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Discussions
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Interactive comment on “Heat loss from the Atlantic water layer in the St. Anna Trough (northern Kara Sea): causes and consequences” *by* I. A. Dmitrenko et al.

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We thank Reviewer #3 for his/her constructive comments and suggestions, which significantly improved our manuscript.

In this article the authors have investigated the relationship between upward oceanic heat flux from the Atlantic water (AW) layer and sea-ice growth/reduction. The eastern flank of St. Anna Trough is identified as an important location where heat loss from a recirculating branch of the Fram Strait AW occurs. Based on observations from 1996 and 2008-2010 as well as model simulations they find that the most likely process contributing to the upward heat flux and subsequent ice reduction is mixing generated

by shear instability.

The study nicely highlights a potentially important location for heat loss and water mass modification of AW in the Arctic Ocean. It is generally well written with an easy to follow and logical structure. However, the evidence for the proposed mechanism – shear nstabilities – is not supported by their data that weakens the conclusions and further studies are thus needed.

General comments: i) Shear instability is proposed to be the main mechanism releasing heat, but no evidence is found in the data. I think the paper could benefit from a wider discussion of what other processes that could be attributed to the heat loss.

We completely agree with this criticism. The problem with all alternative interpretations is that they are too speculative. Winter convection at ice formation regions doesn’t play a role due to the relatively deep location of the AW layer and the surface layer freshening by the river runoff and sea ice melt. Interaction with bottom topography is among the potential explanations, but this mechanism should impact both ST flanks. Addressing this comment we added the following paragraph at the very end of section 4.1: “An important amount of the AW heat loss in the ST may be attributed to strong vertical mixing over the ST flanks associated to rough topography. Sundfjord et al. (2007) and Sirevaag and Fer (2009) concluded that the Arctic turbulent mixing is important along the boundaries and steep bottom topography. The enhanced vertical diffusion can be also associated with elevated tidal forcing over the sloping topography (e.g., Dewey at al., 1999). In the following, however, we show that the enhanced vertical heat loss occurs specifically over the ST eastern flank, the area where the SFSBW flows to the Arctic Ocean.”.

ii) Rudels (2010) argues that the partitioning of the heat loss from the ocean to the ice/atmosphere (in the western Nansen basin) is about 30/70 based on a simple model for heat loss constrained by surface salinity. Could you apply a similar approach and further constrain how much heat is going into ice melt vs atmosphere?

For this exercise in the western Nansen basin, Rudels (Constraints on exchanges in the Arctic MediterraneanâĂŤdo they exist and can they be of use?, Tellus, 2010) suggests that the AW layer is located right beneath the surface mixed layer (his Fig. 2). This is exactly the case for the western Nansen basin where the AW heat is directly available for heating the surface mixed layer and transferring heat further upward to the water/ice/atmosphere interface. In turn, the salinity of the upper layer (S1) becomes reduced due to the sea ice melt (eq. 12 in Rudels, 2010). In our case, however, the AW layer underlies the cold halocline layer (Fig. 4a and 4b) and the important fraction of the AW heat is consumed first for modifying its thermal properties. It is not the case for the 1996 CTD profiles showing no cold halocline above the AW layer (Fig. 4c), which seems to be a seasonal phenomenon (note that the 1996 CTD profiles were taken in July). The CTD profile in the ST mouth (st. 80) also shows no cold halocline layer, suggesting the different water origin, as we discussed in the manuscript. In this context, we believe that the heat loss uncertainty due to the unknown AW heat fraction consumed for modifying the cold halocline layer significantly exceeds the uncertain heat loss to the atmosphere. Moreover, we do not insist that the entire amount of heat lost by the AW layer is available at the water/ice/atmosphere interface.

Specific comments: P546 L27: Why do you use WOA? I believe PHC http://psc.apl.washington.edu/nonwp_projects/PHC/Climatology.html is better suited for the Arctic Ocean.

The domain of our model includes not only the Arctic Ocean, but also the entire Atlantic Ocean (north of 30°S). The PHC climatology indeed outperforms the WOA in the Arctic, but in the rest of the Atlantic Ocean it is based on the outdated WOA98. As we use this model not only for the Arctic related research, we decided to use the WOA climatology (WOA2005), which is the best available product for the period of our model run.

P547 L10: Zhang & Steele (2007) show that to get a realistic AW circulation in their model, using KPP, they need to reduce the vertical background diffusivity to 1*10**-6 m**2/s.

We use a model that is different from that used by Zhang and Steele (2007), and our simulations show proper (cyclonic) circulation of AW in the Arctic Ocean with the background diffusivity mentioned in the text. In order to demonstrate this we show here the mean circulation at 300m (Fig. A below). It is consistent with schemes of the intermediate water circulation presented, for instance, by Rudels et al. (1994).

P547 L13-L27: In this section the model performance is discussed mainly based on results at the entry gates, i.e. Fram Strait and BSO. However, a lot of water mass transformation of the AW takes place downstream of these sections and I think you need to better demonstrate the model performance for AW circulation? This could be done by e.g. plotting a map of max(potential temperature) in depth range 150-800 m as well as sections of modeled potential temperature and salinity across St. Anna Trough.

Following the reviewer's request we generated several figures (i) with the maximum mean temperature in 150-800 m and (ii) with transects of temperature and salinity across the St. Anna Trough. The maximum temperature (Fig. B below) shows that there is a well defined inflow of AW, which turns to the right after entering the Fram Strait and gradually looses its heat content on the way. The mean circulation (Fig. A) shows realistic details of the AW pathways over the shelf and in the St. Anna Trough. The simulated mean temperature (Fig. C below) and salinity (Fig. D below) across the St. Anna Trough at ∼81°N are in agreement with those obtained from CTD observations (Fig. E below). However, we believe that there is already enough model validation in the manuscript and additional details would distract the reader from the main point of the manuscript. Therefore we would like to keep the information on the figures shown below only in the response to the reviewer.

Fig. A. Simulated mean circulation at 300 m depth.

Fig. B. Simulated maximum (averaged over 2000-2009) temperature (in °C) in 150-800m depth.

Fig. C. Simulated mean temperature (in °C) in the St. Anna Trough at ∼81°N.

Fig. D. Simulated mean salinity in the St. Anna Trough at ∼81°N.

Fig. E. Distribution of temperature (in °C) and salinity across the St. Anna Trough according to Schauer et al. (2002).

P554 L1-L11: In this section I think you should mention the uncertainties of the satellite-derived ice thicknesses and drift.

We added the following text to the "Data and methods" section: "According to Kwok and Cunningham (2008), the uncertainty of the ICESat sea ice thickness is ∼ 0.5m based on the assessment with data from submarines and upward looking sonars. Comparisons of the satellite derived sea ice drift data with buoys for a 3-day period shows almost no bias, however the standard deviation for the ice drift velocity and direction is 6.7 km and 35°, respectively (Ezraty et al., 2007). Although the uncertainty of individual scans of satellite measurements is large, the spatial and temporal averaging reduces the associated errors down to about 5 cm and 0.07 km day-1 for the sea thickness and drift, respectively."

Technical comments: Change all "seaice" to either sea ice or sea-ice.

Changed, as requested.

P547 L13: Suggestion: change "The model is capable in realistic reproducing of the AW inflow" to "The model is capable of realistically reproducing the AW inflow"

Changed, as requested.

P556 L4: Suggestion: "In this sense, the St. Anna Trough is generally similar to an "ice bay" known as Whalers' Bay formed by inflowing Fram Strait branch of AW north of Svalbard (e.g., Ivanov et al., 2012)." I think "generally" is unnecessary in this context.

Changed accordingly.

Fig 1: Is (AW)_to a typo?

Yes, thank you!

Fig 4: the text is very confusing with references to "left", "center" and "right" when figures are labeled "a", "b" and "c".

The figure caption was modified accordingly.

Fig 10: I don't think "measured" fits well when you refer to satellite data. I recommend using observed or satellite-derived in this context.

We changed "measured" to "observed".

Please also note the supplement to this comment:
http://www.ocean-sci-discuss.net/11/C227/2014/osd-11-C227-2014-supplement.pdf

Interactive comment on Ocean Sci. Discuss., 11, 543, 2014.

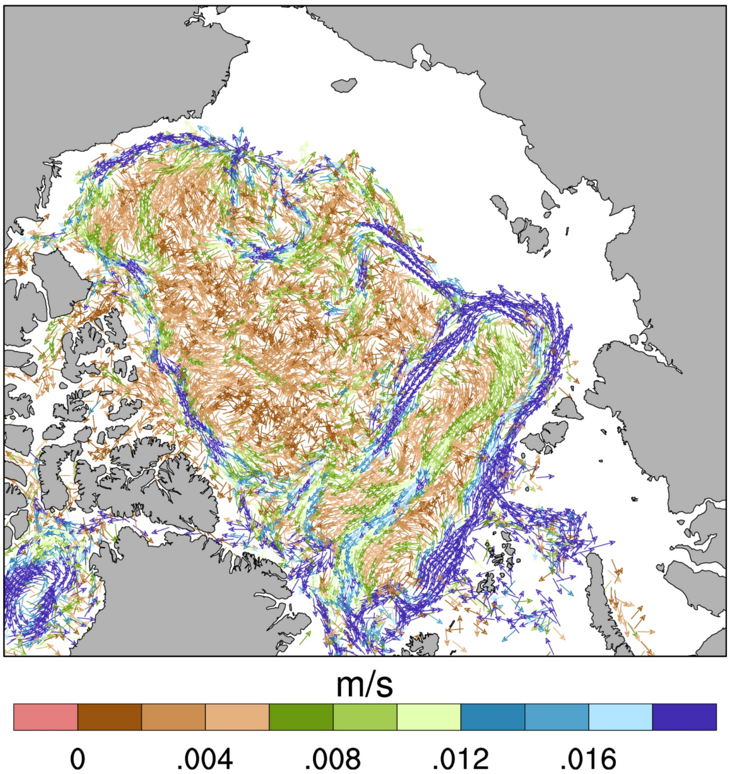

Fig. 1. Fig. A

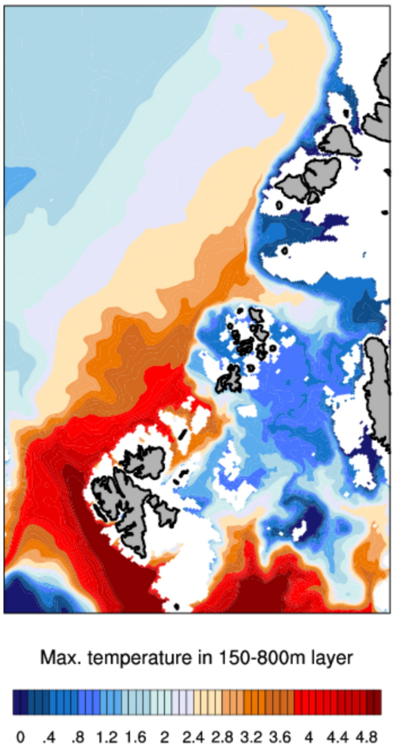

Fig. 2. Fig. B

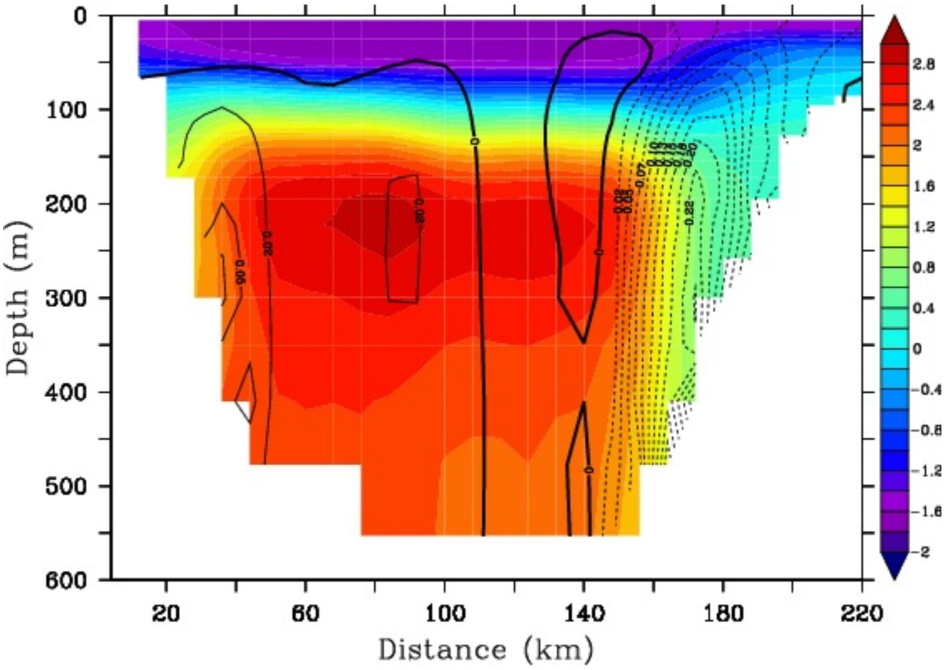

Fig. 3. Fig. C

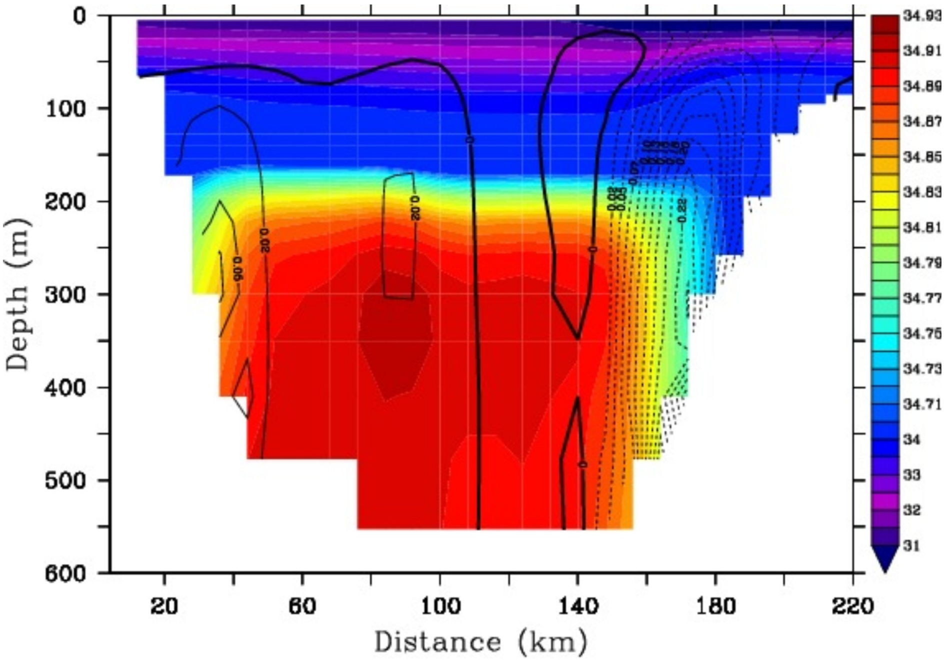

Fig. 4. Fig. D

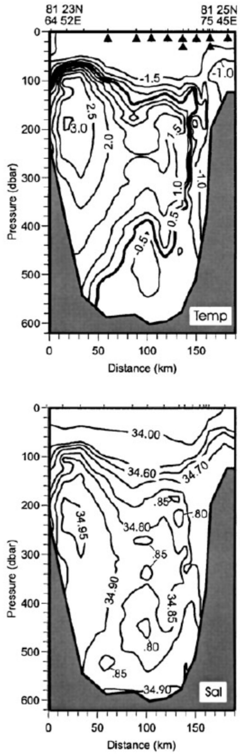
81 23N
64 52E
81 25N
75 45E
-1.5
-1.0
2.5
3.0
2.0
1.5
1.0
0.5
-0.5
Temp
Pressure (dbar)
Distance (km)
34.00
34.60
34.70
.85
.80
34.95
34.80
34.90
34.85
34.90
Sal

Fig. 5. Fig. E