CLIVAR/CliC Southern Ocean workshop, November 2000
Report to CLIVAR SSG

A workshop on the Southern Ocean and Climate was held from 16-18 November 2000 in Perth, Australia. The workshop was sponsored by the Climate Variability and Predictability (CLIVAR) and Climate and the Cryosphere (CliC) programs of the World Climate Research Program. About 35 scientists participated in the workshop, including representatives from all the major nations involved in Southern Ocean research. This brief report summarizes the discussions and recommendations of the workshop.

Workshop objectives:

1. Update and refine the scientific arguments behind the CLIVAR/CliC objectives in the Southern Ocean.
2. Define the mix of sustained observations, process studies, and model experiments needed to meet the scientific objectives of CLIVAR and CliC.
3. Identify scientific objectives of CLIVAR/CliC that are not being addressed by current and planned research, and propose strategies to fill the gaps.
4. Identify and foster links with other programs.

Recent scientific progress:

The workshop highlighted significant progress in a number of areas since the Science and Implementation Plans for CLIVAR had been written. As a result of these advances, it is now possible to define a coherent set of integrated experiments targeted at the Southern Ocean phenomena of direct relevance to climate. The workshop concluded that the existing plans must evolve to reflect the scientific progress made, and that a CLIVAR/CliC Southern Ocean Panel was needed to coordinate the revision of the plan and its implementation.

Some of the recent scientific advances highlighted at the meeting include:

- Recent studies suggest the conversion of dense water to light water required to close the global overturning circulation is primarily accomplished by air-sea fluxes in the Southern Ocean, rather than by diapycnal mixing through the low- and mid-latitude thermocline. This implies the vigor of the overturning circulation may be sensitive to changes in air-sea forcing at high southern latitudes.

- In coupled climate runs with increased greenhouse gas forcing, the surface of the Southern Ocean warms and freshens, leading to a collapse of the overturning circulation. While inadequacies in present climate models make the realism of these projections uncertain, sparse observations suggest the signature of high latitude freshening may already be detected in the Subantarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW) exported from the Southern Ocean to lower latitudes. Determining the sensitivity of the Southern Ocean stratification and overturning circulation to changes in freshwater flux is a key task for CLIVAR.

- SAMW and AAIW are renewed on decadal time-scales and are responsible for the ventilation of the lower thermocline in the southern hemisphere. These water masses also make a dominant contribution to the net oceanic uptake of anthropogenic carbon dioxide and heat (hence determining the rate of sea level rise through thermal expansion). Climate models suggest that the signature of climate change in the ocean will be most evident (greatest signal to noise) in the mode and intermediate waters of the southern hemisphere. For these reasons, studies aimed at the formation, circulation, and sensitivity of these water masses to changes in forcing are high priority.

- The export of warm water from the Pacific via the Indonesian passages is ultimately balanced by inflow of SAMW south of Australia, forming a large-scale gyre which links the Pacific and Indian basins. Where the conversion of SAMW to warmer thermocline water occurs is not clear, nor is the impact of variations in SAMW transport or properties on lower latitudes. However, the heat transport associated with this interbasin circulation is large ($\approx$ 0.5 PW) and therefore potentially a significant element of the climate system.

- A number of recent studies have documented variability of the atmospheric circulation of the southern hemisphere on timescales from interseasonal to multi-decadal. Some of the variability is likely forced from the tropics via atmospheric teleconnections, while low frequency variability of other dominant modes (e.g. decadal changes in the strength of the semi-annual oscillation) apparently reflects coupled ocean-atmosphere-sea ice dynamics. Further work is required to determine the main modes of variability over the Southern Ocean region, whether they are locally or remotely forced, the extent to which they are coupled phenomena, and their influence on climate variability in southern hemisphere nations.

- In recent years, substantial effort has been devoted to understanding the Antarctic Circumpolar Wave (ACW). The ACW has been linked to variability in rainfall and crop statistics on the southern hemisphere continents, and there are suggestions it may be useful as a predictive tool. The longer records now available make it clear that the strength of the ACW anomalies varies with time, with the last decade a period of weak ACW. A number of hypotheses have been put forward to explain the ACW, but the dynamics of the phenomenon remain a topic of debate.

Observations needed:

The recent scientific progress guides the design of an integrated ensemble of experiments for the Southern Ocean region, including in situ observations (both sustained monitoring and process studies), remote sensing, and modelling experiments. The observational requirements include profiling floats (Argo), repeat CTD and XBT sections, moored arrays, and several process studies, as described in detail in the full report from the meeting.. While commitments exist for perhaps a surprisingly large fraction of what is required, significant gaps remain. A major task for the proposed Panel will be to ensure these gaps are filled. The most important gaps are summarized below.

Gaps in commitments to the observational network:

1. *Argo*: many of the key scientific questions in the Southern Ocean require broad-scale profiles of upper ocean temperature and salinity. The only way to obtain such measurements in this vast and remote region is with profiling floats. While a growing number of countries have expressed an interest in Southern Ocean Argo, few firm commitments have so far been made. A substantial commitment from nations both within and outside the Southern Ocean region will be required. Further study is required to define the optimal sampling strategy for Southern Ocean Argo.

2. *Repeat hydrography*: Full-depth tracer/hydrographic sections are needed to define volumes for budget studies, to measure the oceanic uptake of carbon dioxide, to constrain estimates of mixing and water mass formation, to monitor changes in the deep ocean, and to measure changes throughout the water column of properties that cannot be measured by profiling floats or volunteer observing ships. Many of the Southern Ocean lines required to meet the goals of CLIVAR/CliC are committed, but gaps remain, particularly in the Pacific sector.

3. *Mode water formation:* Process experiments: to study Subantarctic Mode Water formation are needed in the southeast Indian and Pacific basins. The experiments should include winter hydrography; time series observations of temperature, salinity (hence stratification) and currents, which might be collected by a combination of moorings, moored profilers, or gliders; and profiling floats to measure the evolution of SAMW/AAIW properties as they propagate away from the source regions.

4. *Improved estimates of surface fluxes (heat, freshwater, and momentum).* Better knowledge of surface fluxes is essential to understand the coupling between the ocean and the atmosphere in the Southern Ocean region. This is particularly crucial for understanding how mode water is formed, the processes controlling the upwelling limb of the overturning circulation, and the nature of teleconnections between high and low latitudes. Present estimates vary dramatically between different climatologies and reanalysis products, and few direct observations exist for validation. A task group was proposed to define the optimal combination of in situ observations, modelling studies and reanalysis activities to deliver improved flux estimates.

Summary:

As a result of the substantial effort during WOCE, our understanding of the Southern Ocean and its role in the climate system is growing rapidly. These developments lay the foundation for a focused program of experiments targeted at testing specific hypotheses, rather than the more “exploratory” nature of the studies proposed early in the planning for CLIVAR. A Southern Ocean Panel is needed to coordinate the revision of the Science and Implementation Plans to reflect recent progress, and to coordinate the implementation of Southern Ocean CLIVAR and CliC.

Attachment 1:

Draft terms of reference for CLIVAR/CliC Southern Ocean panel

To design a strategy to assess climate variability and predictability of the coupled ocean-atmosphere-ice system in the Southern Ocean region.

To develop and refine an implementation plan for the Southern Ocean region which defines the process studies, sustained observations, and model experiments needed to meet the objectives of CLIVAR and CliC.

To work in concert with relevant CLIVAR panels (e.g. regional panels, numerical experimentation groups) and other groups (e.g. Ocean Observation Panel for Climate, Argo Science Team) to integrate Southern Ocean observations with those in neighboring regions to ensure the objectives of CLIVAR/CliC are met and resources are used efficiently.

To enhance interaction between the meteorology, oceanography, cryosphere, biogeochemistry and paleoclimate communities with an interest in the climate variability of the Southern Ocean region.

To serve as a forum for the discussion and communication of scientific advances in the understanding of climate variability and change in the Southern Ocean region.

To work with the CLIVAR data system on issues related to distribution and archiving of Southern Ocean observations.

To advise the CLIVAR and CliC SSGs on progress achieved in the implementation of Southern Ocean CLIVAR and CliC.

Attachment 2:

Proposed membership of a CLIVAR/CliC Southern Ocean Panel

1. Steve Rintoul (Aus) (co-chair)	(ACC, water mass formation, inverse models)
2. Eberhard Fahrbach (Ger) (co-chair)	(high latitude obs., CliC)
3. Arnold Gordon (USA)	(in situ obs, high latitude processes)
4. Kevin Speer (USA)	(SAMW/AAIW, overturning, Argo)
5. Shigeru Aoki (Japan)	(observations)
6. Ian Allison (Aus)	(CliC, sea ice)
7. Rosemary Morrow (Fra)	(in situ obs, altimetry, data assimilation?)
8. Ian Simmonds (Aus)	(atm., modelling, paleo, on SSG)
9. Stuart Cunningham (UK)	(ACC, Drake passage repeats)
10. Chris Sabine (USA)	(Carbon)
11. Gurvan Madec (Fra)	(coupled and ocean-only models)
12. Philip Froelich (USA)	(paleoceanography)
13. Doug Martinson (USA)	(CliC, sea ice – ocean interaction)

Other options/alternates:

Scott Doney (USA) (biogeochemistry, mixed layer, models, tracers)
Teri Chereskin (USA) (ACC variability, ACW)
Sarah Gille (USA) (theory, altimetry, floats)
Alex Orsi (USA) (AABW, tracers)
Mike Meredith (UK) (tracers)
Zhaoqian Dong (China)
Alexander Klepikov (Russia)
Alberto Piola (Argentina)

Attachment 3:

Recent progress, action items and timetable:

Nov, 2000	Southern Ocean CLIVAR workshop held in Perth.
March 2001	Summary report of workshop sent to WCRP - JSC.
	A paper presenting the scientific justification for sustained observations in the Southern Ocean completed (Rintoul et al, 2001: Monitoring and Understanding Southern Ocean Variability and its Impact on Climate: A Strategy for Sustained Observations, OceanObs99 book).
	Presentation made to Ocean Observations Panel meeting in Hobart.
May 2001	Proposed terms of reference and membership of joint CLIVAR/CliC Southern Ocean Panel forwarded to CLIVAR SSG for consideration at the May 14-18 meeting.
	Contribute to Time Series workshop (Woods Hole).
Sept, 2001	Panel completes first draft of updated implementation plan, and circulates plan for comment.
Late 2001	First meeting of Southern Ocean Panel. Review draft implementation plan and comments, identify gaps and means to fill them.
Early 2002	Revised implementation plan completed.

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