CLIVAR/CliC/SCAR Southern Ocean Region Panel SORP-11: Sept. 17-18, 2016

National activities report

Country: New Zealand
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A. Recent and ongoing activities

Does your country have a national committee tasked with oversight of Southern Ocean climate science? No

What major activities have been carried out in the last several years or are in progress now? Contact information for the projects would be useful.

Electromagnetic Sounding of sea ice
Pat Langhorne (University of Otago)
Wolfgang Rack (Canterbury University)
Christian Haas (York University, Canada)
Greg Leonard (University of Otago)
Mike Williams (NIWA)
Gemma Brett (Canterbury University)
Madelaine Rosevear (University of Tasmania)

Continent-wide satellite estimates of Antarctic sea ice thickness are now becoming available but need to be validated by sea ice transects and ice-ocean and oceanographic observations relating to heat transfer in ice shelf-affected waters. EM induction techniques are the only reliable method of determining sea ice thickness from the air. The technique also shows promise for detecting the sub-ice platelet layer. In 2016, EM induction flights will be based out of McMurdo Sound and extend outward into the Ross Sea along new generation satellite altimeter tracks. These will be combined with on-ice surveys to map the geographic extent of the influence of ice shelf meltwater on sea ice. Contact pat.langhorne@otago.ac.nz or wolfgang.rack@canterbury.ac.nz

Influence of glacial melt input on sea ice processes
Pat Langhorne (University of Otago)
Wolfgang Rack (Canterbury University)
Craig Stevens (NIWA)
Inga Smith (University of Otago)
Cecilia Bitz (UW, USA)
Andrew Pauling (University of Otago)

The geographic extent of the sea ice response to changing freshwater fluxes (such as from ice shelf meltwater) introduced artificially to the Southern Ocean is being mapped using a global ESM (CESM1 - CAM5) with an existing sea ice module (the Community Ice

CodE, CICE). The outcome of this study will be an improved understanding of the pathways of heat exchange between the ocean and sea ice. This insight will be useful with regard to the influence of ocean stability and heat transfer on the large-scale sea ice thickness distribution. Modelling will be supplemented by new generation satellite altimeter measurements (CryoSat-2, Sentinel-3 and ICESat-2). These data will reveal basin-wide spatial sea ice characteristics and their temporal variability, while snow on sea ice will be studied using radar imagery.

The instrumented moorings currently deployed near the Drygalski Ice Tongue will be retrieved and re-deployed in order to continue long-term monitoring of the ice shelf-derived plume at the point where it enters the Terra Nova Bay Polynya system. The ice tongue can be considered a proxy for an ice shelf, at a scale that allows for substantial influence on water properties and behaviour while remaining quantifiable. In addition, direct measurements of ice-ocean interactions along the flow path of ice-affected melt water will be conducted from the fast ice of western McMurdo Sound.
Contact pat.langhorne@otago.ac.nz; wolfgang.rack@canterbury.ac.nz; inga.smith@otago.ac.nz or Craig.Stevens@niwa.co.nz

Wave-Ice Interaction
Alison Kahout (NIWA)
Mike Williams (NIWA)

Ocean waves break up sea ice with trends in the retreat and expansion of the sea-ice edge correlated with trends in mean significant wave height. The key to interpreting this correlation lies in understanding wave attenuation in the Marginal Ice Zone, an area of broken ice floes, which is potentially hundreds of kilometres wide, near the sea ice edge. We plan to deploy up to 20 NIWA-funded 2nd-generation waves-in-ice buoys across the marginal ice zone from the Nathaniel B. Palmer PIPERS cruise in the Ross Sea, 2017. Several instruments will be deployed well into the pack ice to ensure we fully capture the propagation of large wave events. The focus of the experiment is the energy decay and change of angular spread of the penetrating directional wave spectra. We will also run an experiment to capture wave-induced ice floe breakup, an area where there is a critical knowledge gap. Subsequent experiments are planned for locations with high wave exposure, for example in the Marginal Ice Zone or in coastal locations like Casey Station, Sea of Okhosk or Alaska.
Contact Alison.Kohout@niwa.co.nz or Mike.Williams@niwa.co.nz

Platelet ice influence on ocean boundary layer
Natalie Robinson (NIWA)
Craig Stevens (NIWA)
Ben Galton-Fenzi (University of Tasmania)

Ice shelf basal melting can drive seawater temperatures below the surface freezing point. Ice crystals persist in this water and are buoyantly deposited beneath coastal sea ice.

There, the crystals may form a porous and friable ‘sub-ice platelet layer’ which may be several metres thick. Therefore it not only causes sea ice to be thicker than it would otherwise be, but it also alters the hydrostatic relationship between sea ice elevation and thickness, and the hydrodynamic operation of the ocean boundary layer. The same mechanism results in the accretion of marine ice beneath ice shelves, with potential implications for the long-term stability of cold-cavity ice shelves. An observational study of these effects in the upper ocean boundary layer will be linked into existing ice-ocean modelling to assess the potential effects on a regional scale. Approximately five fast-ice sites in Southern McMurdo Sound will be visited during October and November 2016 and 2017, allowing a consistent approach to observation of boundary layer interactions along a gradient in properties of both ocean water and sub-ice platelet layer.
Contact Natalie.Robinson@niwa.co.nz or Craig.Stevens@niwa.co.nz

Vulnerability of the Ross Ice Shelf in a warming world
Christina Hulbe (University of Otago)
Craig Stevens (NIWA)

The rate at which West Antarctic ice responds to climate forcing depends on a set of processes involving ice, ocean, atmosphere, and the terrestrial subglacial environment. Previous work has led to the understanding that rapid change is most likely to be driven from the sea and focused at the ice shelf grounding line. We seek here to identify the key process interactions and to reduce uncertainty in future change projections via a coordinated set of investigations centred around two hot water drilling field hubs on the Ross Ice Shelf (RIS). Field camps at each site will support interdisciplinary studies of both modern processes and ice and geological records of past states. The hubs will be connected regionally via satellite remote sensing, airborne geophysics, and numerical modeling. Our programme embraces the surface interface with the atmosphere, and the calving front, but emphasizes the grounding line and sub-ice shelf cavity. We will retrieve sea floor sediments for paleoclimate and ice sheet history studies, measure ocean properties, and conduct novel glaciological research at both sites. A mooring will be deployed in January 2018 in the ocean cavity nearly 200 km upstream of the ice shelf front. In the 2018-19 season, oceanographic observations will be made near the grounding line. When connected with existing observations on the RIS, the new sites yield an effective transect that allows us to consider the coupled system from grounded ice sheet to open ocean.
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Interannual variability in the Ross Sea
Alena Malyarenko (NIWA)
Mike Williams (NIWA)

Multiple drivers contribute to the thermohaline and momentum-driven circulation in the Ross Sea. In recent years massive icebergs, variable polynya activity, changing fast ice

conditions and a long-term trend towards lower salinity deep water have all contributed to high interannual variability in oceanic properties on the Ross Sea continental shelf – including within the Ross Ice Shelf cavity. This project will combine moored and profiled data from a variety of sources with seal-tag temperature/salinity data to improve understanding of the year-to-year variability in ocean properties.
Contact Mike.Williams@niwa.co.nz

Application of ice shelf processes to icy worlds

Jacob Buffo (Georgia Institute of Technology)
Natalie Robinson (NIWA)
Britney Schmidt (Georgia Institute of Technology)

The presence of platelet ice at the ice-ocean boundary will be represented in a finite difference model that incorporates multi-phase physics and accretion/ablation dynamics. This model seeks first to improve numerical representation of Antarctic sea ice and ice shelves, before being applied to the ice shell of Jupiter's moon, Europa. The goal is to produce computationally inexpensive, yet accurate, thermohaline multiphase simulations of basal ice that can accurately model the ice-ocean interface of polar ice and icy moons, as well as be incorporated into a wide variety of geophysical models that rely heavily on floating ice dynamics and processes to simulate a broad spectrum of Earth systems.
Contact Natalie.Robinson@niwa.co.nz

Control of Ross Sea dynamics by competing seasonal processes

Stefan Jendersie (NIWA)
Pat Langhorne (Univerity of Otago)
Mike Williams (NIWA)

An application of the Regional Ocean Modeling System (ROMS) to the shallow Ross Sea continental shelf, including the ice shelf cavity, has identified a system of three anti-cyclonic and one cyclonic circulation cells that facilitate the water mass transports in the region. Constrained by the banks and depressions, the cells are spatially persistent but experience different individual temporal changes. The main control of their dynamics are the horizontal differences in density that drive three mechanisms: baroclinic pressure gradients, gravity driven bottom flows and barotropic pressure gradients through sea surface height gradients. i) Circumpolar Deep Water resupply events seem triggered by a zonal shift of the Antarctic Slope Current (ASC) on the order of ∼10 km that occurs at different times along the shelf break; ii) density gradients are strengthened via High Salinity Shelf Water production during intense winter sea ice formation the south-western Ross Sea; iii) Local horizontal differences in density are enhanced by Ice Shelf Water (ISW) supplied by ice shelf basal melt. The model predicts phase lags of up to 1.5 years between heat import events to the cavity and the subsequent ISW pulse leaving the cavity. Thus the seasonality of flow dynamics in the Ross Sea is a superposition of the ASC variability, the atmospheric cycle, and the heat import signal to the cavity.

Contact Mike.Williams@niwa.co.nz

Bio-geochemical properties in the Ross Sea in CMIP5 models

Graham Rickard (NIWA)

Erik Behrens (NIWA)

A study to evaluate CMIP5 BGC models with respect to their mean physical and bio-geochemical properties and seasonal variability over the Ross Sea region has been undertaken. Historical and future projection (RCP 4.5 and RCP 8.0) have been analyzed. The aim of this study is to identify a robust future scenario response to a changing climate which will be then used for regional downscaling. Results of this study show a large model spread [*Rickard and Behrens*, 2016] in physical and bio-geochemical variables. However the study identifies an increase in surface temperatures, surface chlorophyll a, integrated primary production and iron, but also declines of surface nitrate, phosphate, silicate and seasonal thermocline under increasing CO_2 emission scenarios.

Rickard, G., and E. Behrens (2016), CMIP5 Earth System Models with biogeochemistry: a Ross Sea assessment, *Antarct. Sci.*, *28*(5), 327–346, doi:10.1017/S0954102016000122.

Contact Graham.Rickard@niwa.co.nz

Open Ocean convection in the Southern Ocean in CMIP5 models

Erik Behrens (NIWA)

Graham Rickard (NIWA)

Model data of HadGEM-UKCA and CMIP5 models has been analyzed to investigate variability triggered by deep reaching open ocean convective events in the Southern Ocean. The study [*Behrens et al.*, 2016] shows that these mixing events can trigger strong decadal to multi-decadal signals in Southern Ocean state diagnostics such as sea ice cover, Drake Passage transports, Ross and Weddell Gyre. Convection at the rim of the subpolar gyres decreases the gyre strength but increases the Drake Passage transport. That study also shows that the gyre related sea ice and thus freshwater transport plays a crucial role for preconditioning of and reoccurrence of these convective events.

Behrens, E., G. Rickard, O. Morgenstern, T. Martin, A. Osprey, and M. Joshi (2016), Southern Ocean deep convection in global climate models: A driver for variability of subpolar gyres and Drake Passage transport on decadal time scales, *J. Geophys. Res. Ocean.*, doi:10.1002/2015JC011286.

Contact: Erik.Behrens@niwa.co.nz

High resolution Ross Sea modelling: implications of an improved AABW production

Erik Behrens (NIWA)

Graham Rickard (NIWA)

A HadGEM-based high resolution ocean model using two-way nesting techniques for the Ross Sea region is under development. This model configuration uses a global eORCA1 configuration, with a view to future climate modelling applications. The aim is to improve the representation of mesoscale features and the downslope flow of Antarctic Bottom Water in this region, and to investigate implications for the large scale Southern

Ocean circulation. This project is part of the Deep South National Science Challenge (http://www.deepsouthchallenge.co.nz/). It is planned to couple this model configuration to an active atmosphere at a later stage of this project. Related global hind cast simulations with lower horizontal resolution configurations (eORCA1, eORCA025) have been completed and serve as reference simulations.
Contact: Erik.Behrens@niwa.co.nz

State estimation

No State Estimation Work is being done or planned

Planned Research Cruises

Mike Williams (NIWA)

Two research cruises to the Ross Sea sector are under development and scheduled for Feb/March 2018 and Jan/Feb 2019. Currently Expressions of Interest are being collected and voyage plans developed. It is anticipated the two voyages will support the deployment of moorings in Ross Sea, and provide platforms for other measurements. However, the voyages are anticipated to have slightly different foci, with one focusing on ecosystems and the other on climate. Voyage plans are likely to be finalized in early 2017. Contact: Mike.Williams@niwa.co.nz

SORP terms of reference http://www.clivar.org/clivar-panels/southern

"To serve as a forum for the discussion and communication of scientific advances in the understanding of climate variability and change in the Southern Ocean. To advise CLIVAR, CliC, and SCAR on progress, achievements, new opportunities and impediments in internationally-coordinated Southern Ocean research."

Specific Activities:

1. Facilitate progress in the development of tools and methods required to assess climate variability, climate change and climate predictability of the ocean-atmosphere-ice system in the Southern Ocean.
2. Identify opportunities and coordinated strategies to implement these methods, spanning observations, models, experiments, and process studies.
3. Provide scientific and technical input into international research coordination, collaborating as required with other relevant programs, including the Southern Ocean Observing System (SOOS).
4. Monitor and evaluate progress in Southern Ocean research, and identify gaps.
5. Enhance interaction between the meteorology, oceanography, cryosphere, geology, biogeochemistry and paleoclimate communities with an interest in the climate of the Southern Ocean.
6. Work with relevant agencies on the standardization, distribution and archiving of Southern Ocean observations.