

Ocean glider observations of meltwater circulation in the Bellingshausen Sea, Antarctica

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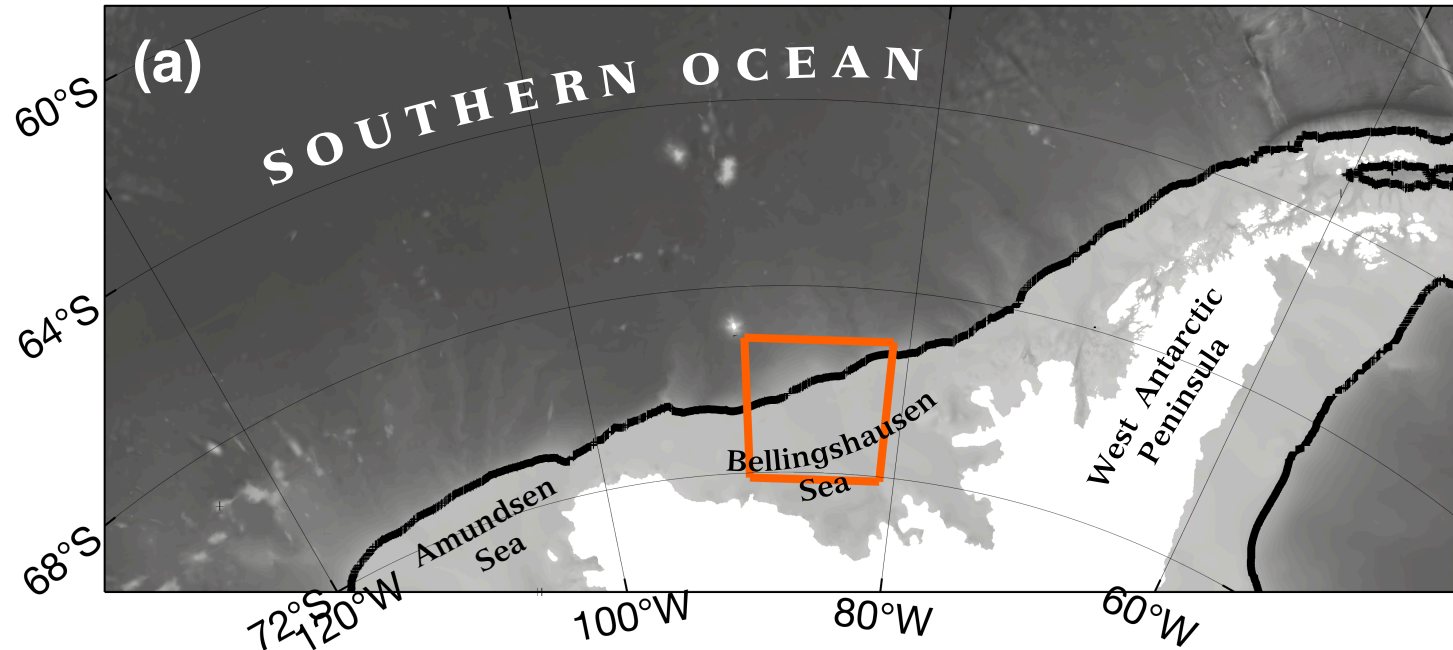
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COMPASS Climate-relevant Ocean Measurements and Processes on the Antarctic
Continental Shelf and Slope



European Research Council
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1 Introduction



We use hydrographic observations from a glider mission in the Bellingshausen Sea between 7th February and 20th March 2020.

In particular, the glider completed 466 dives along and across the Belgica Trough – *see below*.

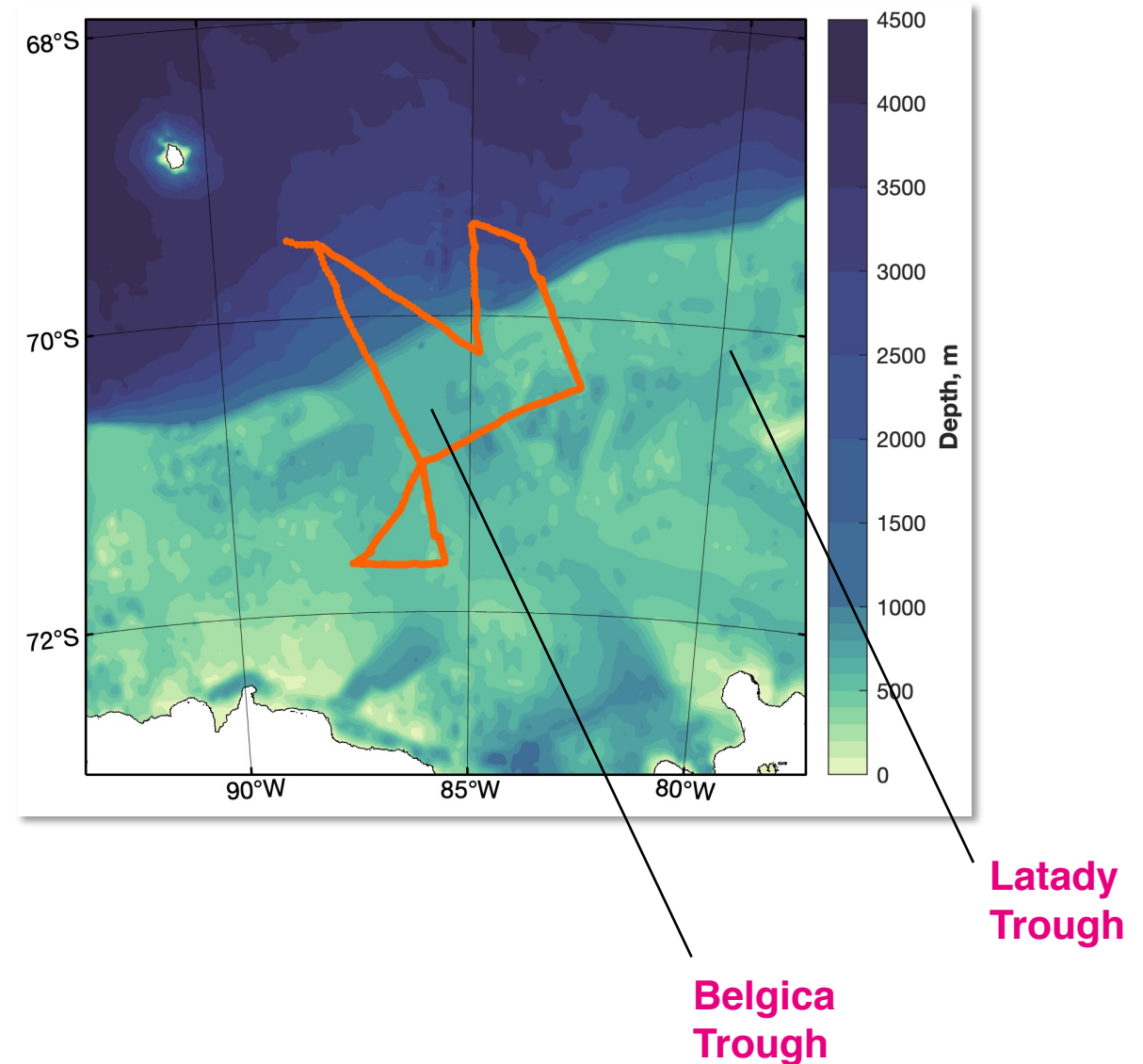
Here, we consider on-shelf dives only – i.e. depth > 1000 m.

1 Introduction

The Bellingshausen Sea is poorly observed compared with other Antarctic shelf seas such as the Amundsen – it is often ice-covered, even in summer.

Like the Amundsen, warm Circumpolar Deep Water (CDW) is near-ubiquitous on-shelf, and many of the surrounding ice shelves are melting rapidly.

We derive distributions and transport of glacial meltwater (GMW). GWM can modify buoyancy forcing of on-shelf circulation and can modify hydrography at key water mass formation sites – e.g. AABW in the Ross Sea.



2 Methods

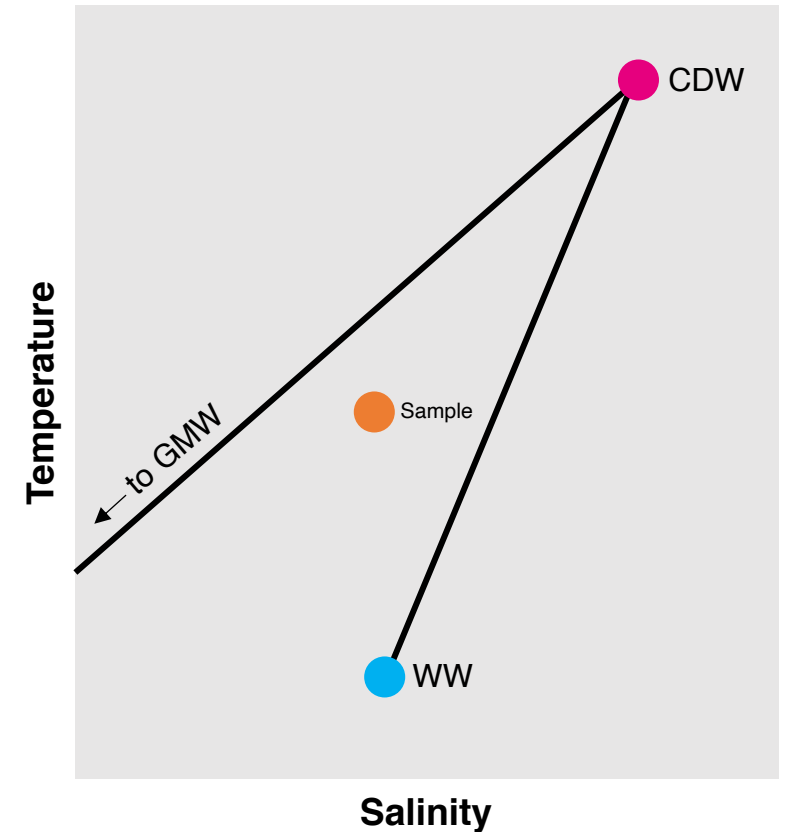
We use the glider's temperature and salinity observations to derive sections of GMW content.

We determine the characteristic temperature and salinity of CDW, found at depth and responsible for melting the ice shelves; and of Winter Water (WW), the cold, fresh layer that overlies CDW.

From the literature, we take characteristic temperature and salinity values of the GMW itself.

The further from the CDW-WW mixing line a sample is, the greater its GMW content – *see right*.

This method was first outlined by Jenkins (1999) and has been used since (eg Biddle et al, 2017; Zheng et al., 2021).



3 Results

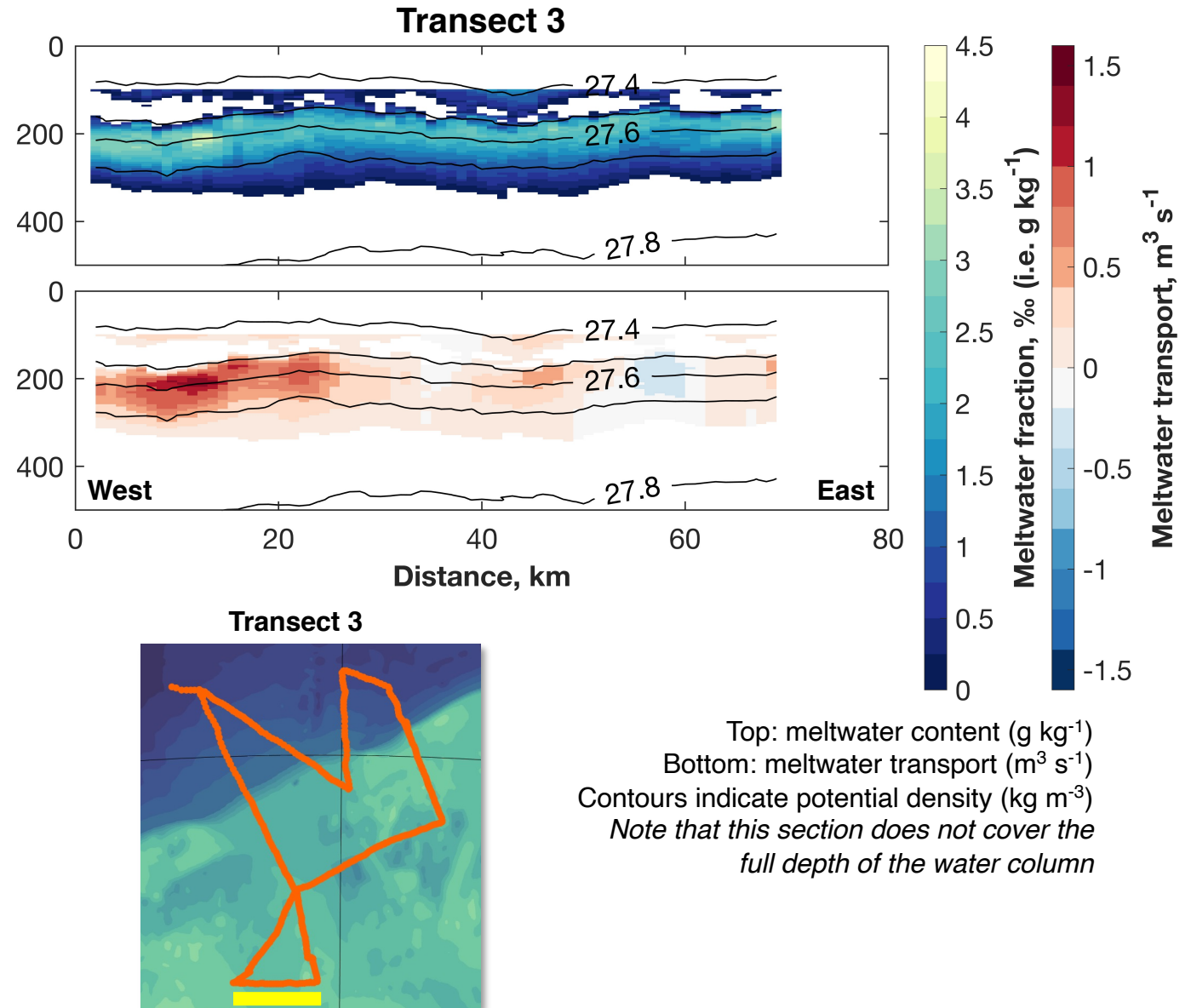
There is a northward flow of GMW in the western Belgica Trough – *see right*.

Here, GMW is found in a single layer, centered on the 27.6 kg m^{-3} isopycnal – i.e. in the upper part of the CDW layer.

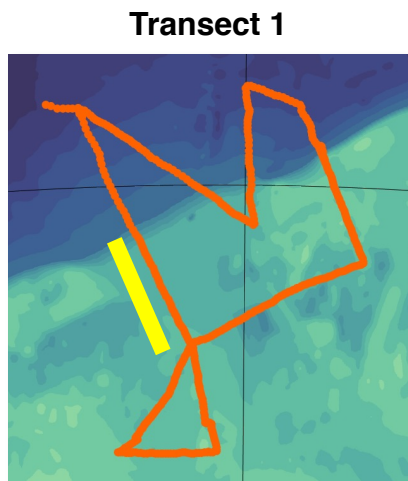
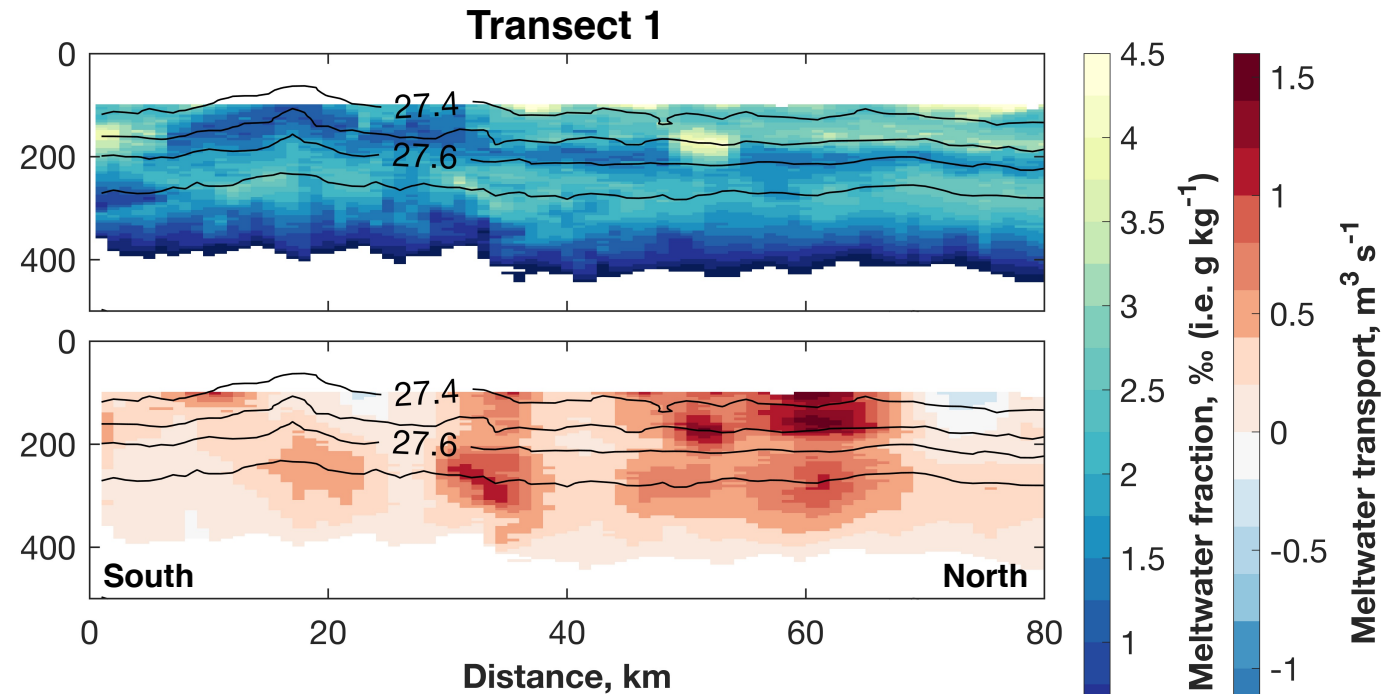
This northward GMW flow is embedded in the northward-flowing limb of the cyclonic gyre that sits in the Belgica Trough.

It is likely composed of GMW from the region of the Venables Ice Shelf in the southern Bellingshausen Sea.

The total GMW transport (across transect 3) is 0.5 mSv .



3 Results



We consider here only the on-shelf portion of the transect

There is an eastward flow of GMW in the northern Belgica Trough, parallel to the shelf break – *see right*.

Here, there are two layers of GMW: a shallow layer above the 27.6 kg m^{-3} isopycnal and a deeper layer below the 27.6 kg m^{-3} isopycnal.

Total GMW transport (across transect 2) is 1.7 mSv .

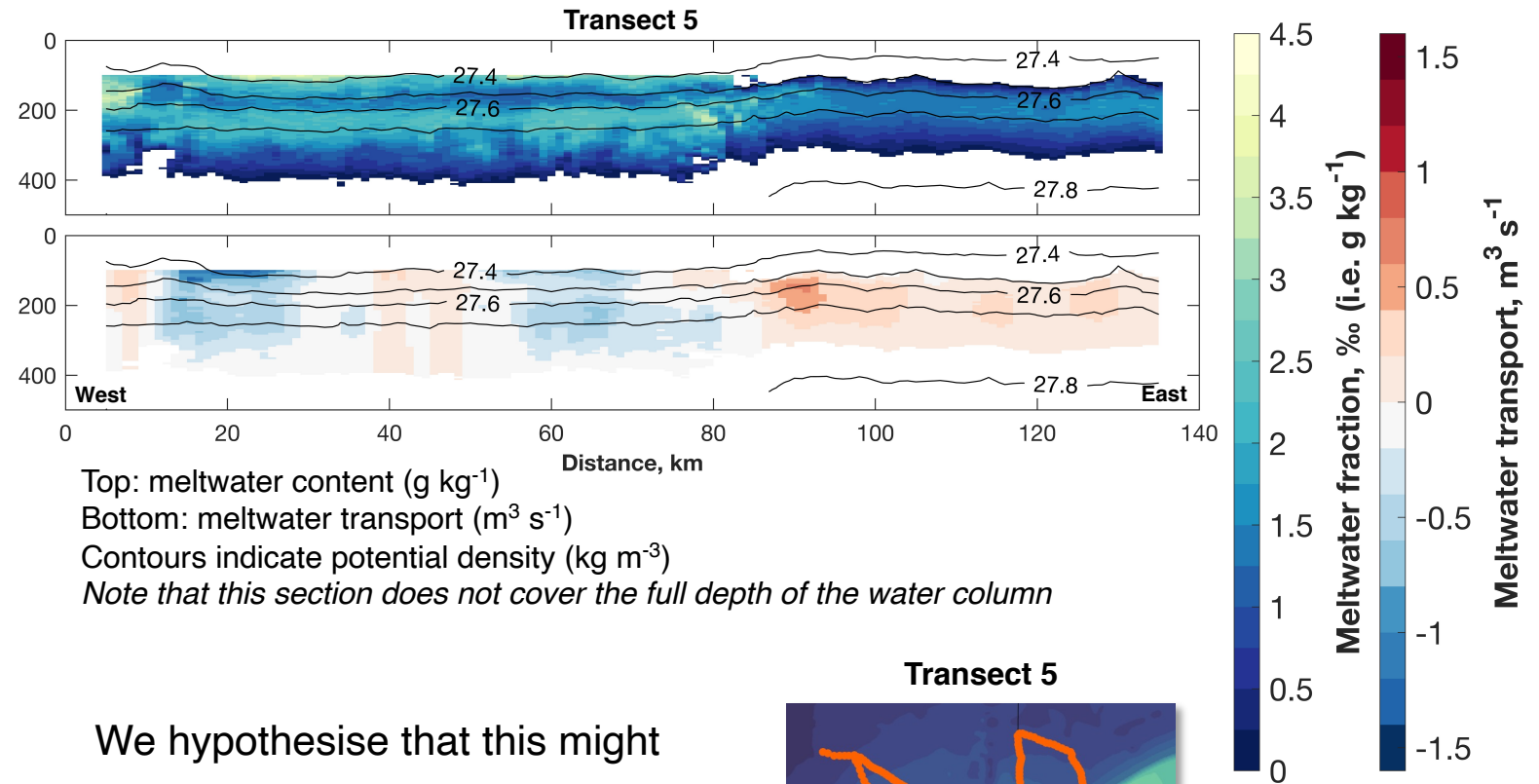
3 Results

We observe a southward re-circulation of GMW in the eastern Belgica Trough – *see above*. To our knowledge, this re-circulation has not previously been identified.

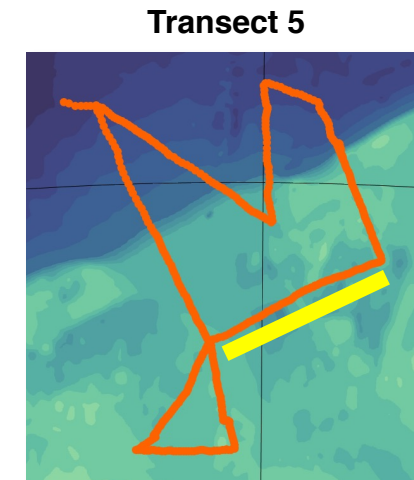
There is very little GMW in the shallow, eastern region between the Belgica and Latady troughs (east of 85 km).

Total GMW transport (across transect 5, between 0 to 85 km) is -0.9 mSv.

GMW is present in two layers, unlike in the northward outflow, and transport is greater than in the northern outflow.



We hypothesise that this might indicate the entrainment of meltwater from non-local sources – i.e. ice shelves that do not abut the Belgica Trough.



3 Results

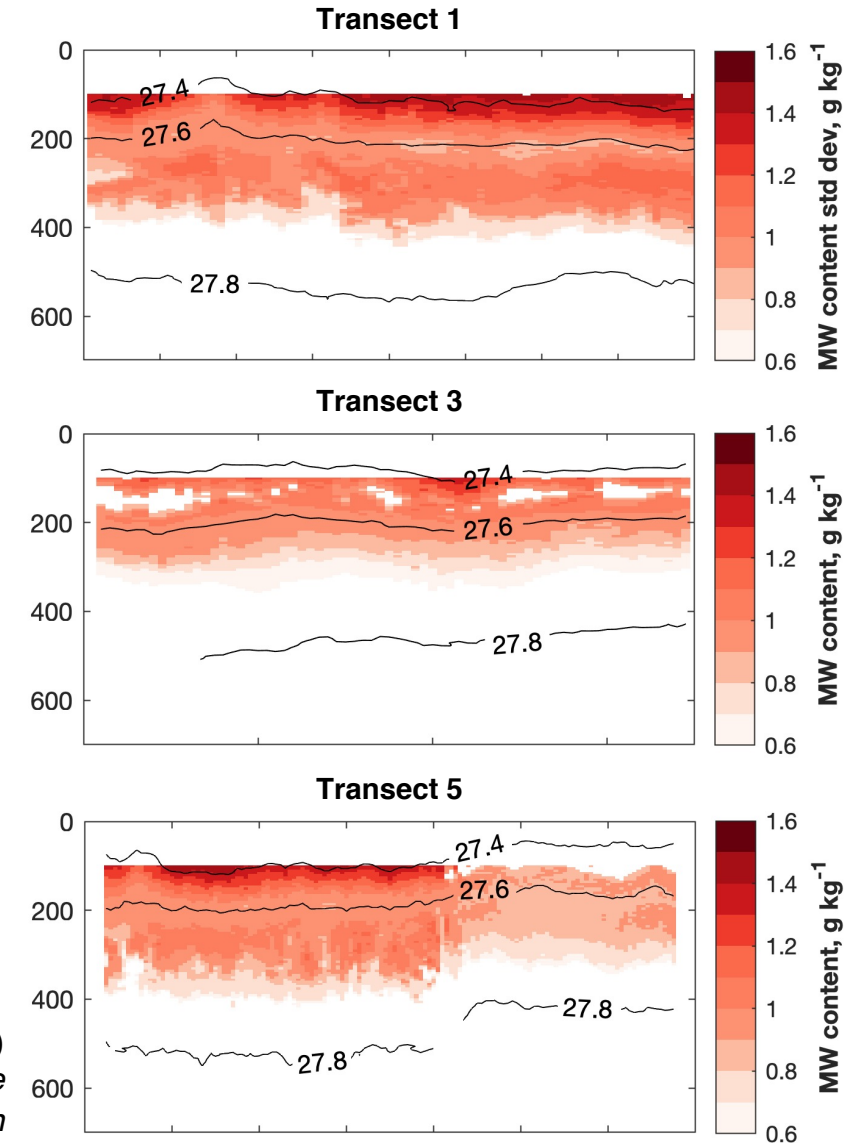
We estimate the uncertainty associated with the GMW content estimates using a Monte Carlo technique.

We perturb the temperature and salinity values of CDW and WW 100 times apiece and recalculate the GMW distribution for each iteration.

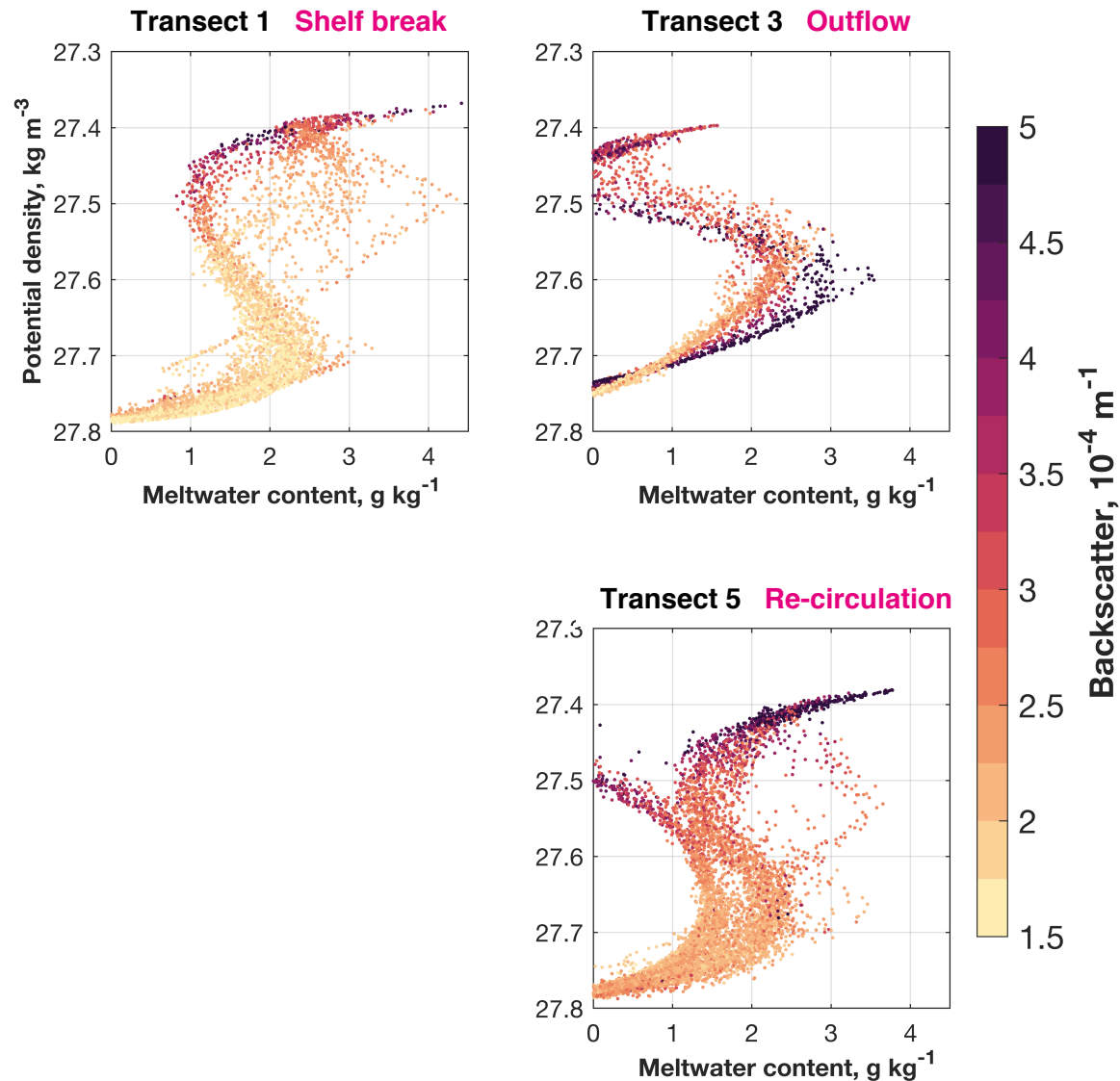
We calculate the standard deviation of the GMW distributions at each grid point.

The uncertainty is greatest closest to the surface, where the influence of other sources of fresh water (e.g. from precipitation and sea-ice melt) would be expected to the greatest.

Contours indicate potential density (kg m^{-3})
Note that this section does not cover the full depth of the water column



3 Results



The GMW signal is associated with water masses of differing turbidity, as measured by optical backscatter intensity – *see left*. Glacial sediment is thought to make GMW relatively more turbid

At the shelf break (transect 1), the meltwater at higher densities is relatively clear; at lower densities it becomes more turbid.

The outflow observed at transect 3 is relatively turbid, with the highest-turbidity water found to the west of the transect (not shown).

The re-circulation, at higher densities, is of an intermediate turbidity, with high turbidity at lower densities.

3 Conclusions & future work

We have mapped the distribution of GMW in the Belgica Trough of the Bellingshausen Sea in higher resolution than in previous studies, some among which didn't consider the vertical distribution – e.g. Zhang et al (2016).

We identify a single layer of GMW in the northward outflow, and two layers of GMW parallel to the shelf and in the return flow. We hypothesise that this indicates the presence of GMW from multiple sources .

We identify a return flow of GMW in the southward flowing limb of the cyclonic circulation in the Belgica Trough which, to our knowledge, has not been directly observed before.

These results enhance our knowledge of on-shelf GMW circulation close to one of the fastest-melting regions of Antarctica, and help illuminate pathways from GMW sources to e.g. shelf break currents and deep-water formation sites

Next, we hope to integrate the present glider observations with historical data sets and models to estimate potential sources of the observed GMW.