

## **Interactive comment on “North Atlantic warming and declining volume of arctic sea ice” by V. A. Alexeev et al.**

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We thank the reviewer for the comments and provide below our answers.

*“Shimada et al. 2006 do not propose that ice is melting because of increased PW inflow at Bering Strait, only that the changing pathways of PW circulation in response to sea ice retreat might cause enhanced sea ice retreat.”*

As a matter of fact, he did. A quote from his paper: “Therefore the delayed development of sea-ice cover in winter enhances the retroflexion (westward turning) of PSW, just as the warmest pulse of PSW arrives on the Beaufort Slope. This anomalous heat flux into the western Canada Basin retards sea-ice formation during winter which, in turn, causes an imbalance between ice growth in winter and ice melt in summer, further

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accelerating seaice reduction.”

*“Figure 1: Please label geographic place names. How is fraction of multiyear ice calculated? How is the temperature time series constructed? Is it smoothed, are there gaps, over what space/time scales is it averaged? How were the data collected? What is the uncertainty in deg C? Is it the temperature of the AW maximum, or some integrated value? Please label the vertical and horizontal scales of your temperature sections.”*

We feel that marking the geography will complicate the figures. All places are very easily recognizable (Novaya Zemlya, Svalbard, Franz Joseph Land). Details of satellite retrievals, data collection and preparation are given in the references in the paper. Added a reference to horizontal scale in Fig.1.

*“I do not see that “The warming accelerated in the 2000s”*

The wording has been changed to ‘peaked in 2000s’.

*“Even though strong stratification in the eastern Arctic.” This is misleading. Most of the Nansen Basin is very weakly stratified, ie it is an extension of conditions in the Greenland Sea. Only in the eastern Nansen Basin, when riverine shelf water flows in, does a permanent winter stratification form (which is still weak compared to conditions in the Canadian Basin). The Amundsen Basin alternates between stratified and unstratified conditions, depending on the state of the shelf water inflow circulation.”*

This statement is wrong. The reviewer is poorly acquainted with the basics of Arctic Ocean hydrography. We can refer to multiple papers by Rudels et al. , Schauer et al .in 1990-2000s. Besides, there are many older Russian papers and monographs (mostly in Russian).

*“A series of transects shows that AW in these sections is in actual contact with sea ice” Probably this is true, but your transects do not explicitly show this, they only show very small-format temperature sections over a large vertical distance (500 m).”*

The format of Fig.1 has been changed.

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*“Why show Feb-March ice thickness in some years, and March-April in others?”*

We can only use the data that are available (which we did).

*“You claim that your model has “reasonable high resolution” of 50 km but soon after you cite a width of the AW core of 5-15 km. Obviously you are nowhere near to resolve the key physical phenomenon of interest in this study.”*

Yes-this is true, the NorESM does not resolve eddies or the narrow along slope current. It does however – do reasonably good both for ice export, and heat transport (studies are ongoing) in the Fram Strait. So the model is not perfect, but reasonably good, that's all.

Your model uses isopycnal coordinates. Can you please comment then on its value in a region with very weak stratification, ie the AW inflow region near Svalbard?

This is a reasonable question. The isopycnal vertical coordinate has some real benefits, and some real limitations. One benefit is that vertical mixing is what it is set to be by the parameterization, and not “artificially high” as with other vertical coordinates that have implicit diffusive mixing. Evaluation of how well the NorESM performs on the AW inflow is ongoing, but it seems to do this in a better way than other CMIP5 models. There is a dynamic mixed layer as the upper cell, and it is the heat in this layer that is interacting with the ice above, and the possible “artifacts” regarding the weak stratification should be much deeper in the water column.

*“Have you validated this model's ice thickness against any ice thickness observations?”*

The NorESM thickness is clearly not necessary a perfect match against the observations, but for large areas of the Arctic Ocean 4 m is a reasonable horizontal average value. More details on comparisons of NorESM ice with observations can be found in articles cited in the paper. Figures from Haas are included in response to Reviewer 1, and shows clearly that the NorESM ice thickness is comparable to observations in this sector.

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*“melting in this sector is much higher than in other regions of the Arctic Ocean” Is this true? It is hard to believe that it is higher than the tremendous melting seen in the Pacific areas of the Arctic Ocean in the past few years.”*

This comment should not be taken out of the context. We are talking here about melting during the cold season. One also needs to remember that the Arctic sea ice systematically moves from the Siberian shelf seas towards the Fram Strait, and melting at the Fram Strait could thus change the “upstream” ice cover as well as the local thickness.

*“There are a number of qualitative associations made in this paper that are interpreted as “proof.” An example is high melting in the model downstream of Svalbard “ that relates to the AW inflow.” Probably you are right, but you offer no quantitative proof. (AW influx correlated with sea ice)”*

We have added plots with correlations between AW temperature and bottom melt.

*“Perhaps you can cite Untersteiner “On the ice and heat balance in Fram Strait” (JGR, 1988) when discussing high melt rates in this area.”*

Reference added, thank you.

*“for an ocean layer under the ice that has a temperature of 0.09 +/- 0.01 K above the freezing point” Where do these numbers come from? IE are these values near Svalbard in your data, or from McPhee? I am confused. In fact why even cite a temperature, since Equation 1 has no temperature parameter?”*

These numbers come from the paper by McPhee – the reference is given.

*“suggests that the temperature directly underneath the ice in Sept'06 and Oct'08 could be” This is confusing since Figure 1 shows a temperature section, ie why “could be?” Probably you should have a more detailed explanation earlier about the observational data set, which I am guessing does not have ocean data near the surface. In fact, at what depth does it begin?”*

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*Perhaps you can cite Steele and Morison "Hydrography and vertical fluxes of heat and salt northeast of Svalbard in Autumn" (JGR, 1993) when you discuss heat fluxes in this area of order 100 W/m<sup>2</sup>."*

Changed the sentence to: "The temperature right underneath the ice in September 2006 and October 2008 is well above the freezing point (NABOS data: [www.nabos.iarc.uaf.edu](http://www.nabos.iarc.uaf.edu))."

Added the reference, thank you.

*"Pages 253 and 254 seem weakly argued and are probably not important to your paper. Is Figure 2 necessary, given Figure 3?"*

Figure 2 is very illustrative because it clearly shows the dramatic change in sea ice conditions on the pathway of the Atlantic Water. We would like to see more specific comments about what is unclear.

*"What ice concentration data set did you use in Figure 3?"*

ICESat. Figure caption says that clearly.

*"Figure 4b: The model shows enhanced melting to perhaps 40 E but not beyond. So why is there thin ice well to the east in Figure 3?"*

The NorESM model is a "state of the art" CMIP5 climate model, but is by no means able to simulate the ongoing changes in the Arctic perfectly. The model fields shown here illustrate that the area affected by AW melting can be quite large, and they also give a reasonable magnitude of the bottom melting associated with the AW. In nature the situation might be substantially different, but there are indeed limited observations available in this area, so we don't know. However, the model results do support that bottom melting in this area is large, and persist through the winter, and is related to the AW inflow.

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Interactive comment on The Cryosphere Discuss., 7, 245, 2013.

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