Variability of the Southern Boundary in the Bellingshausen Sea, Southern Ocean

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Introduction

- The Bellingshausen Sea is located between the West Antarctic Peninsula and the Amundsen Sea
  - The Antarctic Slope Front that rings the continental slope of Antarctica supports a westward current whose structure and variability influences exchange processes close to Antarctica such as the transport of warm Circumpolar Deep Water onto the shelf (Thompson et al., 2018)
  - This water mass is responsible for the transport of heat across the shelf and therefore the basal melting of ice shelves
  - Due to the lack of observations it is still unclear if the Antarctic Slope Front exists in the Bellingshausen Sea or if there are other structures close to the shelf break such as the Southern Boundary of the Antarctic Circumpolar Current moderating the transport of warm water onto the shelf.

- Therefore observations of cross-slope sections in the Bellingshausen Sea from 2007 and 2019 are used in comparison with NEMO 1/12 ° Reanalysis data (GLOBAL_REANALYSIS_PHY_001_030) from 2000 to 2018 to investigate:
  - Current structures
  - Distance of the Southern Boundary to the shelf break
  - Seasonal and interannual variability of the Southern Boundary

Area of Interest

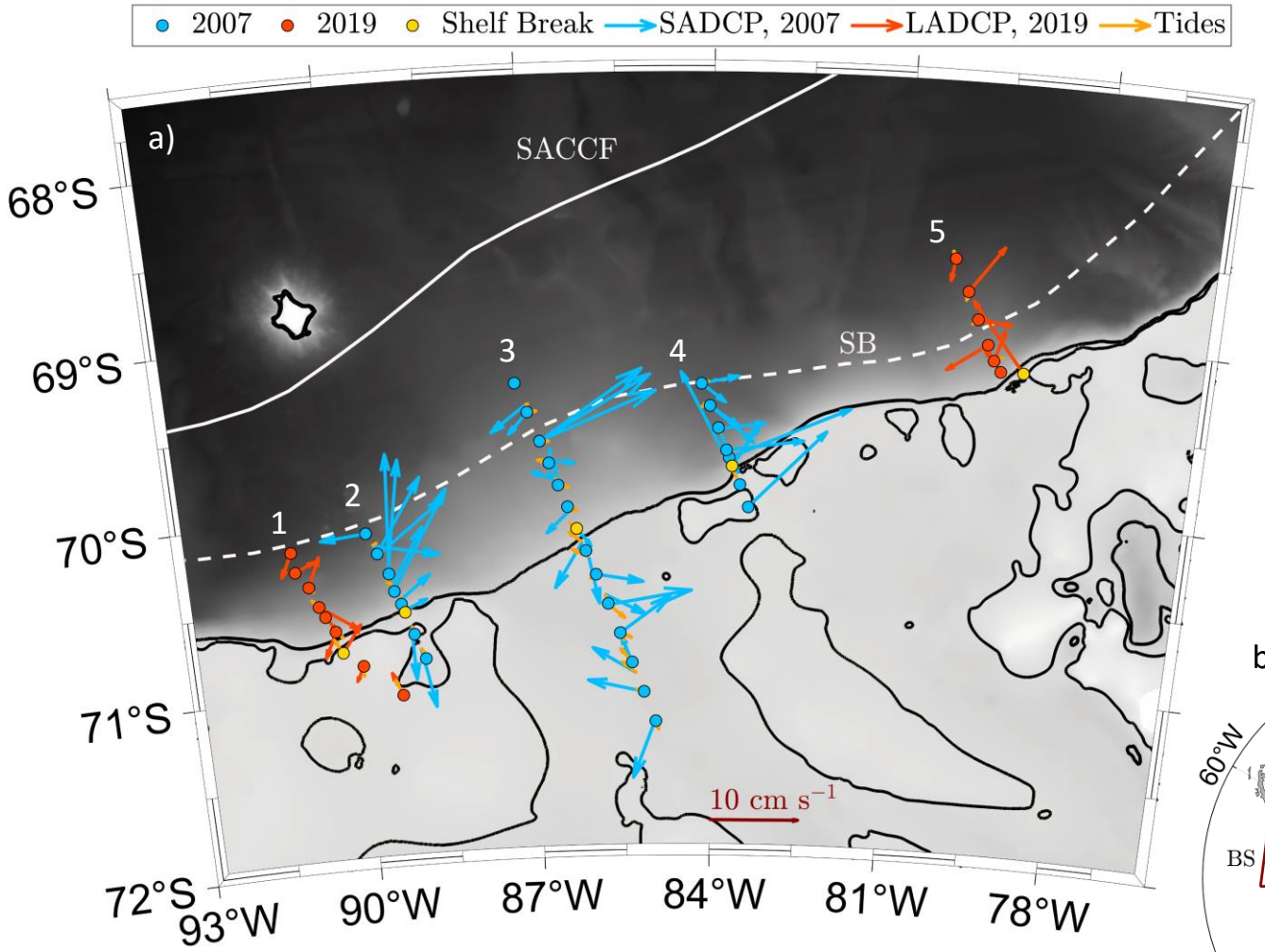
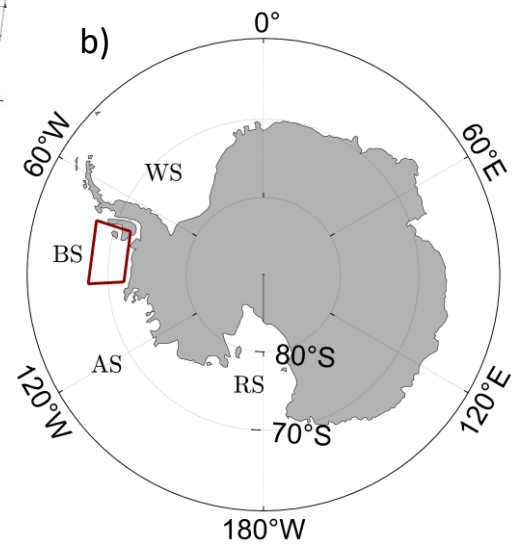


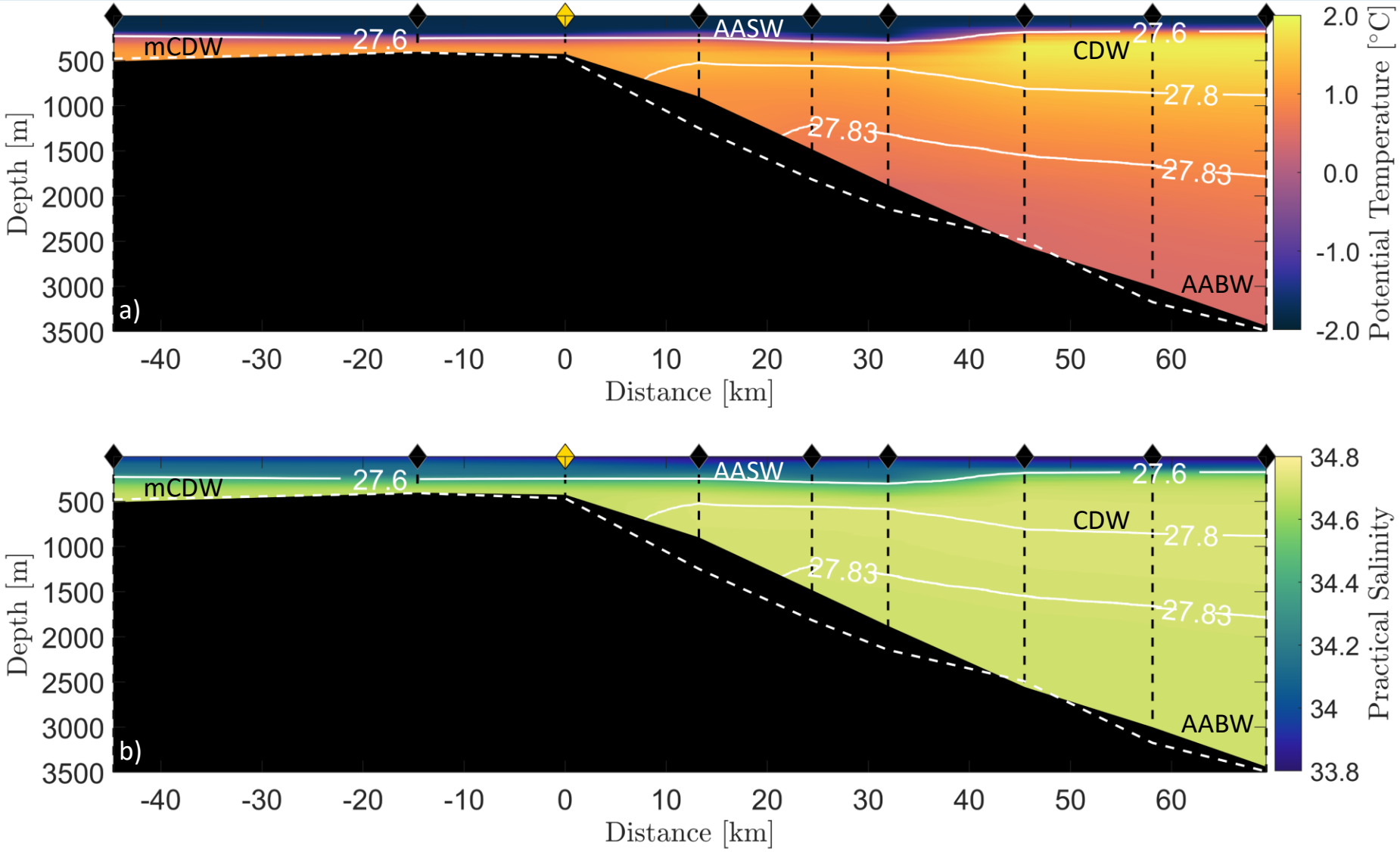
Figure 1:

a) Map of observed cross-slope CTD sections from 2007 (blue) and 2019 (red) along with LADCP / SADCP quivers averaged over the top 500 m. The black contours show the 500 and 750 m isobath based on the IBCSO data set (Arndt et al., 2013). The bold and the dashed white contour mark the Southern Antarctic Cirumpolar Front (SACCF) and the Southern Boundary (SB) of the ACC defined by Orsi et al. (1995). The numbers indicate the different sections 1 to 5. The yellow dots show the station designated as the shelf break on each section.

b) Map around Antarctica presenting the different marginal seas such as Weddell Sea (WS), Ross Sea (RS), Amundsen Sea (AS) and Bellingshausen Sea (BS). The area of interest shown in (a) is marked by the red box.



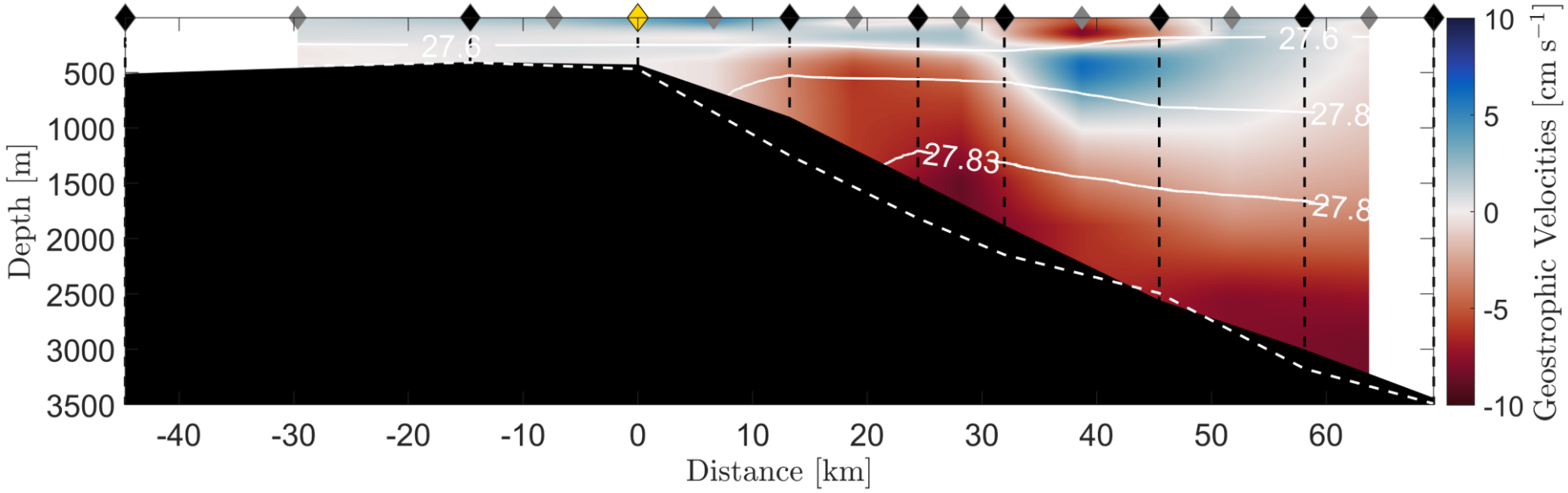
Hydrography - Section 1 - Observations



- Relatively fresh surface mixed layer near the freezing point, Antarctic Surface Water (AASW) (top 100 to 350 m)
- Further off-shelf θ_{max}~ 2°C (400 to 800 m in depth), Upper Circumpolar Deep Water (CDW), also marked with an oxygen minimum (not shown)
- On-shelf, slightly colder and fresher than CDW, modified Circumpolar Deep Water (mCDW)
- Bottom of the slope, decrease in temperature, maximum salinity and increase in oxygen (not shown), Antarctic Bottom Water (AABW)
- Hydrography mostly consistent with (Zheng et al.,2016) and NEMO 1/12 Reanalysis

Figure 2: Hydrography of the observed cross-slope section 1 showing (a) potential temperature and (b) practical salinity with density (white contours) superimposed. The black diamonds mark the stations from on- to off-shelf and the yellow diamond indicates the station where the shelf break is defined to be. The black area shows the bathymetry due to the CTD station depths and the white dotted line indicates the bathymetry based on the IBCSO data set (Arndt et al., 2013).

Geostrophic Velocities – Section 1 - Observations



- Westward flow along the slope, consistent with maximum westward flow of AABW at the bottom of the slope
- Eastward core (blue) within CDW further off-shelf indicating Southern Boundary of the ACC

Figure 3: Geostrophic Velocities referenced to LADCP profiles with density (white contours). Eastward velocities are defined to be positive (blue). Black diamonds mark the stations while the yellow diamond indicates the defined shelf break. Grey diamonds show station mid-points. The black area shows the bathymetry due to the CTD station depths and the white dotted line indicates the bathymetry based on the IBCSO data set (Arndt et al., 2013).

Definition of the Southern Boundary (SB) – NEMO Reanalysis – Example Section 1

The Southern Boundary (SB) of the ACC is defined as θ>1.5°C in a depth of ~200m (Orsi et al., 1995)

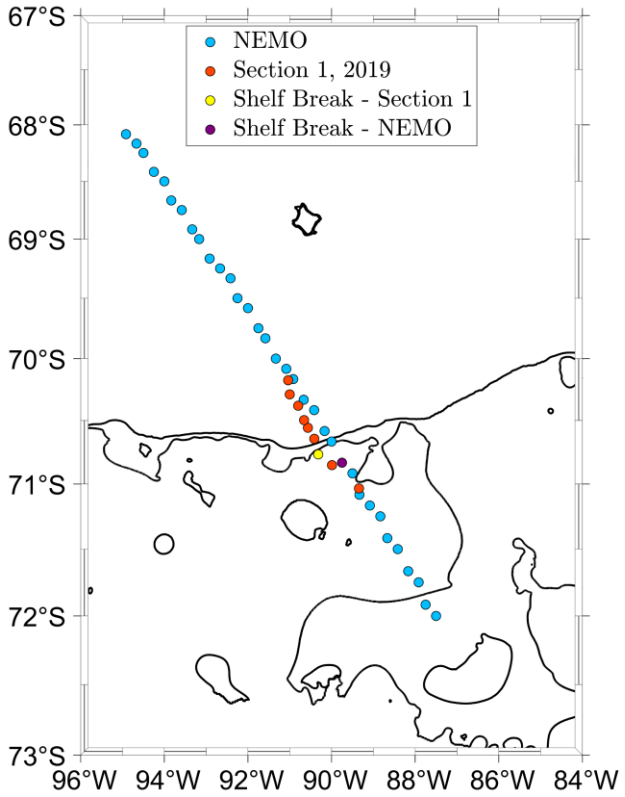


Figure 4: Map of picked cross-slope section for the NEMO Reanalysis data (blue dots) based on the location of the observed section 1 (red dots). The shelf break is defined for both of the sections (NEMO purple, Observation yellow).

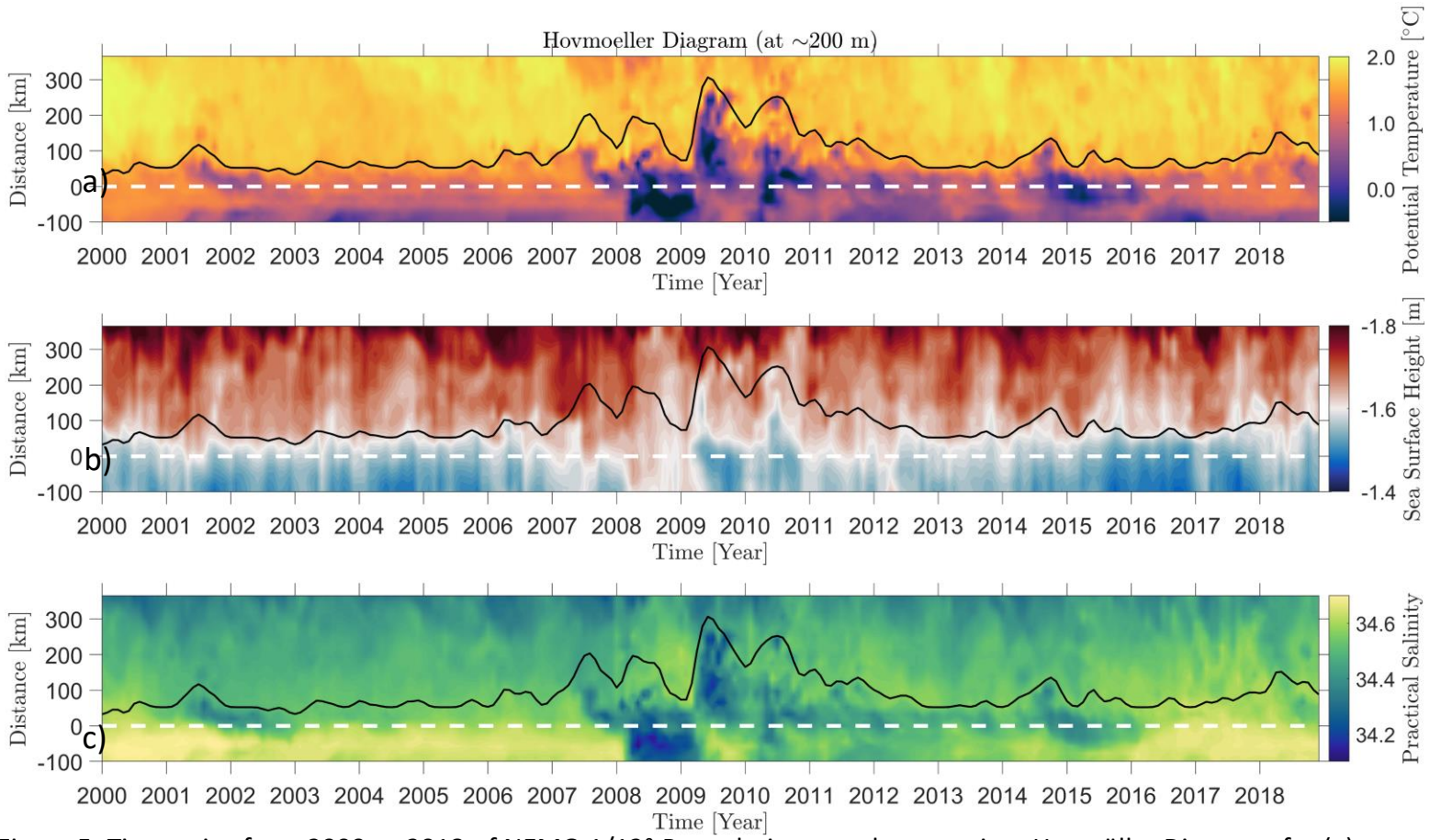
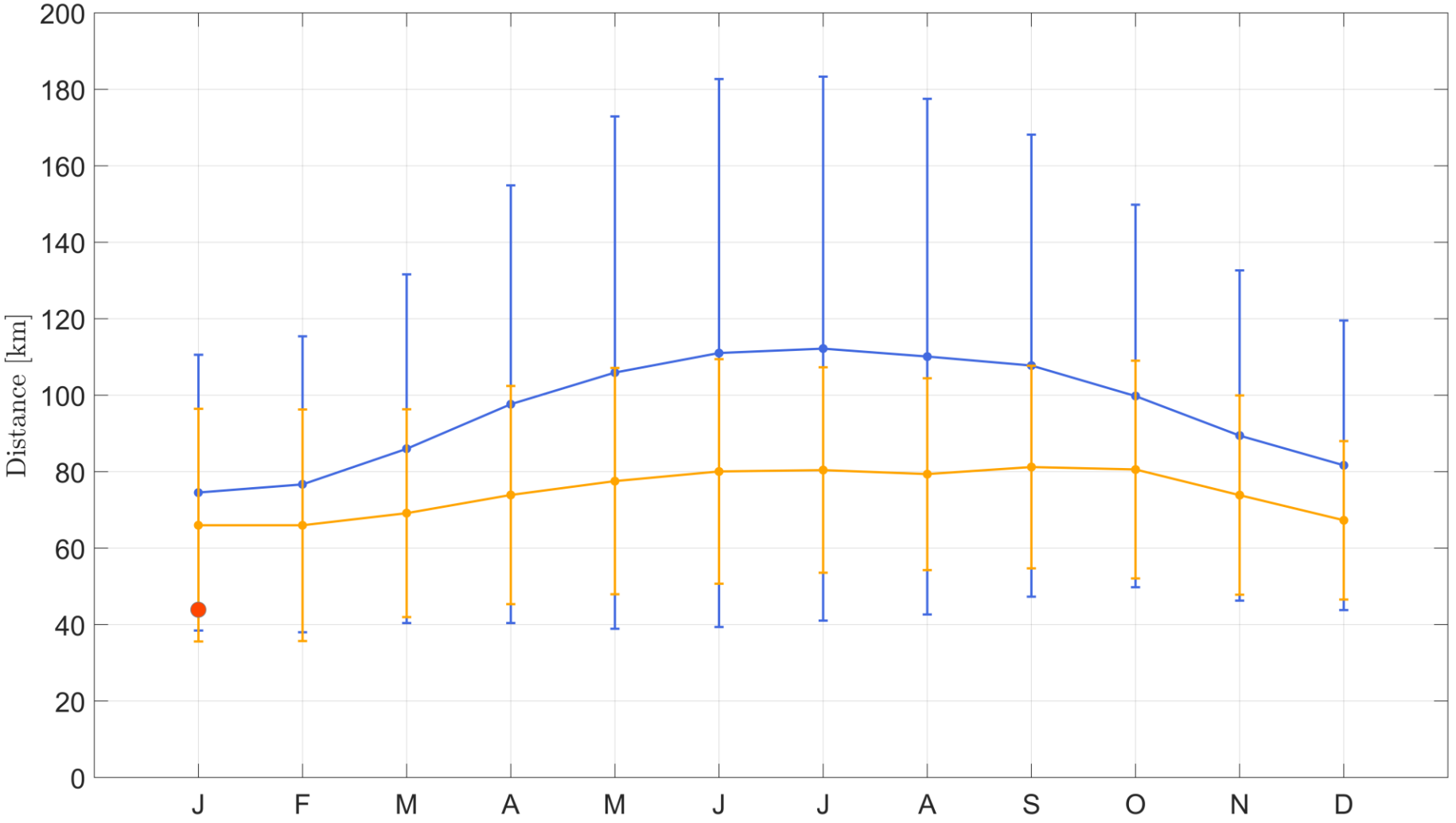


Figure 5: Timeseries from 2000 to 2018 of NEMO 1/12° Reanalysis cross-slope section. Hovmöller Diagrams for (a) potential temperature, (b) Sea Surface Height (SSH) and (c) practical salinity at ~200 m. The black contour line indicates the Southern Boundary of the ACC with θ>1.5°C at ~200 m. The dashed white line is the defined shelf break (purple dot in Figure 4). The x- tick-labels correspond to the 1st of January each year.

- Clear signal of interannual variability, high distances to the shelf break from 2007 to 2010 (Figure 5 (a-c)) . SAM and ENSO index are rather moderate during the entire timeseries (i.e., no clear difference in 2007-2010). Maps of potential temperature over time indicate a cold water inflow to the east originating from the Amundsen Sea and expanding along the shelf in the Bellingshausen Sea during these years, corresponding to the times when the SB is further offshore. Origin of this rather extreme event is currently unexplained Potentially influenced by the Amundsen Sea Low ?

Monthly Mean of Southern Boundary with Distance to the Shelf Break



- Signal of seasonal variability of the SB with distance to the shelf break
  - Closer to the shelf break in summer (November to February)
  - Larger distance to the shelf break in winter (May to September)
- These results show a similar pattern with monthly means from Billany et al. (2007) in the Weddell Sea

Figure 6: Monthly means from NEMO 1/12° Reanalysis from 2000 to 2018 with errorbars presenting the standard deviation for each month. Blue line shows the monthly mean with all years included while in the orange line the years 2007 to 2010 have been excluded as they show a rather extreme event that did not repeat itself over the time series. The red dot indicates the distance of the SB from the shelf break from the observed section 1.

Summary and Outlook

- Seasonal and interannual variability of the Southern Boundary of the ACC
  - Closer to the shelf break in summer and further away from the shelf break in winter
  - Distance to the shelf break of the SB in the observations (section 1) is within the standard deviation of the model mean

- Strong signal of cold water inflow from the Amundsen Sea leading to larger distances of the Southern Boundary to the shelf break within 2008 to 2011
  - Cold water inflow is being tracked using a movie compilation

- Assuming that the Southern Boundary is mostly following f/h contours, distance calculations and monthly means will be accomplished for all observed cross-slope sections to further investigate seasonal and interannual variability along the shelf break in the Bellingshausen Sea

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