The Southern Ocean Observing System

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The Southern Ocean includes the only latitude band where the ocean circles the earth unobstructed by continental boundaries. This accident of geography has profound consequences for global ocean circulation, biogeochemical cycles, and climate. The Southern Ocean connects the ocean basins and links the shallow and deep limbs of the overturning circulation (Rintoul et al., 2001). The ocean's capacity to moderate the pace of climate change is therefore influenced strongly by the Southern Ocean's circulation.

Given the significance of the Southern Ocean to the Earth system, any change in the region would have global impacts. Limited observations suggest the Southern Ocean is changing, with evidence of warming and freshening (Böning et al., 2008; Gille, 2008), accumulation of anthropogenic carbon dioxide (Sabine et al., 2004), acidification (Doney et al., 2009), and changes in the distribution of marine organisms.

However, our ability to detect and interpret Southern Ocean change is limited by a lack of sustained observations. Recognition of this need motivated the community to develop a strategy for a Southern Ocean Observing System, or SOOS (Rintoul et al., 2012).

SOOS addresses six overarching challenges of high scientific and societal relevance:

1. The role of the Southern Ocean in the planet's heat and freshwater balance
2. The stability of the Southern Ocean overturning circulation
3. The role of the ocean in the stability of the Antarctic ice sheets and their contributions to sea level rise
4. The future and consequences of Southern Ocean carbon uptake
5. The future of Antarctic sea ice
6. The impacts of global change on Southern Ocean ecosystems

Sustained observations of the evolving physical, biogeochemical, and biological state of the Southern Ocean are essential to tackle each of these challenges. The SOOS strategy identifies the key variables to be observed and the combination of platforms needed to measure them. Each proposed observation is clearly linked to one or more of the scientific challenges, and the synergy between different observing strategies is highlighted.

The backbone of SOOS is the repeat hydrography program (Figure 1). Hydrographic sections remain the only way to sample the full ocean depth and a wide range of physical, chemical, and biological variables. The high-accuracy measurements collected on repeat hydrographic sections also provide the "gold standard" for calibration of other sensors. As many of the most critical scientific issues require observations in the sea ice zone, ice-capable research vessels play a crucial role in the SOOS.

The development of autonomous profiling floats (Argo) has had a particularly large impact on the remote and poorly observed Southern Ocean. Argo has already collected many more oceanographic profiles south of 30°S than have been collected in the entire history of ship-based oceanography (Figure 2). The map in Figure 2 is cause for both optimism and concern. On the one hand, Argo is providing broad-scale, year-round measurements of the temperature and salinity of the upper 2,000 m of the Southern Ocean for the first time. On the other hand, Argo does not sample the deep ocean, and the sea ice zone remains a major gap in the global ocean observing system.

No equivalent broad-scale sampling exists for most biogeochemical and biological variables. Sustained observations of Southern Ocean biology and biogeochemistry are much more challenging than observations for physical variables, due to the complexity and diversity of phenomena to be measured and the lack of autonomous sensors. The SOOS strategy depends on a combination of approaches, including miniaturized oceanographic sensors on mammals and birds (e.g., Biuw et al., 2007), sampling on repeat hydrographic and ship-of-opportunity transects, remote sensing (with both acoustics and satellites), genomic approaches, and observations of the abundance and distribution of top predators (fish, penguins, seabirds, seals, and whales).

Given that the region is historically one of the most poorly sampled regions of the global ocean, is it really possible to collect sustained multidisciplinary observations of the Southern Ocean? Experience gained during the International Polar Year (IPY, 2007–2008) shows that the answer is yes. Many of the observations identified as "building blocks" of the SOOS were completed during the IPY, when the Southern Ocean was measured in a truly comprehensive way for the first time. The unprecedented coverage led to new insights into the physics, biogeochemistry, and biodiversity of the Southern Ocean, and the coupling between them. The IPY served as a "proof of concept" for SOOS, demonstrating the feasibility and value of integrated, multidisciplinary observations of the Southern Ocean.

Many of the most difficult and pressing issues faced by society—including climate change, sea level rise, and the response of marine ecosystems to ocean warming, acidification, and human exploitation—cannot be addressed without improved understanding of Southern Ocean processes and their sensitivity to change. The SOOS aims to provide the sustained observations of the evolving state of the Southern Ocean needed to tackle these scientific and societal challenges.

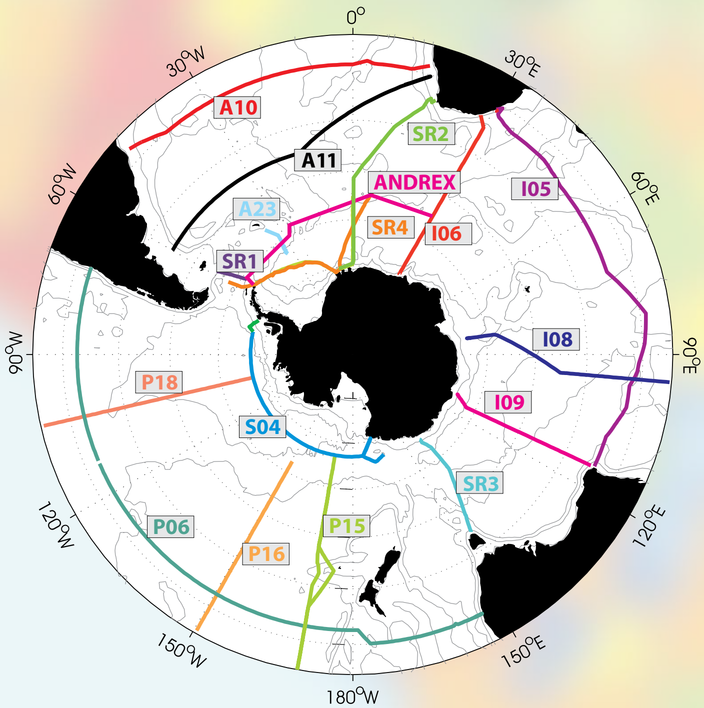

Figure 1. Repeat hydrographic sections to be occupied by the Southern Ocean Observing System. Labels indicate the WOCE/CLIVAR designations for each line.

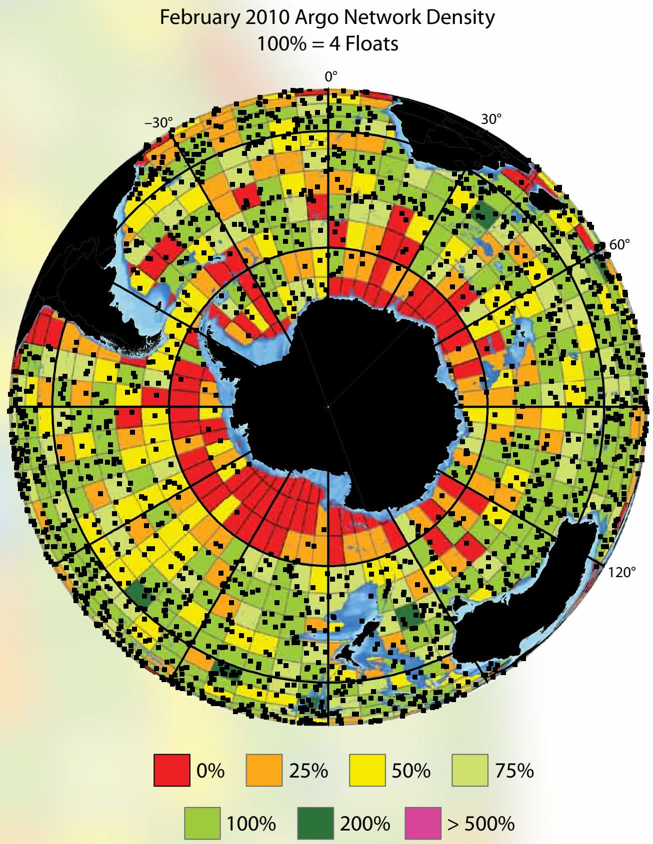

Figure 2. Status of the Argo array in the Southern Ocean, as of February 2010. Blue color indicates 0–2,000 m depth contour. Despite the progress in recent years, large regions of the high-latitude Southern Ocean remain poorly observed, especially in the sea ice zone close to the Antarctic Continent. *Courtesy of Mathieu Belbeoch, JCOMMOPS*

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