We highly appreciate all comments by Reviewer #2.

*The article analyzes observed sections through St. Anna Trough of 1996, 2008-2010 and ocean-ice model simulations. The eastern flank of the St. Anna Trough is identified as important regions for the heat loss of the outflowing Atlantic water coming from both Fram Strait and Barents Sea. Vertical velocity shear is suggested to be responsible for enhanced mixing and upward heat loss from the Atlantic Water. This study further shows a clear link of this heat loss to reduced ice thickness and concentration.*
*This study is important since it helps understanding processes leading to enhanced sea ice melt, which is particularly important in the light of the ongoing warming with a possible increased ocean heat transport from the Atlantic into the Arctic Ocean. The study is generally well written and structured.*

*I miss some more discussion of uncertainties in the observational setup and I would urge the authors to draw their conclusions somewhat more carefully because they are only based on a few observations over a short time period (+ a short model period). Also, the effect of climate variability on the results should be discussed.*

*General:*
*1.) I miss a more detailed uncertainty discussion of the measurements and the quantities calculated from these measurements. It is argued that heat content of the outflowing water might be uncertain due to insufficient spatial resolution of the CTD-measurements. However, no numbers are named and it is not discussed what this means for the other observational results. Even though this insufficient spatial resolution might be most important for the outflowing water, it should lead to uncertainties for the other measurements as well. Please add such a discussion to the "Data and Methods" section.*

This comment is similar to that by Reviewer #1. We have now introduced this discussion in section 4.2 in the last part of the first paragraph. The associated uncertainties in heat flux estimates are discussed at the very end of the third and fourth paragraphs. Please see our response to your specific comments #12 and #13 for more details.

*2.) Related to the uncertainty issue: Given the fact that all observations are based on short time periods (compared to the climate time scale), a discussion of variability is necessary as well. Otherwise, it is very speculative to draw general conclusions from these observational based results. All conclusions should be drawn with some carefulness.*

We agree with this criticism. Our CTD observations are snapshots and cover a relatively short period of time, while over the last several decades the AW temperature shows sustainable tendency to rise with several significant warm pulses in the 1990s (e.g., Schauer et al., 2002b) and 2000s (e.g., Dmitrenko et al., 2008). In fact, our conclusions are based on measurements taken in 1996 and 2008-2010 during the warm pulses of the AW inflow into the Arctic Ocean through the Fram Strait. These conditions relatively well represent the recent tendency of FSBW temperature to rise. At the same time, physical mechanisms explaining the upward heat loss in the ST are not obvious. It seems that they depend not only on the AW temperature in the SFSBW, but also on the velocity vertical shear controlled by horizontal density gradient across the ST eastern flank (Figs. 5 and 7). In turn, this gradient is conditioned by the density difference between the SFSBW and the Barents Sea outflow to the Arctic Ocean through the ST.

We introduced this discussion in Section 5, page 556, below line 26: "**Finally, our CTD observations cover a relatively short period of time, while over the last several decades the temperature of the FSBW shows a sustainable tendency to rise with several significant warm pulses in the 1990s (e.g., Schauer et al., 2002b) and 2000s (e.g., Dmitrenko et al., 2008b). In fact, our conclusions are based on measurements taken in 1996 and 2008-2010 during the warm pulses of the AW inflow into the Arctic Ocean through the Fram Strait. These conditions represent relatively well the modern tendency of FSBW temperature to rise. At the same time, the physical mechanisms of the upward heat loss in the ST are not obvious, in the light of the ongoing warming with a possible increased ocean heat transport from the Atlantic into the Arctic Ocean (e.g., Koenigk and Brodeau, 2013). It seems that they depend not only on the AW temperature in the SFSBW, but also on the vertical velocity shear controlled by the horizontal density gradient across the ST eastern flank (Figs. 5 and 7). In turn, this gradient is conditioned by the density difference between the SFSBW and the Barents Sea outflow to the Arctic Ocean through the St. Anna Trough.**".

*Specific points:*
*1.) Title: I do not like the brackets in the title. I would suggest either only "St. Anna Trough" or only "northern Kara Sea".*

We changed the title to "Heat loss from the Atlantic water layer in the northern Kara Sea: Causes and consequences".

*2.) Introduction: To stress the importance of analyzing the heat loss from the AW, it could be mentioned that observations indicate an increase of Atlantic water transport into the Arctic in the last 1-2 decades (e.g. Skagseth et al. 2008) and that this increase is related to recent sea ice reduction (e.g. Årthun et al. 2012, Schlichtholz et al. 2011) and simulated future ice reductions (e.g. Koenigk and Brodeau. 2013).*

Following this comment we introduced new text below line 5, page 545: "**Over the last decades, observations indicate an increase of AW transport into the Arctic through the Barents Sea (e.g., Skagseth et al., 2008), which impacts the observed sea ice reduction (e.g., Schlichtholz, 2011; Årthun et al., 2012). The AW transport into the Arctic through the Fram Strait shows similar patterns and impacts (e.g., Ivanov et al., 2012; Alexeev et al., 2013). Model simulations of future projections show analogous regularities (e.g., Koenigk and Brodeau, 2013).**".

*3.) Page 545, line 7: I would suggest using another abbreviation for "St. Anna Trough" as "SAT" since SAT is widely known and used as abbreviation for "surface air temperature".*

We replaced "SAT" with "ST" throughout the manuscript.

*4.) Page 546, line 23: Did you use the MIT version described in Marshall et al. 1997 or an updated version of this? If yes, which are the major updates compared to Marshall et al. 1997?*

The model data used in the present work was extracted from a MITgcm simulation using the most updated version of the code at the time when the integrations were executed (during 2010). Citing Marshall et al. (1997) is a common accepted practice when using

the MITgcm (no matter which version) and therefore tells nothing about the code version employed.

*5) Page 546, line 26: "..initialized from rest.." What is "rest" – restart? Please explain more in detail how the model was started.*

The expression "initialized from rest" means that the initial condition for the 3D velocity (in this case for January 1st, 1948) was zero everywhere. This is a common practice when starting a model integration from a given temperature/salinity climatology. Soon, after a few time steps, the velocities acquire a geostrophic balance in accordance with the imposed climatological initial condition of temperature/salinity (and therefore density). In conclusion, the impact of the unrealistic initial condition for the velocity is negligible after about one month of integration.

*6) Page 546, line28: Is there any reference for the ETOPO2?*

A reference to the ETOPO2 database was added as follows:

**Smith, W.H.F. and D.T. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, Science, 277, 1957-1962, 1997.**

*7) Figure 3: the model seems to show stronger interannual variations (particularly 3c) than the observations. Is there any explanation for this, e.g. different time steps or average intervals used in observations and model and thus smoothing short term variations, or is it just a model feature?*

In the quantities shown in Fig. 3c, the model seems indeed to show more variability at interannual scales. The analyzed model data has a daily output frequency, so more processes can be "resolved" with these data, of course, as long as they are allowed to be represented by the model resolution (which is 7 km). We believe that the model does a fairly good job in representing the average and decadal-scale variability, as can be seen by Fig. 3c. We therefore conclude that the lack of variability (or better, the not so pronounced variability) at interannual scales in the observations is most likely due to insufficient resolution in the in situ measurements.

*8) Page 548, lines 16-17: Please add a few words stating where and over which period Hanzlick and Aagard (1980) did measurements.*

Addressing this comment we modified the text below line 16, page 548, as follows: "The same pattern was found by Hanzlick and Aagaard (1980) **based on five CTD transects crossing the ST from ~79°N to 82° in 1966**, except that in the 1960s the temperatures were about 1°C lower.".

*9) Page 548, line 25: Although the 1996 patterns (Fig. 4c) show clear similarities to the 2009 patterns ( Figs. 4a,b), there are also clear differences, e.g T in the upper meters, different mixing depths and different vertical T and S gradients. These differences should be mentioned as well. Furthermore, July 96 values are compared to September 2009 values at slightly different positions: How comparable are these data? Please add some discussion on intra-annual and inter-annual variations? What part of the differences between the 1996 and 2009 values can be explained by these factors?*

We believe that the difference between July 1996 and September 2008 is mainly due to to:

(i) the seasonal patterns of sea ice melting and solar heating;
(ii) the interannual patterns, with extraordinary high AW temperature in the FSBW in the 1990s associated with warm AW pulses through the Fram Strait.

We introduced new text below line 27, page 548: "**The CTD profiles taken in July 1996 show a relatively cool and saline surface layer with lower/higher salinity/temperature vertical gradients when comparing to the 2009 profiles taken in late August – early September (Fig. 4). This difference implies the role of seasonal variability attributed to the sea ice melting and solar heating. The higher temperature of the inflowing SFSBW in 1996 compared to 2008 is due to the warm AW anomaly entering the Arctic Ocean through the Fram Strait in the 1990s (e.g., Schauer et al., 2002b).**".

*10) Page 550, line 11: Which 3 temperature maximums are meant here? Please specify.*

We modified this sentence in line 11, page 550 as follows: "The current view of the AW circulation in the Eurasian Basin, as proposed by Rudels et al. (2004), implies that the FSBW could potentially feed all three temperature maxima along 82°N **recorded at sts. 77, 80, and 85 (Fig. 2).** ".

*11) Page 550, line 10-25: This part is quite speculative to me: this is fine since we lack clear observations showing exactly where which water masses takes it way but it should be marked as a speculation. I am also not convinced that the "diffusive staircases provide evidence", I would prefer a weaker statement like "they indicate". Also, in the introduction you write, FSBW is 2-2.5 C; where does the additional heat comes from to reach 2.74 C in the St. Anna Trough? This section needs some more explanations.*

We agree with Reviewer #2. We replaced "evidence" with "indication". However, the second paragraph of section 4.1 mentioned by Reviewer #2 is already written following the style suggested by Reviewer #2: "The current view on the AW circulation in the Eurasian Basin, as proposed by Rudels et al. (2004), implies that the FSBW <u>could potentially feed</u> all three temperature maxima along 82°N recorded at sts. 77, 80, and 85 (Fig. 2). However, the formation of each maximum is due to different FSBW branches. That is, <u>if</u> the ST on-slope temperature maxima are associated with SFSBW, then the AW temperature maximum in the central ST <u>could be</u> attributed to the boundary current of the FSBW flowing along the Siberian continental slope (yellow arrows in Fig. 2). The double diffusive staircases noticeable in st. 80 (Fig. 4b) provide **indication** for attributing the intermediate temperature maximum of 2.74°C to the core of the FSBW which follows the Siberian continental slope <u>rather than</u> to the SFSBW. In contrast to the SFSBW inflow (sts. 23 and 85), CTD profiles taken in the SFSBW outflow (sts. 25 and 77) show heavily eroded double diffusive staircases (Figs. 4a and 4b). The ST outflow also exhibits strong modification at the upper AW interface that <u>is likely</u> caused by vertical mixing and interaction with cooler and fresher surface water of Barents Sea origin. In contrast, the temperature and salinity profiles in the central ST (st. 80) are only slightly modified at the upper AW interface and maintain double diffusive staircases that are almost disrupted in sts. 25 and 77 (Figs. 4a and 4b)."

Yes, we do suggest undersampling of the AW jet over the ST eastern flank along 81°N which results in heat content underestimate at st. 25 and heat content decreasing from st. 25 to st. 77. We speculate that we missed the AW temperature maximum shifted further on-slope from st. 25 to st. 26. The large cross-slope temperature/heat content horizontal gradients of 0.18°C km$^{-1}$ and 16.25 MJ m$^{-2}$ km$^{-1}$, respectively, between st. 24 and 25 are behind this speculation. For estimating uncertainties related to undersampling of the AW jet, we extended the heat content gradient between st. 24 and 25 to st. 26. This approach allows speculating on heat content between sts. 25 and 26 depending on distance from st. 25. This approach gives heat content estimates from 457 MJ m$^{-2}$ to 630 MJ m$^{-2}$ in ~4 km to 15 km off st. 26, respectively (note that the distance between st. 25 and 26 is ~16 km). This suggests the upper bound of potential heat content underestimate at st. 25 to be 173 MJ m$^{-2}$. Following this comment we added new text below line 10, page 552, introducing an estimate of the uncertainty: "**At 81°N, the horizontal cross-slope temperature gradient between sts. 26 and 27 at 110 m (depth of the temperature maximum at st. 25 – Fig. 3a) is 0.18°C km$^{-1}$ and the horizontal cross-slope gradient of heat content is 16.25 MJ m$^{-2}$ km$^{-1}$ (Fig. 2). We hypothetically extend this gradient further off-slope to st. 26 in order to obtain an estimate of uncertainty related to spatial undersampling of the relatively narrow AW jet between sts. 25 and 26. This approach gives heat content estimates from 457 MJ m$^{-2}$ to 629.75 MJ m$^{-2}$ in ~4 km to 15 km off st. 26, respectively (note that the distance between st. 25 and 26 is ~16 km). This suggests the upper bound of potential heat content underestimate at st. 26 to be 173 MJ m$^{-2}$.**".

We also modified Fig. 2 (page 562) to show temperature/heat content/station numbers for sts. 26 and 27, as shown next.
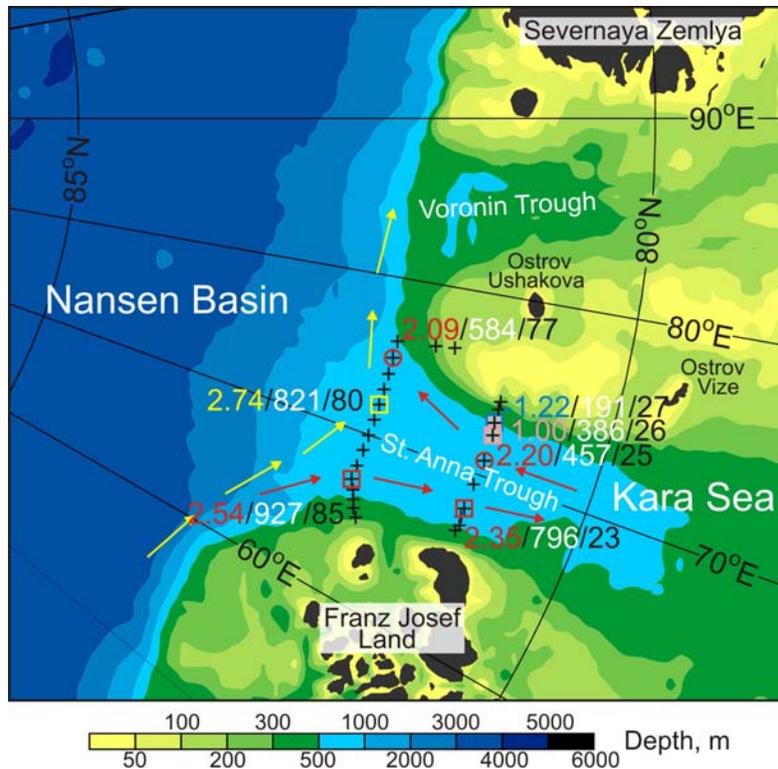
**Fig. 2.** Map of the northern Kara Sea showing the St. Anna Trough (**ST**). Arrows show the Fram Strait branch of the AW inflow into the Arctic Ocean, which recirculates in the **ST** (red arrows, SFSBW) and follows the continental margin (yellow arrows, FSBW). Crosses depict the positions of CTD stations taken in September 2009 at two sections crossing the **ST** at ~ 81°N and 82°N. Red squares and circles identify stations taken through the core of the SFSBW inflow and outflow to/from the **ST**, respectively. The yellow square identifies a station taken through the core of the FSBW boundary current. The **pink** square depicts the mooring position. **The pink and blue squares with gray shading identify the stations used for estimates of uncertainty in the vertical heat flux due to spatial under-sampling of the AW jet.** The first (yellow/red) number shows the FSBW/SFSBW core temperature (in °C) in September 2009. **The first pink and blue numbers give the temperatures at 110 m.** The second (white) number is heat content (in MJ m$^{-2}$), computed relative to the freezing temperature, between 30 to 90 m depth. The third (black) number denotes the station number.

*13) Page 553, lines 5-25: Also this section should include a discussion of uncertainties in the measurements/ observational based results. According to what is written on page 552, a 50 W/m2 difference could be due to uncertainties in measurements.*

We have now introduced this discussion:
(i) at the very end of the paragraph indicated by Reviewer #2 (below line 12, page 553):
"**An estimate of the uncertainty in the vertical heat flux owing to spatial undersampling of the AW jet at 81°N is obtained based on the heat content underestimate by 173 MJ m$^{-2}$, which reveals the heat flux lower bound of ~50 W m$^{-2}$.**".

(ii) at the very end of the next paragraph (below line 21, page 553): "**Finally, the discrepancy between estimates derived from simulations and CTD data can also be explained by spatial undersampling of the AW jet over the ST eastern slope. The lower bound of heat flux at ~50 W m$^{-2}$ retrieved from the CTD data is consistent with the 7-year mean simulated vertical heat fluxes.**".

*Furthermore, the measurement period is short while the model results are based on 7-year averages. Some more discussion here would be helpful as well, e.g. showing a time series of the modelled heat fluxes.*

A time series of the upward heat flux over the eastern flank of the ST at 75m is presented in the new Fig. 9 (reproduced below):
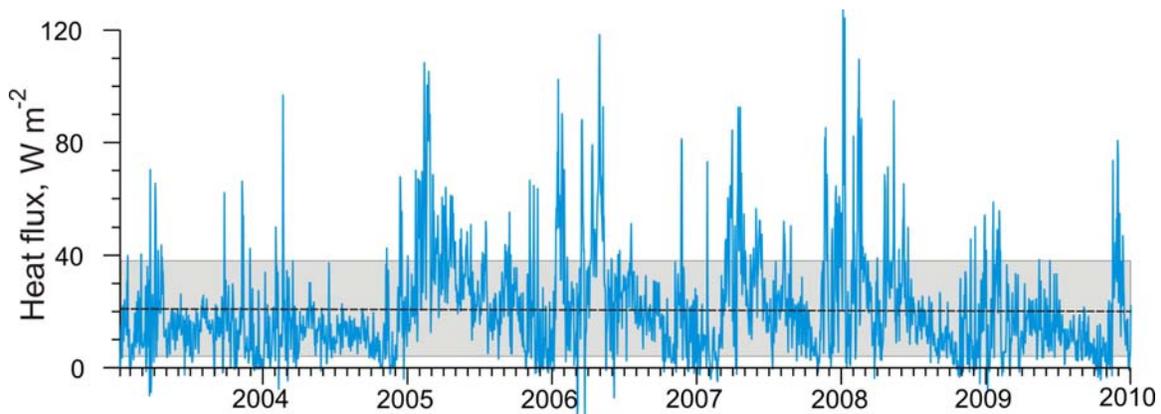


**Fig. 9. Time series (2003-2010) of daily mean simulated vertical heat fluxes (in W m$^{-2}$) across the upper SFSBW interface at 75 m averaged over the ST eastern slope (the area depicted by the yellow dashed rectangle in Fig. 8). The black dashed line indicates the 2003-2010 mean (20.5 W m$^{-2}$) and the gray shading shows ± one standard deviation from the mean.**

The new sentence with a short description of Fig. 9 was added: "**The daily averaged values of the upward heat flux in the model ST eastern flank (Fig. 9) present a seasonal cycle of about 20 W m$^{-2}$, showing a main maximum in early spring and a secondary maximum in early winter. Furthermore, strong interannual variability on the occurrence of the spring maximum can be noticed.**". We also modified Fig. 8 to depict the area over the ST eastern flank where the simulated heat flux is averaged for compiling the time series in Fig. 9.
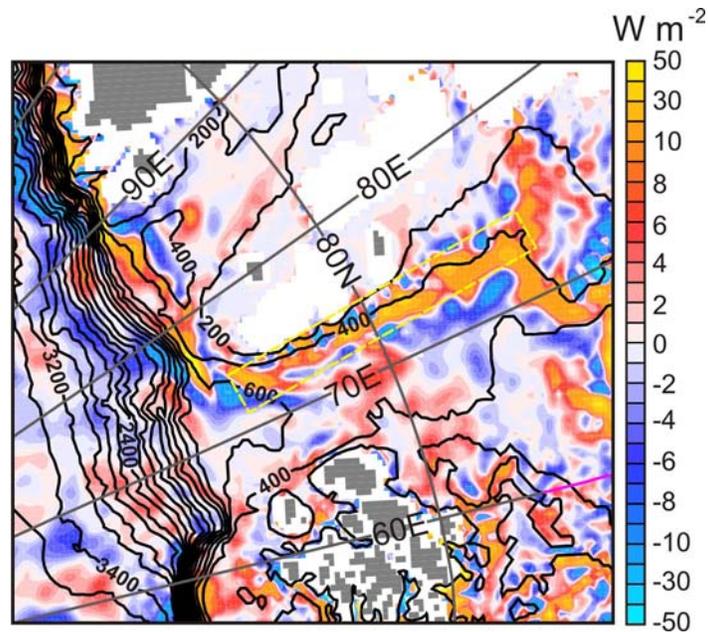
**Fig. 8.** The 7-year mean (2003-2010) simulated vertical heat fluxes (W m$^{-2}$) across the upper SFSBW interface at 75 m showing enhanced heat loss over the ST eastern flank as well as over the Nansen Basin continental margin. Positive numbers indicate upward heat flux. The bathymetry is in meters. **Yellow dashed rectangle depicts the area over the ST eastern flank where the simulated heat flux is averaged for compiling the time series shown in Fig. 9.**

Typings and similar:
*1.) Page 544, line 15 and elsewhere: Please write "sea ice" instead of "seaice"*

Corrected, as requested.

*2.) Page 555, line 4: Stefan's law*

Added, as requested.

*3) Fig. 4: Since you labeled the figures a, b, c, please use a, b, c in the caption as well instead of left, center, right.*

Changed, as requested.