Glacial Meltwater Identification Within the Bellingshausen Sea

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Abstract

Similar to most West Antarctic ice shelves, those in the Bellingshausen Sea have rapidly thinned by hundreds of cubic kilometers over the last decades yet they remain under-studied compared to other regions. The increased melting rates in the West Antarctic Peninsula (WAP) have been linked to warm Circumpolar Deep Water (CDW) that is able to access the continental shelf due to the absence of the Antarctic Slope Current. The exact pathways of CDW flowing on to the shelf and of meltwater flowing away from the ice shelves are essential to understanding the dynamics in this region and how it will change in the future. Here, we propose that the Bellingshausen Sea plays an important role in connecting circulation between the Amundsen Sea and the WAP and may influence water properties that circulate under floating ice shelves throughout the West Antarctica. Using a combination of hydrographic and isotopic data from a recent cruise to the Bellingshausen Sea (December 2018 to January 2019), multiple methods are applied to identify circulation pathways and to quantify glacial meltwater fractions. The meltwater measurements show that the Belgica and Latady Troughs are important pathways for CDW to reach the ice shelves, though almost twice as much meltwater is transported off the shelf via the Belgica Trough. CDW enters the shelf at the deepest part of the Belgica Trough, moving towards the coast along the trough's eastern side. The largest meltwater fractions are found along the western flank of the Belgica and Latady Troughs. The meltwater signature can be tracked to the western edge of the Bellingshausen Sea, where it is then entrained into a boundary current system that flows over the continental slope towards the Amundsen Sea.

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1. INTRODUCTION

Similar to most West Antarctic ice shelves, those in the Bellingshausen Sea have rapidly thinned by hundreds of cubic kilometers over the last decades yet they remain under-studied compared to other regions.

In the Bellingshausen Sea, the increased melting rates along the West Antarctic Peninsula (WAP) have been linked to warm Circumpolar Deep Water (CDW) that is able to access the continental shelf due to the absence of the Antarctic Slope Current (ASC) (Wahlin et al. 2010; Kim, et al., 2016; Zhang et al. 2016). The exact pathways of CDW onto the shelf and of meltwater flowing away from the ice shelves are essential to understanding the dynamics in this region and potential changes in the future. Here, we propose that the Bellingshausen Sea plays an important role in connecting circulation between the Amundsen Sea and the WAP and may influence water properties that circulate under floating ice shelves throughout the West Antarctic.

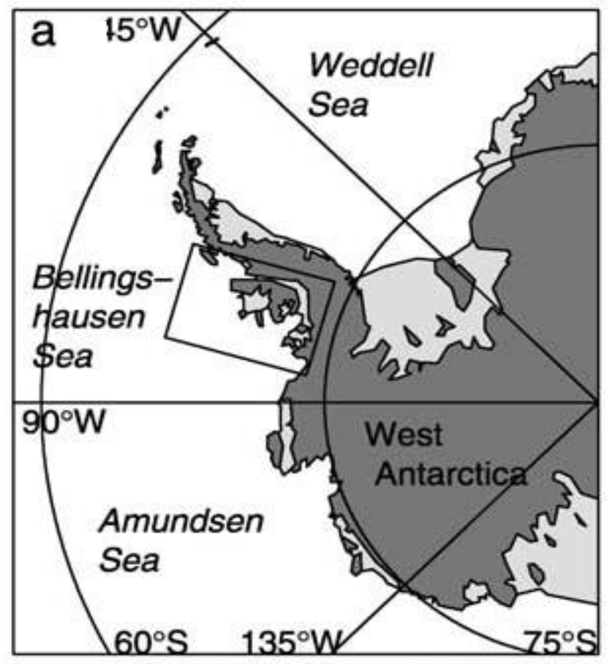

Figure 1: Map of Bellingshausen and Amundsen Sea region, Western Antarctica (Jenkins & Jacobs 2008)

The purpose of this study is to identify meltwater and its potential pathways in the Bellingshausen Sea using hydrographic and isotopic data from a recent cruise.

2. STATION MAP

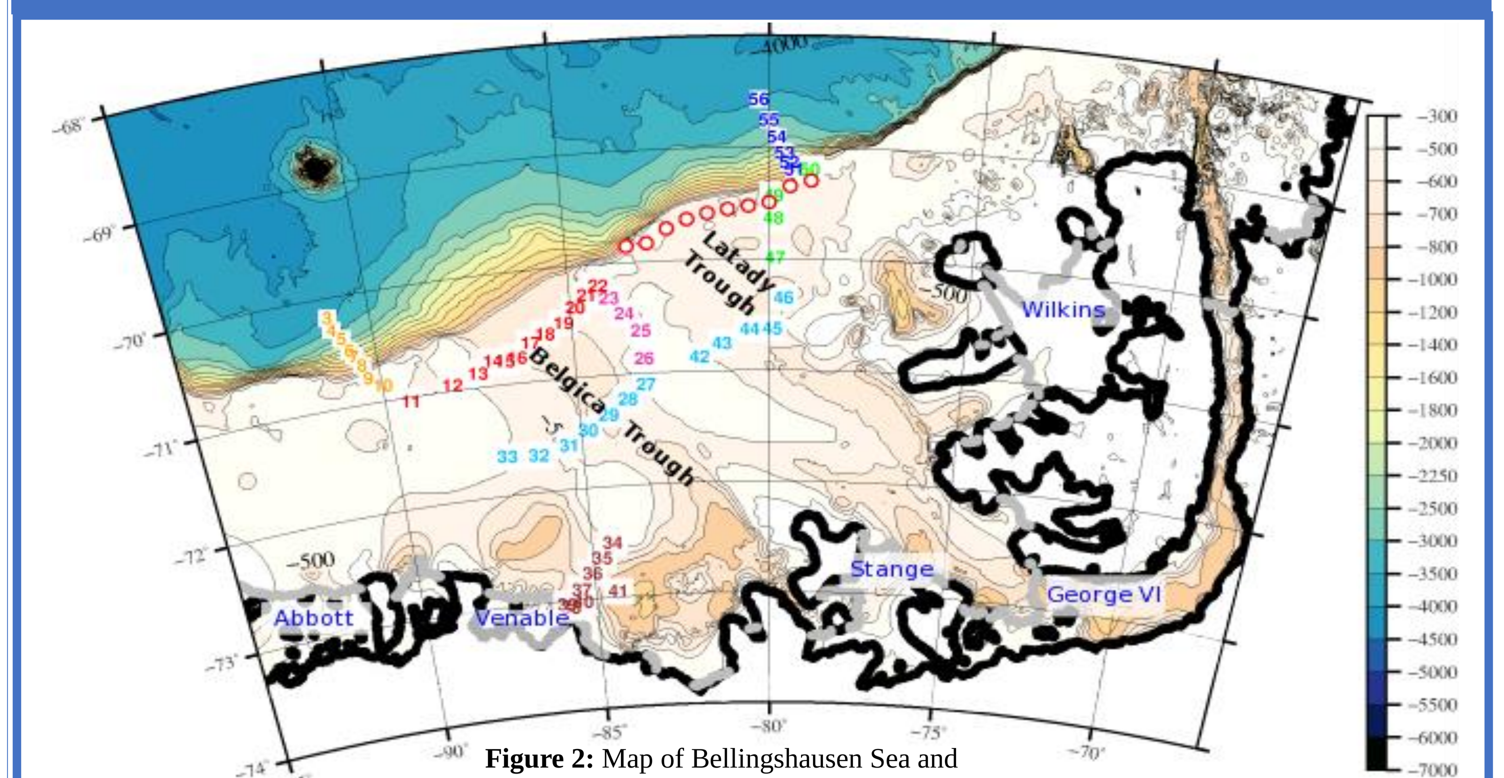

Figure 2: Map of Bellingshausen Sea and stations (colored numbers) and gliders (red circles) occupied during the NBP1901.

The hydrographic data used in this study was collected during the NBP1901 in December 2018-January 2019 (Figure 2). Isotope samples were collected at each station both in the Bellingshausen and Amundsen Seas. In addition, Gliders were deployed to measure hydrography of the shelf (red circles). This data is not included in this study.

The sections shown in Box 4. are stations 11 – 22 (red numbers) and stations 27 – 33 and 42 – 46 (Light blue numbers).

3. MELTWATER FRACTIONS METHOD

To identify Meltwater fractions (MW) we follow the methods described by Biddle et al. [2017] and Jenkins & Jacobs [2008]. For this CDW and WW must be identified in the profiles.

To identify the CDW and WW in each T/S profile, two different methods are employed:

- **Method 1:** CDW and WW are identified individually for each station. This method tends to neglect the fact that the CDW and WW present in a profile can already have MW mixed into them.
- **Method 2:** CDW and WW are identified by analyzing all profiles at once and picking the purest CDW and WW from the bulk profiles. These values are then used to calculate the MW for all profiles.

In addition, MW can be identified using T/S. S/Oxygen, or T/Oxygen. After comparing the two methods for all three combinations of properties (not shown), it was determined that **Method 1,** using **T/S** properties gives the most detail of the meltwater fractions, as well as allow for defining endpoints of CDW and WW easier than S/O or T/O.

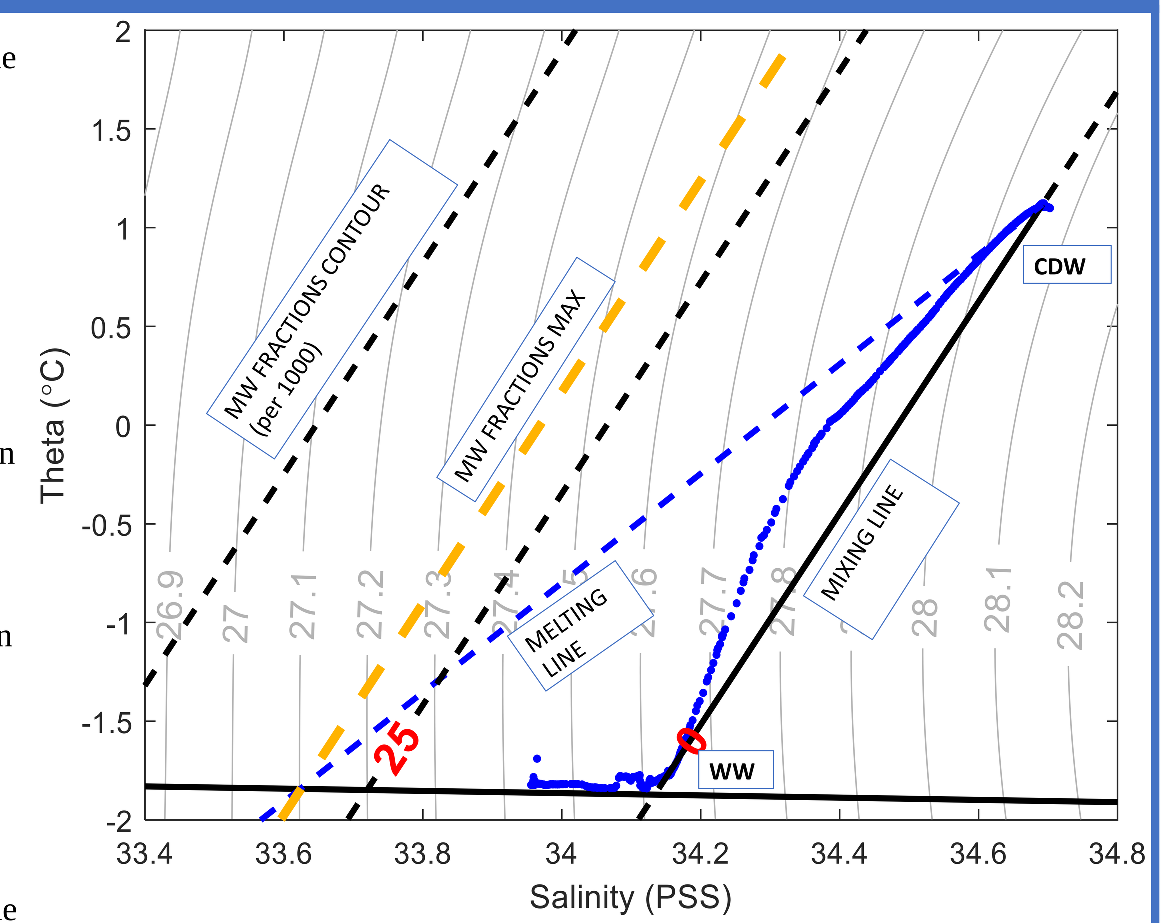

Figure 3: Example for Meltwater calculation for Method 1, T/S. The mixing line (black) is for CDW and WW interactions, melting line (blue dashes) demonstrates CDW and pure MW.

4. MELTWATER CIRCULATION

Both troughs, Belgica and Latady Trough, are important pathways for CDW to reach the ice shelves (Holland et al. 2010; Zhang et al. 2016) and for transporting MW off the shelf (Figure 4).

- CDW, with temperatures of up to 1.3°C, enters the shelf at the deepest part of the trough before moving along the eastern side of the through towards the ice shelves
- Largest amount of MW is seen on the western side of the Belgica trough and most of the Latady Trough
  - Located between 200 – 350 m
- From there, the MW travels towards the mouth of the Belgica, leaving the shelf at the western edge of the trough.
  - Once offshore, it is entrained into the ASC system that transports water along the continental slope towards the Amundsen Sea.
  - A smaller amount of MW is present at the eastern side of the Belgica Trough. This is most likely meltwater that has been recirculated from the Latady Trough (Schulze Chretien et al. in prep.)

In front of the Venable Glacier, the data shows large amounts of MW being injected into the water column before traveling towards the southern Belgica Trough (St. 27 – 33).

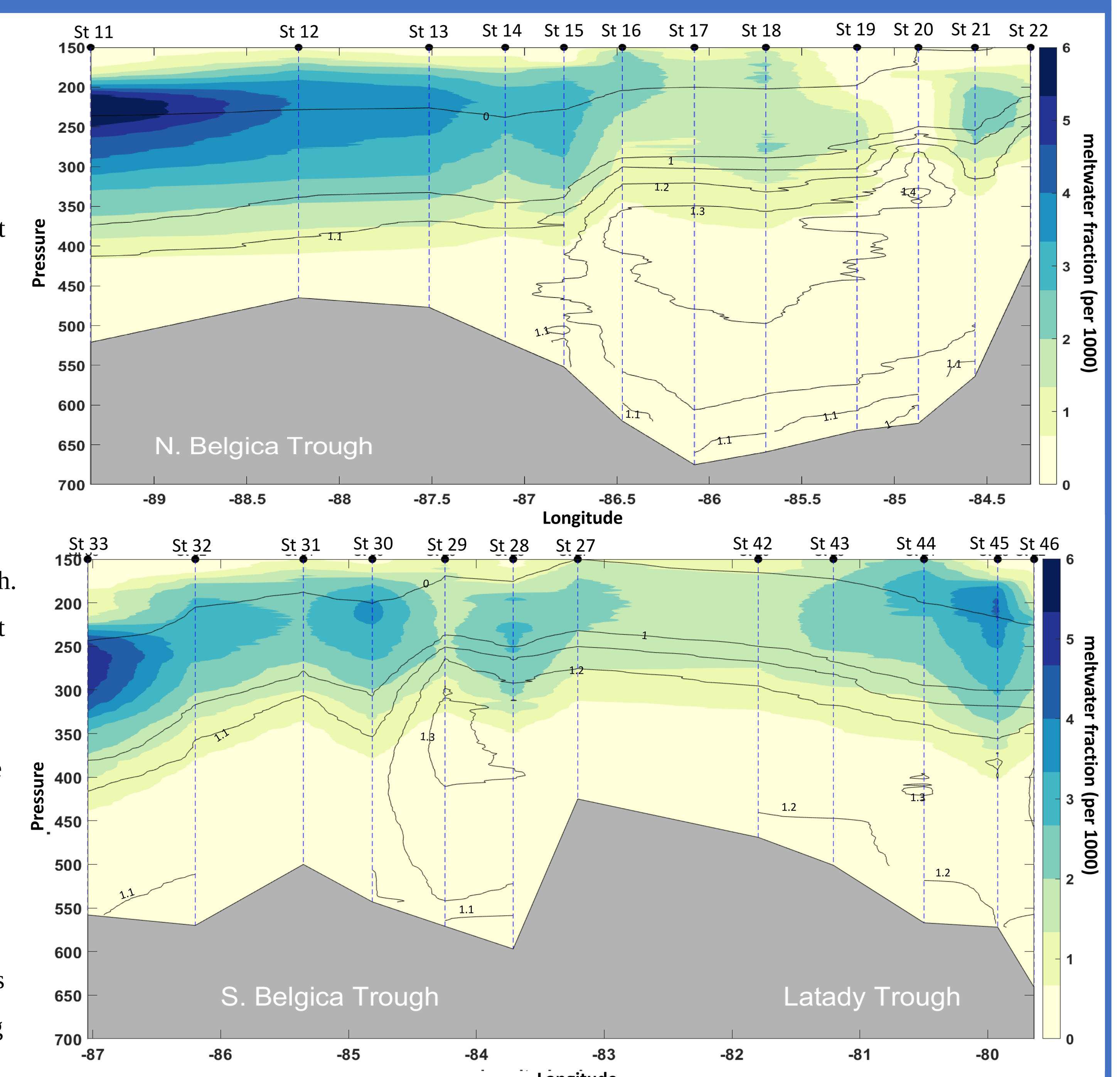

Figure 4: Top**)** Meltwater fractions (per mille) at the mouth of the Belgica Trough, with dark blue showing largest meltwater fraction. Bottom) Same as top but for the Southern Belgica Trough and Latady Trough.

5. ISOTOPE METHOD

An advantage of stable isotope data is a cleaner signal of mixing processes for meltwater (Jenkins & Jacobs 2008). Here, to further understand and show the meltwater's movement on the Bellingshausen Shelf, isotope ratios of $\delta^{18}O$ and δD are being analyzed using the Picarro Model L2130-I. Meltwater will have a deplete signature while incoming seawaters will have a highly enriched signature which will allow us to develop a mixing model.

The goal is to use the isotopic analysis to explain the higher MW fractions along the eastern side of the Belgica Trough. This analysis will explain the origin of this meltwater thought to be recirculated from the Latady Trough. However, other possible origins could be up or down stream, something that can not be proven with the hydrographic data alone.

6. DISCUSSION AND FUTURE WORK

After comparing the two methods for calculating meltwater fractions, we will use Method 1 with T/S properties as this provides more detail than the Method 2. While MW fractions using T/O and S/O properties mostly agree with the T/S method, both crucial water masses (CDW and WW) are often badly defined in them, leading to errors in the calculation of MW. Using the individual end point method versus the bulk end point method allows for greater detail in meltwater fractions as the CDW and WW endpoints have variance from station to station.

While the troughs are important pathways for CDW to access the ice shelves, they are also crucial in transporting MW away from the glaciers and off the shelf. In the next step of this work, we will narrow down pathways and origins of meltwater further with the help of geochemical tracers. This will, for example, clarify questions such as if the eastern portion of the Belgica Trough is receiving meltwater from the Latady Trough or from another meltwater source.

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