PhD Course in Earth Observation
cycle XXXVIII

Spatio-temporal variability of water masses circulation and thermohaline properties along the Ross Ice Shelf

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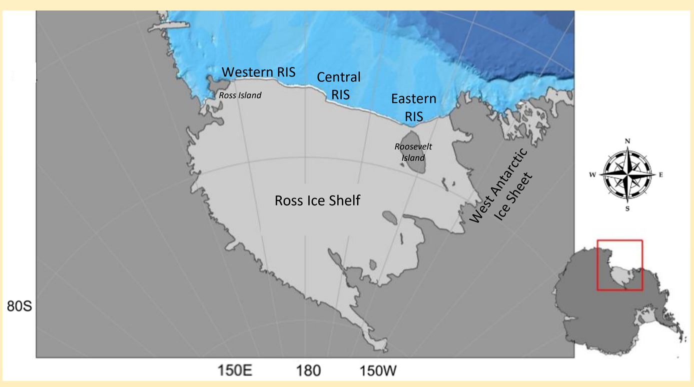
Context

The Ross Ice Shelf (RIS) is the largest ice shelf in the world which stabilizes the West Antarctic ice sheet (WAIS)[1], limiting its contribution to the sea-level rise thanks to its buttressing effect on the upstream grounded ice[2,3]. Although currently considered in a stable state, it may be subject to rapid disintegration[4]. It is necessary to understand its long-term stability in a changing climate and its dynamics concerning interacting principal water masses, since its basal melting depends on the ocean circulation along the ice front and underneath the ice shelf.

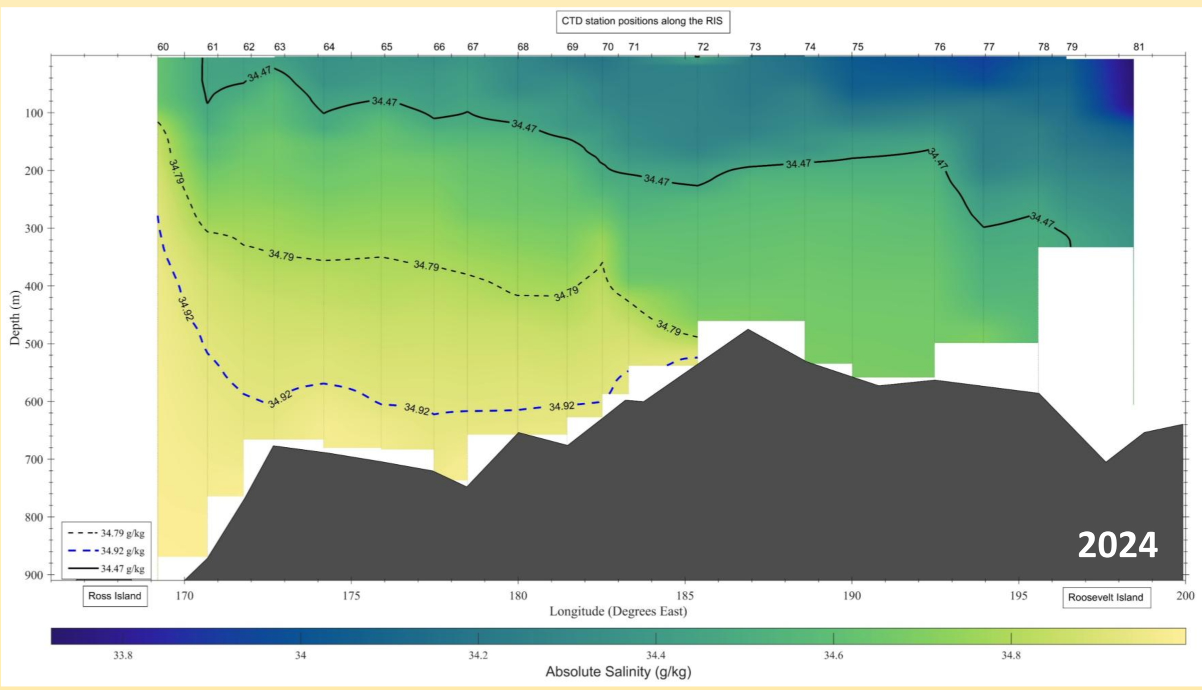


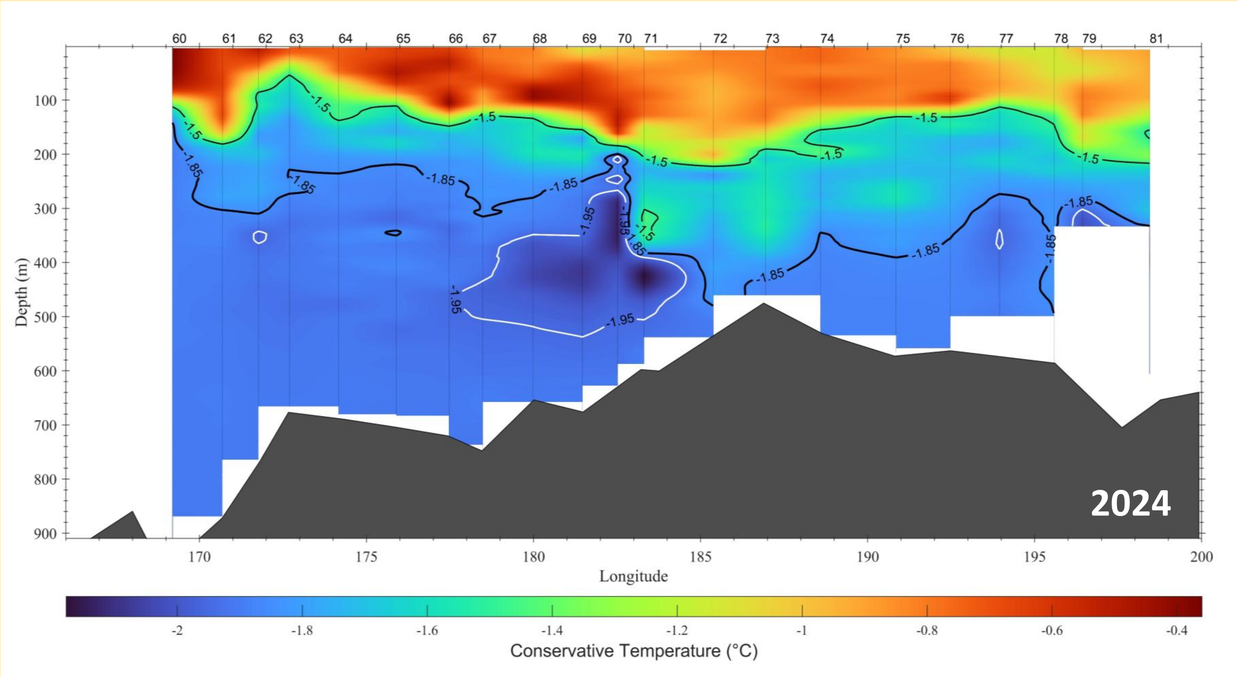
Aim of the research

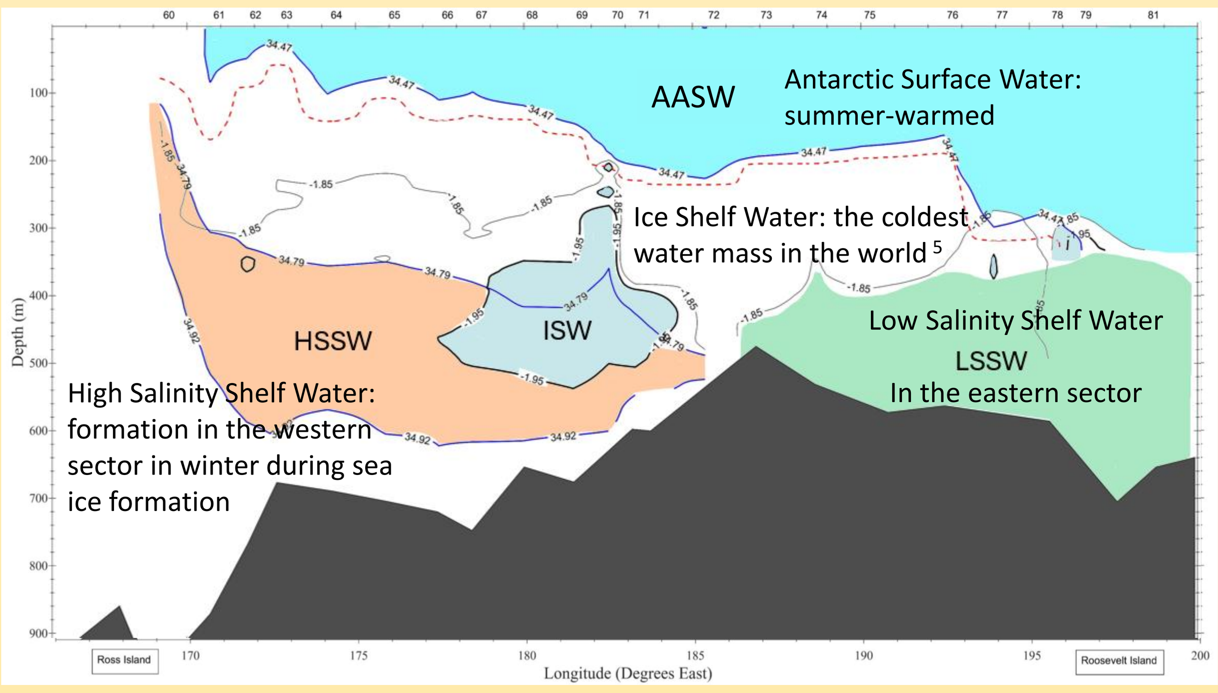
- Through the combination of thermohaline information from CTD (Conductivity – Temperature – Depth sensor probe) data with LADCP (Lowered Acoustic Doppler Current profiler) data: study of the spatio-temporal variability of water masses circulation along the Ross Ice Shelf.
- Focus on the main water masses interacting with the RIS: Antarctic Surface Water (AASW), High Salinity Shelf Water (HSSW) and Ice Shelf Water (ISW).

Multi-year observation of physical parameters and identification of water masses along the Ross Ice Shelf during summer

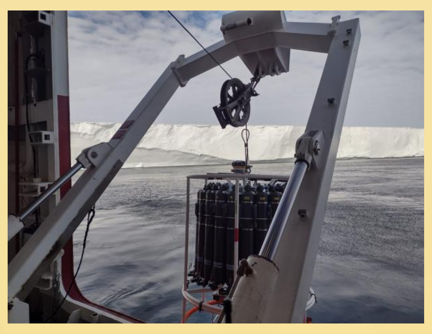
Analysis of **Absolute Salinity** and **Conservative Temperature** from CTD data along the RIS, collected during the Italian National Antarctic Research Programme (PNRA) from 1995 to 2025







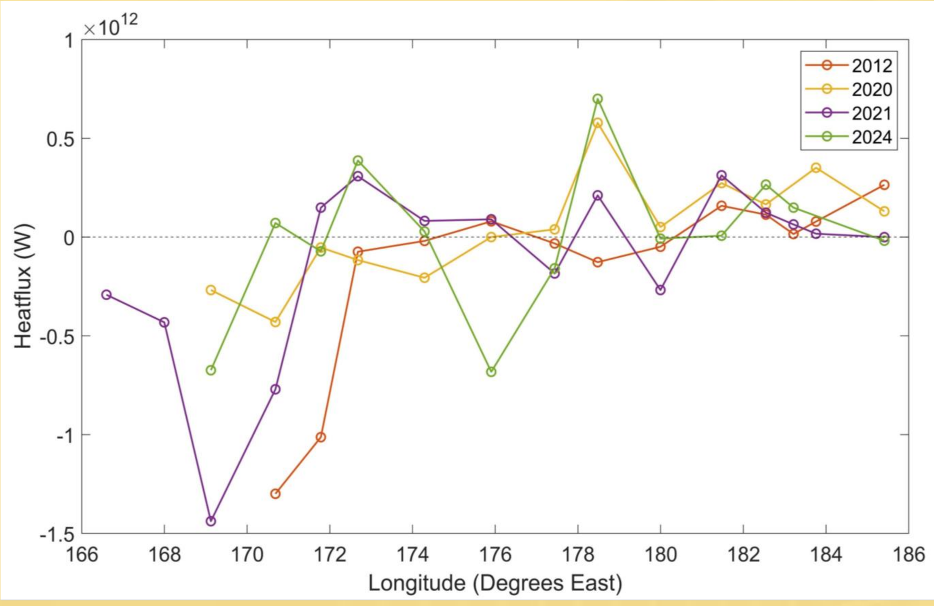
Coupling between CTD and LADCP data along the RIS to understand the water masses circulation: heat flux and transport analysis



The across-section **heat flux** $\boldsymbol{\theta_{flux}}$ (W)[11] is calculated starting from the **Conservative Temperature** (from CTD data) and the **meridional component of the velocity** (from LADCP data) for the area of water mass analysed. The **meridional transport** (*Sv*) of the velocity is calculated from **meridional velocity components** to obtain information on the inflow and outflow across the RIS of each water mass for every year.

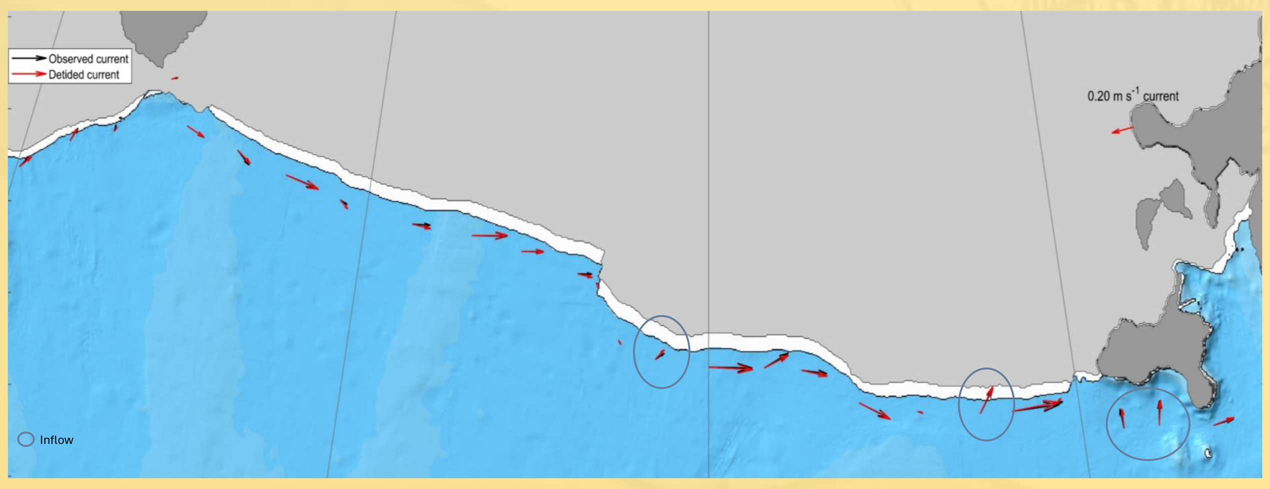
Negative $\boldsymbol{\theta_{flux}}$ - Negative meridional transport: southward, i.e. into the RIS cavity
Positive $\boldsymbol{\theta_{flux}}$ - Positive meridional transport: northward, i.e. out of the RIS cavity

HSSW



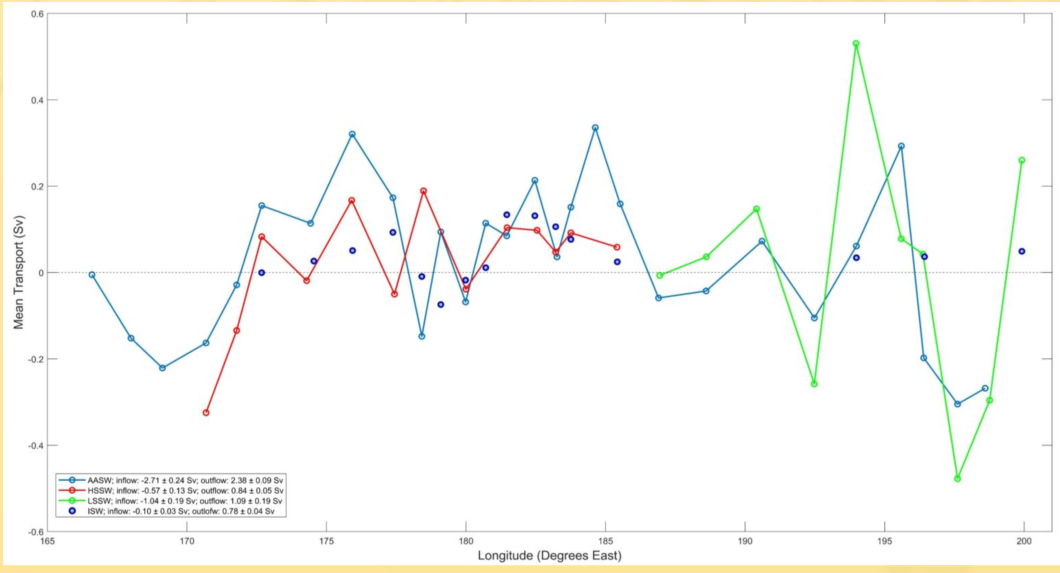
HSSW flows southward under the ice front near Ross Island (167°W)[13]. A strong negative heat flux (into the RIS cavity), coupled with meridional transport, is observed in this area throughout all the years.

AASW



Along the RIS the AASW has a mainly westward flow, but on some occasion it intrudes the cavity in the western and central sector of the RIS, thus presumably entering in contact with the ice base and causing its melting. The highest negative heat fluxes (southward, below the RIS) are observed near Ross Island (167°W), where a strong inflow of warm AASW is known to produce the highest basal melt rate along the RIS[12].

ISW and LSSW



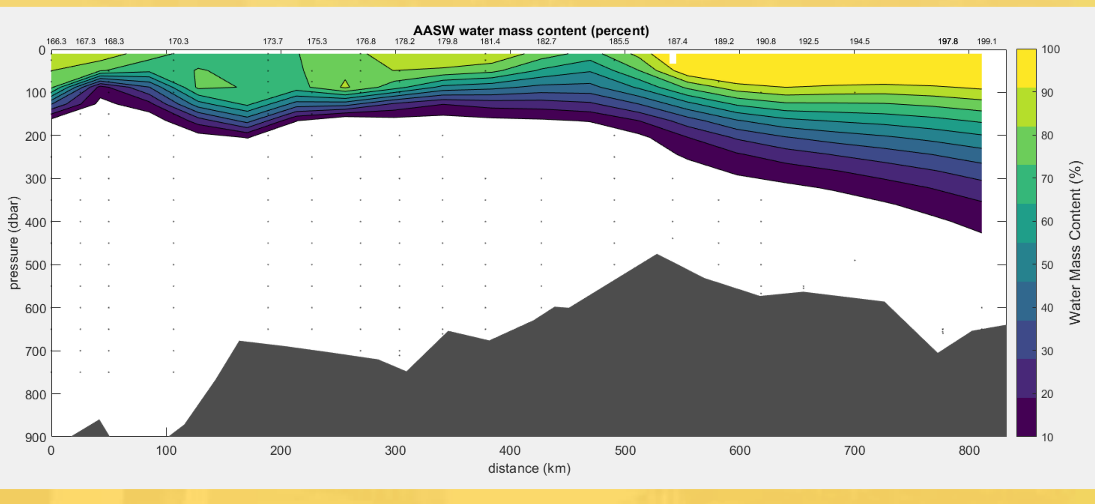
ISW forms in the cavity of the RIS through a transformation process of HSSW, which flows beneath the ice shelf and melts its base near the grounding line, giving rise to cold ISW[13]. At about 180°, the ISW flows out of the RIS[14]. The mean meridional transport of ISW is consistent with the patterns observed in AASW.
LSSW inflow and outflow follow those of AASW in the eastern sector of the RIS.

How water masses changed through the years along the Ross Ice Shelf: multiparameter mixing analysis

We used an optimum multiparameter (OMP) analysis[15] to estimate the extent of mixing between the principal water masses observed along the Ross Ice Shelf. **Conservative properties used to characterize source water masses are conservative temperature, absolute salinity and dissolved oxygen.** The aim is to calculate the relative contributions of:

- local source water types, such as AASW, HSSW, LSSW;
- non-local water masses: modified Circumpolar Deep Water (mCDW), a warm water mass that can intrude on the continental shelf at specific locations, and Amundsen Sea Water (ASW), a cold and fresh water mass that forms in the Amundsen Sea and that can enter the eastern sector of the Ross Sea.

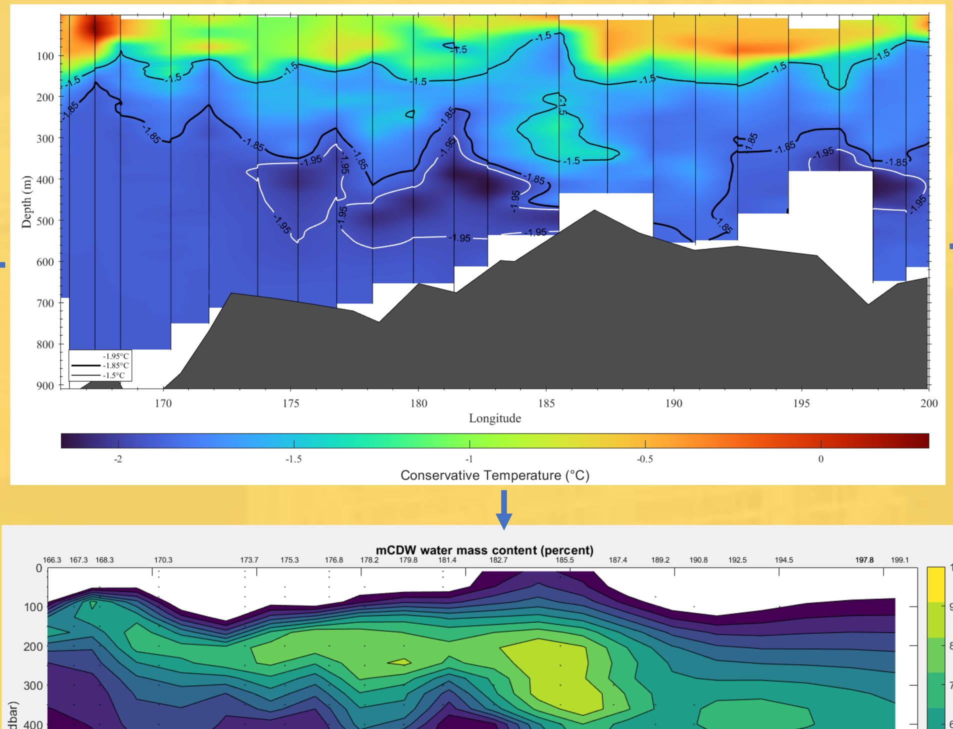
Here are shown the **percentages of contribution of AASW, mCDW and HSSW to the structure of water column along the RIS in 2007:**

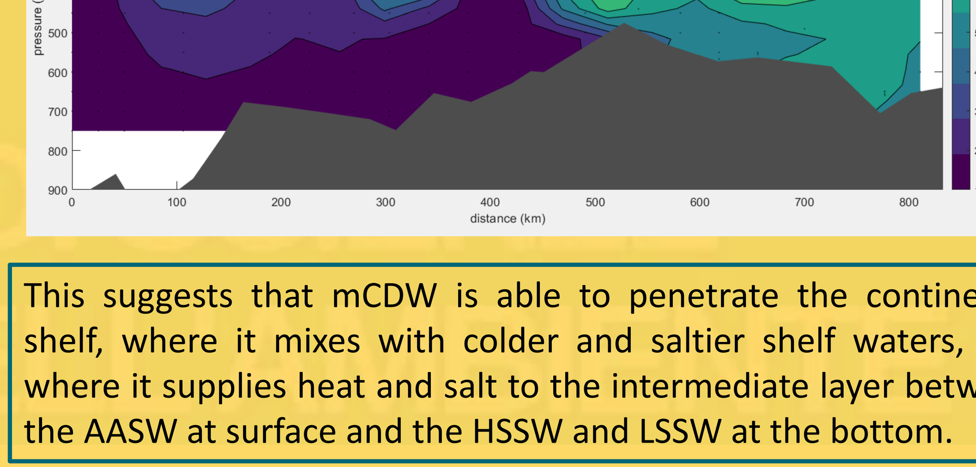


Antarctic Surface Water (AASW) occupies the surface layer, with a small contribution (from 10 to 20 %) of High Salinity Shelf Water (HSSW) in the western sector of the RIS. Here, this layer extend until 150 m, while deepens in the eastern sector, which has a bigger contribution of AASW.

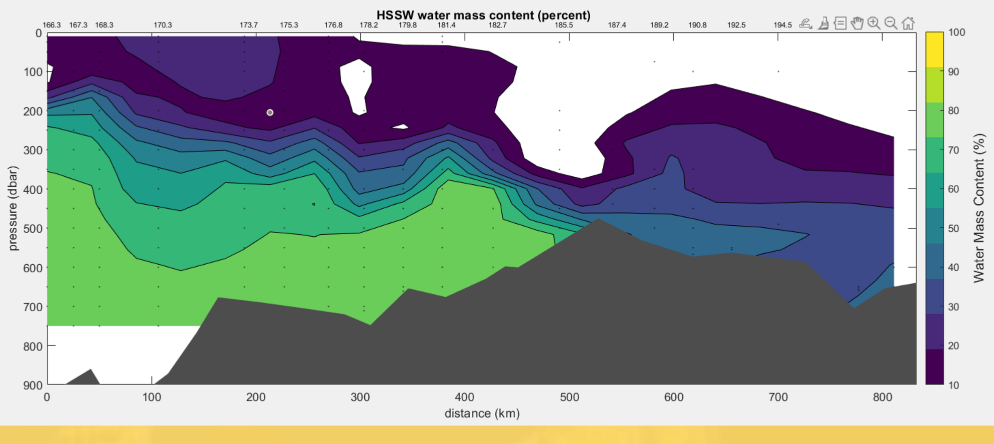
In the central sector, a marked presence of modified Circumpolar Deep Water (mCDW) is detected, with relatively high concentrations.

Vertical section of conservative temperature along the RIS in 2007. The isotherms of -1.5 °C, -1.85 °C and -1.95 °C represent the AASW, HSSW and ISW, respectively.

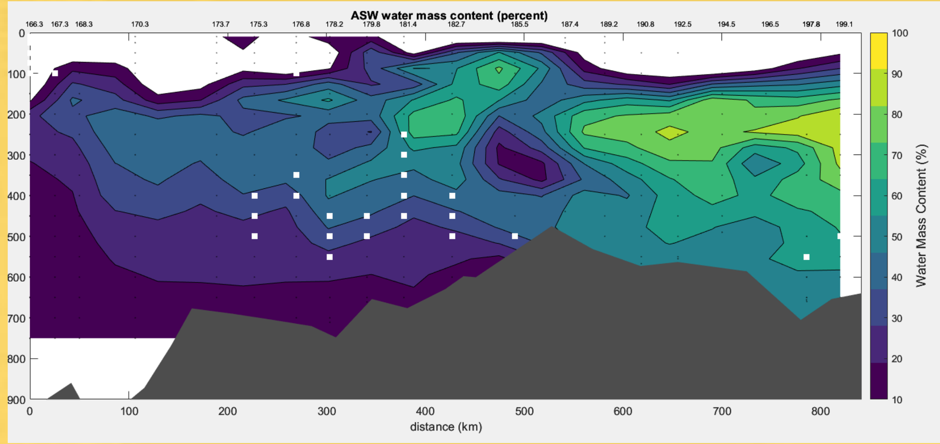




This suggests that mCDW is able to penetrate the continental shelf, where it mixes with colder and saltier shelf waters, and where it supplies heat and salt to the intermediate layer between the AASW at surface and the HSSW and LSSW at the bottom.



On the West, HSSW reaches the surface layer in small percentage, while from 200 meters occupies the water column until 90%. In the eastern sector, the small percentage does not reflect the properties of the Low Salinity Shelf Waters.



Amundsen Sea Water (ASW), originating from the ice discharge from the Amundsen Sea, can provide a significant contribution to the intermediate layer in the eastern sector if included in the OMP analysis.

What's next?

To better understand the circulation and the relative contributions of different water masses along the Ross Ice Shelf, it is essential to include wintertime observations, such as those provided by Argo floats.

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