Panel Business Session
	Future Pacific Panel operations: budget considerations (*R. Boscolo and S. Power*)
	Report from SSG-15 (*R. Boscolo and S. Power*
	Panel membership and Next meeting
17:30	End of the Meeting

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