Exchange Processes in the Ross Gyre, Southern Ocean

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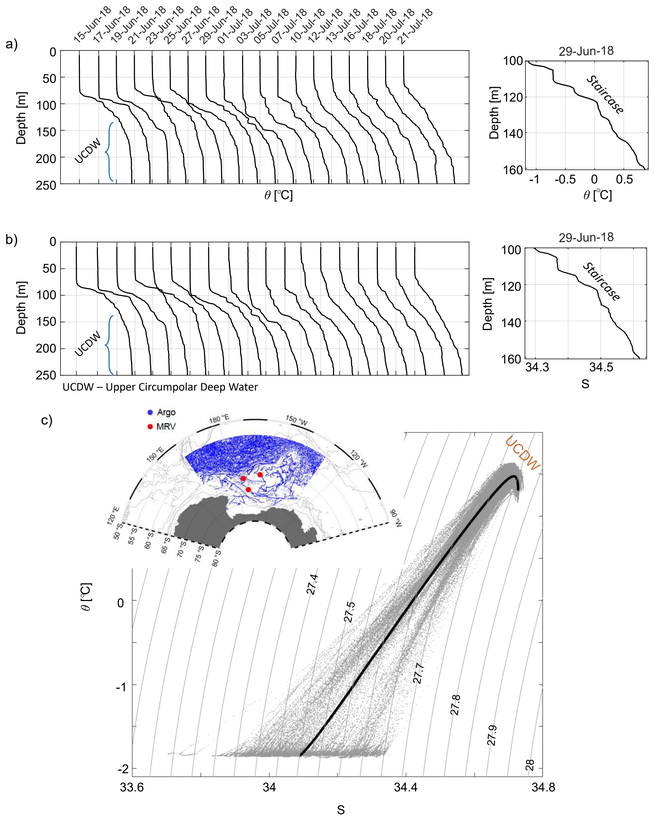
Overview

The Antarctic system is highly sensitive to increasing global temperatures, and the ocean component is crucial in understanding the projections of the melt rate of the Antarctic Ice Shelves and global sea-level rise. Southern Ocean gyres are an intermediate step in the connection of the warm Southern Ocean with the Antarctic Ice Shelves. Recent fine-scale observations in the Ross Gyre of the Southern Ocean revealed a layered structure within the pycnocline underlying the surface mixed layer. These layers (3-5 m in depth) are formed by small-scale mixing processes involving both turbulence and double diffusion. Background changes in stratification and enhanced or suppressed double-diffusive heat fluxes can alter sea-ice growth rates and the meridional propagation of the warm waters towards the Antarctic shelves.

Double-diffusive processes

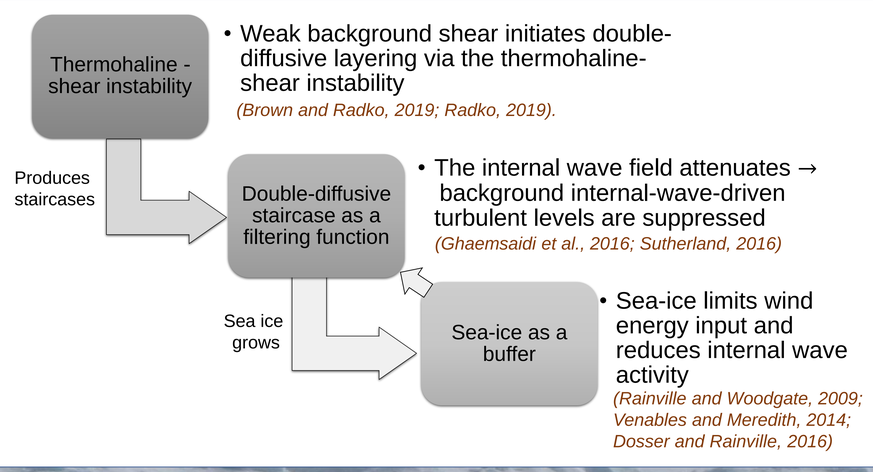
Temperature and salinity measurements from a float that operated in the Ross Gyre in 2018 are analyzed here.



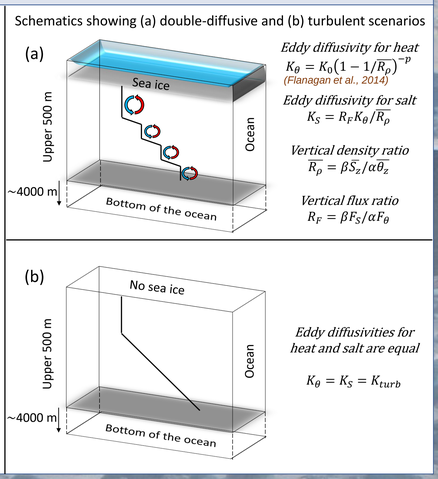
Sequence of (a) potential temperature θ and (b) salinity S profiles from 15 June 2018 to 21 July 2018. Each potential temperature and salinity profile is offset by 1.1 °C and 0.18 from the leftmost profile, respectively. Insets show the closeup structures between ~100- and ~160-m depth for the profiles measured on 29 June 2018.

(c) Potential temperature and salinity values (within 0- to 500-m depth interval) measured by Argo and MRV from the beginning of June to the end of October; the solid black line shows the mean profile for these winter months.

Proposed ice production-entrainment feedback



- Weak background shear initiates double-diffusive layering via the thermohaline-shear instability
  (Brown and Radko, 2019; Radko, 2019).
- The internal wave field attenuates → background internal-wave-driven turbulent levels are suppressed
  (Ghaemsaidi et al., 2016; Sutherland, 2016)
- Sea-ice limits wind energy input and reduces internal wave activity
  (Rainville and Woodgate, 2009; Venables and Meredith, 2014; Dosser and Rainville, 2016)



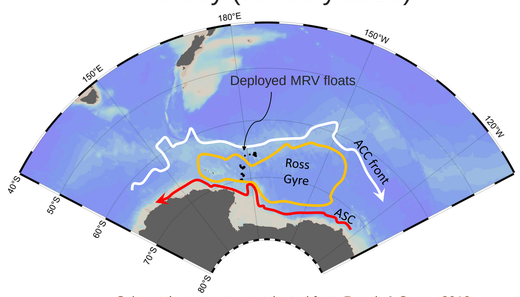
Potential future observations

Year-round in-situ observations with fine-scale/microstructure vertical resolution are necessary to characterize double-diffusive features. Potentially, an array of moorings across the boundaries of the Ross Gyre would help pinpoint the main exchange processes (such as eddy field, intrusions) that can contribute to setting vertical background stratification within the gyre. In addition, a set of autonomous floats (with ice-avoidance mechanism) could provide insight on circulation patterns within the gyre and reveal further details on the sea-ice-ocean feedback associated with double-diffusive mixing.

MRV

RBR*argo*³ C.T.D (8Hz)

Pilot study (January 2020)



Schematic contours are adapted from Roach & Speer, 2019

Preliminary findings:

- Small-scale intrusions at the northern boundary of the Ross Gyre
- Large scale intrusions spanning for ~100 km
- Various layered structures in the upper ocean.

Summary

- The presence of a double-diffusive staircase enhances sea ice formation by suppressing vertical heat fluxes
- There is a potential ice production-entrainment feedback mechanism
- More year-round in-situ observations are needed

More details are in
Bebieva, Yana, and Kevin Speer: "The Regulation of Sea Ice Thickness by Double-Diffusive Processes in the Ross Gyre." *Journal of Geophysical Research: Oceans* 124.10 (2019): 7068-7081.