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Supporting Information for

**A model-based investigation of the recent rebound of shelf water salinity in the Ross Sea**

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**Overview**

We present here additional information related to oceanography data, model simulation setup, summary of perturbation experiment settings, and the additional experiment and analysis (Figures S1 to S7).

**Contents of this file**

1. Method

2. Table

3. Figures S1 to S7

## 1. Method

### 1.1 Oceanography data

The oceanographic data utilized in this study were sourced from the work of Castagno et al. (2019). To capture the salinity changes in the Deep Shelf Water (DSW) of the Ross Sea, specific regions were selected for analysis. The time series in Fig.1a and Supplementary S1 were obtained by averaging the salinity in the 30 dbar layer from 870 to 900 dbar for TNB (74.25°S–75.50°S and 163.00°E–166.00°E), and in the bottom 20 dbar for Drygalski Trough mouth (DT, 72.00°S and 72.67°S and 171.50°E and 174.50°E), Joides Trough (JT, 73.90°S–74.10°S and 174.20° E–176.00°E) and Glomar Challenger Trough (GCT, 75.80°S–76.20°S and 178.00°W–177.10°W).

### 1.2 Climate indices

The Southern Oscillation Index (SOI) captures variability associated with the El Niño/La Niña cycle and represents the dominant modes of atmospheric variability in the Pacific sector of the Southern Ocean. We used monthly SOI provided by NCAR (https://climatedataguide.ucar.edu/climate-data/southern-oscillation-indices-signal-noise-and-tahitidarwin-slp-soi). The monthly location of ASL central was also used in this study, sourced from (https://scotthosking.com/asl_index). The location of ASL central, which is the minimum sea surface pressure, is defined using an ASL detection methodology, described in (Hosking et al., 2016).

### 1.3 Model simulation setup

ACCESS-OM2 is a global model with coupled ocean and sea-ice components driven by prescribed atmosphere forcing. The ocean component is the Modular Ocean Model version 5.1 (MOM5.1; (Griffies, 2012) from the National Oceanic and Atmospheric Administration Geophysical Fluid Dynamics Laboratory (NOAA-GFDL). The sea-ice component is the

Community Ice Code version 5.1.2 (CICE5.1.2;(Hunke et al., 2015)). The coupling of these two components is achieved by the model coupling toolkit from CERFACS and CNRA through the Ocean Atmospheric Sea Ice Soil version 3 (OASIS3; (Valcke, 2006)). ACCESS-OM2 simulation is initialized from rest with zero sea level and with temperature and salinity from the World Ocean Atlas 2013 (WOA13). Surface salinity was restored to the WOA13 monthly climatology with a restoring time scale of 21days over the top layer.

The initial phase of our study involves a 200-year spin-up, which is driven by the repeat year forcing from 1$^{st}$ May 1990 through 30$^{th}$ April 1991 (RYF-9091, repeat-year forcing 1990-1991). This repeat year forcing is chosen due to its neutral characteristics with respect to major climate variability modes. Following this spin-up, the ACCESS-OM2 model is then forced with interannually varying atmospheric variables based on the Japanese 55-Year Reanalysis (JRA-55) dataset for driving ocean–sea ice models version 1.4 (hereafter referred to as JRA55-do v1.4; (Tsujino et al., 2018)) from 1990 to 2018.

### 1.4 Experiment design: Ross Sea-only wind experiment

To ascertain the specific location of the wind responsible for the changes in sea ice, we conducted further experiments called the Ross Sea-only wind experiment. The Ross Sea-only simulation employed a fixed wind forcing (climatology) and real-time other atmospheric forcing approach for the entire Southern Ocean, except for the western Ross Sea (160$^{o}$E-170$^{o}$W, 60$^{o}$S-80$^{o}$S), where real-time wind forcing was implemented. We then compared the Ross Sea-only wind experiment versus the heat-vary experiment (climatological wind forcing and real-time other atmospheric forcing) to isolate the impact of local wind stress anomaly in the western Ross Sea.

## Supplementary References


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