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Reply to Interactive Comment on "Freshwater components and transports in the Fram Strait: Recent observations and changes since the late 1990s" by Anonymous Referee 2

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The abbreviations IMW and IFW have been changed to SIM (Sea Ice Meltwater) and IFB (Ice Formation Brine-enriched water), respectively, to be more easily distinguishable and in accordance with previous work (see our reply to referee 1). The suggestions made by the reviewer are dealt with here in the order they appear in the review.

The main issues mentioned by the reviewer concern the consideration of errors due to the method of interpolating our data and calculating fractions of freshwater components.

First major issue

One persistent feature we observed is the ratio of the fractions of IFB and MW. We stated that this is approximately $\frac{-1}{2}$. A look at these fractions for each of the inventories in the Fram Strait reveals that the ratio lies between $\frac{-1}{1.5}$ and $\frac{-1}{2}$ for most of our observations. Comparisons are made with published observations that show a different ratio in the Canada Basin (Yamamoto-Kawai et al., 2008), $\frac{-1}{1.3}$, but similarities to the Eurasian Basin (Jones et al., 2008). The reviewer questions the similarity with the values in Jones et al. (2008), pointing to the variability on the Eurasian side of the Lomonosov Ridge. In fact, where subsurface maxima of IFB are seen in the cross-Arctic section in Figure 3d of Jones et al. (2008), such as around kms 2000 and 2750, the ratio is close to $\frac{-1}{2}$. However, given that the difference between the values in the Canadian Basin and ours are not larger than the variability in our observations, we will discard the conclusion about pathways based on the ratio of IFB and MW. Therefore, we adjusted our discussion as follows:

Abstract, page 182, lines 20-21: The sentence starting with "Our results..." has been changed to "Our results indicate that the accumulation of increased amounts of river water on the shelves is associated with enhanced ice formation".

Page 598, lines 11-20: The paragraph starting with “Indications...” has been removed.

Page 598, lines 21-25: The paragraph starting with “In addition...” has been changed to “The ratio of the transports of IFB and MW through the Fram Strait section is similar in all years, between $\frac{1}{1.5}$ and $\frac{1}{2}$ (see Fig. 6), suggesting some systematic covariability between ice formation and the accumulation of river water in parts of the Arctic.”

Page 599, lines 21-26: The sentences starting with “For all...’ and “A similar ...” have been removed.

Second major issue

Our conclusion that MW transport was higher in 2005 than in 1998 is not altered by the potential error in our end-member calculation due to the presence of Pacific Water. The reviewer suggests to adjust the Meteoric Water (MW) fraction and transport in 1998 by the potential overestimate of 20% of the value shown in Table 1. Furthermore, the reviewer suggests to decrease the 2005 value by 25%, which is the difference between those transports in 2004 based on measured $\delta^{18}O$ values and those based on reconstructed values. The ’gradual increase’ that results from the downward adjustment of the transports in 1998 (due to the presence of Pacific Water, PW) and in 2005 (interpolation error) even more strongly supports our conclusions of increased MW transports after the 1990s. The above errors are only rough estimates, based on published analyses (PW presence in 1998) and data from 2004 (interpolation error in 2005). Hence, we have added two rows in Table 1 with the adjusted values for 1998 and 2005 to show the transports both with and without the biases. We do not think that Appendix A should be part of the main text as it contains many technical details that have been discussed to a large extent elsewhere and that are not essential for our discussion. To emphasize the importance of the potential transport biases in 1998 and 2005, this is now mentioned several times in the manuscript with reference to Appendix A.

The following changes have been made to the manuscript to emphasize the influence of these biases on our transport calculations:

Abstract, page 582, lines 12-13: The sentence starting with “The average...” has been changed to “We estimate the average transports of MW and IFB to be between 130 to 160 mSv (4100 to 5000 km^3/yr) and 60 to 90 mSv (1900 to 2800 km^3/yr) southward, respectively.”

Page 594, line 26: Added sentence “If we remove the estimated biases due to PW presence in 1998 and due to the interpolation of $\delta^{18}O$ values in 2005 (Appendix A) we obtain averages of 130$\pm$12mSv (4100 km^3/yr) and 60$\pm$7mSv (1900 km^3/yr), respectively.”

Page 597, lines 8-12: The sentences “The inventories...” and “Together...” have been removed.

Page 598, lines 1-3: The sentence “In agreement...” has been removed.

Page 599, lines 15-17: The sentences “In 2004 ... latitude.” have been changed to “In August 2004, an increased amount of river water arrived north of the Fram Strait. Later in 2004 and most notably in 2005, as shown by the observations, high amounts of MW passed the 79° latitude.”

Page 599, line 19: “20%” changed to “20 to 25%”.

Page 601, lines 21-24: The sentence "As the ... both years" has been changed to "As the presence of PW in 1998 and the reconstruction of $\delta^{18}O$ values in 2005 lead to a positive bias in our transports, we will not include these in our error estimates but consider the respective transport values both with and without these biases."

Table 1, caption: The sentence "Transport estimates with the potential bias for 1998 and 2005 removed (Appendix A) are marked by +, where the average transports (Mean$^+$) have been recalculated using values associated with Year 1998$^+$, 2004 and 2005$^+$ for MW and Year 1998, 2004 and 2005$^+$ for IFB." has been added to the caption.

Minor comments

Several suggestions on minor points were made by the reviewer:

Page 583, line 15: Period changed to comma.

Page 583, line 14: The reference "Holfort and Hansen (2005)" has been changed to "Holfort et al. (2008)". The westernmost mooring we used for any transport estimates is at 6.87^{o}W (1998), but Gerdes et al. (2008) study mentions significant transports west of 8°W. In addition to the transports west of 4°E Table 1 also gives values for the approximate extent of the mooring arrays used for the transport calculations in all years, between 7°W and 4°E.

Page 586, line 1: The sentence "We also compare... (2001)." was removed, as the analysis of our data from 1998 by Meredith et al. (2001) is already mentioned earlier in the Introduction.

Page 598, line 14: The sentence was removed (see above).

Figure 2: The three plots have been changed for easier readability (figure attached).

Page 596, line 1: "tha" changed to "that".

Page 596, line 16: Part of the sentence was changed from "were lower in ... (Table 1)." to "increased between 1998 and 2005 (Table 1), with those in 2004 being higher (lower) than the 1998 values if we consider (ignore) the potential bias explained in Appendix A."

Page 598, line 22: The sentence was removed (see above).

References

Gerdes, R., Karcher, M., Köberle, C., and Fieg, K.: Simulating the long term variability of liquid freshwater export from the Arctic Ocean, in: Arctic-Subarctic Ocean Fluxes: Defining the role of the Northern Seas in climate, edited by Dickson, R. R., Meincke, J., and Rhines, P., chap. 17, pp. 405–425, Springer Science and Business Media, 2008.

Holfort, J. and Hansen, E.: Timeseries of Polar Water properties in Fram Strait, Geophys. Res. Lett., 32, doi: 10.1029/2005GL022957, 2005.

Holfort, J., Hansen, E., Østerhus, S., Dye, S., Jonsson, S., Meincke, J., Mortensen, J., and Meredith, M.: Freshwater fluxes east of Greenland, in: Arctic-Subarctic Ocean Fluxes: Defining the role of the Northern Seas in climate, edited by Dickson, R. R., Meincke, J., and Rhines, P., chap. 11, pp. 263–287, Springer Science and Business Media, 2008.

Jones, E. P., Anderson, L. G., Jutterström, S., Mintrop, L., and Swift, J. H.: Pacific fresh water, river water and sea ice meltwater across Arctic Ocean basins: Results from the 2005 Beringia Expedition, J. Geophys. Res., 113, C08012, doi:10.1029/2007JC004124, 2008.

Meredith, M., Heywood, K., Dennis, P., Goldson, L., White, R., Fahrbach, E., Schauer, U., and Østerhus, S.: Freshwater fluxes through the western Fram Strait, Geophys. Res. Lett., 28, 1615–1618, 2001.

Yamamoto-Kawai, M., McLaughlin, F. A., Carmack, E. C., Nishino, S., and Shimada, K.: Freshwater budget of the Canada Basin, Arctic Ocean, from salinity, $\delta_{18}O$, and nutrients, J. Geophys. Res., 113, C01007, doi:10.1029/2006JC003858, 2008.