Southern Ocean Observations & Change: 2019/20 Highlights and 2020/21 Outlook

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Objective and approach

• **Project Objective**: To quantify and understand the processes driving variability and change in ocean circulation and water mass formation in the Australian sector of the Southern Ocean

• **Approach**:
  • Repeat hydrographic sections to quantify/understand Southern Ocean change
  • Deployment of a pilot array of Deep Argo floats
  • Deploy novel ice-capable profiling floats in poorly observed regions
  • Mooring/ship/float/satellite experiment to study dynamics of the ACC
  • Investigate processes controlling ocean heat flux to ice shelf cavities
  • Processes controlling carbon uptake and storage on the shelf and open ocean
Rebound of shelf water salinity in Ross Sea following ~50 years of freshening
AABW formation also rebounded. Why?

Silvano et al., 2020, under review at Nature Geoscience
Physical mechanisms driving recovery of AABW

1. weakened easterly winds
2. reduced sea ice import
3. increased sea ice formation on the shelf
4. saltier DSW
5. increased AABW formation

positive SAM + El-Niño
Dynamics of a standing meander in the ACC

- Australia – USA experiment
- CTD
- Triaxus towed vehicle
- Turbulence profiles
- EM-APEX floats
- Tall mooring
- Collaboration with UTAS
ACC mooring broke loose in March

Current > 3 kn when mooring broke, due to large eddy
CO$_2$ export in dense shelf water

Physical transformation of water on the shelf leads to inorganic carbon enrichment.

Export of dense shelf water provides a pathway for CO$_2$ to the deep ocean.

Observations of TCO$_2$ in DSW $\times$ Modeled DSW Transport $\Rightarrow$ Amount of Inorganic C Exported with DSW
Helping set the Southern Ocean science agenda

Newman et al., 2019

Kennicutt et al., 2019, One Earth
AABW properties in the Australian Antarctic Basin

- 12 active floats and almost 500 profiles to the seafloor Jan 2018 - Jan 2020
- Mapped bottom water properties throughout the basin reveal spatial variability of AABW
- 3 CSIRO Deep SOLO floats have gone under sea ice for winter 2020
Bottom Water properties in the AAB: Properties near 140°E

Deep-Argo $\theta$-$S$ near 140°E (South of 60°S)

$\theta$-$S$ along SR3 (South of 60°S)

Van Wijk and Rintoul, 2014

- Historical changes in T/S along 140°E since the 1990s are similar in range to local variability in deep-Argo profiles from 2018-2020
  - 1970s values unobserved, 1995-2011 values observed from 2018-2020
  - Freshest AABW seen in summer months when ship-based observations taken
Bottom Water properties in the AAB: Properties near 150°E

- Continued rebound of salinity at 150E
- Values in the 2019-2020 up to 0.01 larger than in 2018
Ice shelf-ocean interactions

Changes in Southern Ocean water masses, in particular, Circumpolar Deep Water

Kennicutt et al., 2019, One Earth
Ice shelf – ocean interactions: key process to improve sea level rise projections

Two knowledge gaps:

1. How ocean currents enter an ice shelf cavity

   **Approach:** Combining ocean observations (moorings) with laboratory experiments in a rotating pool.

2. How warm water, that is, Circumpolar Deep Water, crosses the Antarctic continental slope

   **Approach:** Combining ocean observations (moorings), atmospheric dynamics and ocean models.
Ice front blocking of ocean heat transport to an Antarctic ice shelf


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Ice shelf – ocean interactions: key process to improve sea level rise projections

Two knowledge gaps:

1. How ocean currents enter an ice shelf cavity

   **Approach**: Combining ocean observations (moorings) with laboratory experiments in a rotating pool.

2. How Circumpolar Deep Water crosses the Antarctic continental slope

   **Approach**: Combining ocean observations (moorings), atmospheric dynamics and ocean models.
Wind regulates heat delivery to Amundsen ice shelves

Dotto et al., JGR-Oceans, under review
Southern Ocean change: Circumpolar Deep Water variability

Knowledge gap:

What is the contribution of changes in Southern Ocean circulation to the recent acceleration in Antarctic Ice Sheet mass loss?

**Approach:** Resolve the inter–decadal variability of CDW properties in each oceanic sector around Antarctica
CDW has moved southward, resulting in an increase in ocean heat fluxes toward the East Antarctic Ice Sheet

Rignot et al., 2019

Herraiz-Borreguero and Naveira-Garabato, in prep.
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Rignot et al., 2019

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Outlook for 2020-2021

- **East Antarctica - Prydz Bay:**
  - sea ice/polynya dynamics
  - 2 over-wintering floats
  - fertilisation by marine ice melt

- **West Antarctica - Amundsen Sea:**
  - UTAS AUV observations of heat transport to Amundsen Sea ice shelves (analyses of data just started)

- Field work grant applications
- Publish CDW southward shift study
Outlook for 2020-2021

- Recover remainder of ACC mooring (August 2020); begin analysis.
- Deep Argo experiment: publish first two papers, secure support for more floats.
- Navigate deep floats under ice & use Argo to quantify ACC structure (Wallace)
- Ross Gyre float/altimetry experiment
- CO$_2$ observatory on continental shelf
- New proposals for ship time