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Project Report

Report of the 7th CLIVAR/CliC/SCAR Southern Ocean Region Implementation Meeting

19-21 October 2011, Bolder USA

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1 INTRODUCTION

The seventh meeting of the CLIVAR/CliC/SCAR Southern Ocean Panel meeting was held in Boulder, Colorado, USA, between 19th and 21st October 2011. Hosted by NCAR, at the NCAR Foothills Laboratory in Boulder, members of the panel were joined by a variety of experts in Southern Ocean and Antarctic science, taking advantage of the local expertise and those that were in the area ahead of the WCRP Open Science Conference (see Appendix B for a list of attendees).

The meeting focussed on three different themes: Southern Ocean carbon; atmospheric processes over the Southern Ocean; and Southern Ocean physics (see 5 for agenda). The overarching aim was to provide a forum to generate an overview of current understanding in these three main areas. Under each of the three themes, invited speakers highlighted to the panel key open questions and discussed gaps in our current understanding (for presentations and summary see section 4).

Participants heard about the Southern Ocean Biogeochemical Observation and Modeling Program (SOBOM), which is poised to be a major activity with respect to future observations in the Southern Ocean region. Further information on this proposal can be found in section 5.

The meeting concluded with a panel business meeting (section 3).

2 ACTION ITEMS

ACTION: Draft half-page documents under the three themes identifying gaps and future directions under the three themes. (Lovenduski and Sarmiento (carbon), Thompson (atmosphere), Speer and England (physics)).
ACTION: Organise/co-sponsor a meeting to come up with an implementation plan. (Rintoul, ICPO)
ACTION: Invite Sloyan to join the panel. (Beswick)
ACTION: Ask whether Thompson wishes to remain on the panel and extend invitation to Gerber if Thompson rotating off. (Beswick)
ACTION: Ask whether Goosse wishes to remain on the panel. (Beswick)
ACTION: Invite Seb Swart to join the panel. (Beswick)
ACTION: More emphasis needed on ice shelf interactions and sea level intrusion under glaciers under SOP's response to SSG-18 action item 13. (Fukamachi)
ACTION: Contact Gerber for input on stratosphere/upper troposphere propagation activities for SSG-18 action item 15. (Beswick)
ACTION: Add a reference to the synthesis of the report and ocean model assessment in the imperatives document to SSG-18 action item 16. (Beswick)
ACTION: Update SOP's response to action item 22 highlighting the links between CPTs (Speer) and WGCM (Griffies to join the panel subject to SSG approval). (Beswick)

3 PANEL BUSINESS MEETING DISCUSSION

Imperatives and Frontiers

There is a need to be more clear about the imperatives and frontiers for SO atmosphere and SO carbon. It would be beneficial to have three separate documents identifying gaps in the three themes, pointing to future directions, which could be circulated amongst other communities (e.g. SCAR, CliC, SOOS) for input.

ACTION: Draft half-page documents under the three themes identifying gaps and future directions under the three themes. (Lovenduski and Sarmiento (carbon), Thompson (atmosphere), Speer and England (physics)).

A white paper on the state of carbon cycle science in the SO could be developed, accompanied by a series of recommendations. It is also necessary to organise the community to get behind this idea, to build international consensus. This could also serve as a model for the way that SOOS progresses.

A proposal has been submitted (ref. Jorge's talk) which emerged from a US Clivar meeting at WHOI. If successful then a two-year working group on SO physics/climate/biogeochemistry will be established. The broad aim of this working group will be to accelerate progress on the state of understanding and bring communities together. SOP could help draw in the international community to the US activity.

There could be a national/international meeting to discuss the possibilities and prepare a white paper. In terms of the US activity, a workshop is planned in year two to bring the community together, and one of the recommendations of the white paper could be a workshop. An article could also be written for EOS, and a more focussed piece for Exchanges.

A workshop/meeting should also aim to engage the CliC community, bringing together glaciologists, hydrologists, oceanographers etc. to look at ice interactions (this has been identified in vision document and by SOOS). Cryosphere groups such as WASE(sp?) could also be engaged. Also the Argo community regarding measuring beneath the ice, as there would be clear benefits to these measurements. SOP should help organise/co-sponsor a meeting to come up with an implementation plan to answer these questions (could also be sponsored by US Clivar with sufficient lead time).

ACTION: Organise/co-sponsor a meeting to come up with an implementation plan. (Rintoul, ICPO)

Membership

The following decisions on membership were reached:

- Rintoul to rotate off at the end of the year.
- Speich to rotate off at the end of the year.
- Invite Bernadette Sloyan to join the panel.

  ACTION: Invite Sloyan to join the panel. (Beswick)
- Ask whether Thompson wishes to remain on the panel. Invite Ed Gerber to join the panel (if Thompson rotating off).

  ACTION: Ask whether Thompson wishes to remain on the panel and extend invitation to Gerber if Thompson rotating off. (Beswick)

- Ask whether Goosse wishes to remain on the panel (Hellmer as replacement).

  ACTION: Ask whether Goosse wishes to remain on the panel. (Beswick)

- Invite Seb Swart to join the panel.

  ACTION: Invite Seb Swart to join the panel. (Beswick)

SSG-18 Action Items

The paragraphs submitted by the panel members on SOP-relevant SSG-18 action items[1] were reviewed. The following decisions were made:

- Action item 13: Report on ongoing studies of regional sea level changes to ICPO

  ACTION: More emphasis needed on ice shelf interactions and sea level intrusion under glaciers. (Fukamachi)

- Action item 15: Encourage regional panels to explore links to SPARC/DynVar

  This was reviewed by Ed Gerber, who indicated that this is an accurate write up but will think about particular activities that could be brought up in panel discussions in terms of stratosphere/upper troposphere propagation.

  ACTION: Contact Gerber for input on stratosphere/upper troposphere propagation activities. (Beswick)

- Action item 16: Encourage the ocean basin panels to exploit the CORE-II WGOMD experiments

  It was noted that SOP may be having a combined meeting with WGOMD in Hobart, February 2013, which would build on these issues. A reference should be made to the synthesis of the report and ocean model assessment in the imperatives.

  ACTION: Add a reference to the synthesis of the report and ocean model assessment in the imperatives document. (Beswick)

- Action Item 17: Explore linkages with Pages and provide thoughts for opportunities in time for OSC

  No action necessary.

[1] CLIVAR SSG action items

No.	Action	Responsible	Deadline
13	Report on ongoing studies of regional sea level changes to ICPO	PP, IOP, AOP, **SOP**	OSC
15	Encourage regional panels to explore links to SPARC/DynVar	PP, IOP, AOP, **SOP**, VAMOS, AAMP, VACS	OSC
16	Encourage the ocean basin panels to exploit the CORE-II WGOMD experiments	**Basin panels**, WGOMD	OSC
17	Explore linkages with PAGES and provide thoughts for opportunities in time for OSC	**Panels** report to SSG co-chairs	OSC
22	Contribute to the model improvement CPT on issues of ocean eddy mixing and deep ocean overflows	**SOP**, WGSIP, WGCM, WGOMD	OSC

- Action item 22: Contribute to the model improvement CPT on issues of ocean eddy mixing and deep ocean overflows

  The panel already has connectivity to CPT's (Speer) and Steve Griffies will hopefully be joining the panel (subject to SSG approval). The SOP will keep in contact with these groups and keep abreast of their activities (e.g. overlap with Argo floats).

  ACTION: Update. (Beswick)

4 Developing a Vision for Climate Variability Research in the Southern Ocean-Ice-Atmosphere System

The presentations from SOP7 are available for download via the following link: http://www.clivar.org/organization/southern/activities/SOP7

The Southern Ocean region is currently accumulating more heat and anthropogenic carbon than anywhere else in the ocean, which could have global ramifications. Climate models poorly resolve this key region, and produce a wide variety of projected climate states in the future. Ongoing greenhouse gas increases and ozone recovery are both expected to modify Southern Hemisphere wind patterns, with likely implications for ocean heat and carbon uptake (Figure 1). This will exert a strong influence on the global climate system. Much effort has recently gone into improving ocean model representation of the role of eddies, yet these processes are not yet adequately represented in coarse IPCC-class climate models. Improvements to models and our understanding of the role of eddies and air-sea-ice interactions in the Southern Ocean system have been made, but large gaps still exist. To compound this situation, there is a paucity of observations in the Southern Ocean climate system, including ocean circulation/hydrography, air-sea fluxes, and atmospheric properties. The CLIVAR/CliC/SCAR Southern Ocean Panel (SOP) has had a sustained interest in driving forward the observational programmes required in this region, with some notable achievements (e.g. the Southern Ocean Observing System; SOOS).

During 19 - 21 October 2011, the SOP held its seventh meeting (SOP-7) in Boulder, Colorado, USA. The meeting convened experts from three key areas of Southern Ocean research – Southern Ocean carbon, atmospheric processes over the Southern Ocean, and Southern Ocean physics – with the overarching objective to generate an overview of current understanding in these three main areas. Under each of the three themes, invited speakers highlighted to the panel key open questions and discussed gaps in our current understanding. This will ultimately feed into the vision document being developed by the panel: A Vision for Climate Variability Research in the Southern Ocean-Ice-Atmosphere System. The following three sections summarize in turn the main issues highlighted during the meeting across the above three thematic areas.

Southern Ocean Carbon

The Southern Ocean is an important regulator of atmospheric carbon dioxide (CO2). In this region, old, CO2-rich water is ventilated to the atmosphere, and nearly half of the ocean's anthropogenic CO2 is absorbed and stored. It is therefore important to quantify and understand the processes controlling air-sea CO2 exchange in the Southern Ocean, given the implications for the global climate system.

Results based on coarse-resolution ocean models suggest that the physical circulation of the Southern Ocean governs the exchange of CO2 across the air-sea interface, and that changes in the physical circulation have altered the uptake and release of CO2 from the region (Figure 1). However, the community remains concerned about certain aspects of these modeling studies. Central to their concerns are two questions: (1) Can coarse-resolution ocean models accurately represent Southern Ocean circulation and CO2 uptake?; and (2) Do we have enough observational evidence to support these model-based findings?

Learning more about Southern Ocean carbon uptake will require a sustained international effort to observe Southern Ocean biogeochemistry. Such an effort has been proposed by Sarmiento and collaborators (SOBOM; The Southern Ocean Biogeochemical Observations and Modeling Program); they aim to deploy autonomous ARGO floats with biogeochemical sensors in the Southern Ocean region, and to use these observations to better constrain eddy-resolving models of the Southern Ocean.

Analysis of Drake Passage pCO2 and δ14C observations suggests that there has been an increase in the vertical transport of CO2-rich and δ14C-depleted waters over the past few

decades in the region south of the Polar Front. This finding is remarkably consistent with results from coarse-resolution ocean models (Sweeney et al., personal comm.).

Through sustained observations, the Palmer Long-Term Ecological Research (PAL LTER) program has successfully demonstrated the impact of physical climate variability on the Southern Ocean ecosystem. In particular the Western Antarctic Peninsula (WAP) has warmed rapidly over the past few decades, sea ice has dramatically decreased in this region, and phytoplankton productivity has declined in the north WAP and increased in the south WAP (Stammerjohn et al., personal comm.). Such changes have had consequences for all trophic levels.

HIAPER Pole-to-Pole Observations, or HIPPO, an airborne, observational campaign that aims to sample atmospheric O2 and CO2, has completed five missions over the last two years. These data are currently being processed an analyzed. Preliminary results suggest large interannual air-sea O2 flux variability over the Southern Ocean (Bent et al., personal comm.).

The Community Earth System Model (CESM) is being used to assess variability in Southern Ocean carbon uptake. As a full coupled climate model with a state-of-the art ocean biogeochemical submodel, CESM has been fairly successful at representing observed CO2 variability in the region. Results from this model suggest that advection of dissolved inorganic carbon is the dominant control on air-sea CO2 flux variability in the Southern Ocean, with biological processes playing a smaller role (Long et al., personal comm.).

Wang and Moore (2012) coupled an older version of the Community Climate System Model to a modified ocean biogeochemical model, in order to assess the role of the biological pump in controlling air-sea CO2 flux variability over the Southern Ocean. The model included an improved parameterization of the iron cycle, an additional phytoplankton group, Phaeocystis Antarctica, and an improved representation of Southern Ocean mixed layer depths. This study suggests that biological production and circulation play equally important roles in controlling Southern Ocean CO2 flux variability.

Southern Ocean Atmosphere

The Southern Annular Mode (SAM) is the prominent pattern of large-scale climate variability in Southern Hemisphere mid-high latitude circulation. Variations in the SAM influence weather across broad regions of the Southern Hemisphere ocean and land areas (see Thompson et al., 2011, for a recent review). Thus understanding how the SAM will respond to anthropogenic forcing is of key societal importance.

The SAM is believed to be sensitive to both increases in greenhouse gases and decreases in stratospheric ozone. Ozone depletion appears to have played a dominant role in driving low frequency variability in the SAM during the 20th Century; increases in greenhouse gases are expected to play a similarly important role during the 21st Century. But there is considerable uncertainty regarding the underlying dynamical mechanisms. It is unclear for example why the SAM responds to ozone-induced cooling in the polar stratosphere. It is also unclear why the SAM responds to increases in greenhouse gases. In fact, it is arguably unclear why the SAM exists in the first place.

The SOP-7 talks on atmospheric dynamics over the Southern Ocean emphasized the key role of feedbacks between the mean flow and the wave fluxes of heat and momentum in the Southern Hemisphere atmosphere. They explored the role of the SAM in driving changes in the strength and position of the Antarctic Circumpolar Current. They examined the processes that drive variability in the SAM and they explored the mechanisms whereby both the SAM and tropical climate variability influence Antarctic climate.

Southern Ocean Physics

The Southern Ocean is thus far responding to climate change very differently to the Northern Hemisphere; for example the rapid warming observed over subpolar northern latitudes has not yet materialized over the Southern Ocean. The primary reason appears to be the large uptake of heat by the Southern Ocean, although the precise mechanisms at play remain uncertain. Furthermore, there is inconsistency in model estimates of the magnitude of this anthropogenic heat uptake. Recent progress has been made in formulating eddy parameterizations more appropriately in coarse resolution models, so that to first order the response of the Southern Ocean to wind changes is correctly captured (Gent and Danabasoglu, 2011). Ongoing eddy-permitting and eddy-resolving model development is also targeting this issue, to bridge the gap between IPCC-class climate models and the eddy-rich flow patterns seen in observations and high-resolution models.

Other recent work was also highlighted during the meeting. Drake Passage transport was monitored as part of the cDrake study using pressure sensors and echo sounders and bottom velocity sensors. Results show sustained high velocities 50 m off the ocean floor. A significant challenge for climate models is to match these velocities at the bottom, in the presence of bottom topography that controls flow configuration.

Eddying models as well as direct observations have shown that as the Southern Hemisphere subpolar westerly winds increase, so too does eddy activity, producing a greater eddy-driven component to the MOC. This poleward eddy-driven flow mostly balances the wind-driven Ekman increase in the MOC. In contrast, there is unlikely to be such compensation in the net meridional heat flux in response to wind changes, as eddies and Ekman fluxes both modulate heat transfer with different depth profiles. Correct resolution of the poleward eddy heat transport is thus an important consideration in getting the correct temperature and sea ice response to anthropogenic climate change. The eddy response appears to be too weak in current models; consequently the response to Southern Hemisphere wind shifts might not be correct.

Sea ice extent in the Arctic has broadly decreased over the last 30 years, whereas Antarctic sea-ice has shown opposing trends over the western and eastern regions. Kirkman and Bitz (2011) have investigated why no net trend has been observed in the Antarctic. Antarctic warming over the last 50 years has been more prevalent in the west, as compared with the east. Warming is also occurring at depth in the Southern Ocean. Loss of sea ice in the Bellingshausen Sea appears to be via tropical teleconnections and/or changes in the SAM. But there are multiple theories for the expansion elsewhere, including 1) SAM trends (driven primarily by ozone) and 2) freshwater flux trends (either via precipitation changes or ice melt). Warming could be shrinking the overall thickness of Antarctic sea ice but observations are thus far insufficient to detect this.

It is unclear why models do not capture observed Antarctic sea-ice trends. A serious problem for future prediction is that the models show quite large disagreement. This is a key issue as it hampers predictions of future change, even to the extent that the sign of the change is unknown in some cases. One major uncertainty is the contribution from sea ice to salinity budgets in the Southern Ocean. Evidence suggests that sea ice is thinning in some areas; where this occurs, the ice will persist less, resulting in longer periods of open water. This trend could be inferred from water isotopes. However, direct sea-ice measurement systems are one of the most difficult observational programs to sustain on a large-scale. Remote sensing offers some hope of regular measurement.

Progress in other areas includes the incorporation of observations into a statistical estimate of ocean circulation; e.g. the SOSE (Southern Ocean State Estimate) program (Mazloff et al., 2010). As sensors for biogeochemistry become available they are being integrated into Argo profiles, and these might in turn be incorporated into ocean biogeochemistry state estimates. For SOSE going forward, there is a need for better geoid products and mean dynamic

topography products in order to improve the mass balance of ocean volume. State estimates based on a dynamical model such as SOSE provide a basis for evaluating and calibrating climate models. Without adequate observations, no such state estimate is feasible. A concerted community effort is required to bring together the vast array of measurements needed to improve global climate prediction.

References

Gent, P. R. and G. Danabasoglu, 2011: Response to increasing Southern Hemisphere winds in CCSM4. J. Clim. 24, 4992–4998.

Kirkman, C. and C.M. Bitz, (2011), The Effect of the Sea Ice Freshwater Flux on Southern Ocean Temperatures in CCSM3: Deep Ocean Warming and Delayed Surface Warming, J. Climate, 24, pp. 2224-2237 doi: 10.1175/2010JCLI3625.

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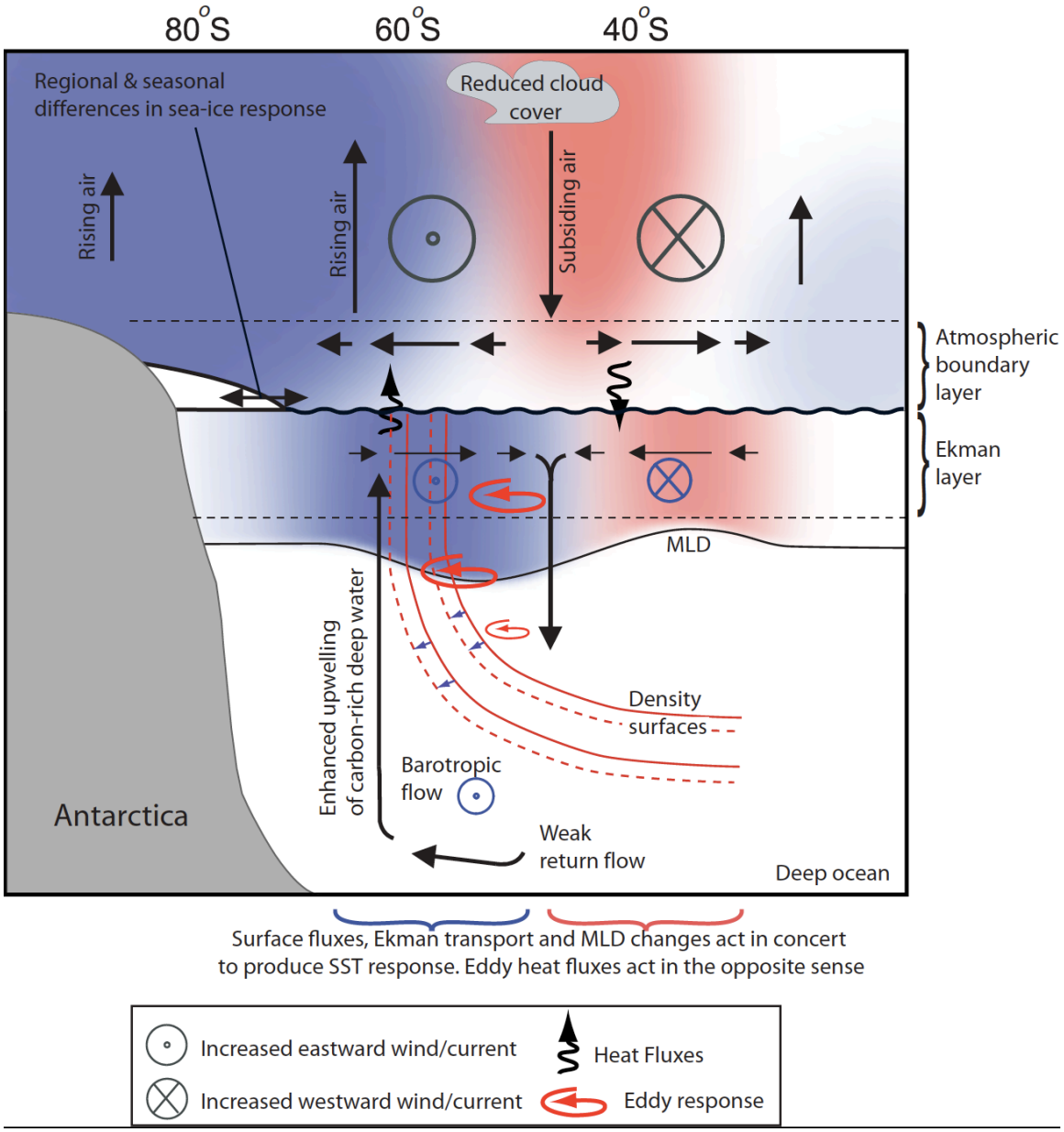

Figure 1. Schematic response of the ocean to the high-index polarity of the Southern Annular Mode (from Thompson et al., 2011). Solid arrows indicate meridional and vertical motion in the atmosphere and ocean. Warm colors correspond to increases in temperature or heat content, and cooler colors to decreases. MLD refers to the ocean mixed-layer depth. All other responses are labeled on the figure or in the legend. All results indicate the climate response to the SAM on timescales less than a season with the exception of the oceanic eddy field, which indicates the response on timescales of 2–3 years. The ocean carbon response indicated remains uncertain; such a response would be considerably weaker if oceanic eddies compensate Ekman fluxes at the near-surface.

5 Southern Ocean Biogeochemical Observations and Modeling Program (SOBOM)

Sarmiento and others are proposing a Southern Ocean Biogeochemical Observations and Modeling (SOBOM) study that will bring together a trans-disciplinary team of observationalists and modelers, and of physical and biogeochemical oceanographers, to facilitate the scientific and technical collaborations that will be required to carry out this complex project.

This study intends to capitalise major new developments in the Southern Ocean region: i) biogeochemical sensors mounted on autonomous floats that sample from the surface to 2000 m and penetrate under ice-covered regions; and ii) the computational ability to carry out climate model simulations that can resolve mesoscale processes and assimilate observations to produce a state estimate of the ocean.

The aim of the programme is to address the gaps in information and understanding, in a region where uptake of anthropogenic carbon dioxide by the ocean, and the resupply of abyssal nutrients back into the productive upper ocean, is prevalent.

The Southern Ocean Panel were fully supportive of this proposal and are interested in being kept updated as the proposal progresses. In the subsequent CLIVAR Scientific Steering Group (SSG) meeting (June 2012), the SSG encouraged the Southern Ocean Panel to provide a framework for international participation in SOBOM related activities.

Appendix A. AGENDA

Wednesday 19 Oct

0900 – 0930 Welcome and logistics, SOP6 review and action items, CLIVAR SSG feedback (Nicole Lovenduski, Matthew England & Kevin Speer)

Theme 1: Southern Ocean Carbon

0930 – 1030 Southern Ocean Carbon – key open questions (Nicole Lovenduski)

40 minute presentation, 20 minute discussion

1030 – 1100 Break

Subtheme 1: Observations of Southern Ocean Carbon

1100 – 1200 Network for observing Southern Ocean carbon (Jorge Sarmiento)

40 minute presentation, 20 minute discussion

1200 – 1330 Lunch

1330 – 1400 The Drake Passage carbon measurement program (Colm Sweeney)

1400 – 1430 Sea ice and ecology in the western Antarctic Peninsula region (Sharon Stammerjohn)

1430 – 1500 HIPPO Project Southern Ocean flights (Jonathan Bent)

1500 – 1530 Break

Subtheme 2: Modeling Southern Ocean Carbon

1530 – 1630 Southern Ocean carbon in the CESM (Matthew Long)

40 minute presentation, 20 minute discussion

1630 – 1700 Variability of primary production and air-sea CO2 flux in the Southern Ocean (Shanlin Wang)

1800 Reception (Backcountry Pizza and Tap House)

Thursday 20 Oct

Theme 2: The Role of the Atmosphere in Southern Hemisphere Climate Change

0900 – 1000 Atmospheric trends in the Southern Ocean region / possible causes (Dave Thompson)

40 minute presentation, 20 minute discussion

1000 – 1015 Sensitivity of Southern Hemisphere atmospheric circulation to strength and location of Equatorial Pacific SST anomalies (Laura Ciasto)

1015 – 1030 Short talk (topic TBD)

1030 – 1100 Break

1100 – 1200 Dynamics of large-scale atmospheric variability over the Southern Ocean (Ed Gerber)

40 minute presentation, 20 minute discussion

1200 – 1215 GEWEX Activities (Kevin Trenberth)

1215 – 1330 Lunch

1330 – 1430 Dynamics of large-scale atmospheric variability over the Southern Ocean (Francis Cordon)

40 minute presentation, 20 minute discussion

1430 – 1530 Role of the atmosphere in Antarctic trends (David Schneider)

40 minute presentation, 20 minute discussion

1530 – 1600 Break

1600 – 1700 Role of the atmosphere in Southern Ocean trends (John Fyfe)

40 minute presentation, 20 minute discussion

1900 Panel Dinner (Zolo Grill)

Friday 21 Oct

Theme 3: Ocean Physics, Ice, Ocean-ice Interactions

0900 – 0930 Southern Ocean Physics – key open questions (Matthew England)

0930 – 1030 Southern Ocean response to wind shifts (Peter Gent)

40 minute presentation, 20 minute discussion

1030 – 1100 Break

1100 – 1200 Advances in our understanding of the role of sea ice in the Southern Hemisphere (Cecilia Bitz)

40 minute presentation, 20 minute discussion

1200 – 1215 Antarctic sea-ice trends (Graham Simpkins)

1215 – 1330 Lunch

1330 – 1430 The upper limb of the global MOC in the Southern Ocean (Kevin Speer & Alberto Naveira Garabato)

40 minute presentation, 20 minute discussion

1430 – 1500 SOSE and related activities (Matthew Mazloff)

1500 – 1530 Break

1530 – 1600 SOOS update/overview (Steve Rintoul)

1600 – 1700 Panel business meeting: SOP future activities and goals and membership

- CLIVAR SSG-18 action items.[2]

[2] CLIVAR SSG action items

No.	Action	Responsible	Deadline
13	Report on ongoing studies of regional sea level changes to ICPO	PP, IOP, AOP, **SOP**	OSC
15	Encourage regional panels to explore links to SPARC/DynVar	PP, IOP, AOP, **SOP**, VAMOS, AAMP, VACS	OSC
16	Encourage the ocean basin panels to exploit the CORE-II WGOMD experiments	**Basin panels**, WGOMD	OSC

- Assessment of progress on atmospheric processes linked to carbon cycle processes, upwelling and CO2 fluxes, and the Polar Jet trends.
- The Southern Ocean freshwater budget with CliC.
- Membership.

1700 Close of Session

17	Explore linkages with PAGES and provide thoughts for opportunities in time for OSC	**Panels** report to SSG co-chairs	OSC
22	Contribute to the model improvement CPT on issues of ocean eddy mixing and deep ocean overflows	**SOP**, WGSIP, WGCM, WGOMD	OSC

Appendix B. ATTENDEES

Panel Members

Catherine Beswick	International CLIVAR Project Office, UK
Matthew England (co-chair)	University of New South Wales, Australia
Yasushi Fukamachi	Hokkaido University, Japan
Nicole Lovenduski	University of Colorado, US
Alberto Naveira Garabato	University of Southampton
Stephen Rintoul	CSIRO, Australia
Kevin Speer	Florida State University, US
David Thompson	Colorado State University, US

Other Invitees

Jonathan Bent	Scripps Institution of Oceanography, US
Cecilia Bitz	University of Washington, US
Laura Ciasto	University of New South Wales, Australia
Francis Codron	Laboratoire de Meteorologie Dynamique, France
Clara Deser	NCAR, US
John Fyfe	Environment Canada, Canada
Peter Gent	NCAR, US
Ed Gerber	New York University, US
Matthew Long	Stanford University, US
Matthew Mazloff	Scripps Institution of Oceanography
Mike Patterson	US CLIVAR Project Office
Jorge Sarmiento	Princeton University, US
David Schneider	NCAR, US
Graham Simpkins	University of New South Wales, Australia
Sharon Stammerjohn	University of California, Santa Cruz, US
Colm Sweeney	NOAA, US
Kevin Trenberth	NCAR, US (co-chair, WCRP/GEWEX)
Shanlin Wang	NCAR, US
Jonathan Woodworth	Colorado State University, US