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Thermodynamics and variability of Antarctic Bottom Water in the Weddell Sea

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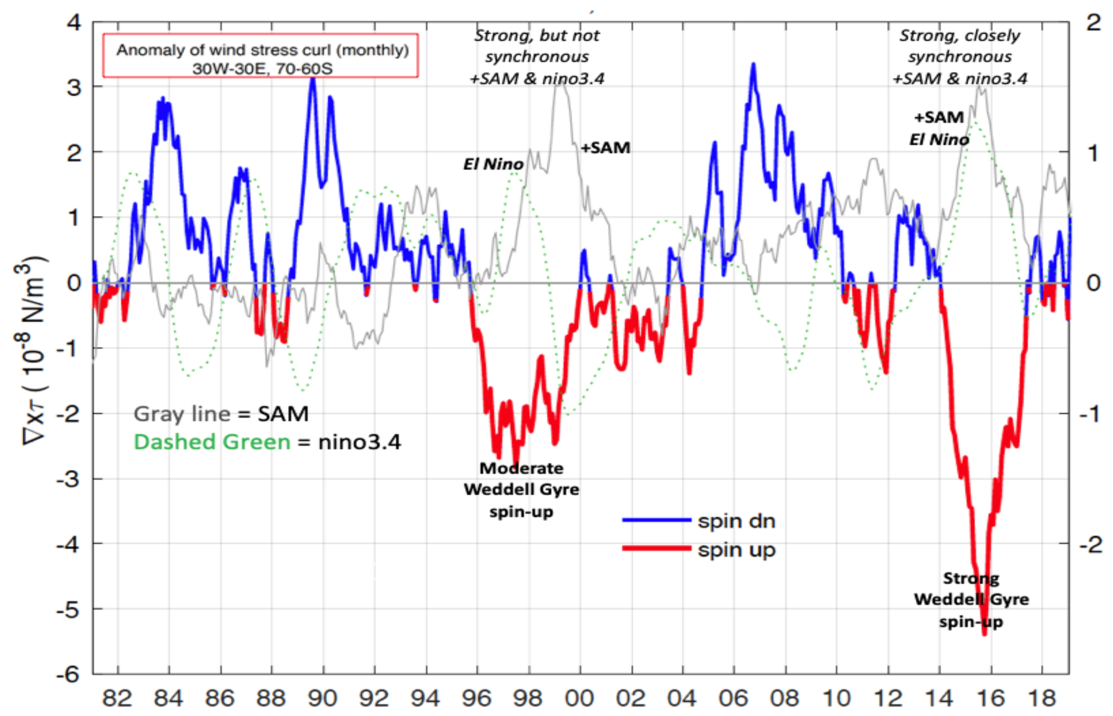
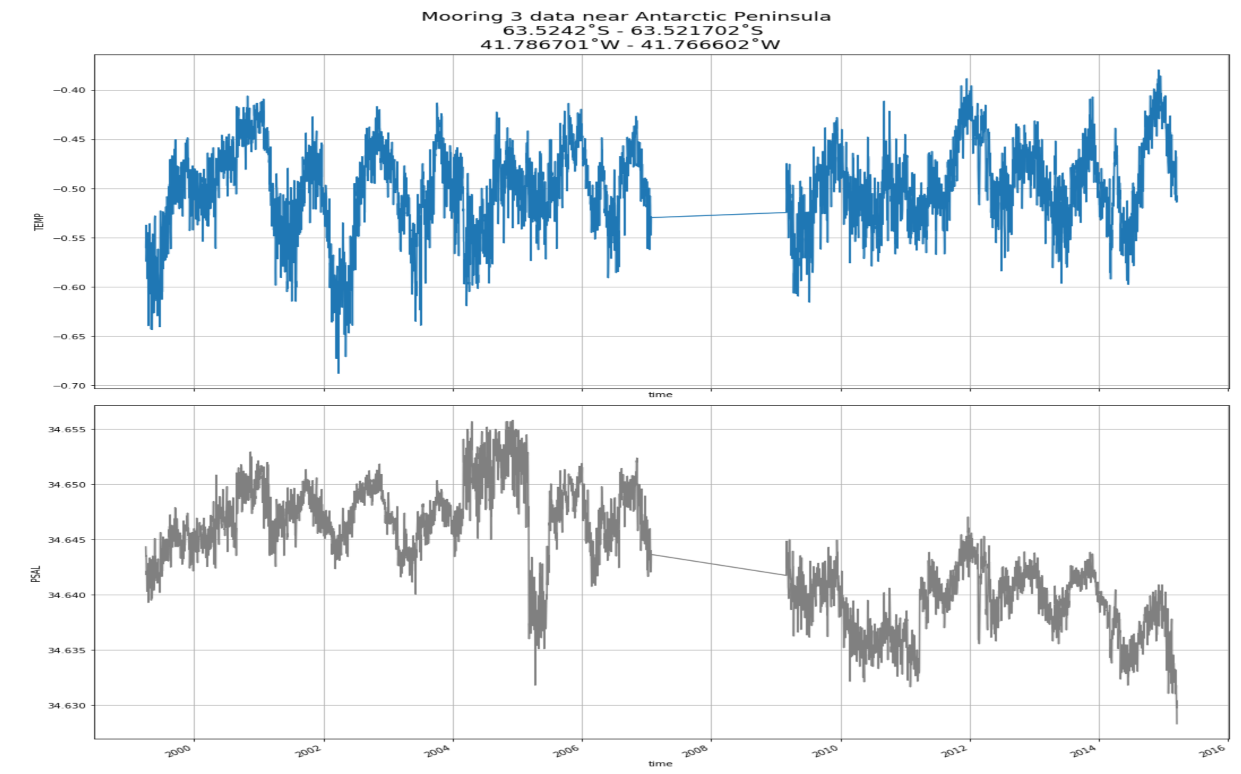
Abstract The circulation of deep and abyssal waters (waters at or below 2,000m) is an important part of the Southern Ocean global meridional overturning circulation (SOMOC). The SOMOC ventilates the deep ocean while transporting nutrients and tracers (i.e. nitrogen, phosphorous and oxygen). Bottom water is a particularly important part of the climate system, because it can store large amounts of heat and carbon. Changes in the circulation of the abyssal ocean may have significant impacts on Earth's climate. Understanding how the deep ocean reacts to a warming climate will improve predictions of sea level rise and oceanic uptake of CO_2.

The densest, coldest and highest-oxygen water in the abyssal ocean is Antarctic Bottom Water (AABW), contributing ~80% to the global deep ocean volume, and most of it being produced in the Weddell Sea region. Climate variability (i.e. ENSO/SAM coupling) has the potential to modify all aspects of bottom water formation; however, the net impact on AABW is not well understood. Recent studies have put additional focus on water-mass transformation (WMT) within the upper branch; however, a robust study of bottom water WMT through a full seawater's equation of state (EOS) has yet to be produced. A key to establishing how AABW formation sources thermodynamically transform due to the nonlinearity of seawater's equation of state (i.e. thermobaric and cabbeling terms), is to consider the fundamental contradiction that Antarctic surface buoyancy fluxes seem to be dominated by freshwater fluxes, but AABW buoyancy is controlled by temperature – because due to the thermobaric effect colder water is heavier with depth.

This project aims to investigate AABW circulation by employing a WMT framework through the use of existing low-resolution models, such as SOSE and NASA's ECCOv4 product. With these models, our project aims to quantify interannual variability of AABW, and to examine how the nonlinearity of the thermobaric effect impacts AABW formation. One of the goals is to determine the extent of this term's contribution to seawater's equation of state in this WMT framework. We expect temperature to play an essential role as we look at the bottom 2,000m of SOMOC's lower branch (i.e. the effect of thermobaricity becomes the dominant term in our framework). It is important to understand the thermodynamic drivers of AABW formation and to quantify its variability, as it will lead to a better understanding of how ocean circulation reacts to a changing climate.





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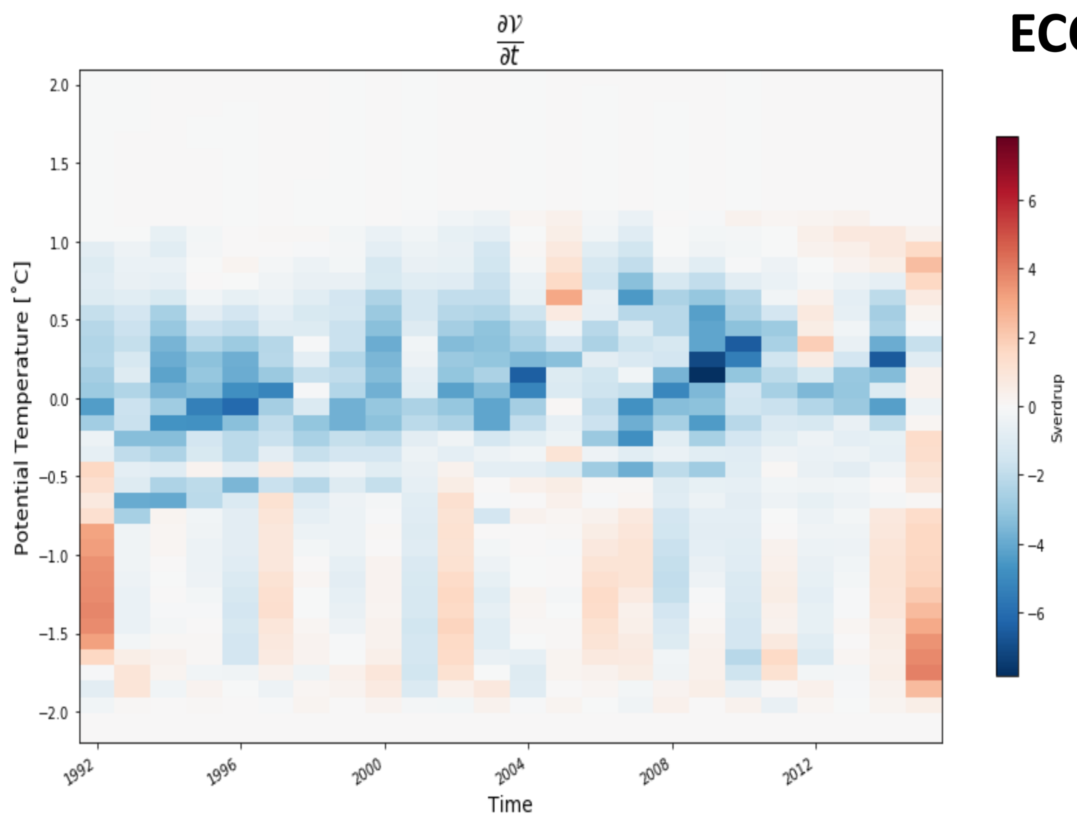

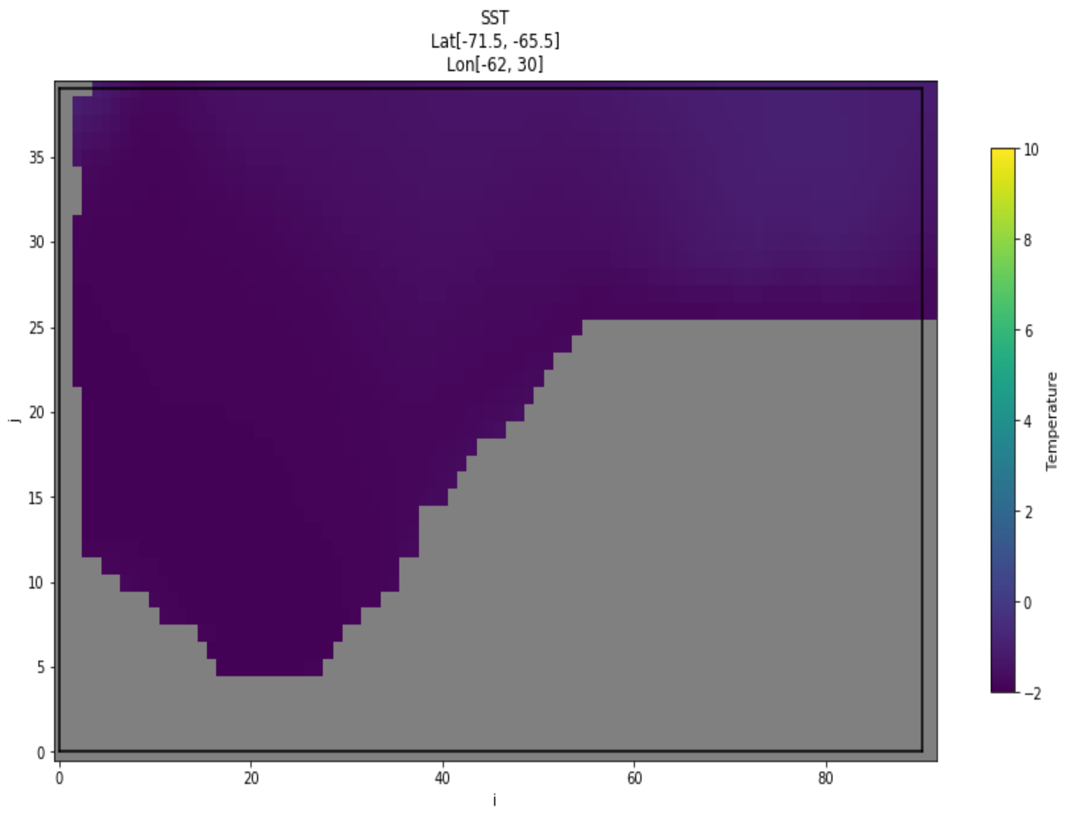

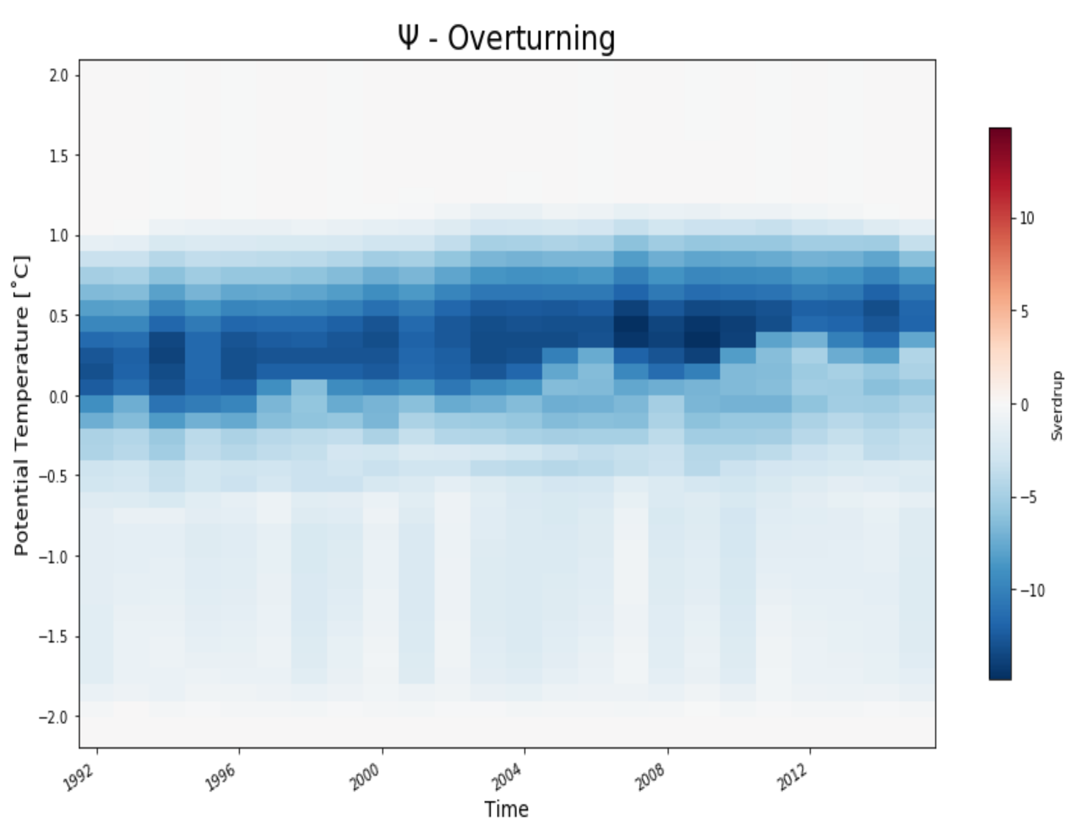

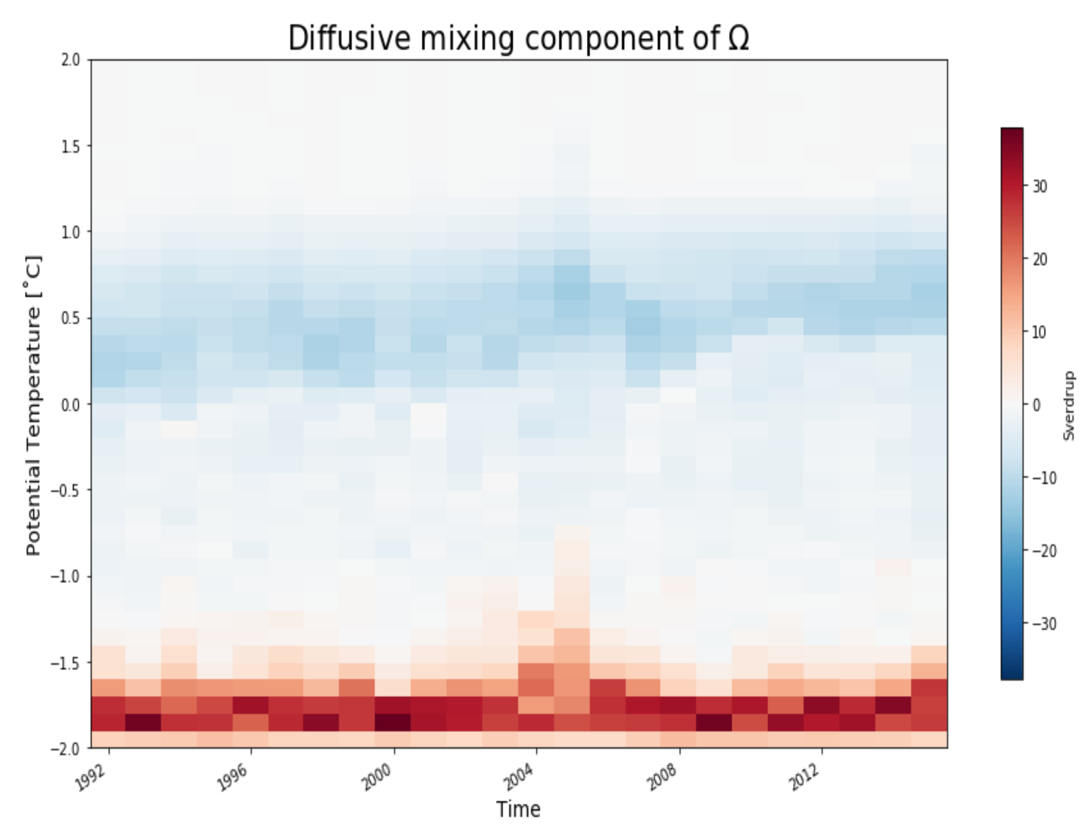

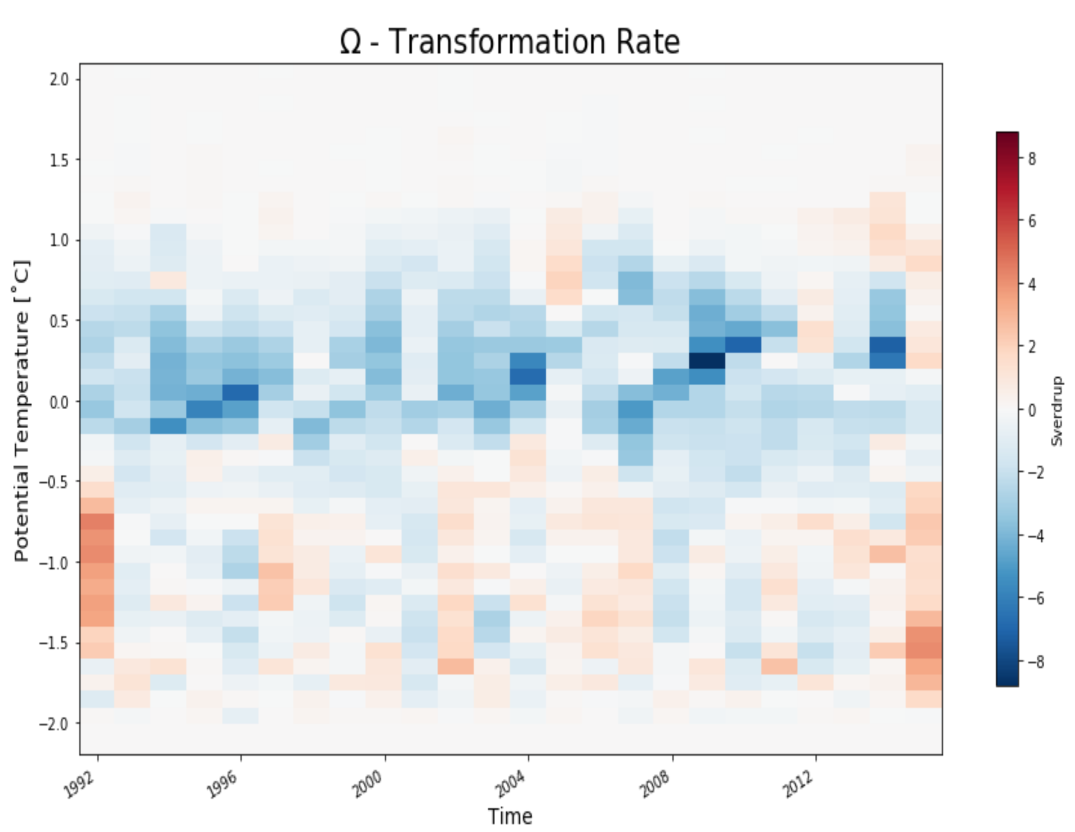

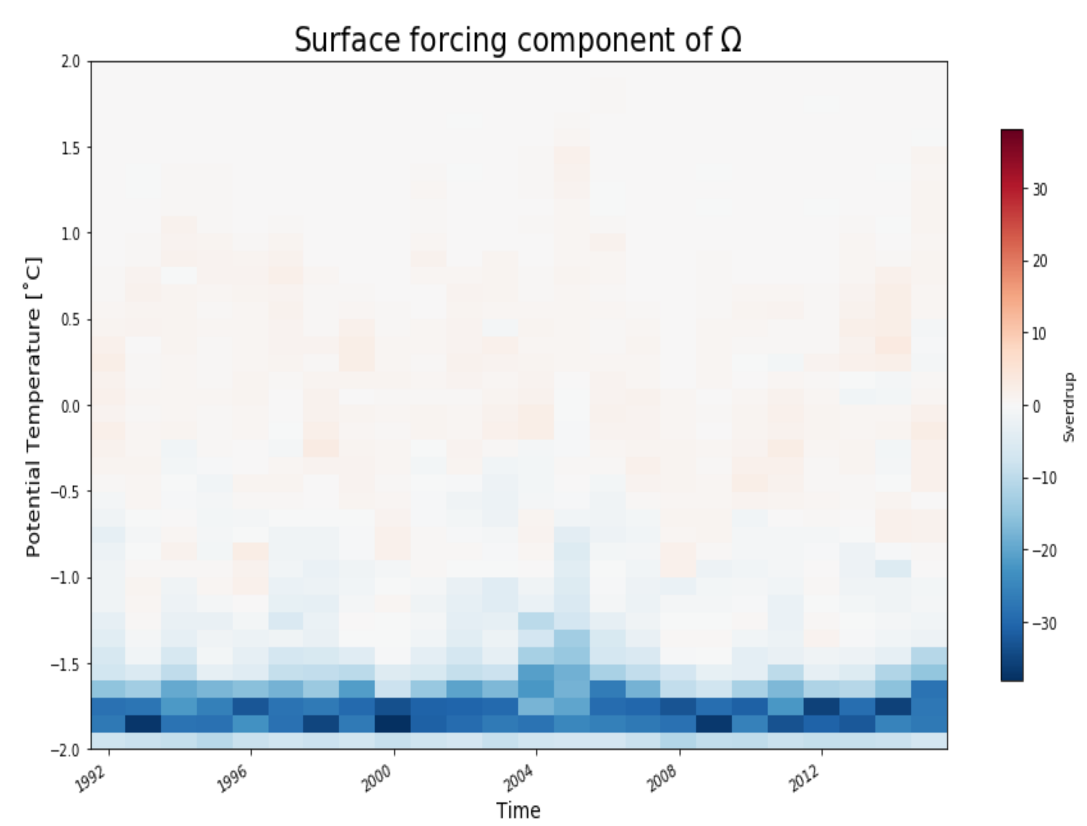

Methods & Models:

- We are using numerical models to employ **the water mass transformation (WMT) framework**, developed by Walin (1982), to investigate and quantify the interannual variability of AABW in the interior Weddell Gyre. The framework is a method to characterize and quantify the impact thermodynamic processes have on circulation. The WMT equation, $\frac{\partial \mathcal{V}}{\partial t} = \psi + \Omega$, expresses the relationship between the rate of change of water-mass volume to the inflow/outflow transports at the boundary of the region, and the thermodynamic transformation occurring in its interior.
- We use **SOSE**, which is a gridded dataset at 1/6˚ horizontal resolution, observation-assimilating model. It is a product of the MITgcm model and includes observations such as Argo float profiles, CTD measurements, NASA satellite measurements of sea surface height and sea ice, various mooring data, and others. This model covers the years 2006 – 2012.
- We also use **ECCOv4r3**, which is a LLC90 gridded dataset at 1˚ horizontal resolution ocean state global model that uses the adjoint method for estimation. It is a product of the MITgcm model and includes data from Argo, GRACE, Aquarius, CTD and XBT measurements, and NASA Satellite Altimetry data. This model covers the years 1992 – 2014.

Results/Conclusions

- The water profiles between 0˚C and 0.5˚C exhibit a warming in both ECCO and SOSE runs, as was shown in Gordon et al., in press.
- Deep/bottom water export is on a similar order of magnitude as other estimates.

References

- Gordon, A.L., Huber, B.A., Abrahamsen, E.P., 2020, Interannual Variability of the outflow of the Weddell Sea Bottom Water. *GRL*, in press.

SOSE