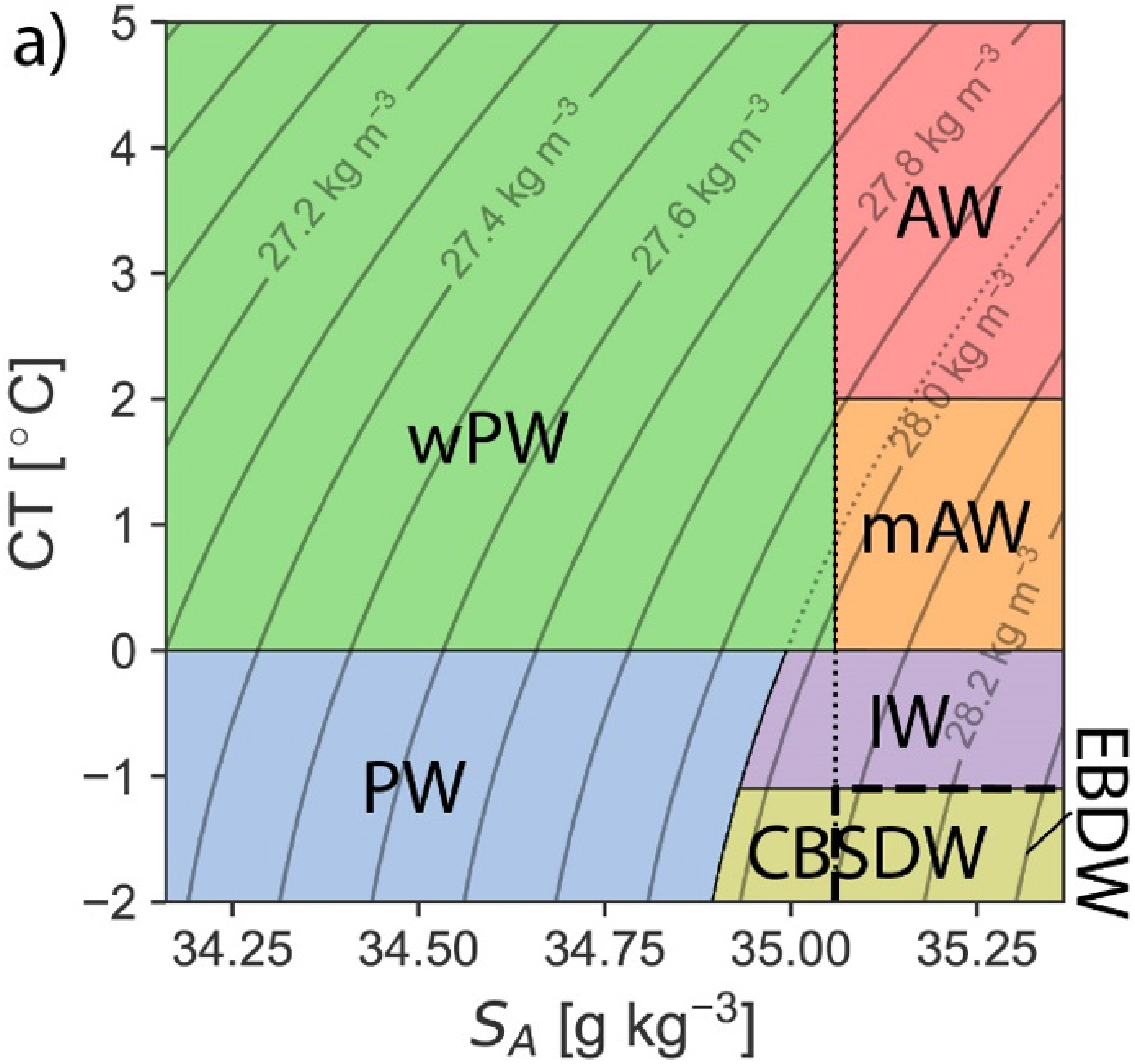
the Nansen LEGACY

Suggested water mass definitions for the central and northern Barents Sea, and the adjacent Nansen Basin

Workshop Report



The Nansen Legacy Report Series 8/2020

Suggested water mass definitions for the central and northern Barents Sea, and the adjacent Nansen Basin

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1 Introduction

The current research focus on the northern Barents Sea and the adjacent Nansen Basin has highlighted a need for common reference terms when discussing water mass origins and modification processes. Several relevant water mass definitions have been proposed and applied over the years, but these often focus either on water masses in the southern and central part of the Barents Sea, or on the deep interior Arctic Ocean. This report provides suggestions for quite broad water mass definitions that can be applied throughout this region – supplied by additional, more specific definitions as needed.

2 Suggested water mass definitions

These water mass definitions can be used for the general purpose of classifying the predominant origin and modification of ocean water found in the Nansen LEGACY project study area. Notes on some of them are given below the table. The definitions (Table below and Figure 1) are given in conservative temperature CT, absolute salinity SA and potential density following the TEOS-10 convention (which should be used in peer-review publications). Also shown are approximate ranges in the previously used salinity S, potential temperature θ and potential density (EOS-80).

PW (Polar Water)	CT <= 0.0°C, σ_0 <= 27.97 kg m^{-3} (θ <= 0.0°C, σ_0 <= 27.97 kg m^{-3})
wPW (warm Polar Water)[1]	CT > 0.0°C, S_A < 35.06 g kg^{-1} (θ > 0.0°C, S < 34.9)
AW (Atlantic Water)	CT > 2.0°C, S_A >= 35.06 g kg^{-1} (θ > 2.0°C, S >= 34.9)
mAW (modified Atlantic Water)	0.0°C < CT <= 2.0°C, S_A >= 35.06 g kg^{-1} (0.0°C < θ <= 2.0°C, S >= 34.9)
IW (Intermediate Water)	-1.1°C < CT <= 0.0°C, σ_0 > 27.97 kg m^{-3} (-1.1°C < θ <= 0.0°C, σ_0 > 27.97 kg m^{-3})
CBSDW (Cold Barents Sea Dense Water)	CT <= -1.1°C, σ_0 > 27.97 kg m^{-3} (θ <= -1.1°C, σ_0 > 27.97 kg m^{-3})
EBDW (Eurasian Basin Deep Water) Note: to be used for data from North of the Barents Sea (e.g. > 500 m isobath)	-1.1°C < CT <= 0.0°C, SA > 35.06 g kg^{-1} (-1.1°C < θ <= 0.0°C, S > 34.9)

[1] If the temperature of wPW is higher than 4°C: check the salinity and geographical location as this could be Coastal Water in/from the Southern part of the Barents Sea.

Some notes on the different water masses:

Polar Water (PW) is characteristically formed by introduction of (cold) sea ice melt water. We suggest a somewhat wider density range compared to that defined by Rudels et al. (2005), who used σ_θ≤27.70, θ≤0.

Warm Polar Water (wPW) as it is defined here can be a) PW that has been heated through solar radiation or b) mixing products between AW/mAW and PW, the latter often being found in the (seasonal) halocline. Rudels et al. (2005) used the same temperature threshold but applied a density limit (σ_θ≤27.70) instead of the salinity boundary chosen here.

Atlantic Water (AW) is relatively warm and saline – although not as warm and saline as in the upstream/origin areas. Loeng (1991) defined (North) Atlantic Water as T>3°C and S>35.0 while Rudels et al. (2005) applied a density threshold 27.70<σ_θ≤27.97, 2<θ.

Modified AW (mAW), as it is defined here, has primarily lost heat but is otherwise not strongly mixed with surrounding water. Rudels et al. (2005) defined a similar Arctic Atlantic Water (27.70<σ_θ≤29.97, 0<θ≤2), again applying density limits rather than salinity.

We suggest two mostly overlapping water mass definitions to be used for different geographical areas. They are both defined by having lower temperature than Modified Atlantic Water. **Intermediate Water (IW)** is colder and typically found at greater depth than AW/mAW in the Barents Sea. It can also have lower salinity than AW/mAW. We use the same density limit as Rudels et al. (2005) apply for Arctic Intermediate Water but we introduce a temperature range instead of a salinity boundary. **Eurasian Basin Deep Water (EBDW)** can be used for waters beyond the 500 m isobath over the continental slope North of the Barents Sea. Our suggested salinity limit is slightly lower than that used by Rudels et al. (2005) (S>34.915).

Cold Barents Sea Deep Water (CBSDW) should only be used for data from the Barents Sea proper. The same density limit is set as for IW but the temperature limits are lower.

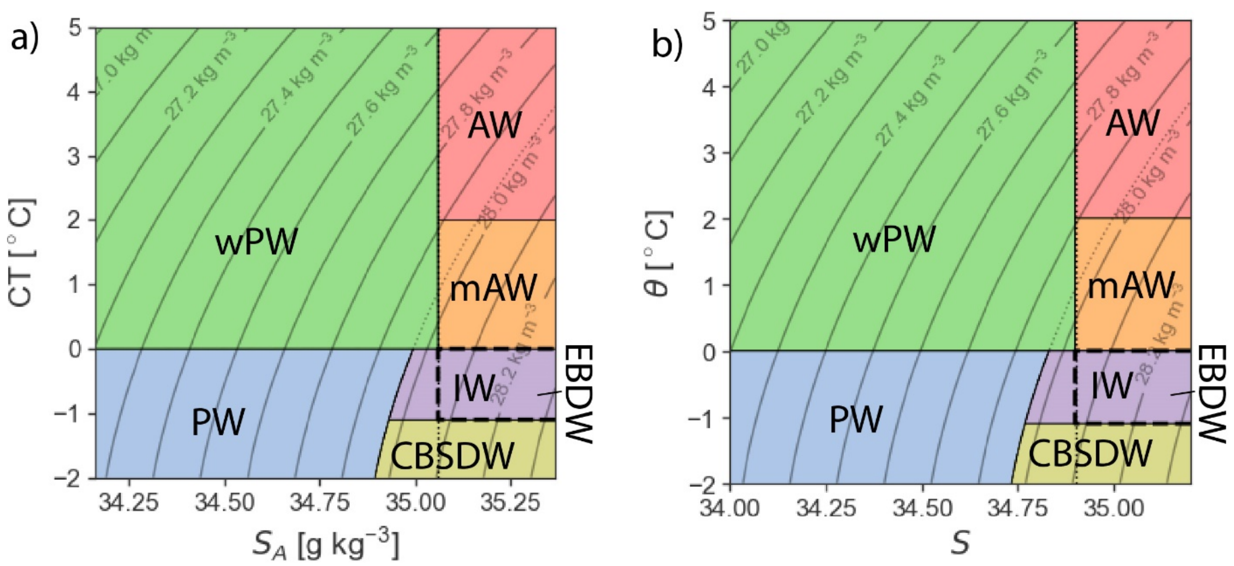

Figure 1. Water masses in T-S space given in a) TEOS-10 and b) "old" EOS-80.

TEOS-10 should preferably be used in peer-review publications. For comparison with published literature, corresponding EOS-values can be given in addition. Data published in open access data bases should be given in the EOS units. Please consult your favourite physical oceanographer for further guidance if needed.

Be aware that water mass definitions are static, artificial limits. In a dynamic system, such as the ocean changing due to global warming, alongside local and seasonal variations, water masses in a particular study can be different from the typical water mass characteristics described here. The northern Barents Sea is the fastest warming region in the Arctic (Screen and Simmonds, 2010). It has been shown that water masses in the upper 100 m of the northern Barents Sea increase in salinity and have become warmer, particularly after 2005 (Lind et al., 2018). Therefore, it may be necessary to adjust the water mass definitions or apply other classifications methods in new publications of this region (consult a physical oceanographer for advice). Other water mass definitions have been used for the northern Barents Sea previously. The concept “Arctic Water” was introduced by Mosby (1938) and used later in a number of observational studies. The Arctic Water definition used by Pfirman et al. (1994) was $34.3 < S < 34.7$ psu and $T < -1$°C. It was later modified to $34.0 < S < 34.7$ psu and $T<0$°C by Lind and Ingvaldsen (2012). However, in the recent decade, Arctic Water has been observed with $S>34.7$ and $T>0$°C at some occasions in the northern Barents Sea (see Lind et al., 2018), illustrating the difficulty of placing static boundaries on a rapidly varying and changing ocean. The reason for recommending use of the Polar Water mass definition here is to bridge water mass definitions in the northern Barents Sea with those presently used in the Nansen Basin, to have common water mass definitions that cover the entire Nansen LEGACY study area.

Examples of how CTD profiles from cruises and mooring time series are distributed with these definitions are given in the following sections.

3 Ship-borne CTD data examples

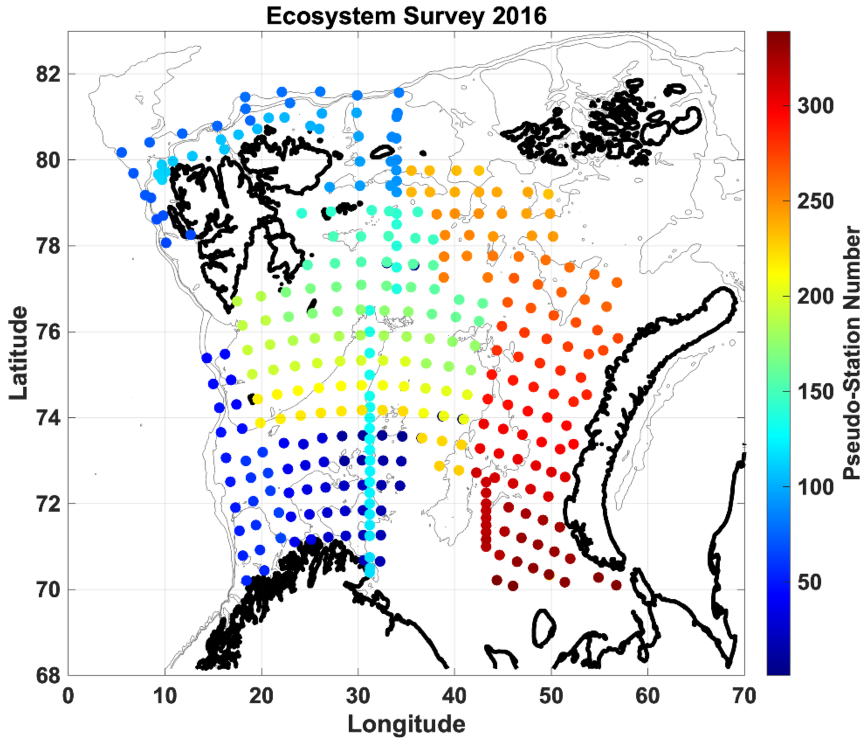

Figure 2. Colour coded geographical distribution of profiles from IMR's 2016 Ecosystem survey.

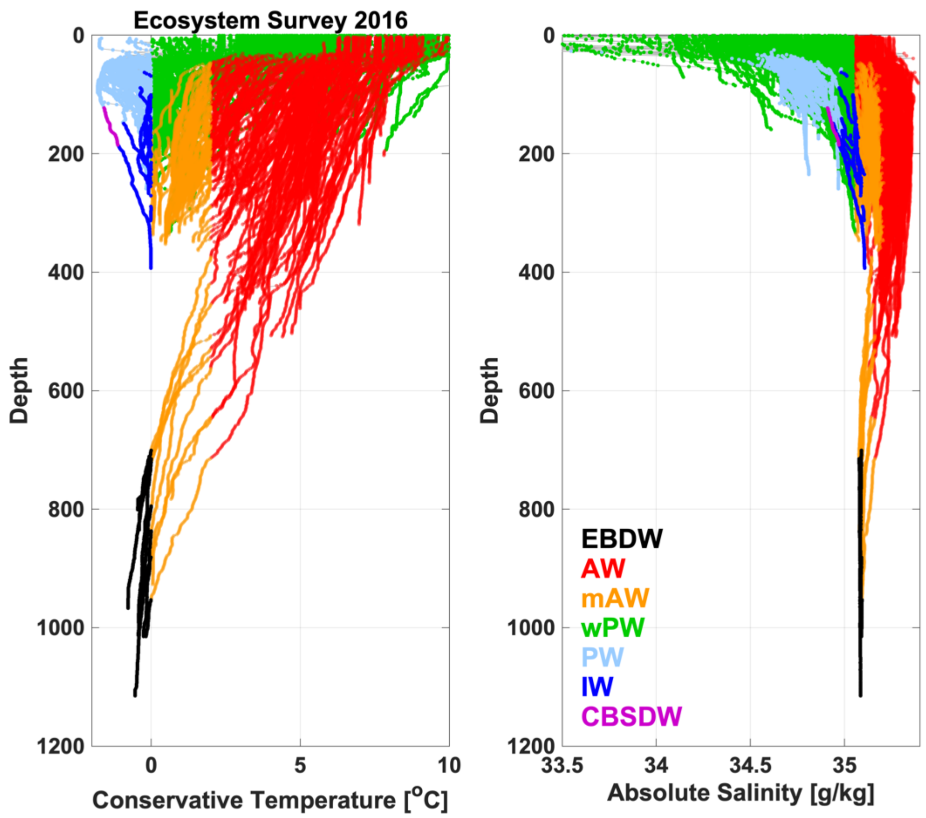

Figure 3. Profiles from IMR's 2016 Ecosystem survey. AW=red, mAW=orange, PW=light blue, wPW=green, IW=blue, CBSDW=purple, EBDW = black (only applied for stations deeper than 500 m north of the Barents Sea shelf).

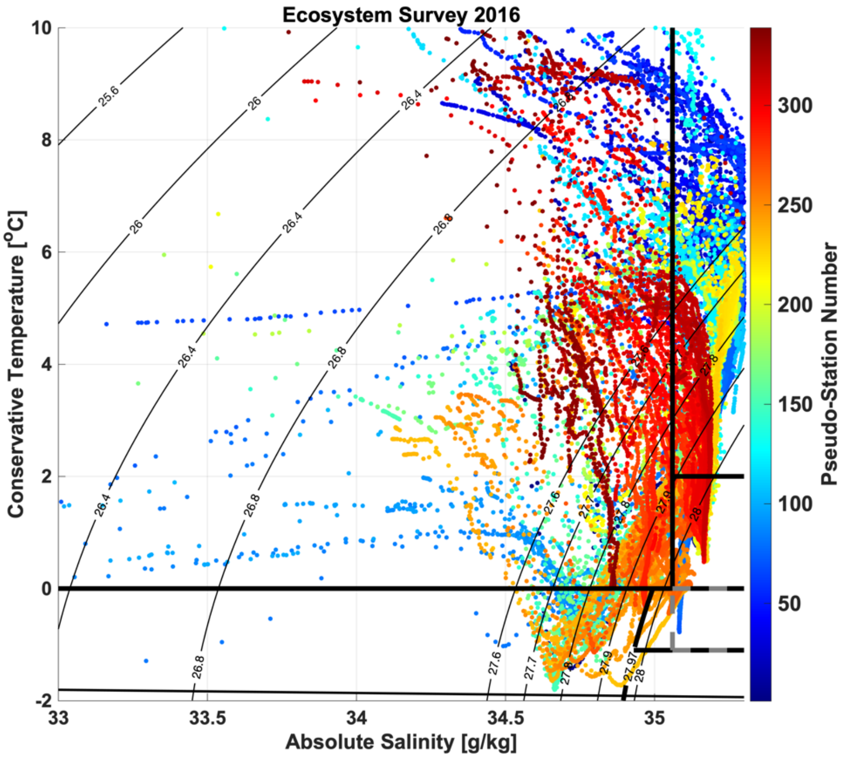

Figure 4. Distribution of data points from IMR's 2016 Ecosystem survey in TS-space. Colour coding indicating station position as in Figure 2. The black lines mark the water mass boundaries in the table with dashed gray lines denoting EBDW.

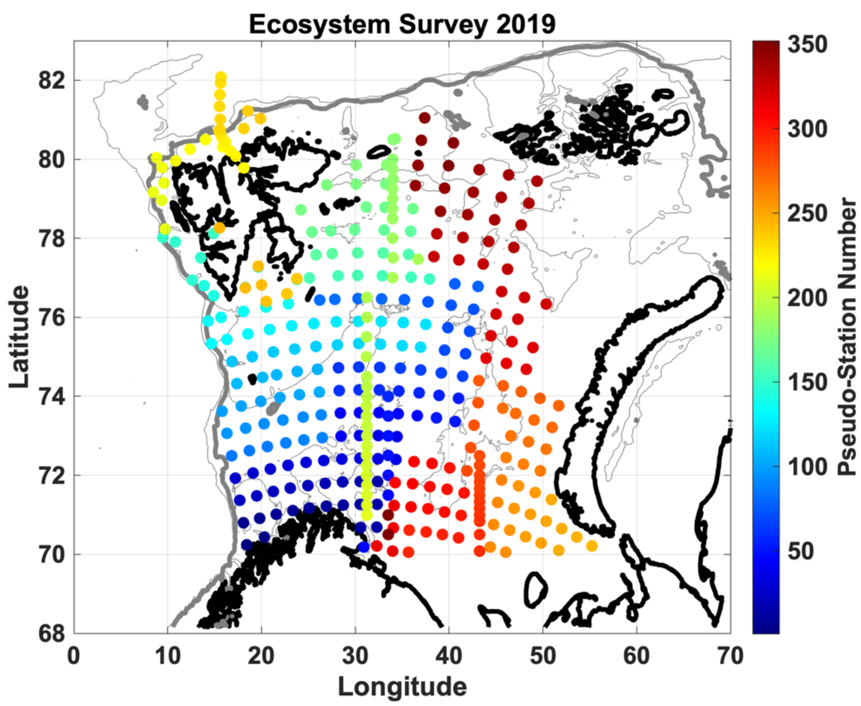

Figure 5. Colour coded geographical distribution of profiles from IMR's 2019 Ecosystem survey.

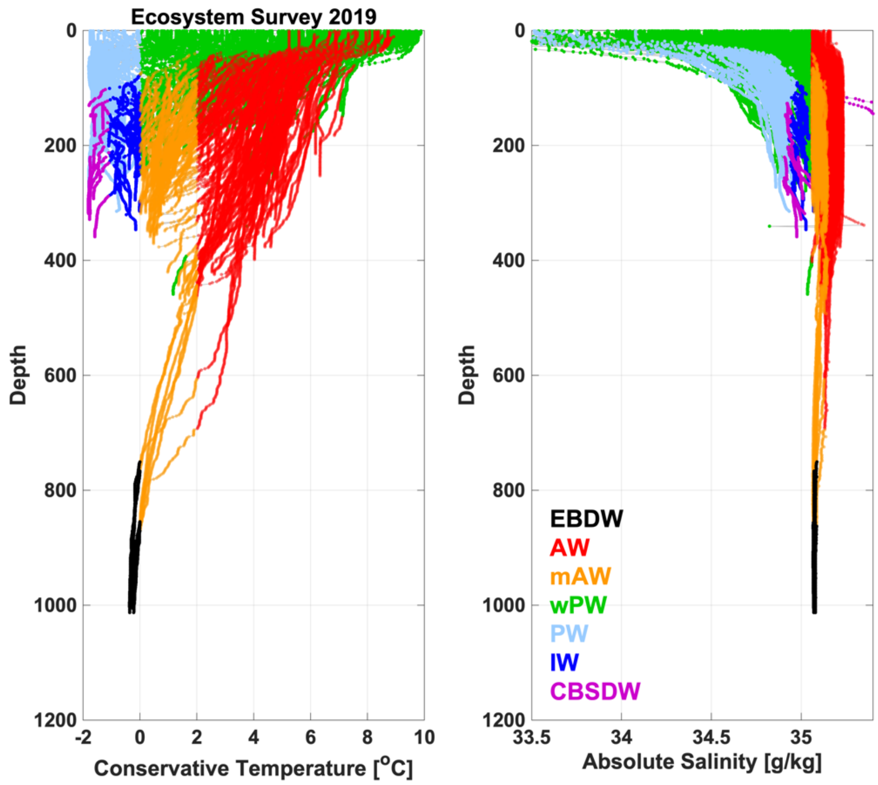

Figure 6. Profiles from IMR's 2019 Ecosystem survey. AW=red, mAW=orange, PW=light blue, wPW=green, IW=blue, CBSDW=purple, EBDW = black (only applied for stations deeper than 500 m north of the Barents Sea shelf).

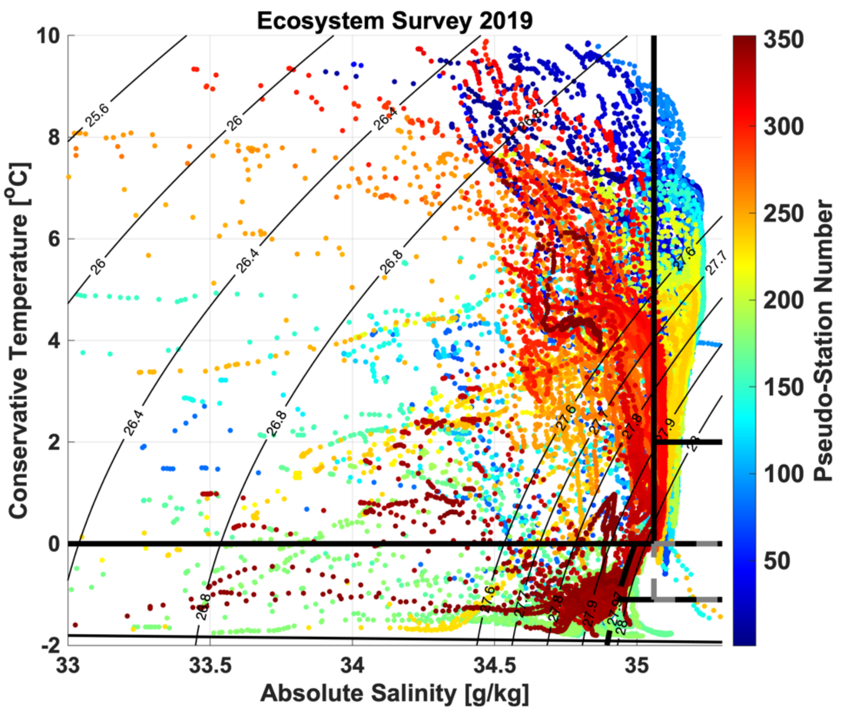

Figure 7. Distribution of data points from IMR's 2019 Ecosystem survey in TS-space. Colour coding indicating station position as in Figure 5. The black lines mark the water mass boundaries in the table with dashed gray lines denoting EBDW.

4 Mooring and ARGO data examples

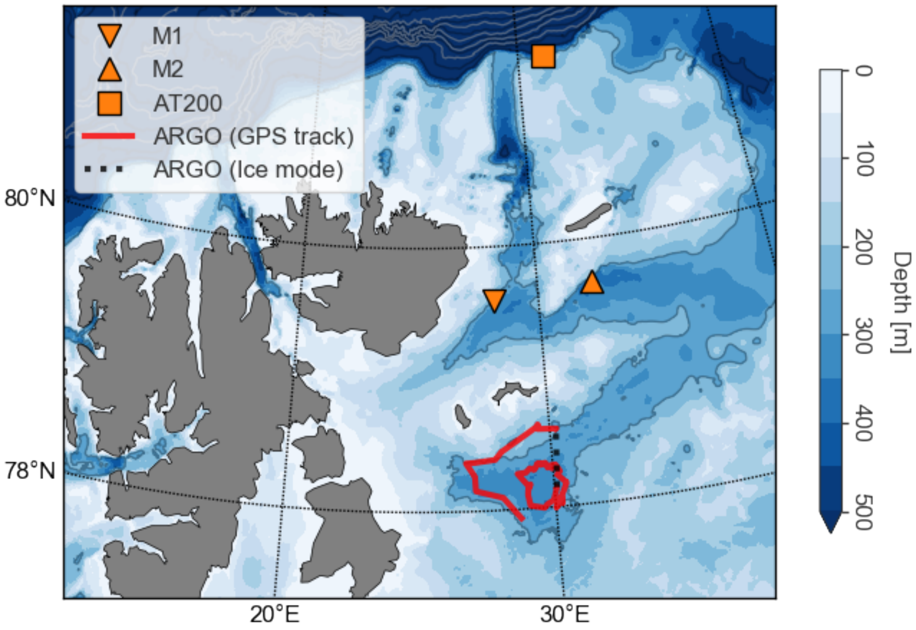

Figure 8. Mooring locations and drift track of ARGO profiler.

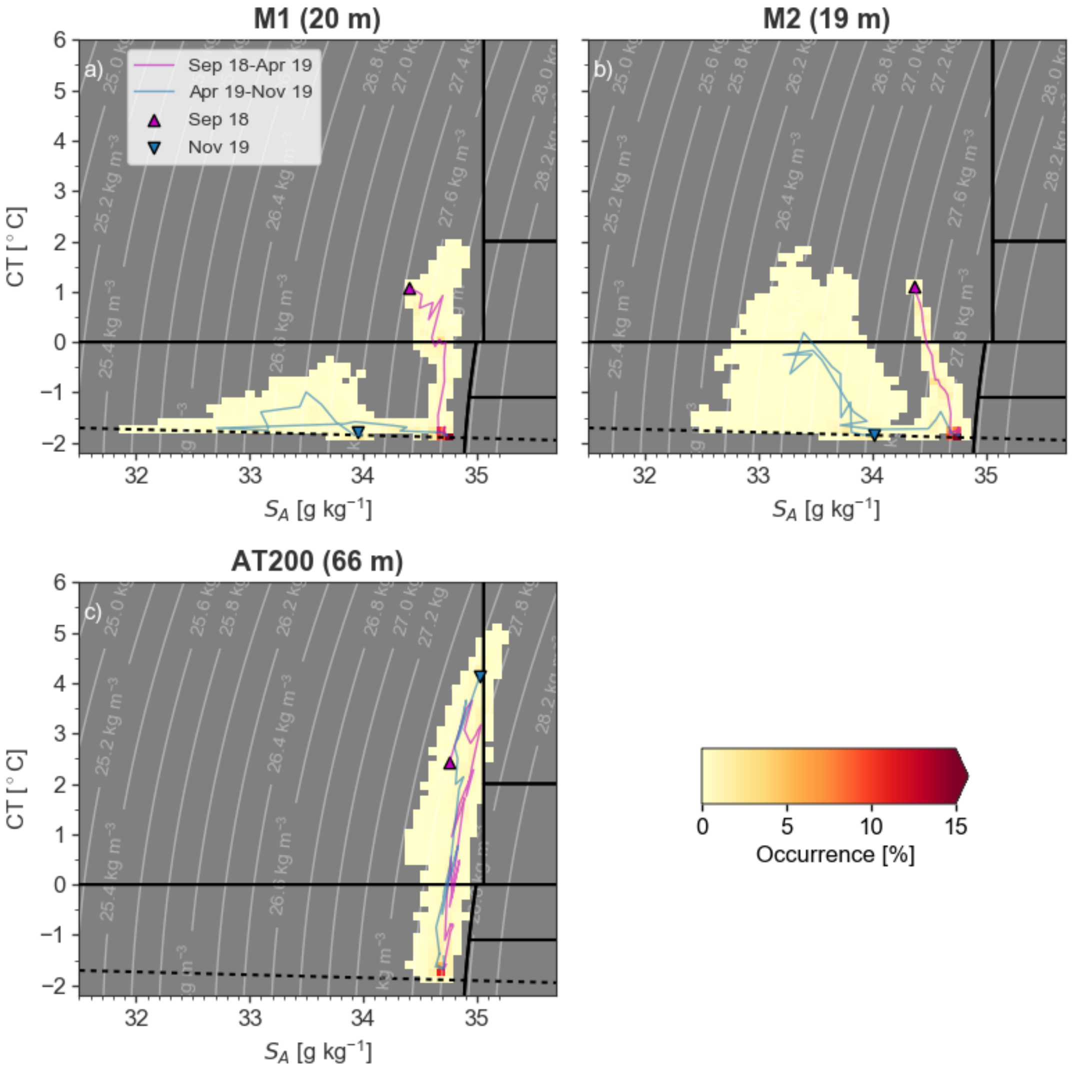

Figure 9. TS distribution of data from mooring sensors at three different locations in northern Barents Sea and over the continental slope, uppermost sensor.

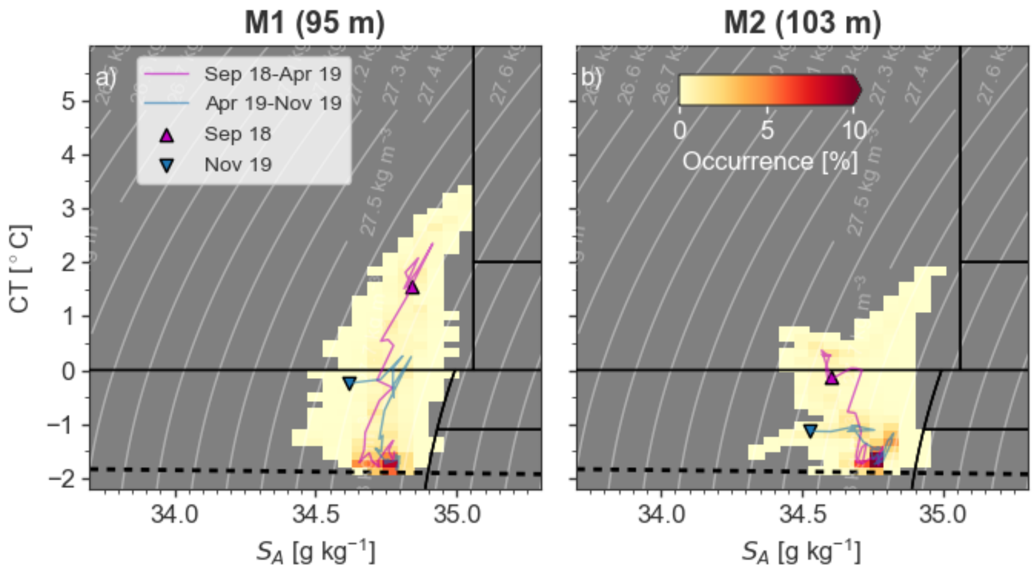

Figure 10. TS distribution of data from mooring sensors at two different locations in northern Barents Sea, sensor near 100 m depth.

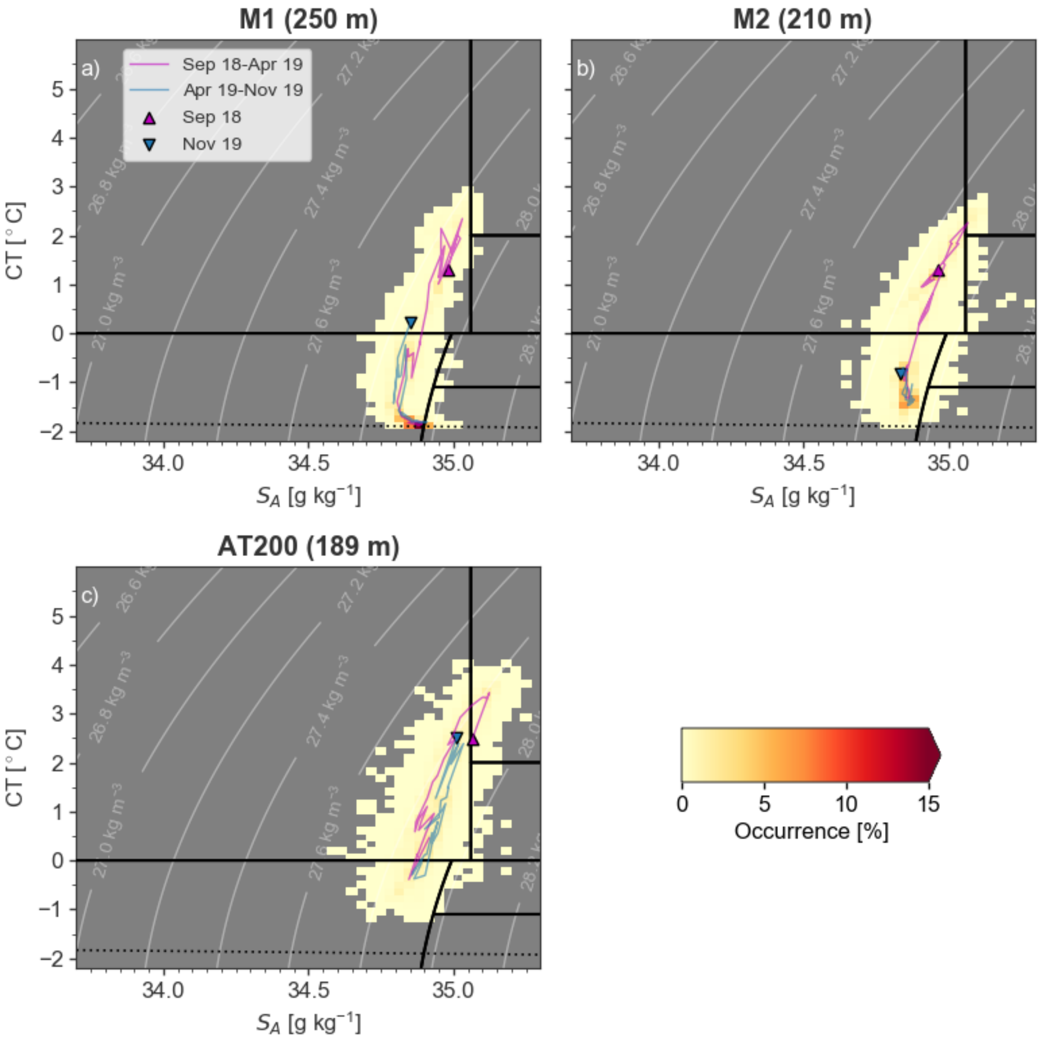

Figure 11. TS distribution of data from mooring sensors at three different locations in northern Barents Sea and over the continental slope, deepest sensor.

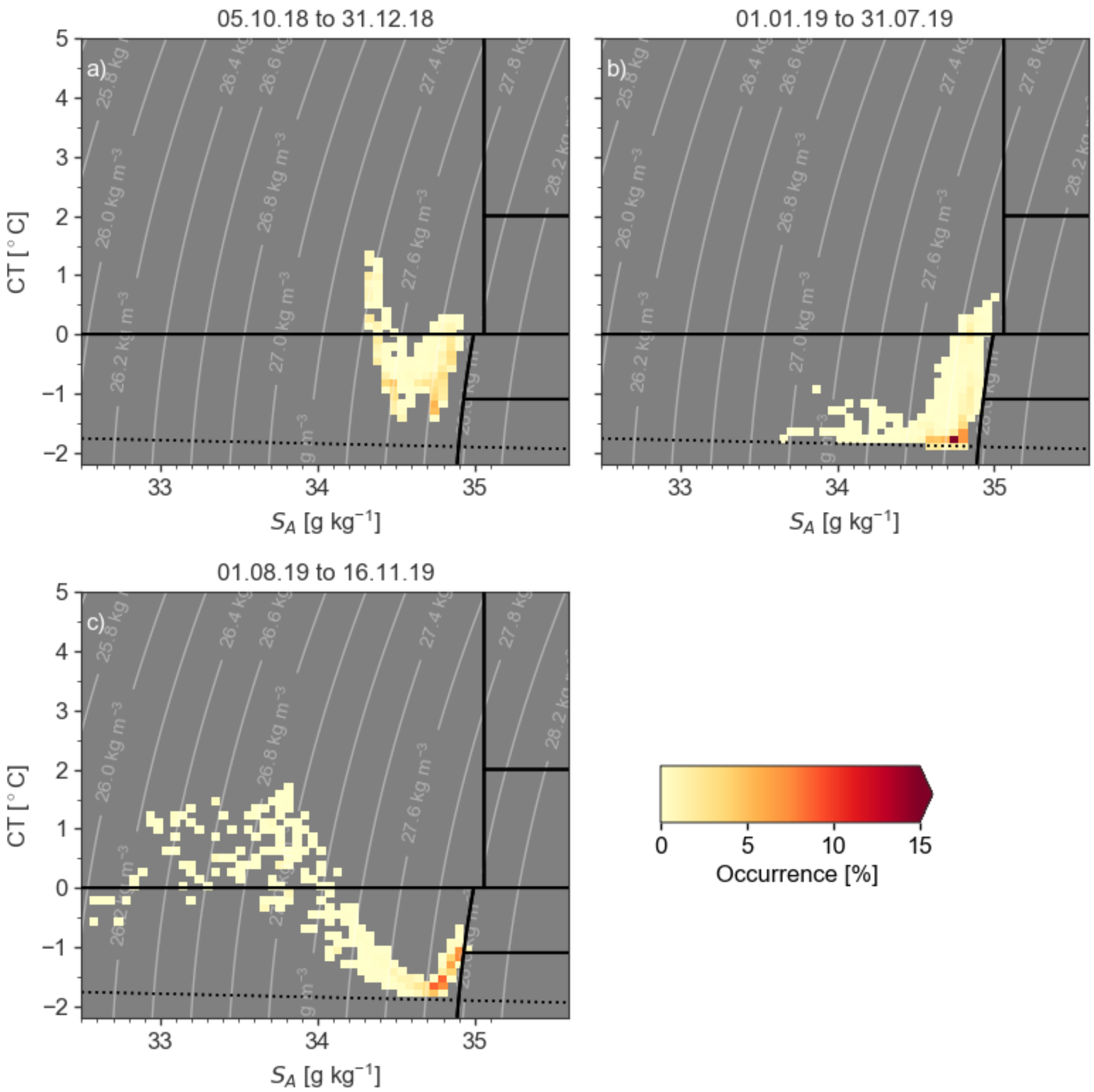

Figure 12. Data from ARGO profiler in Olgabassenget in TS space, in three different periods.

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The Nansen Legacy in numbers

6 years

The Nansen Legacy is a six-year project, running from 2018 to 2023.

200 people

Currently, there are 204 persons involved in the project. By the end of the project period, the Nansen Legacy will have educated a total of 50 PhD students and postdoctoral fellows.

1 400 000 km² of sea

The Nansen Legacy investigates the physical and biological environment of the northern Barents Sea and adjacent Arctic Ocean.

10 institutions

The Nansen Legacy unites the complimentary scientific expertise of ten Norwegian institutions dedicated to Arctic research.

>10 fields

The Nansen Legacy includes scientists from the fields of biology, chemistry, climate research, ecosystem modelling, ecotoxicology, geology, ice physics, meteorology, observational technology, and physical oceanography.

50/50 financing

The Nansen Legacy has a total budget of 740 million NOK. Half the budget comes from the consortiums' own funding, while the other half is provided by the Research Council of Norway and the Ministry of Education and Research.

>350 days at sea

The Nansen Legacy will conduct 15 scientific cruises and spend more than 350 days in the northern Barents Sea and adjacent Arctic Ocean between 2018 and 2022. Most of these cruises are conducted on the new Norwegian research icebreaker RV *Kronprins Haakon*.

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Illustration cover: Øyvind Lundesgaard