IP 50

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The Southern Ocean Observing System (SOOS)

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Introduction

1. The Southern Ocean plays unique and critical roles for both the physical Earth system and its overall ecology, by both driving global weather and climate and harbouring unique and diverse biological communities. For example it is there that Antarctic Bottom Waters sink to ventilate the global ocean, and Antarctic Intermediate Waters descend to provide the world ocean with 75% of the nutrients required to support ocean productivity. The ocean absorbs 40% of the anthropogenic emissions of CO_2 into the atmosphere, and 40% of that is absorbed by the Southern Ocean.
2. Despite its importance, the Southern Ocean is poorly monitored, not least because of its harsh conditions and geographical remoteness. Many more Southern Ocean observations are needed to understand and predict global climate change accurately. Antarctic resupply vessels can make many observations routinely. A key problem concerns measurement of ocean properties year-round beneath the sea ice. Moorings, gliders, instrumented marine mammals and modified Argo floats provide various means of escaping from this constraint. But commitments are needed to sustain the necessary *in-situ* observations in this remote area.
3. The development of a Southern Ocean Observing System (SOOS) meets the initial requirements of ATCM Resolution 3 (2007), which welcomed and supported "the proposal by SCAR to establish a multi-disciplinary pan-Antarctic observing system, which will, in collaboration with others, coordinate long-term monitoring and sustained observation in the Antarctic". It is one of the key recommendations from the Antarctic Climate Change and the Environment Report (Turner et al., 2009). The SOOS is also a significant legacy of the recent International Polar Year.
4. The design of a SOOS was led by a partnership of organisations: SCAR, the Scientific Committee on Oceanic Research (SCOR), The Census of Antarctic Marine Life (CAML), the Global Ocean Observing System (GOOS), the World Climate Research Programme (WCRP) and the Partnership for Observations of the Global Ocean (POGO). Other groups such as IAATO and COMNAP have provided significant feedback. The US NOAA programme also provided funds for holding SOOS workshops to further the SOOS design plan. Views have been solicited from as wide a range of interested parties as possible in order to finalise the plan.

The Vision for a Southern Ocean Observing System

5. The need to better understand global climate change and its impacts requires a Southern Ocean Observing System that is:
   - Sustained
   - Circumpolar, from the Subtropical Front to the Antarctic continent
   - Multi-disciplinary
   - Feasible
   - Cost-effective
   - Integrated with the global observing system
   - Based initially on proven technology but evolves as technology develops
   - Integrated with a data management system built on existing structures
   - Able to deliver observations and products to a wide range of end-users
   - Builds on past, current and future research programmes
6. The purpose of the SOOS effort is to enhance support for a truly global ocean observing system by articulating the relevance and significance of the Southern Ocean and by demonstrating that a feasible, cost-effective observing system in the region is within reach.

The Scope of the SOOS

7. The geographical domain of the SOOS is circumpolar, from the Subtropical Front southwards to the coast or the ice sheet grounding line, and from the sea surface to the sea floor. The temporal domain relevant to the SOOS extends from days to decades. The SOOS spans a range of disciplines, including ocean physics, sea ice, ecology, marine biology, biogeochemistry and surface meteorology.
8. While the emphasis of the SOOS is on sustained observations, models will make a significant contribution to the SOOS by informing the design of the observing system and guiding the interpretation and interpolation of sparse measurements. Similarly, process studies can contribute to the SOOS by identifying processes or variables that need to be measured on a sustained basis.

The Structure of the SOOS

9. Six key science challenges were identified in the SOOS plan that require sustained observations to be addressed:
   - Impacts of global change on Southern Ocean ecosystems
   - The stability of the Antarctic ice sheet and its contribution to sea-level rise
   - The role of the Southern Ocean in the global heat and freshwater balance
   - The stability of the Southern Ocean overturning circulation
   - The future of Southern Ocean carbon uptake
   - The future of Antarctic sea ice
10. The variables for which sustained measurements are required to address the key scientific challenges and the combination of platforms and techniques needed to provide sustained observations of each of the fields were identified. From this the elements of a SOOS could be identified, which include but are not limited to:
11. ***Repeat hydrography:*** Hydrographic sections from research vessels provide water samples for analysis of properties for which *in situ* sensors do not exist, the highest precision measurements for analysis of change and for calibration of other sensors, accurate transport estimates, a platform for a wide range of ancillary measurements and the only means of sampling the full ocean depth.
12. ***Enhanced Southern Ocean Argo*:** Year-round, broad-scale measurements of the ocean are needed to address many of the key science challenges in the Southern Ocean. A sustained commitment to enhancement and maintenance of a profiling float array in the Southern Ocean is critical.
13. ***Underway sampling from ships***: The full hydrographic sections need to be complemented by more frequent underway sampling transects, to reduce aliasing of signals with time-scales shorter than the 5-7 year repeat cycle of the repeat hydrography.
14. ***Time-series stations and monitoring of key passages***: Several key passages and boundary currents in the Southern Ocean are high priorities for sustained observations because of their role in the global-scale ocean circulation.
15. ***Animal-borne sensors:*** Oceanographic sensors deployed on birds and mammals can make a significant contribution to SOOS in two ways: by relating predator movements and behavior to fine-scale ocean structure, and by providing profiles of temperature and salinity from regions of the Southern Ocean that are difficult to sample by other means (e.g. beneath the winter sea ice).
16. ***Sea ice observations***: Measurements of both the extent and thickness of sea ice are needed to understand the role of Antarctica in the climate system. A variety of satellite instruments provide continuous, circumpolar observations of sea ice extent, with varying spatial resolution. Measuring sea ice volume, however, remains a significant challenge and requires in situ sampling to provide ground-truth for the satellite sensors. These measurements need to include a combination of sampling from ice stations, helicopters, autonomous vehicles, moorings and underway observations.

17. ***Enhanced meteorological observations:*** An enhanced atmospheric observing system is needed to improve Antarctic and southern hemisphere weather forecasts. Both climate research and operational activities benefit from improved weather forecasts through the increased accuracy of the flux products derived from model re-analyses. The air-sea fluxes of heat and moisture are poorly known at high southern latitudes, making it difficult to diagnose the interactions between atmosphere, ocean and sea ice that lie at the heart of climate variability and change.

18. ***Phytoplankton and primary production***: Sustained observations of phytoplankton biomass, species distributions and primary production are needed to relate environmental variability to biological activity.

19. ***Zooplankton and micro-nekton***: Antarctic plankton may be particularly sensitive and vulnerable to climate change. Global warming will affect sea ice patterns and plankton distributions (e.g. a decrease in the amount of sea ice has been linked to a decline in krill numbers). Increased UV levels, ocean acidification, invasive plankton species, pollution and harvesting impacts are also potential threats. Underway sampling by continuous plankton recorders provides the backbone of the zooplankton observing system, but needs to be supplemented by targeted net tows and acoustic sampling.

20. ***Ecological monitoring***: Observations of the distribution and abundance of top predators can provide indications of changes in the ecosystem as a whole. Long-term monitoring programs have been established at a few sites around Antarctica and must be continued. For example, significant changes in penguin populations have been observed in some locations. SOOS aims to provide the integrated multi-disciplinary observations needed to understand the interactions between physics, chemistry and biology in the Southern Ocean.

21. ***Remote sensing***: Access to high quality remote sensing data is particularly critical in the Southern Ocean, where *in situ* data is difficult to obtain. High priority satellite systems include radar and laser satellite altimetry, ocean colour, scatterometer, infrared and microwave sea surface temperature, passive microwave, and synthetic aperture radar.

Conclusions

22. The SOOS plan presents a community view of the need for, relevance of and feasibility of a sustained observing system in the Southern Ocean. The comprehensive sampling carried out during the IPY shows a SOOS is possible. The scientific achievements of the IPY demonstrate the power and value of integrated, multi-disciplinary observations. The challenge in the years ahead is to build on these IPY achievements to ensure a sustained commitment is made to observations of the Southern Ocean.

23. To succeed with the implementation of the SOOS, a SOOS Secretariat is required. Through the ATCM, Antarctic nations are requested to support this initiative.

Reference

Turner, J., Convey, P., Di Prisco, G., Mayewski, P., Hodgson, D., Fahrbach, E., Binschadler, R., Gutt, J., and Summerhayes, C.P., (eds.) 2009, Antarctic Climate Change and the Environment. Scientific Committee on Antarctic Research, Cambridge, 560pp