CLIVAR/OOPC/Argo/GOOS/CPPS workshop on the South Pacific

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Executive Summary

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 organized through the committees identified at Appendix A. It was arranged in coordination with OOPC and the Argo Programme, and it was sponsored financially by WCRP, US CLIVAR, GOOS/OOPC and Argo.

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 4-day meeting was open to the community and had a very good attendance with 59 participants from 13 different countries (see Appendix C). It 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. A complete meeting agenda is provided in Appendix B. Participants abstracts of their oral or poster presentations are provided in Appendix D. In addition to these sessions, participants took part in working groups which discussed aspects related to basin and regional scale issues. There was also a working group which discussed the observing network in the region.

Air-sea interaction in the South Pacific was identified as being a critical factor in forecast systems for South America. This is an interesting area to pursue, and a possible area for future strong collaboration between CLIVAR's Pacific Panel, its Variability of the American MOnsoon System (VAMOS) panel, and its Working Group on Seasonal to Interannual Prediction (WGSIP). In particular, model experiments were proposed that would address the role of Central South Pacific (CSP) sea surface temperatures (SSTs) in driving atmospheric changes over South America, and how these SST changes are related to tropical SSTs.

Two process studies in the Pacific area of great relevance to the South Pacific were presented. The first was the Pacific Upwelling and Mixing Physics (PUMP) experiment, which is organized under US CLIVAR and designed to improve the understanding of the complex of mechanisms that connect the thermocline to the surface in the equatorial Pacific cold tongue. Its goal is to observe and understand the interaction of upwelling and mixing with the larger-scale equatorial current system. The outcome of PUMP will be advancements in our ability to diagnose and model both the mean state of the coupled climate system in the tropics and its interannual and interdecadal variability. The second study was the Southwest Pacific Circulation and climate Experiment (SPICE). SPICE reflects a strong sense that progress to perform a regionally-coordinated experiment to measure, study and monitor the ocean circulation, and to improve and validate numerical models of the southwest Pacific region can only be made through collaboration among South Pacific national research groups, and should be fully coordinated with the broader South Pacific projects. Both projects are still in

the planning stages but were strongly encouraged to continue to pursue funding due to their importance for the region and general oceanographic knowledge that will provide.

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 was 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 of any additional sustained program that would enable a long term study of the eastern boundary current's impact on the South American continent.

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 deployments by the US Argo program. The University of Concepción (UdeC) presently has 30 profiling floats in their inventory, which include dissolved oxygen sensors. Because the areas targeted by UdeC might have some overlap with the ones targeted by US, it was recommended that a close interaction should be undertaken between the UdeC and the US Argo, with oversight from the 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. Considerable discussion also centred on the utility of gliders equipped with CTDs to sample the strong currents in the coastal zone. This discussion also noted that Argo floats are not very well suited to monitoring flow in boundary currents, but gliders are ideally suited. Gliders are poorly suited to sampling many locations in distant parts of the ocean, so there appears to be complementary features between these two systems.

The main outcomes of the workshop were proposals to review the current knowledge of the decadal variability in the South Pacific region, to explore a possible collaboration between the Pacific Panel, VAMOS and WGSIP to jointly develop a strategy to address air-sea interaction making use of numerical experiments, and to develop investigations of the eastern boundary of the South Pacific in association with the Pacific Panel and VOCALS. In relation to the observing system in the region, joint efforts for deployment of Argo floats in the region were agreed, in addition to encourage use of new observational technology, such as the use of gliders.

LIST OF RECOMMENDATIONS AND ACTIONS

RECOMMENDATION - Review literature describing decadal variability in the South Pacific, its cause and predictability **(Scott Power, Niklas Schneider, Oscar Pizzaro, Wenju Cai, Ben Giese, Josh Willis)**

RECOMMENDATION - Explore a 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 this scientific issue making use of numerical experiments already made by WGSIP and by other modelling groups. Possible contact with WGCM should be also considered **(Scott Power, Carolina Vera, and Tercio Ambrizzi)**

RECOMMENDATION: – Further develop the proposal for investigation of the eastern boundary of the South Pacific in association with the Pacific Panel and VOCALS **(Oscar Pizzarro, Billy Kessler)**

ACTION - Track Argo deployment by UdeC and follow recommendation to deploy floats in areas with gaps **(Oscar Pizzarro)**

ACTION – Take offers of deployment opportunities to the Argo Executive and Steering Team **(Howard Freeland)**

ACTION – Report the suggestion of addition of SST to the standard Argo float mission to the Argo Executive and Steering Team **(Howard Freeland)**

ACTION – Report on the recommendation of repeat of transect at 85W to participants of the International Repeat Hydrography Workshop **(Nico Caltabiano)**

RECOMMENDATION – SHOA to submit data from Valparaiso-Juan Fernandez surveys to CCHDO **(Steve Diggs and Ricardo Rojas)**

1. Introduction

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 organized through the committees identified at Appendix A. It was arranged in coordination with OOPC and the Argo Programme, and it was sponsored financially by WCRP, US CLIVAR, GOOS/OOPC and Argo.

2. Motivation, Scientific Background and Objectives of the Workshop

Central to the objectives of CLIVAR are an improved understanding of climate variability on timescales out to decadal and improved predictions of seasonal to interannual variability on regional and global scales. Achieving CLIVAR objectives requires a combination of coupled models that capture the essential physics and an observational network that samples the appropriate spatial and temporal scales. The workshop focused on the South Pacific was aimed at bringing together these two elements from a regional perspective.

Pacific Decadal Variability (PDV), of which the Pacific Decadal Oscillation (PDO) is a part, is known to have impacts on climate variability over the South Pacific Ocean, Australasia and South America. Progress has been made in elucidating the factors that influence the spatial and temporal patterns of decadal variability in the North Pacific. Much less is known about the South Pacific, in part because of the limited sampling of the ocean. What drives decadal variability in the South Pacific and to what extent can it be predicted? What fraction of PDV in the South Pacific is connected with ENSO? The Interdecadal Pacific Oscillation (IPO) is known to extend into the South Pacific, but its cause, its links to the El Niño-Southerm Oscillation (ENSO), and its predictability have not been fully elucidated. Looking more specifically, does variability of the East Australian Current have a major influence on PDV, and what role does the South Pacific Convergence Zone play? And what is the connection between PDV and the Southern Ocean?

Recent analysis of observations and modelling studies suggest that the subtropical South Pacific may play a key role in the decadal variation of ENSO through changes in the subtropical cell. But again key questions remain. What factors influence the ocean/atmosphere interactions that drive changes in the subtropical cell? How important are changes in subduction and the subtropical cell in driving changes in ENSO and the Pacific generally? Do the decadal changes drive SST changes that underpin important atmospheric teleconnections over Australasia or South America? What can the models tell us about these processes?

The South Pacific has been rather poorly sampled by the observational network. There have been recent efforts to increase deployments by the surface drifter program and the Argo float program in the South Pacific, but continuing attention on development of the climate observing system in the South Pacific is needed. The South Pacific impinges directly on the regional climates of Australia and South America. Improvements in both the monitoring system and coupled models have the potential to improve the skill of seasonal to interannual forecasts for these regions.

Results from multi-model climate hindcast experiments are becoming available through programmes such as the Seasonal Modelling Intercomparison Project (SMIP), DEMETER and the Coupled Model Intercomparison project (CMIP) and the ocean only model comparison Coordinated Ocean and sea ice Reference Experiment (CORE). Results from Argo floats deployed in the last 18 months in the South Pacific will be available and will provide valuable data on the evolution and spatial structure of the seasonal thermocline. Observations taken during EPIC have documented the cloud and boundary layer structure in the SE Pacific. A WHOI IMET buoy is providing valuable long-term flux data.

In addition, capacity and interest in climate observations in countries in South America continues to develop. A key motivation for this workshop was therefore to promote both the benefits of climate research in these countries and the contribution they can make to the international effort. Overall workshop objectives were as follows:

- 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 the South Pacific on 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

3. Structure of the Workshop

The 4-day meeting was open to the community and had a very good attendance with 59 participants from 13 different countries. The Workshop was structured around four sessions on Climate, Regional Impacts, Prediction and Predictability, and the Observing System. For each there was a series of invited presentations, interspersed with discussion-sessions to develop crosscutting ideas and consensus. Poster Sessions were organized to allow additional contributions. Two working groups were formed for further discussion on basin-scale and regional issues and to formulate recommendations for future scientific plans in the South Pacific. The last two days of the meeting were dedicated to the observing system in the region, with a special session on the impact the Argo Programme has had on monitoring the South Pacific. A third working group also made recommendations for increasing the observational capabilities in the region overall. Working groups and their leaders were, therefore, as follows:

WG1 – Basin-scale issues (Leaders: Scott Power, Bo Qiu)
WG2 – Regional Impacts (Leaders: Rene Garreaud, Yuqing Wang)
WG3 – Observing System (Leaders: Howard Freeland, Ben Giese)

A complete meeting agenda is provided in Annex B. Participant's abstracts, where available, are provided in Appendix D. The remainder of this report summarises the outcomes of the three working group discussions

4. The Working Groups Reports

4.1 Working Group 1: Basin-scale issues

This working group discussed a large number of issues that fell under five overarching areas:

1. What is the role of the South Pacific in the global climate system?
2. What causes variability in the South Pacific, and how predictable is the variability?
3. Does variability in the South Pacific drive important atmospheric responses (e.g. directly through South Pacific SSTs, by subsequently influencing the tropical Pacific?

4. What data issues stem from items 1-3?
5. On what basis should we make recommendations and what are these recommendations?

Important specific issues and uncertainties that need attention were identified as:

- Tropical –subtropical connections
    - Spiciness – subduction, how are anomalies advected? Do the anomalies influence the tropics? Do anomalies survive the journey e.g. through Western Boundary Current regions?
    - How important are the various dynamical connections (internal waves, changes in and advection by the sub-tropical cells and Western Boundary Currents)?
    - Clarification of intermediate water formation processes in the South Pacific and the influence that this water has in setting equatorial ocean climate. Does variability in intermediate water formation influence the position of the gyre boundary?
    - Has intermediate water become shallower, warmer and fresher?

There are also clear questions concerning decadal variability in the South Pacific, in particular related to ENSO and East Australian Current decadal variability and how predictable the decadal variability in the South Pacific is in coupled GCMs?

RECOMMENDATION - Review literature describing decadal variability in the South Pacific, its cause and predictability (Scott Power, Niklas Schneider, Oscar Pizzaro, Wenju Cai, Ben Giese, Josh Willis)

The emergence of new data sets in recent times was stated to be very welcome, though the need for verification and more accurate surface flux data remains a high priority. There is however a continuing requirement to have long historical records and sustained observing systems into the future to characterize decadal variability and longer term trends. The group noted that emerging and existing South Pacific data sets need to be in formats that can be readily analysed and accessed (in particular put Argo data on to density surfaces). There is also a need for improved coordination of regional datasets and improvements to their availability. It would also be useful to have error bars available on e.g. SST products so we know how seriously to take the variability in the data as some of it might be very unreliable/spurious – especially pre 1950.

The influence of air-sea interaction in the South Pacific on Climate predictability was a topic of heavy discussion. To what extent are Southern Hemisphere teleconnection patterns and frequencies, the SPCZ, and upper ocean conditions determined by air-sea interaction in the South Pacific? There is a need to check if there is good physical understanding of the physical validation of statistical prediction schemes used in models in this region. Given the potential importance of air-sea coupling in the South Pacific to climate variability over e.g. South America, the meeting noted with interest the experiments proposed by Ben Kirtman (COLA and co-chair of CLIVAR's Working Group on Seasonal to Interannual Prediction, WGSIP) to examine extratropical air-sea coupling in AGCM-mixed layer/slab runs. Contact will be made with Dr Kirtman and the results of the experimentation, when they become available, should be discussed by VAMOS and the Pacific Panel

RECOMMENDATION: - Explore a 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 this scientific issue making use of numerical experiments already made by WGSIP and by other modelling groups. Possible contact with WGCM should be also considered. (Scott Power, Carolina Vera, and Tercio Ambrizzi)

Regarding the interaction between ITCZ and the Pacific cold tongue, why cannot global models simulate the cloud decks very well? Why do some regional models seem to de a better job? Can we learn how to improve the simulation of the cloud decks in global models from regional studies? Are things intricately balanced in deck regions and is fine tuning of existing physics packages in AGCMs/CGCMs sufficient to produce a good simulation or is the problem more fundamental than this? There is a need to improve our understanding of the processes that cause cloud-decks, and consequently, the simulation of interactions among SPCZ, ITCZ and stratocumulus decks. How well are these interactions simulated? This is a particular important problem since forecast skill in this region can have large implications over countries in the region. The VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) is a key upcoming programme in this respect.

There is a need for improvement in our understanding of the vertical structure of the eastern South Pacific Ocean, the upwelling, wave processes and the seasonal cycle in the region, and the connections this region has with the equatorial ocean-atmosphere system. It has been noted that the South Pacific Gyre has changed in recent decades and that this appears to have influenced the temperature structure of the South Pacific. The changes appear to have been driven by changes in the Southern Annual Mode (SAM). Changes in SAM can be driven internally and in response to changes in atmospheric ozone and greenhouse gases. A more detailed understanding of these processes is desirable. A proposal (see Annex A below) was put forward for investigating oceanographic processes in the eastern boundary of the South Pacific.

RECOMMENDATION: – Further develop the proposal outlined below for investigation of the eastern boundary of the South Pacific in association with the Pacific Panel and VOCALS (Oscar Pizzarro, Billy Kessler)

Annex A. Proposal for an investigation of the eastern boundary of the South Pacific

The eastern South Pacific comprises one of the most important upwelling regions of the world ocean. Here, cold waters, rich in nutrients and greenhouse gases (CO_2 and N_2O) are transported to the surface where they interact with the lower atmosphere exchanging heat, gas and momentum. Upwelling favourable winds drive an energetic alongshore jet that flows meandering along a rather sharp thermal (and density) front that separates the cold, nutrient-rich, coastal waters from the warmer, and well stratified, oceanic ones. Mesoscale eddies originating in this region, together with direct Ekman drift, transport coastal waters toward the ocean interior interacting with the biology and the adjacent atmosphere.

One of the most productive marine systems on the world is related to this upwelling region, which sustains important pelagic fisheries with a large regional economic impact. It has recently been hypothesized that cold water from the Peru-Chile upwelling region plays a major role in the formation and maintenance of the largest and most persistent subtropical stratocumulus deck in the world (see the VOCALS program). This cloud deck is, in turn, a significant loss term in the global radiation budget.

The efficient propagation of equatorial and coastal Kelvin waves means that the west coast of South America is particularly sensitive to equatorial disturbances. The strong intraseasonal, interannual and interdecadal variability of the sea level, alongshore currents, SST and thermocline depth observed in the eastern South Pacific has been directly related to disturbances of equatorial origin. These perturbations may strongly modulate coastal upwelling impacting biological productivity, fisheries, air-sea heat

exchange, and precipitation in the coastal plain west of the Andes. At low frequency, like the energetic ENSO and interdecadal bands, thermocline depth (and heat) anomalies may propagate offshore as long Rossby waves, disturbing wider regions of the South Pacific.

A.1 Science topics/issues, needed observations and analysis:

A.1.1 Upwelling variability in the eastern South Pacific

1. Determine the vertical and offshore and meridional structure of the upwelling in response to wind anomalies.

   The principal observed quantity will be isotherm depth variability, in concert with local and remote wind fluctuations.

   The aim is to estimate upwelling transport variability based on detailed mapping of isotherm depth variations. This will enable diagnosis of the dynamical influences that modulate upwelling.

   Questions to be resolved include:
   a. What is the relation between the upwelling pattern and transport compared to local winds?
   b. How deep does upwelling penetrate? (in depth and in relation to isopycnals)
   c. What is its offshore scale?
   d. How does it depend on background stratification (which can change due to remote forcing)?
   e. How does it depend on frequency (high-frequency wind events to annual to interannual)?
   f. How fast does the upwelling spin up in response to wind anomalies? Does this have a meridional structure?
   g. Is the near-coastal variability correlated along the coast (southern Chile to Peru to Ecuador)?

2. Diagnose the dynamical and property transport influences on the region, and that radiate outward from the region.

   a. Determine the sources of the upwelled water.
   b. Trace the outcropping quantities back along geostrophic streamlines to their origin in the equatorial eastward flows (EUC, Tsuchiya Jets).
   c. Is property variability along the South American coast primarily wave-driven (i.e., thermocline depth fluctuations) or is there a signature of variability of property transport originating upstream?
   d. Ventilated thermocline theory suggests that the deep interior ocean is forced where isopycnals outcrop, which makes the South American coast a possible source of decadal variability of the subtropical gyre. Can these signals be observed or modelled?
   e. How far offshore do SST variations produced by upwelling extend? Are these extensions beyond the region directly influenced by upwelling driven by Rossby wave propagation, or by Ekman advection? Is there coupled feedback through SST modulation of the stratus decks?

A.1.2 Eastern boundary transport

Transport processes are crucial for low frequency ocean variability. A realistic quantification of large and regional gyre scales requires adequate estimations of the boundary flows, which can significantly vary at small space scales (10-100 km). In

particular, transport estimations along the South Pacific eastern boundary are rather uncertain. This region presents a complex current system, which is subject to a large interannual and interdecadal variability. Realistic estimations of water and property transport require both direct observations to fill a large gap of data in this poorly sampled region, and implementation of regional high-resolution models nested in global models to properly describe both the remote (e.g., ENSO) and locally-driven variability. There is thus a need to:

3. Enhance regional observations using new available technologies (satellite data analysis current meter moorings, gliders, Argo floats, etc…) in order to improve and update our understanding of the ocean circulation in the eastern South Pacific.

As part of an early observational initiative, slope and deep ocean current meter moorings are being maintained near 21ºS, 30ºS and 37ºS. These moorings are part of a long-term program that started in November 1991 with observations near 30ºS, except for relatively short gaps; long time series for this site are presently available. In fact, these current meter records are the longest existing time series from any eastern ocean boundary system. Further initiatives have been accomplished during the last 3 years to extend observations to northern and southern locations. Currently, three oceanic sites off northern and central Chile are maintained as part of the Peru-Chile Current observing system.

From a modelling perspective there is a need to:

4. Reinforce regional dynamical modelling covering space-time scales from intraseasonal to interannual, and from the regional to the mesoscale.

Presently, global ocean circulation models poorly reproduce mean circulation and ocean current variability along the eastern South Pacific. Boundary phenomena like upwelling and the associated poleward flows are very sensitive to the near shore topography and mass distribution. Similarly, coastally trapped waves, related to the important equatorial forcing, are also not well represented in global ocean models. On the other hand, coastal upwelling is very sensitive to the details of coastal wind stress and wind stress curl variability over the continental shelf, but this narrow band is not well resolved by satellite data nor from the sparse (and in many cases poorly exposed) coastal meteorological stations located along the Peruvian and Chilean coasts. High-resolution atmospheric numerical models, with proper boundary conditions (including realistic SST fields) are fundamental to simulate the coastal wind field correctly and consequently, for modelling upwelling variability along this region.

Cold upwelling waters off the western coast of South America, in combination with warm and dry air aloft, play a major role in the formation and maintenance of the large and persistent subtropical stratocumulus deck. This cloud deck may, in turn, support the permanence and large zonal extent of the low SST in the region. Time scales that dominate this feedback are rather unknown, and may include diurnal – one of the important scales for the upwelling – intraseasonal, and seasonal timescales, the timescales of large interannual disturbances associated with the El Niño-La Niña cycles, and subtler interdecadal variability. In addition, relevant spatial scales extend from mesoscale, characterizing the coastal upwelling and the energetic eddy field, to basin scales related to El Niño.

Global or large-scale model results, together with regional, high-resolution, coupled model experiments, may contribute to our ability to evaluate how SST variability feeds back to the cloud decks, and the main mechanisms and scales involved. This

modelling will help, in turn, to determine the shape of the needed observing system, where to put observations, and what scales need to be measured. On the other hand, observations will contribute by validating model results and may also be useful to improve regional simulations through data assimilation.

4.2 Working Group 2: Regional impacts

4.2.1. Scientific Issues

The Southeast Pacific is believed to be a key region for the equatorial tropical eastern Pacific mean climate, annual cycle and interannual variability. It has a long meridional coastline with the Andes upright up to about 4 km immediately to its east. The narrow Andes exert a large forcing on the coastal winds and act as a barrier to the mass/moisture exchanges between the South American continents and the Southeast Pacific. These regional features have an impact not only on the regional scales but also on the basin-scale circulation and variability through ocean-atmosphere interactions. Because of their small scales, these regional features cannot be properly represented in current state-of-the-art global coupled general circulation models (CGCMs). As a result, most CGCMs have considerable biases in the Southeast Pacific coastal region and the tropical eastern Pacific. These include a warm bias in the coastal region in the Southeast Pacific, westward displacement of the eastern Pacific cold tongue, double ITCZ in the eastern Pacific, etc. The features that are difficult for models to simulate in the region include the low clouds (stratocumulus/stratus) in the far eastern Pacific, the coastal winds, and the position of the eastern Pacific cool tongue, and their seasonal cycle. In addition to the resolution issue for CGCMs, the lack of understanding of many feedback processes involved in the air-sea interaction in the region and their realistic representation in models could be largely responsible for the systematic biases which appear in many CGCMs. Several relevant scientific issues are listed below:

a) What are the effects of the Andes on the coastal winds and low cloud deck over the Southeast Pacific? What is the consequence of the under-representation of the Andes in coupled climate models, and whether, how and to what degree this may affect the tropical biases in most CGCMs?
b) How does the low cloud deck interact with the ocean and atmospheric circulation? What determines its seasonal transition in cloud regimes and how are both the cloud deck itself and its regime transition represented in CGCMs?
c) Given the known biases in the eastern Pacific, what are their effects on both regional and global scale simulated climate and its variability?
d) What are the detailed mass exchanges in the coastal region and how important they are for the realistic simulation of SST?

To help address the above issues, the following need to be tackled.

Item 1. *To improve understanding and simulation of the coupling between the low cloud deck and upper-ocean over the Southeast Pacific at time-scales from diurnal to interannual.*

The Southeast Pacific stratus/stratocumulus cloud deck is poorly simulated in global models despite its importance in maintaining the latitudinal asymmetry of eastern Pacific climate and climate variability. The low-cloud deck displays considerable variability on various timescales, from diurnal, subseasonal to seasonal and interannual. Further analyses are required to identify the variability and the involved physical mechanisms. Atmosphere-only model simulations of cloud variability are another critical test of the realistic model response to SST forcing and large-scale circulation changes. Coupled, especially regional coupled, modelling could help understand the complex circulation-clouds-ocean feedback processes.

The marine boundary layer (MBL) structure and clouds exhibit a clear regime transition. Near

the coast off South America, the boundary layer is shallow with unbroken stratus under a strong inversion. Away from the coast toward the west the well-mixed boundary layer deepens in response to the increase in the underlying SSTs, and stratocumulus (SCu) clouds become dominant with patched or rolled structures. Both stratus and SCu clouds belong to the so-called *coupled cloud regime* as they form in the well-mixed MBL that couples the clouds to the surface turbulent fluxes. Further to the west, the inversion height increases, with a stable layer separating the mixed layer below and a cloud layer above. In this *decoupled cloud regime*, the upward transport of moisture by trade cumuli helps maintain the SCu cloud layer under the inversion. Here trade cumuli are also called *shallow convection* as their vertical development is limited by the inversion. The transition from the coupled to decoupled cloud regime was observed during the Atlantic Stratocumulus Transition Experiment (ASTEX) off the coast of West Africa and over the Northeast Pacific. There is some indirect evidence for such a cloud-regime transition in the subtropical Southeast Pacific but there have been no direct observations in the region.

This cloud regime transition is an important process for low cloud-SST interaction as cloudiness decreases from stratus, SCu, cumuli under SCu, to trade cumuli. Cloud regime transition takes place not only in space but also on various timescales. The daytime solar heating reduces turbulence generation at the cloud top, decoupling the cloud layer from the sea surface and causing a decrease in cloudiness. On the seasonal timescale, large SST warming in March-April possibly causes a shift in the coupled low cloud type to the decoupled regime with decreased cloud cover in much of the Southeast Pacific. This SST-induced transition in cloud regime is important to the seasonal cycle of tropical eastern Pacific and thus is a major topic which needs to be explored. The ability of climate models to simulate the regime transition needs to be assessed, while observations are needed to document the vertical structure of different cloud regimes for model verification.

VOCALS is a key CLIVAR programme aimed at addressing many of the issues identified above. It has planned a field campaign in the Southeast Pacific in October 2007. Its main theme is to better understand and simulate how marine boundary layer cloud systems surrounding the Americas interact with the coupled ocean-atmosphere-land system on diurnal to interannual timescales. This community is encouraged to participate in the VOCALS project to attack item 1 above.

Item 2. *To investigate the effects of the Andes on the coastal winds and low cloud deck over the Southeast Pacific and to assess the possible contribution of the under-representation of the Andes in the coupled climate models to the tropical biases in eastern Pacific in most CGCMs*

The high Andean mountains, as elevated heat sources and barriers for mass and moisture transport, can conceivably affect the Pacific climate by generating an along-shore low-level jet that favours oceanic upwelling and by modifying large-scale subsidence and the formation of stratus cloud deck to the west. These effects of the Andes may seem coastally trapped, but recent coupled ocean-atmosphere modelling studies have shown that such seemingly local effects can lead to basin-wide development of a northward-displaced ITCZ and a cold tongue near the equator, which are the defining features of the Pacific climate key to its seasonal cycle and interannual variability.

Despite their climatic importance, the Andes are poorly resolved in current coupled ocean-atmosphere general circulation models (CGCMs) whose grid size is typically 2-3 degrees, the same as the width of the mountain range. As a result, the effects of the Andes have not been adequately investigated and remain poorly understood in the coupled context.

Regional coupled models provide adequate tools for addressing the above issues. In particular by comparing regional atmosphere-only model results with those from large-scale atmosphere and coupled models, we can study the feedback processes due to the effect of

the Andes. We can also identify and study key processes/mechanisms by which the Andes affect the Pacific climate, in both uncoupled and coupled contexts. They include the southerly coastal jet, temperature inversion at the top of the planetary boundary layer and stratus cloud deck, and the interaction of these atmospheric features with the ocean through upwelling and surface heat flux. A group at IPRC is actively working in this area.

Item 3. *To assess the impact of a better representation of the Southeast Pacific coupled system on both regional and global climate simulations, in terms of not only climatology, but also variability, predictability and prediction skills.*

Current state-of-the-art CGCMs suffer from systematic bias in the tropical eastern Pacific. Most models simulate a too equatorially symmetric mean climate with poorly represented low-cloud deck, westward displaced cold tongue, too warm SST along the coastal region and double ITCZ. There is some evidence that most of these biases originate from bias in the coastal upwelling area and the representation of vertical mixing in the ocean. It is unlikely that the modelling community will be able to completely remove these biases in coupled climate models in the near future.

It is not clear to what degree and how these biases affect model simulations of climatology and climate variability either on regional or global scales. An assessment of their impacts is important because it is not clear to what degree our current simulation and prediction skills are limited by them. Some sensitivity experiments can be designed to address this issue both using regional and global coupled climate models. For example, the flux adjustment scheme can be applied in the tropical eastern Pacific to remove the systematic biases in the region. The results then can be compared with those without the regional flux adjustment with the latter supposedly involving considerable systematic biases in the region.

The group also discussed what would be the impact of coastal observations on ocean data assimilation schemes. The conclusion appears to be that nobody has looked yet. This would seem essential if we are to assess the utility of coastal observations in this region and the impact that the new glider technology can have.

Item 4. *To study the mean transport and variability of the heat budget of the Eastern Boundary Current System in the South Pacific.*

As indicated above, there is some evidence that most of the biases over the tropical eastern Pacific originate due to bias in the coastal upwelling area and the representation of vertical mixing in the ocean. Efforts to enhance our understanding of coastal ocean dynamics with the focus on the heat budget and ocean mixing process, as well as the interaction with the atmospheric boundary layer and the stratus cloud deck are thus recommended. Because of lack of adequate observations in the near coastal region, it is urgent to deploy buoys and also improve the network of atmospheric observations in the coastal region to provide data to improve our understanding and to verify model simulations and validate model physics parameterizations.

To attack this problem, the following observations are recommended:

a). Air-sea interaction buoys in the coastal strip (within 100 km off the coast) in the upwelling area: Central Peru – Central Chile, including atmospheric boundary layer observations.
b) Air-sea interaction transection cruises across the PBL transition zones between coastal stratus and SCu and between SCu and trade cumulus clouds (from the coast to 105ºW along 10ºS to 15ºS).
c). Enhancement of the coastal network of radiosonde/wind profilers along the west coast of South America to better define marine boundary layer and PBL transition across the coastline.

4.3 Working Group 3: South Pacific Observations

This working group discussed the needs for developing the ocean observing system in the South Pacific region.

A) Ocean structure:
A1) Argo
Argo was discussed at considerable length. It was noted with some pleasure that the University of Concepción (UdeC) presently has 30 profiling floats in their inventory: 10 APEX floats with Dissolved Oxygen and fluorescence and 20 PROVOR floats with Dissolved Oxygen sensors on board. The meeting appealed to UdeC to ensure that floats are deployed in areas where there are presently gaps in the South Pacific Argo array since US floats are about to be deployed in the same area being targeted by UdeC.

ACTION - Track Argo deployment by UdeC and follow recommendation to deploy floats in areas with gaps (Oscar Pizzarro)

Deployment strategies were discussed and offers were made by representatives of National Oceanographic Institutions from Peru, Chile, Ecuador and Colombia to contribute to Argo float deployment and increase interaction with Argo projects in the region. Howard Freeland will take these offers to the next Argo Executive and Steering Team meeting in Hyderabad, India, in January 2006.

ACTION – Take offers of deployment opportunities to the Argo Executive and Steering Team (Howard Freeland)

It was noted that SST can probably now be observed from APEX floats. The utility of this received a spirited discussion with the conclusion that the Argo float deployers should be strongly encouraged to add SST to the standard float mission. This was viewed as a minor financial and transmission cost with enormous value in some parts of the world where near-surface gradients are large. The data would assist the calibration of satellite IR images.

ACTION– Report the suggestion of addition of SST to the standard Argo float mission to the Argo Executive and Steering Team (Howard Freeland)

A2) WOCE Repeat Surveys
Plans for repeat surveys along WOCE transects were noted but participants were surprised that the WOCE transect at 85W is not scheduled for repeat. Given the importance of the area as a likely source of Antarctic Intermediate Water the group considered this to be a high priority. Nico Caltabiano pointed out that an International Repeat Hydrography Workshop will be held in Shonan Village, in November 2006 and this could be brought to that meeting's attention.

ACTION – Report on the recommendation of repeat of transect at 85W to participants of the International Repeat Hydrography Workshop (Nico Caltabiano)

A3) Time Series Sections
SHOA is executing a survey from Valparaiso to the Juan Fernandez Islands twice a year (using a SeaBird-19 CTD) and appears to be on schedule for continuation. This is an effort greatly to be praised, but these valuable data sets need to be submitted to international data centres. For example, in the northern hemisphere the Line-P surveys are routinely placed in CLIVAR and other data collections. It was noted that Steve Diggs had already begun

negotiations to have some of the surveys transferred to CCHDO holdings at Scripps. We encourage SHOA and CCHDO to continue these negotiations

RECOMMENDATION – SHOA to submit data from Valparaiso-Juan Fernandez surveys to CCHDO (Steve Diggs and Ricardo Rojas)

A4) High resolution XBT surveys.
We noted that the tracks into Valparaiso were no longer being occupied. This was discussed though no way forward was identified.

B) Future Directions.
Considerable discussion centred around the utility of gliders equipped with CTDs to sample the strong currents in the coastal zone. This discussion also noted that Argo is not very well suited to monitoring flow in boundary currents, but gliders are ideally suited. Gliders are poorly suited to sampling many locations in distant parts of the ocean, so there appears to be complementary features here. Gliders are not overwhelmingly expensive and can be relatively cheap to operate. For example, a glider can be brought in very close to a coast and recovered from a small boat. South American nations planning contributions to sustained ocean observations might like to consider operating a few gliders rather than buying Argo floats. The Argo array is being deployed, but observations of the coastal current systems appear to have large additional value.

Appendix A: Organising Committee

Organising Committee
Kelvin Richards, Oscar Pizarro, Thierry Delcroix - CLIVAR Pacific
Celeste Saulo, Bob Weller - CLIVAR VAMOS
Kevin Speer - CLIVAR Southern Ocean
Ed Harrison - OOPC
Stan Wilson - GOOS and IOC
Howard Freeland, John Gould - Argo
Scott Power - CLIVAR WGSIP
Tony Hirst - WCRP JSC/ CLIVAR WGCM
Pilar Cornejo - ESPOL, Equador
Rodney Martinez - CIIFEN
Pablo Lagos - IGP
Ena James - SENAMHI
Mary Kayano - CPTEC

Local Committee
Oscar Pizarro - Universidad de Concepción, Chile.
Rene Garreaud - Universidad de Chile, Santiago, Chile.
Rodrigo Nuñez - SHOA, Santiago, Chile.
Carlos Ereño - Universidad de Buenos Aires, Argentina.

Appendix B: Agenda

TUESDAY 11th October

OPENING SESSION

08:00 Registration

08:30 Welcome (K. Richards and UDEC's Vice-rector)
Workshop objectives (K. Richards)
Logistics (O. Pizarro)

SESSION 1: CLIMATE

09:00 David Dewitt (IRI) Coupled modelling and applications related to the South Pacific, and surrounding areas (keynote)

09:40 Scott Power (BOM) Climate and sea-level in the South Pacific: variability and change (keynote)

10:20 **Break**

10:40 Tercio Ambrizzi (USP) Teleconnection Patterns in the South Pacific

11:00 Niklas Schneider (IPRC) Coupled air sea interaction in the South Pacific: A model study

11:20 Wenju Cai (CSIRO) Change of the Eastern Australian Current induced by an upward trend of the Southern Annular Mode

11:40 Alexandre Pezza (Univ. Melbourne) Links between the Pacific Decadal Oscillation and Southern Hemisphere cyclone and anticyclone behaviour

12:00 Bo Qiu (UH) Decadal Variability in the Large-Scale Sea Surface Height Field field of the South Pacific Ocean: Observations and Causes

12:20 **Lunch**

13:20 Dewitte B., et al (CNES) Rectification of the ENSO variability by interdecadal changes in the equatorial background mean state in a CGCM simulation.

13:40 Gokhan Danabasoglu (NCAR) Transpacific Climate Influences of the Southeast Pacific as suggested by ARGO Floats and climate models

14:00 Wolfgang Schneider et al (UDEC) Property changes in South Pacific Water masses: BEAGLE (2003) - WOCE (1992)

14:20 Discussion

15:00 **Break**

SESSION 2: REGIONAL IMPACTS

15:20 Rene Garreau (U Chile) Clouds and circulation over the eastern South Pacific (keynote)

16:00 Y Wang (IPRC) Regional Coupled Modeling of The East Pacific Climate (keynote)

16:40 Alexis Chaigneau (COPAS/PROFC) Surface circulation and turbulent flow characteristics in the eastern South-Pacific from surface-drifter measurements

17:00 David Enfield (NOAA/AOML) Interannual to Multidecadal Variations of the Divergent Circulation Affecting the Southeast Pacific Region

17:20 Ken Takahashi (UW) On the annual cycle in heat content in the Peru Current region

17:40 Aldo Montecinos (Univ. Concepcion) Equatorial origin of interdecadal variability in the eastern South Pacific

18:00 **Welcoming reception**

WEDNESDAY 12 October

08:40 Jorge Carrasco (Meteochile) Precipitation events in central Chile and its relation with the MJO

09:00 Samuel Hormazábal (UDEC) Interannual modulation of seasonal-scale variability in alongshore flow off Chile

09:20 Tercio Ambrizzi (USP) The role of the tropical convection over the western Pacific and the Indian oceans in the generation of frost events in the southern cone of South America

09:40 Discussion

10:20 **Break**

SESSION 3: Prediction and Predictability

10:40 Carolina Vera (FCEN) The South Pacific and forecast skill of seasonal variability over South America (keynote)

11:20 Rodney Martinez (CIIFEN) Current Initiatives in SE Pacific to improve the Seasonal Forecast along the Western Coast of South America and the new challenges to get a regional forecast for El Niño (keynote)

12:00 Discussion

12:20 Lunch

13:20 Breakout sessions I: scientific issues

14:40 **Break**

15:00 Short plenary

15:20 Breakout sessions II: requirements from observing system

16:30 Final Plenary

17:00 **Poster session**

Note: Break-out sessions themes and chairs

Climate (Chairs: Scott Power and Bo Qiu)

Regional Impacts: (Chairs: Rene Garreau and Yuqing Wang)

Prediction and Predictability: (Chairs: Carolina Vera and Tercio Ambrizzi)

THURSDAY 13 October

SESSION 4: Observing system: Argo

08:20 Howard Freeland (IOS) Argo: A global ocean climate observatory

09:00 Steve Riser (UW) Sensors on Argo floats

09:40 Nobuyuki Shikama (FORSGC) Japanese Argo activities in the South Pacific

10:10 **Break**

10:30 Mark Ignaszewski (FNMOC) An introduction to the Argo Data System

10:50 Josh Willis (JPL) Estimates of interannual to decadal changes in upper-ocean thermal structure and circulation from a combination of satellite, Argo and other in situ data

11:20 Open Discussion

12:00 Lunch

SESSION 5: Observing system contd. and related programmes

13:00 Ted Strub (COAS) Satellite Observational Capabilities – Past, Present and Future

13:20 Etienne Charpentier (JCOMMOPS) Global Drifter Program

13:40 Howard Diamond (NOAA) The Pacific Islands Global Climate Observing System (PI-GCOS)

14:00 Maria del Carmen Grados (IMARPE) Current status and improvements in the ENSO climate monitoring system and regional modelling off Peru

14:20 Alexandre Ganachaud (IRD) Plans for the SW Pacific

14:40 **Break**

15:00 Ben Giese (TAMU) Southern Hemisphere Pacific Variability in SODA-POP

15:30 Andreas Schiller (CSIRO) Operational Ocean Forecasting in the Southern Hemisphere: Observations, Models and Systems

16:00 Billy Kessler (NOAA/PMEL) The Pacific Upwelling and Mixing Physics (PUMP) Experiment

16:20 Ricardo Rojas (SHOA) Activities by SHOA

16:40 Steve Diggs (CCHDO) Data management issues for hydrography datasets

17:00 Carina Lange (COPAS) Integrated Marine Biogeochemistry and Ecosystem Research (IMBER)

17:20 Jürgen Alheit (IOW) Global Ocean Ecosystem Dynamics (GLOBEC)

17:40 **END**

FRIDAY 14 October

08:20 General Discussion, including issues to be addressed in breakout sessions

09:00 Breakout sessions

Observing Systems (Chairs: Ben Giese and Howard Freeland)

GLOSS/GRASP/CIIFEN (Chair: Rodney Martínez)

10:30 **Break**

10:50 Breakout sessions resume

12:00 **Lunch**

13:00 Plenary

15:30 **Break**

16:00 Writing final recommendations and action items

18:00 **END**

Appendix C: List of Participants

1. GERMANY

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Appendix D: Abstracts

CLIVAR/OOPC/Argo/GOOS/CPPS workshop on the South Pacific Concepción, 11-14 October 2005

Abstracts

Tércio Ambrizzi
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Teleconnections patterns in the South Pacific

The word “teleconnection” means connection at a distance. Hence, a teleconnection analysis comprises a global view of atmospheric circulation where local forcings or instability act to influence remote regions in the atmosphere. They have been used mainly to study the large scale fluctuations of low frequency in the atmosphere. Studies of teleconnection have provided a good example of a link between observations, theory and models. The presentation will give a brief overview of the main studies produced by the Climate Studies Group (GrEC) of the University of São Paulo related to the teleconnection patterns between the Tropical and South Pacific Ocean and the climate variability over South America.
Among the research currently under development by GrEC, the Sea Surface Temperature (SST) anomalies in the tropics and extratropics and their influence on the general atmospheric circulation over the Southern Hemisphere have largely been studied. One of the main focuses is the impact of El Nino/Southern Oscillation (ENSO) events over the precipitation patterns in South America. Based on observacional analysis and numerical experiments it was found that the position and amplitude of the SST anomalies in the central-east Pacific are important to modulate the rainfall distribution over the South American continent, particularly in the Southern Brazil, Northern Argentina and Paraguay. In the North and Northeast of South America, Atlantic SST anomalies may dominate the ENSO signal when it is in a favorable condition affecting the rainfall season over these regions. In fact, some recent work have also demonstrated how the intraseasonal precipitation patterns in Eastern Amazon and Northeast Brazil are influenced by explosive convections over the west tropical Pacific and are usually related to the Madden and Julian Oscillation (MJO). Anomalous SST and convection in the Pacific will have an impact on the Walker and Hadley circulations and they can affect the South American Monsoon System (SAMS) during Austral summer. Some observational analysis and a few numerical experiments have demonstrated that the position and intensity of the Low Level Jet east of the Andes are related to the SAMS and it is important to modulate the precipitation patterns over the South America during the warm season. A large field experiment was carried out last summer (2002/2003) in order to confirm this relationship.
The variability of Southern Hemisphere cyclone and anticyclone behavior has been investigated through the use of an automatic scheme for tracking these kinds of systems. A climatological view of cyclone and anticyclone tracks and ENSO composites have been produced. One of the results found is that the trends and the average of the total hemispheric number of cyclones and anticyclones are not significantly affected by the ENSO phase. Cold surges over South America and their relationship with extratropical Rossy wave propagation has also been demonstrated by statistical analysis and numerical experiments.

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Interdecadal Variability and El Niño Events Variations.

An out of phase in positive sea surface temperature (SST) anomalies between the central and eastern tropical Pacific was observed in El Niño events during the period 1854–2003. Most of them exhibit a peak in sea surface warming on the central Pacific from November to January. In many cases the peak warming in SST at the eastern tropical Pacific occurs several months after the peak in the central Pacific SST, usually during April and May of the year after the El Niño onset (commonly indicated as (+)). These events were referred to as DF+ events. Conversely, when the peak warming at the eastern tropical Pacific leads that of the central Pacific, the events were referred to as DF– events. There were also a number of events during which both peaks occur simultaneously.

At the interdecadal timescale, it was determined the existence of periods each one dominated by one kind of event. The DF– events dominates the periods 1888–1930 and 1951-1976, with the only exception of the 1968/69 event. From the two events that occured during the period 1931–1950, the most important was DF+. Another period is 1982–1997, when all the events were almost DF+.

According to other studies, the major impacts of El Niño during autumn(+) in Southeastern Southamerica are explained in terms of DF+ events. In this study we intend to detect the prediction capability of this kind of events in connection with the interannual variability. In this way, a comparision with the phases of the Pacific Decadal Oscillation (PDO) was performed. Our results indicate that the periods characterized by El Niño DF+ events occur during the warm phase of the PDO, while the periods with DF– events occurs during its cold phase. This behavior means that a change from DF+ to DF– could be interpreted as a change in the PDO phase, as in the case of the latest DF– event of 2002/03.

Wenju Cai
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Change of the Eastern Australian Current induced by an upward trend of the Southern Annular Mode

The response of the Southern Hemisphere ocean circulation to climate change is not as well studied as the Northern Hemisphere counterpart. Observational studies have revealed an upward trend of the Southern Annular Mode (SAM) over the past few decades, although the relative importance of greenhouse, ozone depletion and natural variability in forcing the trend is not fully conclusive. Here we demonstrate, via the Sverdrup relationship, that the associated change in wind stress curl causes a southward shift of the Southern Hemisphere subtropical gyre, particularly the Eastern Australian Current (EAC), leading to an intensification of the southern part of the gyre circulation. Climate models forced by the Intergovernmental Panel for Climate Change scenarios project a continuing upward trend of the SAM into the future. In response, the EAC moves southward by up to 8o by year 2070. The southward shift is a part of annular-scale circulation changes that involve all subtropical gyres of the Southern Hemisphere. The changes significantly alter the boundaries of bio-diversity and generate accelerated warming and sea-level rises in regions where the southward flowing current intensifies.

Jorge F. Carrasco
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Precipitation events in central Chile and its relation with the MJO

A study about precipitation in central Chile and its relation with the Madden and Julian Oscillation (MJO) was conducted for the 1979-2004 period. For these, daily precipitation data from seven representative stations located between 30ºS and 38ºS were used. Correlations between precipitation events and MJO index was done for each station. Results indicate a correlation above 0.55 for the region between 30º and 34ºS, but south of 34ºS the correlation are below 0.55. The correlations are higher between precipitation events and the negative phase of the MJO. Synoptic-scale pattern for MJO negative indices showed similar features than El Niño, i.e., a pattern that favours precipitation en central Chile. It is concluded that when the juxtaposition of El Niño (La Niña) and MJO negative (positive) periods takes place, precipitation are likely (less likely) occurs in central Chile.

Alexis Chaigneau and Oscar Pizarro
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Surface circulation and turbulent flow characteristics in the eastern South-Pacific from surface-drifter measurements.

Circulation of the eastern South Pacific region (10º–34ºS, 70º–100ºW) was studied using drifting buoy trajectories from 1979 to 2003. Three different current regimes were highlighted: the South Equatorial Current, flowing westward north of 26ºS with surface velocities of 7–8 cm s^{-1}; the South Pacific Current, an eastward current of ~2 cm s^{-1} south of 25º–30ºS; and the Chile-Peru Current, a northwestward flow of ~6 cm s^{-1} found to the east of 82ºW and south of 22ºS. The velocity variance distribution showed the regional flow to be anisotropic in nature. Maps of eddy kinetic energy obtained from drifter measurements and satellite altimetry data showed similar patterns, with higher energy levels near the South American coast. The Lagrangian time and length scales of the turbulent flow revealed typical values of around 6 days and 40 km in the zonal direction and of around 3.5 days and 30 km in the meridional direction. The estimated diffusivities were ~5×10^7 cm^2 s^{-1} and ~2.5×10^7 cm^2 s^{-1} in the eastward and northward directions, respectively. Finally, we estimated the respective role of horizontal advection and lateral diffusion on the mixed layer heat and salt budgets. Near the coast, the lateral turbulent fluxes in the surface layer were two times larger than the horizontal transports associated with the large-scale circulation; mean horizontal heat and salt diffusive fluxes were around 25 W m^{-2} and 50 g m^{-2} d^{-1}.

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"Chile-Peru Current Eddy" characteristics.

The main eddy characteristics (length scales, rotation period, swirl and translation velocities) are determined in the eastern South Pacific region (10º–35ºS and 70º–100ºW) based on surface drifter measurements, satellite altimetry, and hydrographic data from the WOCE-P19 section. The ''Chile-Peru Current eddies'' have a typical diameter of order of 30 km, smaller than the typical Rossby radii observed in the region. They are principally formed near the South American coast and propagate seaward with a translation velocity varying from 3 cm s^{-1} in the southern part of the study domain to 6 cm s^{-1} north of 15ºS. Long-lived anticyclonic eddies propagate northwestward with a mean angle of around 283ºT, whereas cyclonic vortices propagate westward, consistent with the vortices propagation theory on a β plane. The radial distribution of the swirl velocity shows that the Chile-Peru Current eddies have a maximum diameter of order 200 km with a swirl velocity of around 14 cm s^{-1} and a rotation period of 50 days. No significant difference is observed between the tangential velocities of cyclonic and anticyclonic eddies. Geostrophic balance can be considered for large radii, whereas ageostrophic dynamics may play an important role near the eddy centers.

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Transpacific Influences of Climate Processes in the Southeast Pacific as Suggested by Climate Models and ARGO Floats

In the Community Climate System Model (CCSM) coupled simulations of the present day conditions, the biggest mean positive Sea Surface Temperature (SST) biases develop along the eastern boundaries of subtropical gyres. The solutions indicate that the local atmospheric forcing is only part of the problem in these regions, with the representation of upwelling another likely contributor. The largest area-averaged bias is more than 3C, occurring off the coasts of Peru, Ecuador, and Chile. This bias locally exceeds 5C, extending several thousand kilometers along the South American coast, but with relatively narrow offshore extent. We use sensitivity experiments, in which the model potential temperature and salinity are restored to observations, to show that this warm bias significantly degrades precipitation across the Pacific, subsurface ocean properties on both sides of the equator, and the seasonal cycle of the equatorial SST anomaly in the eastern Pacific. Because these signals extend beyond the reach of advection by surface currents, we suspect atmospheric and oceanic (tele)connections.

Ocean model solutions show that vertical mixing processes where the upper ocean is weakly stratified because of large destabilizing salinity gradients produce large inter-annual variations in spiciness. ARGO float data from the southeast Pacific are examined to verify this process of spice generation. They reveal the same seasonal cycle in the upper ocean spiciness slope (defined as the ratio of mean vertical salinity and density gradients). In the model pycnocline, inter-annual variations in this winter-time spiciness injection account for significant decadal variation on isopycnals. We find that the formation zones where the spiciness slope is negative and subject to large amplitude seasonal cycle are in fact the origins of significant low frequency pycnocline change, because the model variations derive from inter-annual fluctuations in the slope upstream of the station location. Model hindcasts show the propagation of the injected spice across south Pacific and to the equator. Data limitations are also discussed.

David G. DeWitt
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Coupled Modeling and Applications Related to the South Pacific and Surrounding Areas

Current generation coupled climate models manifest common systematic errors in the Pacific which are suspected to be due to deficiencies in modeling of the southeastern Pacific. Foremost among these systematic errors is the double ITCZ phenomenon. Previous diagnostic work suggests that the double ITCZ is due, at least in part, to warm sea surface temperature (SST) errors in the southeastern Pacific during late Northern Hemisphere winter and spring. These warm SST errors have been linked to deficiencies in physical parameterizations and numerics in both atmospheric and oceanic models. We will show results from coupled and uncoupled component models exploring these issues in an attempt to better understand why the models are behaving badly and hopefully how they might be fixed.

Seasonal forecasts over South America are influenced by SST anomalies over the Pacific via teleconnections. Using a set of experiments from an atmospheric general circulation model (AGCM) in coupled and uncoupled mode we will attempt to diagnose the effect of the Pacific on forecast skill for precipitation and near-surface air temperature over South America.

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A regional model simulation of the South Eastern Pacific: intraseasonal to annual propagating variability and baroclinic modes dispersion.

The oceanic variability of the South-Eastern Pacific is peculiar in that the coastal variability off Peru and Chile connects the equatorial Kelvin waves to the extra-tropical Rossby waves at a variety of timescales, from intraseasonal to interannual. Here, we present the results of a medium resolution, eddy permitting regional model simulation for the eastern south Pacific. The model is forced with observed climatological fluxes during 5 years. Our objective is to investigate the intraseasonal to annual propagating signal in the model and understand how the energy is transmitted both from the open boundaries along the coast and to the inner basin and from the coastal zone to the off-shore ocean.

Comparison with available observations indicates that the model mean state is realistic enough to further investigate the characteristics of the propagating variability along the coast and off-shore. The simulated sea level anomalies are first compared to the TOPEX/POSEIDON satellite derived data. Despite mesoscale features not resolved by the model, the simulated variability has a pattern in rather good agreement with the observations with a comparable decrease of the variability from the coast to the open ocean and southward. A vertical mode decomposition of the simulated pressure field is then carried out. Results indicate that the sea level variability projects to a large extend on the first three baroclinic modes, with an eastern extension of the variability from the coast for the gravest mode of the seasonal cycle. The semi-annual cycle associated variability is more concentrated near the coast and exhibits less consistent off-shore propagating characteristics than the annual cycle. The intraseasonal variability display peaks in the inner basin between 33°S and 15°S and a minimum in a 'shadow zone' just off-shore, between 27°S and 17°S. The higher the mode order, the more to the North the location of maximum variability consistently with the extra-tropical Rossby waves triggered at the critical latitudes. Analyses of the seasonal propagating variability indicates that it is forced both locally by the annual cycle and remotely at semi-annual timescales by the equatorial variability. On the other hand, propagating characteristics of the intraseasonal variability results to a large extent from wave interactions processes. The horizontal heterogeneity of mean stratification generating modal dispersion as a source of the intraseasonal variability in the model is also explored. Several experiments with and without northern boundary forcing or wind stress variability are further carried in order to investigate the role of coastal Kelvin waves in the triggering process of Rossby waves along the coast. It is show that the instability of the coastal mean current system is not sufficient for explaining the off-shore propagating variability, which characteristics is to a large extend controlled by coastal Kelvin wave activity.

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Rectification of the ENSO variability by interdecadal changes in the equatorial background mean state in a CGCM simulation.

There is an ongoing debate in the climate literature as to whether the tropical Pacific decadal variability is forced by the extra-tropics, or is the result of nonlinearities in the coupled tropical system. Here, a 260-yr long coupled general circulation model (CGCM) simulation and an Intermediate Coupled Model (ICM) of the tropical Pacific are used to investigate the link between the changes in equatorial background stratification and the ENSO modulation, with a focus on the role of non-linearities associated to equatorial wave dynamics. As a first step, a vertical mode decomposition of the CGCM mean vertical structure is performed and changes in corresponding "shallow-water" parameters are documented. They exhibit a different variability according to the baroclinic modes which can explain why a flattening thermocline does not necessary lead to reduced ENSO activity. Estimated baroclinic mode contribution to zonal current anomalies indicate that the decadal variability projects differently on the baroclinic mode as compared to the interannual variability, with the decadal (ENSO) mode of the high-order modes most active in the western (eastern) Pacific.
In the light of the results of the CGCM vertical mode decomposition, we test if the non-linearities associated to change in the baroclinic mode energy distribution can lead to coherent ENSO modulation in the ICM. The results indicate that consistent rectification of the interannual variability (ENSO timescales) by the decadal variability associated to changes in the oceanic mean states takes place. The magnitude and characteristic (phase relationship between ENSO modulation and decadal mode of thermocline depth) of this rectification depend however on the climatological state prescribed in the ICM. In particular, the seasonal cycle as simulated by the CGCM amplifies the zonal advective feedback in the western Pacific, which tends to mask the rectified effect of changes in mean stratification. In the CGCM, the atmospheric response associated to the ENSO modulation forces through Ekman pumping the decadal mode of thermocline depth with a peak variability in the South-Western Pacific. A tropical mechanism for producing ENSO modulation is proposed, which conceals both the rectified effect associated to non-linearities of the equatorial wave dynamics and the tropical decadal mode of thermocline depth arising from Ekman pumping anomalies located in the central Pacific, south of the equator.

Howard Diamond
National Oceanic and Atmospheric Administration (NOAA)/National Climatic Data Center

The Pacific Islands Global Climate Observing System (PI-GCOS)

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. 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 fro 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. Since 2000, support for PI-GCOS from the U.S. has amounted to $350K (US). These funds continue to address the actions and proposals from the PI-GCOS Action and Implementation Plans developed over the past couple of years. The U.S. GCOS Program Office also 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 other 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. That position is funded by the U.S. GCOS Program Office as part of the integrated Pacific Islands team effort of which the U.S. is an active participant along with Australia, New Zealand, and the member nations of SPREP.

David Enfield
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Interannual to Multidecadal Variations of the Divergent Circulation Affecting the Southeast Pacific Region

The two large tropospheric heat sources for the austral winter divergent circulation are the western Pacific warm pool and the Western Hemisphere warm pool (WHWP). The WHWP is comprised of a portion in the eastern North Pacific off Central America and a larger portion centered over the Intra-Americas Sea (Gulf of Mexico and Caribbean)). The combined WHWP undergoes large interannual variations in size, the largest usually occurring during the austral winter following the peak of El Niño events. The Hadley circulation from the WH warm pool has a descending branch over the Southeast Pacific in the region of the subtropical high pressure system — centered near 20°S, 95°W — that also coincides with the large region of stratiform cloudiness west of South America. We have found that when the WHWP is anomalously large, the Hadley flow into the SE Pacific is energized and subsidence in the region is increased. Independent rainfall data indicates a positive correlation of rainfall west of the Peru-Chile border with the size of the WHWP, suggesting that the effect of the increased subsidence is to increase the drizzle under the stratocumulus deck. The significance of this is the likelihood that the cloudiness itself is also affected by the subsidence anomaly and that coupled models will need to replicate the natural variability that we see in the WHWP and the Hadley circulation, in order to correctly reproduce interannual variations in the Pacific sector of the ocean-atmosphere system. The secondary effects of the interaction may potentially include co-located SST anomalies and the behavior of winter frontal systems impinging on the southern cone of South America.

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Argo: A global ocean climate observatory

This presentation will begin by outlining the present status of the Argo ocean climate observatory. The summary will touch on float performance, deployment strategies and the growth of the array to date. Critical to the success of a global observatory is the general agreement to a common data policy. This has been achieved among the 23 nations presently deploying floats in support of Argo. The prospects for achieving full implementation will also be discussed.

When fully deployed the Argo array will supply more ocean climate information each year in the southern ocean than has been acquired by all previous research missions to the southern ocean. This should prompt innovative approaches to observations of the state of an ocean basin. Methods will be outlined that permit such assessments to be made. Since Argo floats observe both the vertical structure of the ocean and deep velocities, it should be possible to compute near surface currents relative to a level of known motion. Methods for doing this will also be outlined.

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SPICE: Southwest Paclfic Circulation and climate Experiment

The Southwest Pacific is a region of complex ocean circulation. Thermocline waters, carried by the broad westward flowing South Equatorial Current, split in strong zonal jets upon encountering the different island archipelago. 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.
In August 19-21, a 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.
This project, named 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.

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Interannual to interdecadal changes in eastern Tropical Pacific ITCZ variability

After having investigated the seasonal variability of the ITCZ's on the eastern pacific (Garces et al., submitted 2005), we wished to appreciate better the different time scales which may influences its latitudinal position at seasonal time scales.
By using Global Merged Land-Air-SST Reconstruction, FSU winds and Precipitation Reconstruction data sets between 1950-2000, we establish the interannual to interdecadal variability of the mean position and the area occupied by the Intertropical Convergence Zone (ITCZ) in the eastern tropical Pacific (20°N-20°S and 180°-70°W). As well, given the differences appreciated on its position between different estimates of the ITCZ at seasonal time scales, the relationship between precipitation, wind convergence and SST were also investigated.

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Southern Hemisphere Pacific Variability in SODA-POP

A new reanalysis using SODA (Simple Ocean Data Assimilation) and POP (Parallel Ocean Program) is used to explore low frequency (decadal) variability in the tropical and South Pacific Ocean. The ocean model resolution is 0.4 degrees of longitude, 0.28 degrees of latitude and has 40 vertical levels. The model was run from 1958 - 2001 using the ERA-40 reanalysis winds, GPCP precipitation, and bulk formulae for the surface heat flux. Temperature and salinity are assimilated using the SODA implementation of the optimum interpolation routines. A second reanalysis using QuikSCAT winds covers the period from 2000-2004. The analysis is used to explore Pacific climate on decadal timescales. In particular, we explore the possibility that decadal climate variability in the Pacific is forced by the Southern Hemisphere. A heat budget analysis of the Southern Ocean, and the implications for global climate variability, will also be discussed.

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Low-frequency modulation of coastal upwelling in Concepcion and its impact on fisheries.

Amplitude of interdecadal fluctuations of the ocean-atmosphere system along the western coast of South America is rather small in order to explain dramatic changes of main pelagic fisheries in the region. In particular, the upwelling system off southern-central Chile (Concepcion) is characterized by its strong seasonality, showing interdecadal variability. In the present work, the low-frequency modulation of coastal upwelling system in Concepcion-Chile (37ºS) is study by means of compositing analysis of several indices of the upwelling and downwelling processes (e.g., onset of the upwelling season, upwelling events frequency, Ekman transport, turbulence, storminess, lasker events, etc.) based on the warm and cold phases of the interdecadal oscillation described for the region.

Early results shows the modulation of the onset of the upwelling season,which starts earlier (later) by several weeks in relation to the cold (warm) interdecadal oscillation phase. This produces higher (lower) amount of available feed for pre-recruit of anchovy (Engraulis ringens) and common sardine (Strangomera bentincki) during the spring season, in association with enhanced (decreased) primary productivity. The juvenile surviving until the adult stage would be influence by the coupling (uncoupling) between the local productivity peak and the larval abundance, as pointed out by Cushing hypothesis. Therefore, the mechanism of advanced (delayed) onset of the upwelling season could explain, in part, interdecadal fluctuations of anchovy and common sardine landing off southern-central Chile.

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Current Status and improvements in the ENSO climate monitoring system and regional modelling off Peru

The Peru ENSO Climate Monitoring System is a coordinated system devoted to collect and to gather climate data at sea and inland territory. These data are analysed to provide analytical environmental pieces of information that feed an Early Warning System to detect extreme high and low-frequency events. This is a top priority task for the Peruvian Government and society in order to prevent climate anomalies hazards and mitigate their socio-economical and ecological consequences.

An overview of the ongoing real time observational network, the different strategies for monitoring the environment and fisheries in Peru and their data transmission and processing systems, as well as planned observations are presented. Recent efforts have been undertaken for generating comprehensive meteorological, oceanographic and fishery data sets, and for improving sampling strategies to resolve mesoscale and submesoscale oceanic structures. The latter has been motivated by a retrospective analysis of historical *in situ* cruise data calling for the refinement of the present sampling strategy for a better understanding of the oceanic-biogeochemical coupling and coastal to off-shore exchanges. This activity is performed in parallel with the design and implementation of a high-resolution regional model that comprehends: a high resolution regional model forced by satellite-observed winds and fluxes and with oceanic boundary conditions provided by an oceanic re-analysis and/or a forecast system, a hydrological, and a biogeochemical components.

Preliminary results will be presented with a focus on the retrospective analysis of historical *in situ* data and their use for validating the mean circulation and variability of a high-resolution regional model. The benefits of such observing system will be addressed in relation to ENSO impacts on the different socio-economic sectors in Peru. The present challenge is to develop a high quality, integrated approach to coastal monitoring and forecasting.

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International Research Center on El Niño (CIIFEN), Ecuador

Current Initiatives in SE Pacific to improve the Seasonal Forecast along the Western Coast of South America and the new challenges to get a regional forecast for El Niño

After El Niño 1997-1998, some important developments were achieved in the South Eastern Pacific region. The amount of human and economic losses caused immediate responses in several Governments and call the attention to enhance the observational networks and forecast capabilities in each country. Some of these achievements were the Ocean Observation Programs of Ecuador (Spondylus) and Peru (Naylamp), the deployment of buoys in front of Chile and the improvement of the sea level observation network from Colombia to Chile with more than 57 stations, most of them with near to real time data transmission. Other important regional effort in this region have been the agreement between Governments of Colombia, Ecuador, Peru and Chile to perform regional cruises to assess the state of the ocean every year. 8 regional cruises has been made, observing periods with El Niño, La Niña and neutral conditions in the region. Other important milestones at Institutional level, was the creation of the International Center on research El Niño (CIIFEN) in 2003 and the forming GOOS Regional Alliance for South Eastern Pacific (GRASP) in the same year. CIIFEN is focused to reduce the impacts of El Niño and Climate variability with the most suitable application of global and regional forecast to the economical sectors: Agriculture, Health, fisheries and Water Resources, linking the climate science with the users. GRASP is building an Institutional network to coordinate, promote and develop sustained and continuous ocean and atmospheric observations.

The CIIFEN approach to ENSO is built on the basis that for users, the most important issue at the end is to receive most accurate, friendly and reliable information about rainfall behaviour (intensity, persistence, distribution, absence, duration and occurrence of abrupt suppression). The ENSO global definitions at global scale has demonstrated to be not valid for all the regions in the world, and along South Eastern Pacific region, the poor correlation between Central Pacific and NIÑO 1+2, has been critical during the past 5 years and generated looses to users who continued applying the global predictions at regional and local scale.

From November 2004, after the Third Climate Outlook Forum for Western South America (WCSA) with the participation of National Meteorological Services of Venezuela, Colombia, Ecuador, Peru, Bolivia, Chile, the support of WMO, NOAA/OGP, IRI, UNESCO-PHI and the coordination of CIIFEN, the Seasonal Forecast for Western South America is being produced monthly, using a standard numerical methodology, and the climate information of 107 meteorological stations in the region. Results of processing are integrated in CIIFEN, a document including a map of probabilities is prepared for discussion with members, and when is approved is shared and widely distributed along the region. The next steps to improve this product will be the inclusion of Probability of Exceeding for each station, and the inclusion of validation using outputs of ensemble models with the cooperation of IRI.

CIIFEN is intending to apply prediction tools to improve regional seasonal forecast, foster the research about the PDO correlations with NIÑO 1+2 to improve predictions of Sea surface temperature, air temperature (maximal and minimal) and rainfalls with better temporal and spatial resolution, work on dynamical and statistical downscaling for the region with the participation of Oceanographic Institution of SE Pacific and implement the application of tools to evaluate Climate Change as RClimdex and PRECIS in this part of the world. This will provide better input information to build climate risk scenarios in each socio economical sector, and assist to decision makers to reduce significantly climate impacts in the near future.

Key words: ENSO, CIIFEN, GRASP, WCSA

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Interannual modulation of seasonal-scale variability in alongshore flow off Chile

The analysis presented here is based on decade-long records (1991-2001) of current and sea level observations off central Chile at 30°S and simple models of low frequency waves, forced in part by wind stress derived from satellite obserations. Results show that coastal trapped waves and Rossby waves govern the variability of coastal currents for periods less than and greater than about 120 days, respectively. During El Niño periods, semiannual fluctuations dominate seasonal scale variability of coastal currents and can be explained to a large degree by Rossby waves forced by equatorial winds by way of equatorial Kelvin waves. During La Niña periods, annual fluctuations dominate the seasonal-scale variability of coastal currents and appear to be more related to winds along the South American coast than to winds along the equator.

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An Introduction to the Argo Data System

The Argo project is a collaborative effort of many different research and operational organizations from more than 18 countries that use instruments from several different manufacturers. The Argo data system is designed to meet the requirements of a wide range of users. Despite this diversity, the Argo data system provides a global dataset that is highly consistent and freely available to all users. The data is available from Global Data Assembly Centers (GDACs) in France and the United States. The data is available in near-real-time, usually within 24 hours of its transmission from the instrument. A standard set of automated quality control checks flags or removes gross errors at this stage. Operational users can receive this data via the GTS. Later, more detailed quality control processes are applied to the data to detect and correct salinity drift and a more refined dataset is available 6 to 12 months after the data is first received. This talk will describe the Argo data system, including the data access options that are available.

William S. Kessler
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The Pacific Upwelling and Mixing Physics (PUMP) Experiment

The PUMP experiment 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 convolution of surface fluxes, upwelling and mixing that determines equatorial SST has 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 develoment 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.

William S. Kessler
NOAA/PMEL, Seattle, USA

The high-salinity tongue in the South Equatorial Current

High-salinity surface water produced in the high-evaporation/low-rainfall region of the eastern subtropical gyre is subducted into the geostrophic circulation. This water mass flows west in the thermocline, traceable across the Pacific to the Coral and Solomon Seas. It splits into several recognizable cores that marks the splitting of the SEC into distinct jets, due both to the presence of islands and to the structure of the wind forcing. Although information about the variability of this water mass is limited in the pre-Argo era, strong ENSO variability of the SEC is apparent that should influence the high-salinity tongue and make it a useful marker of circulation changes. Observation and diagnosis of the formation properties of the water mass, the processes by which it is subducted, and its downstream signatures would advance our interpretation of South Pacific variability.

Carina B. Lange[1] and IMBER Scientific Steering Committee[2]
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Integrated Marine Biogeochemistry and Ecosystem Research (IMBER)

IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) is a decade-long international project that will develop new knowledge of ocean biogeochemical cycles and ecosystems. It will build on the successes of the JGOFS and GLOBEC projects, and will seek to merge the knowledge bases of marine biogeochemistry and ecosystem research. The vision of IMBER is to provide a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society.
This need for understanding system sensitivities is the basis of the IMBER goal:

- To investigate the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades.

In pursuit of this goal, IMBER is structuring its research around four themes, each of which addresses a number of specific issues.
Theme 1 "Interactions between Biogeochemical Cycles and Marine Food Webs", brings together biogeochemical and ecosystem research, and provides the scientific underpinning for the remaining themes. *Theme 2 "Sensitivity to Global Change"*, is the heart of IMBER research, and considers the impact of global change on biogeochemical cycles, ecosystems and their interactions. *Theme 3 "Feedbacks to the Earth System"*, considers the roles of ocean biogeochemistry and ecosystems in regulating climate, and *Theme 4 "Responses of Society"*, considers the interactions between the open ocean (its biogeochemical cycles and ecosystems) and human society.

Answering the broad interdisciplinary questions of IMBER will require an effort much larger than any single nation can mobilise. IMBER encourages the development of collaborative activities that will draw on the expertise of other international research projects and programmes.

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Sea level change over the recent decades and the role of thermal expansion

During the past few decades, tide gauges records indicate that the global mean sea level has been rising at a rate of 1.8 +/- 0.3 mm/yr. Over the last 12 years, satellite altimetry from Topex/Poseidon and Jason-1 report a rate of rise somewhat higher, of 3.1 +/- 0.4 mm/yr. Two main processes are responsible for the observed sea level rise : thermal expansion of sea water due to ocean warming and land ice melting. We have computed the thermal expansion contribution over the past 50 years and last decade, using different global ocean temperature data sets. For the period 1950-2003, we use two global temperature data sets published recently (Levitus et al., 2005 and Ishii et al., 2003). These data sets provide gridded temperatures down to 3000 m for Levitus and down to 700 m for Ishii. Analyses based on 'Empirical Orthogonal Function' show that the interannual variability of the thermosteric sea level is dominated by the signatures of El Nino-Southern Oscillation, Pacific Decadal Oscillation and is also influenced by North Atlantic Oscillation. As a result, regional thermosteric sea level trends are not stationary on a century time-scale and have a typical life-time on the order of a decade. In terms of global mean, the rate of thermosteric sea level change computed over 10-year windows displays high variability, with values reaching up to three times the 40-year (1950-1990) average at some periods. Even negative values are noticed at other periods. One important consequence is that the pattern of sea level trends derived from Topex/Poseidon altimetry over 1993-2005, which is mainly caused by thermal expansion, is very likely a non-permanent feature. Quantitative estimates of the climate-related contributions to sea level rise indicate that for the past 50 years, thermal expansion accounts to 25% of the observed sea level rise, while for the last decade, it explains about 60%. For both periods, there is direct and indirect evidence that ocean mass change due to land ice melting accounts to ~ 1. mm/yr.

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Equatorial origin of interdecadal variability in the eastern South Pacific.

Observational and modeling analyses show that sea surface temperature (SST) and thermocline depth variability along the western coast of South America is characterized by an out-of-phase relationship at interdecadal timescales: i.e. deeper (shallower) thermocline depth fluctuations are related to positive (negative) SST anomalies. These fluctuations are remotely forced by interdecadal variability of the Trade winds in the equatorial Pacific. Furthermore, at subtropical and mid-latitudes these anomalies are reinforced by local fluctuations of favorable upwelling winds. Thus, during periods characterized by westerly (easterly) wind anomalies in the equatorial Pacific, northerly (southerly) alongshore wind anomalies are present off Chile. In both cases, SST fluctuations are the result of vertical temperature advection changes: i.e. changes due to thermocline depth fluctuations remotely forced by equatorial winds and due to Ekman transport divergence fluctuations forced by local winds.

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The role of the tropical convection over the western Pacific and the Indian oceans in the generation of frost events in the southern cone of South America

This work indicates how anomalous convection observed in the western Pacific and South Indian Ocean can play an important role in generating extratropical wave patterns which favor the development of extreme cold events over the southeast of South America (SSA). Numerical simulations using a primitive equation model were carried out and their results were compared with observational data analysis.
From the composite analysis it turned out that an anomalous heating observed in the region of the tropical Pacific Ocean to the northeast of Australia during austral winters with maximum occurrence of Generalized Frosts (GF) over SSA can trigger Rossby waves that propagate towards the South American continent favoring the occurrence of these events. Numerical experiments indicate that the extension of the anticyclonic region and the cold advection over SSA generated when the heat forcing is placed over the western Pacific Ocean are similar to that observed during GF winters. However, the amplitudes seem to be insufficient to generate the mass field and motion anomalies observed in the composites of GF winters. When another heat source is placed over the western South Indian Ocean, the expected wave pattern observed during these events is achieved. The results indicate the existence of a double train of Rossby waves which propagate along the subtropical and polar jets, respectively, whose phases coincide just before they reach South America. This pattern generates a strong polar air advection over the southern cone of the continent with the consequent decrease in surface temperature and large areas of generalized frosts in the region. This mechanism suggests that tropical and extratropical wave interaction over the South Pacific is important to generate the appropriate atmospheric dynamical environment for the occurrence of GF in the southern and southeastern regions of South America.

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A study on the influence of anomalies in the Pacific on the climate shifts and extreme hydrological conditions in India

Changes in humidity and aridity patterns and resulting shifts in local climate and extreme hydrological events are challenges to the agriculture based economy and life of millions in India. Spatial and temporal variations in rainfall, especially monsoons and anomalies in regional temperature are reflected in humidity and aridity patterns. The indices of aridity and humidity depend on rainfall and temperature conditions and can be used as a measure in assessing the tendencies in local climate. This paper analyses the temporary shifts in climate and extreme hydrological conditions in different zones of India during the period 1900-2000. Their relationship with fluctuations in global temperature and anomalies and oscillations in the Pacific and with different phases of Southern Oscillation Index has been examined. Humidity and aridity indices showed large variations and climate shifted widely in all zones during the last century, and the influence of the rainfall seasonality was more pronounced than the deviations in total rainfall. Extremes in India coincide with global anomalies in certain occasions, but a direct one to one relationship could not be established in any of the zones. Though the east pacific sea surface temperature variations in the last 3 decades showed some strong relationship with Indian monsoon rainfall, it is not evidently reflected climate shifts or extremes. In many parts of India rainfall associated with western disturbances, pre-monsoon thunderstorms and winter monsoon play important role in soil and atmospheric moisture conditions and thus the local climate and aridity patterns. However, their relationship with Pacific or Global anomalies is not well established.

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Links between the Pacific Decadal Oscillation and Southern Hemisphere cyclone and anticyclone behaviour

The climate variability in the Pacific Ocean is one of the important mechanisms associated with synoptic activity in the Southern Hemisphere. Here we show, through the use of a state-of-the-art automatic tracking scheme, that the mode known as the Pacific Decadal Oscillation (Mantua et al 1997) has important impacts on the SH circulation over the tropics and mid-to-high latitudes.

Three complementary analyses were considered. These consisted of the superposed cyclone and anticyclone trajectories, the System Density (SD) defined as the number of cyclones/anticyclones found in a given grid box per unit of area, and the system Depth (D) defined as an objective measure of cyclone/anticyclone strength (in hPa). Composites of these properties and MSLP were calculated for the years when the PDO index was more than one standard deviation above and below the mean for all seasons. The ERA 40 data set for the period 1958-2002 has been used.

For the Southern Hemisphere winter (JJA), more cyclone tracks appear in the subtropical and tropical belts during the positive PDO phase. The SD anomaly has a similar pattern and also shows a strong dipole between the Ross Sea, with positive anomalies, and to the north of the Bellingshausen Sea, with negative SD anomalies (positive PDO phase).

The negative PDO phase is associated with roughly the opposite patterns for JJA, suggesting a surprisingly strong linear response. The cyclone Depth indicates more intense extratropical cyclones in most of the SH during the positive PDO phase, with high variability but again presenting a close-to-linear response. However, a strong positive depth anomaly is found over the Tasman Sea during the negative phase, suggesting a different local response which may have a significant impact on southeastern Australian rainfall. As expected, the anomalies resemble some ENSO teleconnection patterns, although the ones associated with the PDO phases have considerable annular structure over the Southern Ocean. Further studies are being carried out for the other seasons and are to be complemented with the anticyclone tracks. Possible relationships with polar outbreaks in South America and other features of weather extremes are also under investigation.

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Decadal variability and longer term trends in the South Pacific

Recent trends

Numerous studies have shown that global warming over the past 50 years is likely to have been largely driven by anthropogenic forcing (IPCC 2001). While data is patchy in some parts of the South Pacific, surface temperatures over the South Pacific have generally increased and sea-levels have generally risen in recent decades (IPCC 2001; Church et al. 2004). The upper ocean warming in the South Pacific is generally consistent with climate models when the forcing used includes anthropogenic changes in greenhouse gases and sulphate aerosols (Barnett et al., 2001). The magnitude of surface temperature and sea-level trends vary spatially over the South Pacific (Church et al. 2004). Increases approaching 3mm/yr occurred in the off-equatorial South Pacific from 1950-2000, while rises over this period near the equator and in the southwest Pacific were more modest. This structure appears consistent with changes arising from a combination of both anthropogenic and natural changes. Further warming and substantial sea-level rise is expected in the future, even if human emissions of greenhouse gases are somehow drastically reduced to the point where greenhouse gas levels are stabilized at current levels (Meehl et al. 2005).

ENSO-like decadal variability and the decadal modulation of ENSO

Decadal variability in the South Pacific is heavily influenced by ENSO-like variability (e.g. Salinger 2005). ENSO-like teleconnection decadal patterns can, in theory, arise without predictability beyond interannual time-scales (Power and Colman 2005). In practice, however, there are robust differences between IPO/PDO and ENSO indices and their corresponding spatial patterns (Mantua et al. 1997; Folland et al. 1999; Newman et al. 2002; Power and Colman 2005). These differences can point to differences in physics on interannual and decadal time-scales. The differences, their physical cause and predictability will be discussed. Substantial decadal variability in ENSO teleconnections can also occur. The strength of ENSO teleconnections to Australia, for example, vary in association with the Interdecadal Pacific Oscillation in observations (Power et al. 1999) and a coupled GCM (Power et al. 2005). The predictability of this modulation and the reasons why modulation occurs will be discussed.

Recent changes to the South Pacific Gyre

The South Pacific's subtropical gyre has intensified and shifted south in recent years in response to increased wind-stresses at mid-latitudes that are largely independent of ENSO. Changes in the gyre seem to have led to important regional changes in upper ocean temperature (Roemmich et al. 2005; O'Farrell 2005). Modelling work (Cai 2005a) and theory (Godfrey 1989) suggests that the gyre changes are strongly influenced by changes in zonal wind-stress at mid-latitudes associated with the atmospheric Southern Annular Mode (SAM, Roemmich et al. 2000; Cai 2005a). While SAM can change naturally e.g. as internally generated variability, modelling studies also suggest that SAM has been influenced by decadal changes in anthropogenic changes in ozone (e.g. Gillett and Thompson 2003) and other greenhouse gases (e.g. Fyfe et al. 2003). Climate change projections suggest that anomalous gyre circulations will continue into the future (Cai et al. 2005b; O'Farrell, 2005).

South Pacific variability as a precursor to tropical decadal variability

Evidence from theory (Godfrey 1989), ocean reanalyses (Giese et al. 2002), ocean models (Wang et al. 2004; McGregor et al. 2005) and climate models (Liu et al. 2003) suggest that some of the decadal variability in the South Pacific away from the equator may have a subsequent influence on the tropical Pacific. Changes in off-equatorial wind-stresses, for example, can change the rate of overturning in the Pacific's tropical/subtropical shallow overturning cell (e.g. Kleeman et al. 1999; Nonaka et al. 2002) and this has the potential to

subsequently alter the equatorial Pacific. The extent to which changes in the overturning cell influences ENSO and SSTs generally is a current area of active research.

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Decadal Variability in the Large-Scale Sea Surface Height Field of the South Pacific Ocean: Observations and Causes

Large-scale sea surface height (SSH) changes in the extratropical South Pacific Ocean are investigated using satellite altimetry data of the past 12 years. In the midlatitude region south of 30S, the decadal SSH signals are dominated by an increasing trend in both the western basin around New Zealand and the eastern basin centered around 45S and 105W, and a decreasing trend in the central South Pacific Ocean poleward of 50S. Spatially-varying, low-frequency SSH signals are also found in the tropical region of 10--25S where the decadal SSH trend is negative in the eastern basin, but positive in the western basin. To clarify the causes for these observed spatially-varying SSH signals, we adopted a 1-1/2-layer reduced-gravity model that includes the wind-driven baroclinic Rossby wave dynamics and the responses forced by SSH changes along the South American coast. The model hindcasts the spatially-varying decadal trends in the midlatitude and the eastern tropical regions well. Accumulation of the wind-forced SSH anomalies along Rossby wave characteristics is found to be important for both the long-term trends and their reversals in recent years. While it has little impact upon the midlatitude interior SSH signals, the boundary forcing associated with the time-varying SSH signals along the South American coast is crucial for the observed SSH signals of all timescales in the eastern tropical South Pacific basin.

(For more information: http://www.soest.hawaii.edu/oceanography/bo)

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Seasonal Modulations in the Eddy Field of the South Pacific Ocean

Decade-long satellite altimeter data from the TOPEX/Poseidon and ERS-1/2 missions are analyzed to investigate the eddy signals in the South Pacific Ocean. High eddy kinetic energy (EKE) bands with well-defined annual cycles are detected along the eastward-flowing surface currents of the South Tropical Countercurrent (STCC) in 21--29S and the South Equatorial Countercurrent (SECC) centered ~9S. Overriding the westward-flowing South Equatorial Current (SEC), the STCC layer has the sign of its mean potential vorticity gradient opposite to that in the SEC layer, subjecting the vertically-sheared STCC-SEC system to baroclinic instability. In austral winter, the STCC/SEC system is baroclinically more unstable than in other seasons due to the large vertical shear and weak stratification. This seasonal variation in the intensity of baroclinic instability is responsible for the seasonal modulation of the STCC's EKE field with a November/December maximum and a June/July minimum. The large deformation radius in the low-latitude SECC region, on the other hand, prevents the vertically-sheared SECC-SEC system from becoming baroclinically unstable. With the broad, westward-flowing SEC weakening the stabilizing planetary beta effect, the high EKE level observed along the SECC is found to result from the barotropic instability associated with the horizontal shear of he SECC-SEC system. Together with an analysis of energetics, we show that the seasonal variation in the intensity of barotropic instability accounts for the seasonal modulation of the SECC's EKE field, with a maximum in April and a minimum in August.

(For more information: http://www.soest.hawaii.edu/oceanography/bo/QC04.pdf)

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Decadal and interdecadal variability in atmospheric angular momentum

Atmospheric angular momentum (AAM) provides a convenient framework to study the role of various transport mechanisms in variability ranging from intra-seasonal to interdecadal and beyond. AAM is useful as an index of the large scale zonal flow since it is highly correlated with independent length-of-day measurements and with phenomena such as the ENSO, the stratospheric QBO, the MJO and global warming. Over the past decade observations have been published demonstrating the appearance in the tropics and subsequent poleward propagation of interannual anomalies in zonally averaged atmospheric angular momentum. The emergence of these anomalies in the tropics appears to be associated with El Niño-Southern Oscillation (ENSO) events. Instead upward and downward variations in the stratosphere have been associated with the stratospheric quasi biennial oscillation. The variability of atmospheric angular momentum has been shown to present decadal as well as interdecadal time scales. Here we will extend the work to investigate regional origin and transport of decadal oscillations present in reanalyzes as well as different model runs from NCAR and CERFACS. Both the AAM from reanalyzes and the atmospheric run present decadal (10-12 yr) and interdecadal periods, as well the same geographical variability. Its variability originates primarily from the Pacific Ocean region, but we find also an important variability originating from the Atlantic. We also analyze decadal signals in AAM from different model runs of NCAR; It shows too a well-represented decadal and interdecadal variability well above the statistical significance level. Their propagation into, or at least appearance in, the subtropics and middle latitudes suggests that this decadal generated signal, a signal with some potential for predictability, may make a significant contribution to decadal variability in middle latitudes.

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Technical advances and new sensors for profiling floats in ARGO

The state variables of the ocean circulation are temperature, salinity, pressure, and velocity. The Argo program has deployed nearly 2000 profiling floats in the world ocean, with more deployments to come, with the goal of measuring these state variables at approximately 3 degree intervals globally, thus enabling a time-dependent estimate of the 3-dimensional global ocean circulation to be constructed. The profiling float configuration used in Argo is generally performing well, and presently a number of advanced capabilities are being tested for use on future floats. These capabilities include improved communications using the Iridium system, allowing full 2-way communication with the floats and the ability to change float missions after deployment. A number of test floats using Iridium instead of ARGOS have now been deployed. Floats have also been deployed that use composite, carbon fiber hulls instead of the normally-used aluminum hulls, allowing greater payloads on the floats and a greater depth capability. In addition to these improvements, a number of new sensors have been employed on Argo floats, including 2 varieties of dissolved oxygen sensors, wind speed and rainfall sensors, low-frequency acoustic sensors that can be used for RAFOS tracking, and nutrient sensors. These technological advances will be discussed in this talk.

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Biological Data Management activities at CENDHOC related to research cruises in the chilean inner southern channels

The region of the Chilean fiords extends from 41º31'S to 55º00S. It can be divided into three big areas which encompass the following geographic features : the Gulf of Reloncaví (41°31´S) to San Rafael Lagoon (46°32´S), the Gulf of Penas to the northern border of Magellan's Strait (52°30'S) and from Magellan's Strait until Cape Horn (56°S).

This whole large area, one of those fewer populated and more unknown of the Chilean territory, presents multiple queries from the oceanographic, geological and marine biodiversity point of view, and for which a growing demand of use of its coastal area exists, especially for the development of the aquaculture and tourism.

For this reason, the National Oceanographic Committee (CONA) located at SHOA, a committee that includes most of the academic and governmental institutions related to marine sciences in Chile, identified this area as a high-priority one in 1994, and managed to get funds from the government to support a a long-term multidisciplinary research study to the fiords. The first CIMAR Fiordo cruise started in 1995 and up to present a total of 8 research cruises, on board Chilean navy research vessel AGOR Vidal Gormaz, have been performed into this area, collecting data and samples for meteorology, geomorphology, physical and chemical oceanography, geochemistry of sediments, fish, crustacean, plankton and benthos. The results of, at least, the first 6 cruises of this research as a whole has produced a considerable amount of scientific papers, presentation to workshops in national and international forum.

Nevertheless this rapid growth in academic production, the data management was phased until 2000 when the chilean NODC (CENDHOC) was tasked to start gathering, quality control and archiving the data as well as all the information obtained from those cruises that were piling up at CONA. In order to obtain prompt results, due to delayed starting time, CENDHOC prepared oceanographic products in the form of Data Reports in CD. So Far, four data reports have been produced (http://www.shoa.cl/cendoc/organizacion/datareport_cimar.htm) and an on-line bibliographic index web page was created (http://www.shoa.cl/cendoc/ib/ibc/ibc1-7.html). Besides the data center has handled to archive all the physical metadata an data on its databases.

Regarding the biological management of the CIMAR Fiordo data, besides that the data have been included in the Cds, there is still some uncertainty regarding what is the best way to handle such heterogenic parameter. So far CENDOC has collected the biological metadata of the cruises and archived accordingly and plans called for a new data organization in order to be better suited to build new oceanographic data products, such as GIS charts. Some contacts have been made with the CONA´s Task Team on Marine Biodiversity in order to be advised on how to apply standards in classifying taxonomic groups to CIMAR data.

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Examining the effect of height anomalies on dry conditions over Buenos Aires

One objective of the present work is to explore the influence of mid-tropospheric circulation anomalies as factors in determining the local lack of precipitation in extended periods of one week or two weeks. High geopotential anomalies centred about 38ºS, 75ºW over the Pacific coast covering the western side of Argentina and adjacent Pacific Ocean low geopotential anomalies about 28ºS, 45ºW over the Atlantic Ocean and the south-eastern Brazilian coast are associated with a week without any precipitation at Buenos Aires, Argentina. When considering a somewhat more persistent dry period of two weeks, say initial drought circulation conditions, flow anomaly patterns become considerably significant showing particular large- and synoptic-scale characteristics associated with initial drought at Buenos Aires. A “tripole” pattern is the striking feature, with the high or positive anomaly at the same latitude but near completely over the Pacific Ocean, and two strongly significant low anomalies. One of them may be found at south-western Atlantic region including the Drake Passage, and the other conspicuous low anomaly at tropical latitudes west of 110ºW. This “tripole” anomaly pattern associated with a two-week dry period clearly has a NW–SE direction, contrasting in some way with that of a one-week period. Anomalous cyclonic activity appears to be an important feature of the southern hemisphere circulation at subpolar latitudes about 60ºS in the south of the continent in association with initial drought at the humid pampas of Argentina. Additionally, anomalous cyclonic activity at tropical latitudes, perhaps in connection with anomalously strong convection over the Pacific Ocean about 115ºW seems to greatly influence the circulation pattern propitiatory of downward vertical motion at the Buenos Aires region in a fortnight period. The persistence of these flow patterns would lead to longer dry periods in the eastern part of southern South America.

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Operational Ocean Forecasting in the Southern Hemisphere: Observations, Models and Systems

The Australian Government, through the Bureau of Meteorology, Royal Australian Navy and CSIRO has initiated BLUElink - *Ocean Forecasting Australia*, a project to deliver operational short-range ocean forecasts for the Asian-Australian region by 2007. The forecasts will provide information on coastal and ocean currents and eddies, surface and subsurface ocean properties, that impact and are linked to maritime and commercial operations, defence applications, safety-at-sea, ecological sustainability, regional and global climate. Global advances in technologies necessary to observe and simulate the oceans have provided scientists at CSIRO and the Bureau of Meteorology with the tools to deliver near real-time information on ocean behaviour. The aim of the project is to generate ocean charts for marine users similar to weather forecast charts available to the rest of the community. Central to BLUElink is the development of a global and nested ocean prediction system. The ocean prediction system combines satellite observations (sea-surface height and SST) and in-situ ocean observations (temperature and salinity) from Argo profiling floats and other measurement platforms with a global ocean general circulation model. Global ocean forecasts will be updated to include the latest changes in the ocean state weather systems, particularly extreme conditions such as from tropical cyclones. CSIRO currently develops a relocatable high-resolution, coupled atmosphere-ocean model predicting out to three days which will be nested within the global system. The nested modelling system has been specifically designed for coastal and shelf applications.

The presentation will provide an overview about the project components with particular emphasis on the Southwest Pacific region, show examples of the outputs from the prototype forecasting systems (e.g., ocean reanalysis) and outline future research directions of the project.

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Coupled Air Sea Interaction in the South Pacific: A Model Study.

In the North Pacific, the variability of the sea surface temperature (SST) is dominated by a pattern called the Pacific Decadal Oscillation. Recent analysis of observations and models suggest that this pattern results from a first order, autoregressive (AR-1) process forced by the Aleutian Low, by El Nino, and in the Kuroshio-Oyashio Extensionregions by ocean circulation anomalies.

In this study, we employ a similar methodology to explore the variability of SST in the South Pacific. Lacking a long observational record, output from an extended integration of a coupled climate model (PCM) is used. Results indicate that the SST reconstruction based on an AR-1 model is similarly successful as in the North Pacific. However, in contrast to north of the equator, more than one pattern of atmospheric sea level pressure are essential to explain SST variations. Ocean dynamics, as described by ocean sea level, are important in the East Austral Current, off New Zealand, and in arc that extends from the tip of South America in the north-westward direction towards 30S. As a result, the SST anomaly pattern in the South Pacific is not dominated by a single pattern, and there is no direct counterpart to the Pacific Decadal Oscillation in the South Pacific. The possible role of ocean to atmosphere feedbacks, detectable but small in the North Pacific, will be explored for the South Pacific.

Wolfgang Schneider, H. Freeland and L. Bravo

Results of 6 ARGO floats west of Drake Passage: 2003-2005

The Canadian Institute of Ocean Sciences launched 6 ARGOS profilers by air drop in the eastern South Pacific Ocean west of the Drake Passage between 52-58°S and 83-92°W where formation of Antarctic Intermediate Water is assumed. Besides the most northern profiling float all of the deployed ARGOS floats drifted into the South Atlantic Ocean through the Drake Passage during their first, second or third year after deployment thus allowing to monitor about 200 profiles from surface to 2000 m depth within the target region in the eastern South Pacific. Average mixed layer depth was estimated to be 75 m (STD = 19 m) during austral summer. Below the mixed layer a halostad up to approximately 600 m thick was found. The halostad's salinity equalled about 34.2 in the northern section (50-55°S), but was more variable in the higher latitudes (55-60°S) with salinities being fresher, ranging between 34.1 -34.2. Surface salinity was generally lower at the surface than in Subantarctic Mode and Intermediate Water. Vertical convection owing to winter time cooling occurred during September/October exceeding 700 m at some places hereby mixing lower salinity surface water into intermediate depths.

Wolfgang Schneider, M. Fukasawa, H. Uchida, T. Kawano and I. Kaneko

Property changes in South Pacific Water masses: BEAGLE (2003) – WOCE (1992).

The BEAGLE expedition repeated during August to October 2003 the WOCE P06 section along approximately 32.5°S in the Pacific Ocean occupied earlier in 1992 during May to July. Potential temperature and salinity changes for the main water masses of the South Pacific Ocean were estimated. Water masses were approximated by neutral density layers based on zonal averaged Potential Temperature and Salinity diagrams. Surface, Thermocline, Antartic Intermediate, Upper Circumpolar, Circumpolar, Lower Circumpolar and Bottom Water were analyzed. Based on zonal averaged Potential Temperature and Salinity, the most pronounced property change took place in the upper three water masses which were significantly fresher in 2003 than in 1992. Nevertheless, significant west to east differences were also observed. E.g., Antarctic Intermediate Water was saltier and warmer in the eastern South Pacific, but fresher and cooler in the western section.

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Japanese Argo activities in the South Pacific

JAMSTEC in cooperation with other Japanese organizations has deployed 425 Argo floats in total since 2000, i.e., 307 floats in the North Pacific, 37 in the South Pacific, 27 in Indian Ocean and 54 in the Southern Ocean. JAMSTEC has been developing various techniques, e.g., to estimate float drift by a Ocean General Circulation Model prior to actual deployment, to launch floats from cruising vessels and to recover floats to examine conductivity sensor drift. JAMSTEC has used two types of Argo float, APEX and PROVOR and got the average life time for these two types.
JAMSTEC has very few opportunities to come to the South Pacific to deploy Argo floats, so it would appreciate any kind of help from the nations associated with the South Pacific.
Regarding Argo data, JAMSTEC constitutes the Argo Pacific Regional Center along with CSIRO/Australia and IPRC/USA monitoring the quality of any Argo data obtained in the North and South Pacific.
The distribution and seasonal change of barrier layers obtained from Argo data in the South Pacific will be described in comparison with those calculated from previous climatological data. Barrier layers more than 10-m thick are observed by Argo in the South Pacific (20°-5°S, 140°-90°W) throughout a year and they are thicker and observed more frequently between July and November. A patchy distribution is one of remarkable features of the barrier layers observed by Argo floats. In addition, the spatial and temporal variability of the South Pacific Subtropical Mode Water will be presented on the basis of high resolution XBT line (PX06) data.

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Circulation Variability Along Pacific Eastern Boundaries: Low, Mid and High Latitudes

This is an initial study for the NASA Ocean Surface Topography Science Team, looking at how well the existing altimeter record captures the basic modes of basin-scale variability in the North and South Pacific. Although our project focuses on the large-scale eastern boundaries, these analyses cover the entire Pacific basin. We compare three data sets: the 1993-2004 altimeter data set; a new 1993-2004 “Pathfinder SST” product; and the 1981-2004 “Reynolds SST” data set. We find some possible problems in the last two years of the Pathfinder SST, for which the coefficients had not been adjusted by comparison to global drifters and buoys. The Reynolds SST time series captures the major climate variability modes: the El Niño and La Niña signals, a moderate shift around 1989, a 1996 mid-latitude “pre-curser” to the strong 1997-98 El Niño, and an apparent basin-scale shift after 1998 that appears to have disappeared by 2004. The altimeter record finds the same or similar spatial patterns for the strong 1997-98 El Niño and the post-1998 “shift.” The signals are strongly symmetric between Northern and Southern Hemispheres for the El Niño signals, moderately or weakly symmetric for the other signals.

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Satellite Observational Capabilities – Past, Present and Future

Climate studies require long time series. For satellite products, this means the retrospective production of "climate data records," i.e., consistent processing and cross-calibration of sequential sensors. A brief review of the historical and planned sensors will be given, along with examples from the South Pacific.

- **SST:** Our longest records are of SST from the AVHRR sensor. The "Pathfinder" program has produced reasonably consistent records, with 4km to 9km spatial resolution, from 1985 to recent years, with a lag in time caused by the necessity of gathering all surface SST data from buoys and drifters, before adjusting the coefficients in the retrieval algorithms. A longer, but much smoother data set consists of the "Reynolds" SST data set, extending from 1981-present. Resolution is too coarse to look at coastal processes, but captures basin-scale climate signals (El Niño and a major shift after 1998) very well.
- **SSH:** The next longest continuous record is of sea surface height from altimeters. Precision altimeters began with TOPEX ~1993-present, continued in Jason-1 and aided by the European ERS and ENVISAT altimeters. The 13-year record also captures the basin-scale climate signals that occurred during its sampling period.
- **COLOR:** Modern, high-quality continuous ocean color is available from late 1997 to present from SeaWiFS, complemented by the more sensitive, more multi-spectral, less-stable MODIS sensors. The records display interannual variability but are not yet long enough to capture major climate signals. If these can be combined with the less sensitive CZCS records from 1979-1983, climate signals may be investigated.
- **WIND:** Continuous vector wind measurements from QuikSCAT are available since mid-1999. Further scatterometers are not planned by the U.S. Rather, vector winds will be estimated by passive microwave sensors (WindSat at present and CMIS in the future).

In the future (NPOESS) era, **SST and Ocean Color** will be measured by the VIIRS instrument, combining channels from the AVHRR and MODIS/SeaWiFS heritage. Consistent climate data records should be possible. A new sensor, the Hyperspectral Environmental Suite – Coastal Water (HES-CW) imager is planned for the next generation GOES satellites, beginning in 2012. This sensor will provide higher resolution, **multi- or hyper-spectral color** measurements for advanced applications in the coastal regions (HAB's, phytoplankton pigments and fluorescence, etc). **SSH measurements** along the same repeat tracks as TOPEX and Jason-1 will be carried out by Jason-2, beginning around 2008. The European ENVISAT altimeters will continue to complement these measurements, producing CDR's of 20+ years (barring failures). The greatest uncertainty is for **ocean vector winds**, where the passive microwave sensors will replace active radar scatterometers after QuikSCAT stops working. This will create at least a discontinuity in CDR's, with a change in data characteristics and possibly quality. There may also be a gap in the data record, since QuikSCAT launched in mid-1999 and WindSat launched in early 2003 and has already had one major near-failure. The first CMIS will be on the C1 satellite of NPOESS, with launch at the end of 2009 or later.

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On the annual cycle of heat content in the Peru Current region

The relative importance of the processes responsible for the annual cycle in the upper ocean heat content in the Peru Current, in the southeastern tropical Pacific, was diagnosed from an oceanic analysis dataset. It was found that the annual cycle of heat content is forced mainly by that of insolation. However, the ocean dynamical processes play an important role in producing different regional budget characteristics.

In a band 500 km from the coast of Peru the annual heat content changes in this region are relatively large and can be approximated as sea surface temperature (SST) changes in a fixed depth mixed layer. The annual cycle of the albedo associated with low-level clouds enhances the annual cycle in insolation, which explains the relatively strong annual cycle of heat content. These clouds, to a large extent, act as a feedback to SST but a small additional forcing, which we propose to be cold air advection, is needed to explain the fact that the maximum cloudiness leads the lowest SST by around a month. Ocean dynamics is important closer to the coast, where upwelling acts partly as damping of the heat content changes and forces it to peak earlier than farther offshore.

In a band farther to the southwest, locally wind-forced thermocline motions, which becomes shallower (deeper) in the warm (cool) season, cancel partially the effect of net surface heat fluxes, whose annual cycle is comparable to that in the region previously mentioned, producing a relatively small annual cycle of heat content. The local forcing appears to be associated with the annual meridional displacements of the South Pacific Anticyclone. The annual cycle in SST is also relatively small, which is probably due to the changes in the temperature of the water entrained into the mixed layer associated with the thermocline motions, but also to a mixed layer deeper than that closer to the coast.

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ENSO Cruises: monitoring ocean conditions in central Chile

Since 1999, SHOA started the development of a biannual oceanographic cruises monitoring program, the ENSO Cruises. Its goal is to keep monitoring oceanographic conditions in central Chilean coasts; cruises are carried out usually in may and December every year, having to the present a total of 13 oceanographic cruises completed.

The ENSO Cruises, consist of two crosshore lines, extending 200 nautical miles offshore, where 11 oceanographic stations are distributed and CTD casts until 1000 meters depth are performed. As a complement of this information, water sampling at standard depths is carried out, for salinity and dissolved oxygen content analysis,

During June this year, ocean monitoring through these cruises, was enhanced with the incorporation of SHOA to the operational phase of ARGO Program, by launching the first Chilean APEX float at ENSO 13 Cruise, through a successful cooperation management with the Institute of Ocean Sciences (IOS), Gov. Canada.

Time evolution of oceanographic conditions is shown in this poster, sea surface temperature and sea level registered at northern and central Chilean coasts. Variability of the upper 2000 meters of the ocean through ARGO floats information at the central Chilean coast are also shown as part of the integrated monitoring program.

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Coastal winds regime and its influence on shelf circulation in central Chile

Central Chile is under the influence of the Eastern South Pacific High Pressure Center, main modulator of atmospheric conditions in the region. In this area, from October to April SW winds are predominant, the rest of the year, storms come more often carrying NW winds. Wind stress over the ocean surface is recognized as an important driving force on shallow water circulation. This action has a direct response, through internal friction, in the upper layer at the ocean.

In this research, main features of coastal winds and its influence over coastal currents are analyzed, between 1991 and 1995. Wind registered in meteorological stations in La Serena, Valparaíso, and Talcahuano, was available from Dirección Meteorológica de Chile (DMC). Current meter data was available at 30º S from JGOFS-Chile Project (Joint Global Ocean Fluxes Study), and at 34º S from UCV-DGI 223.757 Project (Shelf Circulation on central Chile), both current meter moorings included measurements around 170, 400 and 700 meters depth. Wind and currents analysis, was based on determinations of Spectral Density, Coherence and Phase functions.

Between 1991 and 1995, frequency domain energy distribution revealed similar spectral composition in the study area, where highest energy was concentrated at low frequency bands, lightly increasing southern; high energy was found also around 2 and 5 days. Wind variability associated to 5 days periodicity might be due to coastal laws propagation, atmospheric perturbations at synoptic scale traveling southward in that frequency band.

Currents at 170 meters depth, showed a clear response to wind variability around periods of 5 days, where alongshore flow was driven by the wind at 30º and 34º S. Currents measurements at 400 and 700 meters depth, didn't respond significatively to wind modulation at any particular frequency.

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The South Pacific and forecast skill of seasonal variability over South America

A number of studies made during the past decade in the context of the WCRP/CLIVAR/VAMOS program, have revealed the major elements of the South America Monsoon System (SAMS), including its context within the annual cycle, and some aspects of its variability. In particular, progress has been made in understanding the year-to-year variability in the SAMS region and their associated levels of predictability.
The first leading pattern of precipitation variability on interannual timescales over South America is that forced by ENSO, characterized by an out-of phase relationship between precipitation anomalies over east-central Amazon and Northeast Brazil, and those over southeastern South America. Current climate models used to perform seasonal predictions are able to reproduce such pattern of precipitation anomalies although it accounts for a larger percentage of precipitation variance than observed. It has been recognized, however that considerable year-to-year variability over tropical and subtropical South America is not explained by ENSO, and significant progress have been made in describing the influence of the tropical Atlantic. The role of the South Pacific conditions over the climate variations in the SAMS region has not received considerable attention yet although there are some evidences that confirm the existence of such influence.
Differences in the response of precipitation over South America among different ENSO warm events have been detected and traced back to differences in the atmospheric and oceanic conditions over subtropical south central Pacific (SSCP) region. It has been found that ENSO warm events associated with colder than normal conditions in the SSCP exhibit enhanced convection in the South Pacific Convergence Zone (SPCZ) extended southeastward; a distinctive atmospheric Rossby wave pattern longitudinally extended along the Pacific Ocean and increased precipitation over southeastern South America. Neither the atmospheric Rossby wave pattern over the central South Pacific, nor the precipitation increment over South America, are evident during ENSO warm events associated with warm conditions in the SSCP and inactive SPCZ. Such differences in the atmospheric response over the SH during ENSO warm events seem to be influenced by the interdecadal variability detected in the Pacific by many studies.
The existence of decadal and longer time-scale variability in South American rainfall, related to ocean surface changes on those timescales in both the Pacific and the Atlantic Oceans has been recognized in many studies. Significant influence of the PDO has been found on precipitation variability over southeastern South America during summer, independent of ENSO. Furthermore, positive trends in the poleward moisture transport between tropical and extratropical South America as well as in the associated the precipitation anomalies at the subtropics are linked to trends in the Pacific Decadal Oscillation. In particular, there are many evidences showing that the climate shift that occurred in the Pacific around the late 1970s had a large influence on South American climate.

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Regional Coupled Modeling of The East Pacific Climate

In this talk, we will first introduce the regional atmospheric model developed at the International Pacific Research Center (IPRC–RegCM) and the regional coupled ocean-atmospheric model (iROAM), which couples the IPRC–RegCM with the Modular Ocean Model Version 2 (MOM2) developed at the Geophysical Fluid Dynamical Laboratory (GFDL). We will highlight some results from the applications of both the atmospheric model and the coupled model to the studies of eastern Pacific climate processes with the focus on the simulations of boundary layer stratus and stratocumulus clouds over the Southeast Pacific and the seasonal cycle of the equatorial tropical Pacific and the tropical instability waves (TIWs) in the coupled system. We will show that the iROAM has considerable skill in simulating the eastern Pacific climate. This is achieved mainly due to the capability of its atmospheric component model (IPRC–RegCM) in simulating the boundary layer clouds over the Southeast Pacific. The regional coupled model can thus be used as a test bed for parameterizations (constrained by field observations) and as a useful tool to understand the coupled physical processes in the eastern Pacific.
Some scientific issues that need to be addressed in future studies will be also discussed briefly, including 1) how strong is the TIW-induced wind & cloud variability and how does it affect the variations in ITCZ convection in a coupled system? 2) what is the role of shallow convection in the decoupled boundary layer? 3) what processes are responsible for the pronounced subseasonal variabilities in the stratus/stratocumulus clouds over the Southeast Pacific? 4) how does drizzling in modifying the subcloud layer and surface fluxes, affecting SSTs in a coupled system? 5) how do aerosols affect stratus clouds and how can we consider their effect realistically in numerical models? 6) how strong the synoptic-scale variability in the stratocumulus clouds, affecting the mean climate and lower frequency variability? 7) what are the roles of Andes in modifying both stratus clouds and the ITCZ in the eastern Pacific? 8) how does southeast Pacific stratus deck affect the seasonal cycle and ENSO?

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Estimates of interannual to decadal changes in upper-ocean thermal structure and circulation from a combination of satellite, Argo and other in situ data

Satellite-based measurements of sea surface height provide information that is highly complimentary to a wide variety of in situ data sets. In previous studies (*Willis et al., **JGR**, 2003;2004*) satellite data was combined with temperature profiles from various instruments including Argo floats to produce improved estimates of upper-ocean thermal variability on interannual to decadal time scales. In the south Pacific, upper-ocean temperature estimates show substantial ENSO-related variability as well as a steady warming signal in the southwest that extends deep into the water column. As the Argo array reaches target density, further improvements in accuracy and time resolution of estimates such as these will be possible. Satellite altimeter data was also combined with float displacements from the Argo array. Results suggest that in many locations altimeter data contains information about the anomalous velocity field at depth and may be used to improve estimates of time-mean circulation at depth. A technique for combining sea surface height and float displacements will be presented as well as an initial estimate of the time-mean circulation at 1000 m over parts of the South Pacific.