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Ocean Science Discussions



# *Interactive comment on* "Observations of water masses and circulation in the Eurasian Basin of the Arctic Ocean from the 1990s to the late 2000s" *by* B. Rudels et al.

**B. Rudels et al.**

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First we would like to thank the referees for their comments. Our responses to all referees are given below.

REFEREE 1:

Section 2.1. The discussion of the transports through and the relative importance of the Fram Strait and the Barents Sea inflows will be expanded and the referee's suggestions as well as the critique from referee 3 (see below) will be taken into account.

Page 2705, line next to last. To us variation suggests a possible, perhaps even likely,



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Interactive Discussion

Discussion Paper

return to a previous situation, while change is more permanent. This difference will be made clearer.

Page 2706, line next to last. That polynyas often occur around Franz Josef Land is known (Martin and Cavalieri, 1989) (the reference will be added). That a polynya was responsible for the more chaotic interleaving observed in 2007 was a speculation that we did not check with observations. This will be done and if no strong polynya was observed in 2007 this speculation will be removed.

Page 2714. The Anderson et al. (1999) reference will be added.

REFEREE 2:

1) Title: We will add “with focus on the Eurasian Basin” to the title.

2) The requested Atlantic and intermediate water circulation diagram will be added.

3) Section 2 & 3: Self citations: We shall search for additional references.

2703, line 22, reoccupations: This will be changed to: “sections approximately follows previous sections taken in the Eurasian Basin”

2704 , line 7. The longitude was 33 E. This will be changed.

2705, lines 22-23: The reason for including the Quadfasel et al. (1992) references is that in the 1980s a situation with warm, saline inflow in the Barents Sea, covering the Central Bank, cooling in winter resulted in a smaller density increase than when the inflow was less warm, or weaker, and an upper less saline layer lead to ice formation and haline convection over the bank. In 2007 cooling the saline Atlantic water created high densities similar to those resulting from ice formation in the 1980s. This could indicate a partial change in the dense water formation mechanisms in the Barents Sea. This will be elaborated in the text.

2710, line 2: “Transport of Fram Strait branch water is almost extinguished” This statement will be changed to “The much lower temperature and especially the much lower



OSD

9, C1229–C1235, 2012



salinity observed in the Atlantic core in the boundary current and in the basins beyond the Nansen Basin suggest that the transport of Fram Strait branch water is almost extinguished in the boundary current beyond the Laptev Sea".

2710, line 9-19: Circulation diagram will be added

Section 5, Advection velocities: These can only be broadly estimated. It appears that the warm and cold pulses arrive at the North Pole from the Laptev Sea after 2-3 years, which suggests mean advection velocities of about 2 cm/s.

Table: A table may be to overdo it, but a summary paragraph of the implications of the observed changes will be added.

2713, lines 18-19: Woodgate et al (2001) estimate the advection velocities in the boundary current to 2-5 cm/s, while e.g. Walsh and Carmack (2003) estimate the velocities in the intrusions to about 0.2 cm/s, at least a magnitude smaller. This statement and these references will be added here.

Fig 18, Increase in temperature towards the bottom: The stations mentioned are those, where the increase is most clearly seen, nothing else. The blue station could also be included.

Technical comments:

1) Maps: We think that to see the relative positions of the different sections is more important than to distinguish the exact positions of the different stations on the shorter sections. The important information here is rather over how short distances the changes occur.

2) We shall try to make the section plots more readable.

3) Fig 3a: The figure will be revised

4) Orvig will be changed to Orvik,



OSD

9, C1229–C1235, 2012

REFEREE 3:

Analyses of water transport through Fram Strait and the Barents Sea

a) Nansen (1902), in the footnote on page 335, states that Petermann (1870) considered the Barents Sea as being the main entrance of warm Gulfstream water to the Arctic Ocean and that this also was his (Nansen's) view before the Fram expedition. After Fram he changed his mind because of the shallowness of the Barents Sea, which, in his opinion, only would allow the upper 200m to pass eastward into the Arctic Ocean. The warm, >0oC layer, observed in the Arctic Ocean he assumed entered through Fram Strait. However, he still considered the possibility that dense water formed by brine rejection on the Barents Sea shelf could be responsible for the high salinities observed in the Arctic Ocean deep water from Fram (Nansen, 1906). Only after observation north of Svalbard made from his ship Veslemøy 1912 did he become convinced that the Arctic Ocean deep water salinities measured from Fram were too high and he adopted the view that also the deep water entered through Fram Strait from the Greenland Sea. We want to thank the referee for bringing this up. The text will be rewritten.

b) Nikiferov & Shpaiker (1980) In our view "comparable magnitude" does not necessarily mean equal but just comparable. A difference in a factor of 2 is comparable, a difference by a factor of 10, as in the Aagaard & Greisman (1975) budget, is not.

Furthermore, the claim in the text was: "much, if not most of the water . . . . . passes over the Barents Sea". Therefore we do not see any reason to change the statement "comparable magnitude". We will, however, enlarge the discussion of the earlier estimates.

b continued) We don't understand the reviewers remark that the fluxes from the Fram Strait mooring array presented in Schauer et al. (2004) and (2008) and Beszczynska-Möller et al. (2012) differ beyond uncertainties inherent in the different methods and definitions. BM2012 estimate about 3 Sv in the WSC for Atlantic water as defined



OSD

9, C1229–C1235, 2012

being warmer than 2°C. Schauer et al. (2008) and Schauer and Beszczynska-Möller (2009) (reference will be added) show ca. 6 Sv of water warmer than 1°C flowing northward, but this includes also branches of the (likely) meandering flow further west. Hence, their numbers include flow that feeds the boundary current in the Nansen Basin as well as flow that returns immediately within Fram Strait. They do not (and cannot) distinguish the two in their observations. Moreover, the net southward flux of ca. 2 Sv (Schauer et al., 2008) are in perfect agreement with water from the Barents Sea exiting through Fram Strait.

c) Neither do Schauer et al. (2004) state AW inflow of 9-10 Sv, nor do Schauer et al. (2008) state AW inflow of 12 Sv. These high numbers are reported as total northward flow across the mooring line respectively (the difference being due to different averaging periods), i.e. including deep waters and including water that recirculates in the Fram Strait.

b&c general) We consider it would be somewhat presumptuous to, in one paragraph, evaluate the published transport estimates through Fram Strait. The authors of the cited publications have done just that, and by giving the references we allow these authors to speak for themselves. We shall go through our own manuscript to make sure that the estimates are consistently cited throughout the text.

Analyses of water temperature and salinity.

Most of these questions and critique we do not really understand.

a) Regional criteria can only mean that what we call Fram Strait branch enters through Fram Strait, the Barents Sea branch over the Barents Sea. East of the St. Anna Trough, before the branches start mixing, the Barents Sea branch is mostly found over the upper part of the slope, Fram Strait branch over the lower part of the slope. The different properties of the branches as they meet north of the Kara Sea can be seen in Figures 4 and 9 and the Barents Sea characteristics are described on page 2707.



OSD

9, C1229–C1235, 2012

There is one caveat, mentioned on page 2711, lines 14-18, that part of the warm Atlantic core of the Fram Strait branch could move up the St. Anna Trough and join the Barents Sea outflow, contributing to its warm Atlantic part. What speaks against this is that the cold layer above the thermocline has similar salinity as the winter mixed layer in the Barents Sea, which is determined by the temperature the cooled Atlantic water of the Barents Sea branch has, when it encounters and melts sea ice (Rudels et al., 2004). The possibility that the Atlantic water of the Fram Strait branch can join the Barents Sea branch in St. Anna Trough will be mentioned also on page 2707.

b) We agree. But which analysis is ever complete? We very much doubt that for the interpretation we make a volumetric analysis would be of any use. In any case, a more quantitative approach was used in Korhonen et al.. (Ocean Science Discuss., 9, 2621-2677, 2012), which we refer to in the revised ms.

c) We do not understand this question. We don't state anywhere that the AW properties discussed in the ms, being from the Fram Strait or the Barents Sea Branch, bear NO sign of seasonality. On the other hand we don't understand why the seasonality of the Barents Sea branch would be particularly strong, when it fills the Amundsen Basin.

d) This work is largely an interpretation of data. The data used are presented in figures. If errors are made, they are errors in judgment. Any reader can challenge our interpretation and argue for a different interpretation of the data.

There is the question of how representative the studied observations are. In another situation the Fram Strait branch might penetrate deeper into the Arctic Ocean. The warm pulse observed in the 1990s might be an example of this. This is brought up on pages 2710 and 2711.

The conclusions of the ms are qualitative, and three possible interpretations of the observations are provided for the main statement of the ms with a clear favor to one interpretation. Any error discussion would go something like: maybe it is true, maybe it is false; we believe it is true.



OSD

9, C1229–C1235, 2012



This concludes our responses to the referees.

Interactive comment on Ocean Sci. Discuss., 9, 2695, 2012.



OSD

9, C1229–C1235, 2012