SOUTHERN OCEAN OBSERVING SYSTEM

Report of the Ross Sea Working Group Meeting Held in Shanghai – September, 2017

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Overview of the Ross Sea

The Ross Sea sector of the Southern Ocean extends from approximately 160°E to 120°W and from the southern extreme of the Ross Ice Shelf to 50°S. It encompasses the continental shelf (depths less than 750 m) and slope, and the deeper portions of the southern Pacific (and its associated sea mounts and islands; Figure 1 and 2). The terrestrial portion of the Ross Sea is largely ice covered and is the site of a number of major research stations including Scott Base (NZ), McMurdo Station (US), Mario Zucchelli Station (IT) and Jang Bogo Station (Korea). China has plans to build a new base in the coming years.

The Ross Sea sector has been scientifically investigated since the initiation of Antarctic exploration in the early 1900's. Aspects of the oceanography and ecology are very well known relative to other areas in the Southern Ocean, allowing for increasingly sophisticated research to be conducted. The Southern Ocean is exceptionally important to global processes; for example,

- **It is the single most important site for removal of atmospheric heat. Specifically, 93% of the total heat energy has been removed by the ocean, and 75% of this has entered the Southern Ocean;**
- **30% of anthropogenic CO2 emissions have been absorbed by the ocean, and 40% of this by the Southern Ocean; and**
- **A 2% drop in ocean oxygen levels in the past century has occurred as a result of slowing circulation, with ~50% of this change supplied from the Southern Ocean.**

The Ross Sea contributes substantially to all of these changes. In addition, the Ross Sea continental shelf has been estimated to be responsible for 28% of the total removal of anthropogenic CO2 in the Southern Ocean (Arrigo et al., 2008, GRL), which emphasizes the extreme importance of the region to processes in the entire ocean.

Ice concentrations have been shown to be significantly increasing in the Ross Sea sector (Stammerjohn et al., 2012, JGR), and the Ross Sea has been described as the "driver" for changes in the entire Southern Ocean ice concentrations. In contrast the Amundsen-Bellingshausen sector (ABS) has shown decreased concentrations of ice since 1979. Both appear to be driven by changes in the location of atmospheric pressure systems, which provide heat from the north (in the case of the ABS sector) and cool temperatures from the continent (in the case of the Ross Sea).

The region is known to be the site of formation of High Salinity Shelf Water along the coast of Victoria Land and in the Ross Sea Polynya during winter. This water flows northward in topographic depressions and off the coast to join the oceanic thermohaline circulation. Exchanges between the continental shelf and slope are very energetic, and likely include substantial fluxes of nutrients and biogenic matter as well. The area also likely is important for food web processes, as it is the site of substantial foraging activity by penguins and has substantial concentrations of Antarctic krill. The shelf break is also the site of concentrations of Antarctic toothfish (*Dissostichus mawsoni*), a commercially important and harvested species. Much of the toothfish life history is poorly or completely unknown.

The Ross Sea continental shelf is the most productive marginal sea in the Antarctic, with mean productivity estimates ranging from 120 – 160 g C m^{-2} yr^{-1}. Productivity is limited in spring by irradiance (both by the presence of ice and by deep vertical mixing) and in summer by substantially reduced iron concentrations. Vertical flux rates of organic material are reported as substantial, and mesoscale and sub-mesoscale contributions to these fluxes have been suggested as being important. Higher trophic levels reach substantial standing stocks as well (Smith et al., 2014, GRL). Despite this, the food web is poorly characterized with critical uncertainties existing in our knowledge, especially with regard to energy and carbon transfer between trophic levels, the temporal and spatial variations in important species, and the ecological connections among important species.

The Ross Sea Marine Protected Area (MPA) has 11 specific objectives (CCAMLR conservation measure CM91-05), but has the broad aim protect and conserve the populations of Antarctic toothfish. Much of the Ross Sea continental shelf has been closed to fishing for many years, but the MPA creates regions designated for research and others that are closed to fishing. The life history of toothfish is very poorly documented, and it is controversial whether fishing has had an impact on the extant food web of the continental shelf and slope. The establishment of the MPA provides an opportunity to couple SOOS observational needs and designs with those of the CCAMLR scientific community.

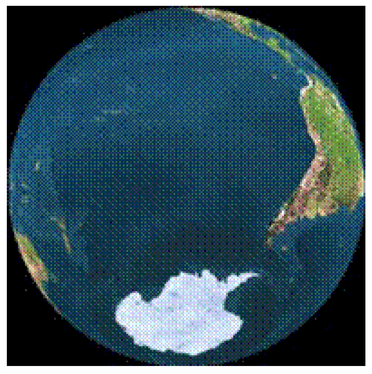
Present Efforts

The Ross Sea is studied by numerous nations, including Italy, Korea, USA, and New Zealand, and China is poised to initiate a large-scale research effort there as well. Research topics include studies of the physical oceanography and interaction of currents with the ice shelf, benthic surveys, ice dynamics, vertical fluxes of organic matter, higher trophic level dynamics, and the role of iron in plankton ecology and biogeochemistry. Focused programs also are funded that investigate specific areas of interest.

SOOS Questions and Objectives

The workshop developed the following regional-scale, interdisciplinary science questions:

- ***How does the coverage (thickness, extent, concentration) of sea ice change?***
- ***How does changing sea ice affect the Southern Ocean heat and fresh water budgets and what are the implications on circulation?***
- ***What impact does freshening/weakening of AABW formation have on natural/anthropogenic CO2 uptake and storage?***
- ***What are the sources of nutrients to the Ross Sea and how will/are these changing?***
- ***What will happen to Ross Sea primary production in the future?***
- ***What are the anticipated biological changes to the structure and functioning of the lower trophic levels?***
- ***How will the mesopelagic biota (krill, silverfish) respond to changes in the physical system and in primary production?***
- ***How will the efficiency of the biological pump change in response to the above?***
- ***How does changing ocean chemistry (i.e., ocean acidification) impact the pelagic and benthic marine systems?***



The workshop also identified the shelf break and shelf break boundary as being critical to our understanding to exchanges between the shelf and Ross Sea Gyres, as is the role of mesopelagic fish on food webs. Future alterations in primary productivity and vertical flux in response to changing environmental conditions were also considered to be a primary research objective.

Issues and recommendations

The following recommendations were agreed upon at the workshop:

- **Given the present rates of change within the Southern Ocean and in particular the Ross Sea, and the potential for significant global impacts, an international, multidisciplinary program to monitor the expected changes is necessary to provide assessments of change rates and provide data to generate credible projections for future states;**
- **Integrated, international cooperation is essential to the formation of various aspects of monitoring climate change and should be initiated and formulated at the highest levels of governments;**
- **Close coordination with CCAMLR and the Ross Sea MPA should be continued and expanded;**
- **Investigations should include all temporal scales (from days, weeks, months, seasons, years, and decades) and a large spatial scale to include the ice shelf (and waters beneath it), the continental shelf, and the deeper waters and islands of the northern Ross Sea Sector; and**
- **Understanding the linkages among physical processes, biogeochemical cycles, and biological processes should be essential components of all national and international efforts in the Ross Sea.**

The full workshop report is available at http://www.soos.aq/resources/reports?view=product&pid=53