



Project Report

Report of the 8th Session CLIVAR/CliC/SCAR Southern Ocean Panel

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ACTION ITEMS

ACTION: Develop list of processes to be further investigated by models and observation studies.

ACTION: Propose sessions at large conferences (EGU, AGU, Ocean Sciences) to engage atmosphere and ocean, observations and modelling communities.

ACTION: SOP to assess Antarctic Bottom Water formation estimates and make recommendations for modelers.

ACTION: Discuss with WGOMD further modeling activities in the Southern Ocean.

ACTION: Discuss with WGOMD activities related to new CORE experiments on SO wind perturbations and impacts of land-ice melting.

ACTION: Replace Yasushi Fukumachi as a panel member, and work on other panel rotations.

ACTION: Discuss cross-membership with CliC.

Report of CLIVAR/CliC/SCAR Southern Ocean Panel – 8th meeting

1. Introduction

Matthew England, co-chair of the CLIVAR/CliC/SCAR Southern Ocean welcomed all participants to the meeting. Apologies were received from panel members Nicole Lovenduski, Seb Swart, Gareth Marshall and Yasushi Fukumachi. Matthew England reviewed with the group the panel's terms of reference. Some of the terms are about activities that the panel is required to develop, others are about engagement with other groups and organizations. The Southern Ocean Panel needs to develop more activities with CliC, particularly as the project is a co-sponsor of the panel. Also, links with OOPC should be maintained. Recent panel activities include engagement with observation initiatives e.g. DIMES (Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean) and SOBOM (Southern Ocean Biogeochemical Observations and Modelling) programme, and an article reporting on Southern Ocean initiatives in ocean basin themed issue of CLIVAR Exchanges 58, and a poster poster on Southern Ocean Hydrography and Circulation during the WCRP Open Science Conference. In addition, the panel has further developed its Vision Document including three themes: Southern Ocean carbon, Atmospheric processes over the Southern Ocean, and Southern Ocean physics.

Several scientific questions will guide panel activities in the next five years, which are consistent with the new CLIVAR Research Opportunities and WCRP Grand Challenges:

- a. What is the future of Antarctic ice, including sea ice, ice shelves, and land ice?
- b. What is the impact of acidification? How will the Southern Ocean store of CO₂ change in the future?
- c. How will the ongoing projected trend in the Southern Annular Mode impact on air-sea heat, moisture, and carbon fluxes? What will be the impact on Southern Hemisphere regional climate?
- d. What is the future of the Antarctic continental margin?

Good ways for the panel to make an impact regarding these topics is by producing white papers, and ultimately review articles to be published in the peer-reviewed literature.

The panel also needs to make sure that the modelling and the observational communities are well connected, and should identify processes that need further joint investigation. A leading example is freshwater flux. Progress is needed in this area. CliC should be involved in those discussions. Another topic is the impact of episodic changes of ice shelves, and land ice melt on water mass formation. In order to get good estimates of the freshwater budget, melting is not the only factor. Large perturbations of the systems (episodic events) need to be seen as an important topic. A major problem with assessing the impact of these events is that they may not happen during field campaigns.

ACTION: Develop list of processes to be further investigated by model and observation studies.

2. Southern Ocean Observing System

Alberto Naveira-Garabato updated the panel on the Southern Ocean Observing System, which has formed a scientific steering committee and opened a project office at the University of Tasmania in 2011. Since the first meeting in February 2012 a number of subsequent meetings have been held. Science themes for SOOS include global freshwater and heat, stability of the overturning circulation, stability of the ice sheet and contribution to sea level rise, future of carbon uptake, future of Antarctic sea ice, and impacts of global change on Antarctic ecosystems. Because many of these themes are also integral to the CLIVAR SOP, it is important for both groups to find the best way to interact, avoiding duplication of efforts. SOOS will coordinate efforts of data provision through a data portal, although atmospheric data is not a focus. SOP recommends to SOOS that such data should be included in the data portal, and make the necessary links with GEWEX. Good bathymetry data is essential to models but those are difficult to obtain. Links with groups like PANGEA should be made to facilitate bathymetric data sharing.

3. SOOS Under-Ice Observation Workshop

Steve Rintoul reported on the SOOS under-ice observation workshop, which was held in October 2012 in Hobart. Observation of the ice-shelves is very important but logistically very difficult. Antarctic sea-ice extent is increasing slightly, with nearly balancing losses in the Pacific sector and gains in the Atlantic sector, but the exact reasons for these regional and overall trends is still being explored. Argo floats are now being equipped to obtain data under ice, with some notable success. Data can be stored and then transmitted when, and if, floats reach the surface. The one particular problem is the positioning of the observations but interpolation with several profiles from different floats makes it possible to reduce uncertainty. Moorings have also been deployed, and acoustic sources used to relay data collected.

4. Centre for Southern Ocean Biogeochemical Observations & Modeling (C-SOBOM)

Lynne Talley gave an overview of the proposed Center for Southern Ocean Biogeochemical Observations and Modeling (C-SOBOM / <http://sobom.princeton.edu>), with lead scientific P.I.s Jorge Sarmiento, Ken Johnson, Joellen Russell and Lynne Talley. (As of July 2, 2013, NSF had declined to fund the center, although its science was extremely highly reviewed, and the center ranked equally with four other proposed centers out of hundreds that were proposed; because of a major shortfall in US government funds in 2013, NSF could fund only three centers, which are presumably in areas of science and technology that are unrelated to the oceans and climate). C-SOBOM's goal was to improve carbon modeling of the Southern Ocean, and to monitor its large anthropogenic carbon uptake, heat uptake, acidification, and nutrient sources for net community production. Its plan was to operate with three themes:

- 1) Observations.
- 2) Modelling.
- 3) Education, Diversity, and Outreach.

Although funding has been declined through this particular NSF mechanism, the scientific work and the organizational structures of interdisciplinary physical-chemical-biological study and close interaction between observations and modeling could form the nucleus of an international scientific thrust that the SOP can support. The SOP will be discussing the form that this might take, which might include close interaction with IMBER/SOLAS because of the carbon and ecosystem components of CSOBOM. The core observing system for C-SOBOM is a circumpolar deployment of Argo-type floats with biogeochemical (BGC) sensors (oxygen, nitrate, optical backscatter, and a brand new pH sensor that would be widely introduced through this program); the US Argo programme has committed to provide 50% of the floats that will be deployed as part of the center, which increases the total number of BGC floats that can be deployed. The target number was 200, with additions from other countries greatly welcomed to increase the numbers. The core modeling effort was to be a Southern Ocean Model Intercomparison Project (SOMIP), with major input from NOAA GFDL, plus an OSSE study focused on the float deployment, and process modeling. Knowledge transfer is also an important component of the programme and will include a broad informal education initiative to stimulate public interest in the Southern Ocean's role in climate change, along with a program to spread the benefits of float technology via technical training certificates and entrainment of industry in sensor development.

C-SOBOM has formed an International Collaborations Committee, chaired by Steve Rintoul, and has begun developing plans for joint studies with groups in Australia, Argentina, South Africa, the UK, and France. Although the center itself was to be fully funded by the US, initiatives from other countries around the core objectives were to be highly welcomed. SOP members enquired if international groups will be able to assist in framing new paradigms and having them adopted by the center, and the answer is certainly yes. The center would not be developing new large Southern Ocean climate models but would be focused on the SOMIP activity, which had already begun partnerships with non-US institutions (Hadley Centre, with the goal to expand to many more) in order to carry out the SOMIP.

5. Diagnosing Ocean Circulation in Temperature-salinity Coordinates

Jan Zika presented a new technique he has developed to diagnose ocean circulation in temperature-salinity coordinates. The so-called 'thermohaline streamfunction' is the integral of transport in temperature-salinity space. He proposed this as a diagnostic to understand oceanic circulation and its role in the global movement of heat and freshwater. Physical pathways and ventilation time scales can be naturally diagnosed,

so too the roles of the mean flow and turbulent fluctuations. Because potential density is a function of temperature and salinity, the framework is naturally isopycnal and is ideal for the diagnosis of water-mass transformations and advective diapycnal heat and freshwater transports. The thermohaline streamfunction is easy to implement as a diagnostic for ocean models, and is being explored in COREII models (this links to WGOMD activities).

6. Eddy Physics in the Southern Ocean

Andy Hogg gave a talk on eddy physics in the SO and impacts on MOC and the ACC. Over the last decade, advances in computational capacity have allowed us to model the effects of eddies explicitly in the Southern Ocean, first with idealised and now with primitive equation models. Several key concepts have emerged from these numerical experiments. Firstly, it is clear that ACC transport sensitivity to changes in wind is reduced (perhaps eliminated) when eddies are resolved. Secondly, the sensitivity of the overturning to changes in wind stress is also reduced. Theories describing the ACC transport and its sensitivity to change predict that, while there remains some sensitivity to wind, it is clear that ACC transport also responds to surface buoyancy forcing (both locally and remotely). In short, it can be argued that the ACC is an integral diagnostic for all processes altering the global ocean stratification. The relationship between ACC and overturning sensitivity has also been clarified recently. Eddies may partially compensate wind-driven changes in the upper cell of the overturning, but the depth dependence of eddy vs wind-driven changes means one cannot expect full compensation. There are important distinctions between the way the ACC and the overturning respond to wind, and zonally averaged theories of the Southern Ocean need further work to account for these effects.

7. Antarctica 2K Working Group Activities

Tas Van Ommen reported to the panel on the activities developed by the Antarctica 2K working group. The idea of the 2K network was to develop a regional and global picture of reconstruction. The 2K network took over the activities of ICEPICS, a project that was developing something similar. Results show that Antarctica had a strong warming around 580 and 625 AD, followed by a long term trending of cooling, both obviously due to natural variability. Warming in recent decades is the highest since 625 AD, particularly in West Antarctica.

The interaction between oceanic and atmospheric observations is very important and the panel is always looking for these collaborations. Christian Jakob gave a presentation on Southern Ocean clouds physics. Observations (SWR) have improved mainly due to new ways of assigning clear skies. However, CMIP models have not made much progress and model errors due to clouds are still a problem. Middle top cloud regimes are the most frequent regimes in the Southern Ocean, and usually appear always further south. Perhaps these are the main source of errors. The major problem with models is that, although they can recreate those cloud regimes, there is still a lot of spread regarding the reproduction of the frequency they appear. More observations of clouds in the Southern Ocean are critical. A large field experiment, SOCRATES, is planned for the in 2016-2018 and it would be important for the ocean community to be involved.

8. Midlatitude Southern Hemisphere Jets

Dave Thompson presented the latest findings and gaps in the knowledge about the midlatitude Southern Hemisphere jets. In the CMIP5 simulations, the model response depends on the climatology. However, as this is a coupled problem, sea surface temperature gradients are important, which in turn are affected by clouds. Some outstanding areas of research in this topic are: atmosphere-ocean interaction over the Southern Ocean on seasonal to decadal scales, the two way coupling between clouds and the sea surface over the Southern Ocean, and the two way coupling between Southern Hemisphere sea-ice and the atmospheric circulation. New cloud datasets, particularly over the Southern Ocean, are extremely important for a better understanding of the ocean-atmosphere interaction in the region.

Participants of the meeting discussed coordinated ocean and atmospheric observations in the Southern Ocean. As mentioned before, SOOS and SOP need to coordinate efforts to avoid duplication. SOOS differs from SOP with its more pragmatic way of defining the observations and identifying those that have not been

implemented. The SOOS implementation plan has a list of met stations that are part of the network but more needs to be added regarding observations of clouds. There are some mobile facilities that can be installed in ships and operate as an autonomous instrument. The one issue with these instruments is that they use a lot of space on board. It would be useful to identify stations in Antarctica where these instruments could be deployed in order to replace visual observations that exist at the moment. The panel should propose sessions, for instance at EGU meetings, and involve atmosphere and ocean, observations and modelling communities. One topic that needs to be further discussed is SST biases in models, which may not be a coupled problem. Perhaps the use of fine scale models will provide some advance in this area.

ACTION: Propose sessions at large conferences (EGU, AGU, Ocean Sciences) to engage atmosphere and ocean, observations and modelling communities.

9. WGOMD – SOP Joint session

Gokhan Danabasoglu started the joint WGOMD-SOP session talking about the CORE activity and the ongoing comparison projects. Coordinated Ocean-ice Reference Experiments (COREs) were proposed by WGOMD as a venue for comparing global ocean – sea-ice models run under a common prescribed atmospheric state, with boundary fluxes computed via the same bulk formulae. The second phase of COREs, CORE-II, uses inter-annually varying atmospheric forcing over the 60-year period from 1948 to 2007. In the oceanographic community, the CORE-II simulations are usually referred to as hindcast experiments. These hindcasts provide a framework to evaluate ocean and sea-ice model performance and study mechanisms of time-dependent ocean phenomena and their variability from seasonal to decadal time scales for the recent past. Specifically, we believe that the CORE-II hindcast experiments directly contribute to:

- i) Evaluation, understanding, and improvement of the ocean components of earth system models.
- ii) Investigation of mechanisms for seasonal, inter-annual, and decadal variability.
- iii) Attribution of ocean-climate events to trends and forced and natural variability.
- iv) Evaluation of robustness of mechanisms across models.
- v) Bridge observations and modeling, by complementing ocean reanalysis from data assimilation approaches.

Finally, the CORE-II hindcast simulations can provide consistent ocean and sea-ice initial conditions for decadal prediction experiments. We are extremely pleased to have participation from eighteen modeling groups in this CORE-II effort. The CORE-II website (www.clivar.org/wgomd/core/core-2) has been developed to serve the community with information on how to participate in analysis of these CORE-II experiments. A special issue of Ocean Modelling will be produced in late 2014, and the CORE-II website is being advertised as part of the special issue announcement. ECCO is not part of CORE at the moment as the group does not use CORE-II.

One potential activity to be developed jointly between WGOMD and SOP is to investigate the lower cell in the Southern Ocean. However, studies with forcing with a 60-year cycle may not be enough for deep ocean. Also, comparison of results between some of the CORE models and climate models from the same groups forced by CORE would be an interesting activity.

9.1 Southern Ocean CORE Comparisons

Riccardo Farneti gave a talk on the Southern Ocean CORE comparisons. The study shows large different responses in the interior, producing different sensitivities to the forcing. IPCC models point to a large role for buoyancy forcing. However, in the CORE dataset wind changes are far larger than buoyancy changes. For the 20th Century, and results shown by only one model, wind stress effects seem to dominate. There are still several interesting topics that could be investigated: bottom water formation (although perhaps models have not been run long enough, and model bias/drift is hard to remove; interannual variability; sensitivity tests on the forcing.

J.B. Sallee showed some of the latest results of the representation of Southern Ocean processes in CMIP5 runs. Literature shows a large spread of estimates made by observations of the Antarctic Bottom Water

formation rate: a task for SOP could be to reassess this rate and arrive at a recommendation for modelers on the AABW formation and how much goes to the Atlantic, Pacific and Indian oceans.

ACTION: SOP to assess Antarctic Bottom Water formation estimates and make recommendations for modelers

9.2 Surface Winds & Buoyancy Fluxes

Stephanie Downes gave a talk that focused on the role of surface winds and buoyancy fluxes in varying the meridional overturning circulation under a climate scenario where atmospheric CO₂ reaches over 1300 ppm by the year 2100. The study evaluated the overturning, winds and buoyancy fluxes using models from the Coupled Model Intercomparison Project Phase 5 (CMIP5). The CMIP5 models have a distinct advantage compared with CMIP3 models: the eddy-induced overturning circulation is outputted. This allows for an easier multi-model comparison of what role eddies play in counteracting or enhancing the Eulerian mean overturning circulation changes. Results show that, under RCP8.5 forcing in eight CMIP5 models, the westerly winds are strengthened and shift polewards, and the surface heat fluxes into the ocean increase (i.e., ocean warming). Stronger winds increase Ekman pumping and upwelling. A poleward shift in the winds combined with surface warming shift density outcrops for deep and upper ocean water masses similarly poleward. These surface changes strongly correlate with increased upper and decreased lower overturning circulation (diagnosed in density space here) across the CMIP5 models.

9.3 Future Southern Ocean WGOMD Activities

Simon Marsland presented a summary of future Southern Ocean related WGOMD activities. Polynyas and climate change are an important topic that will be further discussed by the panel. Studies of ice shelf water need more in situ data in order to compare with models. Regarding studies of downslope overflow, NCAR has implemented it on their model but there are still some problems since parameterization is not trivial. In relation to CORE experiments, WGOMD will look into developing some process studies and feedback from SOP will be important.

ACTION: Discuss with WGOMD further modeling activities in the Southern Ocean

9.4 Ocean Model Development Related SOP Activities

Matthew England presented a summary of Ocean Model Development related SOP activities. The panel supports efforts from the community to develop process studies to better understand the ACC, eddies and their impact on heat and freshwater fluxes, the midlatitude jet, ocean-shelf flow and interactions. Studies combining observations, theory, models, and process experiments are particularly encouraged. One possible focus could be on the lower cell in the Southern Ocean.

Air-sea fluxes is one topic that the panel has not discussed much in the past. The lack of air-sea flux observations in the Southern Ocean remains a problem. At present there is only a Japanese mooring at 60S. Perhaps the panel should focus their next panel meeting on air-sea fluxes in the Southern Ocean. Biogeochemistry is another area requiring enhanced observations.

Some potential CORE-like ocean models experiments could be done with wind perturbation and land-ice melting, but a protocol for both need to be developed with guidance from SOP, and in coordination with WGOMD.

ACTION: Discuss with WGOMD activities related to new CORE experiments on wind perturbation and land-ice melting

10. National Reports

Representatives of Australia, Japan and US gave a brief presentation on the activities of their respective countries in the Southern Ocean. Details can be found in the written report available from the Southern Ocean Panel webpage.

11. Panel Executive Session

Members of the panel have discussed several issues of panel business, which included membership, outreach and capacity building, and knowledge transfer.

Regarding membership, Yasushi Fukumachi has stepped down so a replacement is needed. Also, it is important to identify an existent, or a new, panel member to liaise directly with CliC; or to ensure a CliC panel member also sits on the SOP.

ACTION: Replace Yasushi Fukumachi as a panel member.

ACTION: Discuss with CliC regarding cross-membership.

12. Outreach, Capacity Building & Knowledge Transfer

Outreach, capacity building and knowledge transfer are key areas that the CLIVAR SSG has asked panels to develop activities. In the US, students are invited to apply for positions in cruises so that they can have hands-on experience. It is possible for students from other countries to participate in those cruises if their nations provide financial support. Germany and Brazil have had a long history of research and student exchanges and this programme is likely to continue.

Attendees:

Panel Members		
Chereskin	Teresa	panel member
England	Matt	co-chair
Griffies	Steve	panel member
Hellmer	Hartmut	panel member
Naveira Garabato	Alberto	panel member
Orsi	Alex	panel member
Speer	Kevin	panel member
Talley	Lynne	co-chair
Thompson	Dave	panel member
Invited experts		
WGOMD	Various	Joint session Fri 9:00-12:30
Downes	Steph	CMIP5 - SO eddies
Farneti	Ricardo	CORE SO MIP
Hogg	Andy	SO eddies - fluxes
Hutchinson	Dave	PhD
Jakob	Christian	SO Clouds
Katsumata	Katsuro	Japan Rep
Klocker	Andreas	Mixing
Rintoul	Steve	SO observations
Sallee	Jean-Baptiste	CMIP5
Sloyan	Bernadette	SO observations
Taylor	Fiona	SOOS
Van Ommen	Tas	Ocean 2K
Zika	Jan	SO T-S flow

National Reps (reporting to SOP8, not attending unless listed above):

- Argentina - [Alejandro Bianchi](#)
- Australia - [Steve Rintoul](#)
- Belgium - [Hugues Goosse](#)
- Brazil - [Mauricio Mata](#)
- Chile - [Dante Figueroa](#)
- China - [Zhaoqian Dong](#)
- Finland - [Aike Beckmann](#)
- France - [Sabrina Speich](#)
- Germany - [Eberhard Fahrback](#)
- Italy - [Enrico Zambianchi](#)
- Japan – [Katsuro Katsumata](#)
- Netherlands - [Michiel van den Broeke](#)
- New Zealand - [Mike Williams](#)
- Norway - [Svein Osterhus](#)
- Russia - [Alexander Klepikov](#)
- South Africa - [Chris Reason](#)
- Spain - [Damià Gomis](#)
- United Kingdom - [Alberto Naveira Garabato](#)
- USA - [Kevin Speer](#)