

Interactive comment on “Volume and temperature transports through the main Arctic Gateways: A comparative study between an ocean reanalysis and mooring-derived data” by Marianne Pietschnig et al.

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Dear Matthew Hecht, Dear Referees, Dear Prof. Schauer,

Thank you very much for taking the time to read our manuscript and contribute to the online discussion. We especially thank the reviewers for their insightful and constructive comments, which are a great guidance for our revision and will help to improve the quality of our manuscript. We will submit a revised manuscript in which we aim to address all comments raised by the reviewers. Below we include a more detailed list

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of how we plan to address the individual comments.

First and foremost, since there has been a consensus among the reviewers and Prof. Schauer on the temperature transports through each section, we agree to remove this part from the manuscript. Reviewer #1 The authors showed the total heat budget of the Arctic Ocean based on the observation (153TW; OBS) in the period from September 2005 to August 2006. Is this value expected as normal one or significantly particular one? Can the authors infer and discuss based on the long-term mooring dataset (e.g., at the Fram Strait; Beszczynska-Möller et al., 2012)?

Answer: We will include a comparison to long-term estimates presented in recent literature.

To directly compare the temperature is better for validation of OBS or reanalysis dataset. What does seem sure is that the “temperature transport” defined in this paper should not be used.

Answer: As stated above, we will remove the section under discussion from our manuscript but keep the net heat transport and the temperature distributions, both of which we will discuss in more detail. We will change the title of our manuscript to “Volume transports and temperature distributions in the main Arctic Gateways: A comparative study between an ocean reanalysis and mooring-derived data”

Reviewer #2

1. Focus on volume transport analysis: a. Qualify what new knowledge this manuscript contributes to the topic in addition to Tsubouchi et al. (2017a,b), given the ‘mixed’ skill of C-GLORSv7 and relatively large differences in estimated net fluxes;

Answer: We will try to explain this more clearly in our revised manuscript. Our study contributes to the body of knowledge in that it assesses a state-of-the-art ocean reanalysis using a new, internally consistent and comprehensive observation-based dataset, which was previously not possible. Tsubouchi et al. provide, for the first time, piece-

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wise mass and salt conserved velocity fields across the main Arctic gateways based on observation data using a box inverse model. Our comparison of monthly integrated transports (Fig. 2) and cross-sections of velocity and temperature (Figs. 3 – 7) provides insight into how appropriate recent reanalysis products are for Arctic mass, energy and freshwater budget calculations. A comparison of the reanalysis-based values in single straits to literature values would not be consistent, since in situ observation-based estimates do not satisfy mass and salt conservation (see Figure 3 in Tsubouchi et al., [2017]).

b. Quantify uncertainty of flux estimates based on each source / method, not just as standard deviations within each time series but also due to the extrapolation / interpolation methods, use of hydrography to calculate geostrophic currents or use of other model results to fill in gaps and / or missing data;

Answer: We thank the reviewer for making this important point. However, quantifying the uncertainty of the two datasets is outside of the scope of our research and is in practice not possible for us. We will include a discussion on the topic of uncertainty for each dataset in our revised manuscript, relying on the publications discussing the individual datasets and the uncertainties given there.

c. provide more information about the NEMO model and quality of its output at the four gates where OBS were supplemented, including the upper water column and shelves;

Answer: We will address this point based on a more thorough literature research.

d. include volume flux estimates based on all the grid points from C-GLORSv7 for each section and e. discuss those in comparison to the subsampled estimates and those based on OBS;

Answer: We are not quite sure what is meant here. Our estimates presented in Table 1 are based on all C-GLORSv7 points in each section. We are not sub-sampling at this point, but rather we are trying to follow a latitude circle on the model-native tripolar grid.

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We obtain a closed line in each strait. By including more points, some of the meridional or zonal transports would be added twice. We will try to explain this more clearly in the revised manuscript.

Concerning the spatial resolution of OBS, our manuscript includes a paragraph on the effect of reducing the spatial resolution in C-GLORS to the locations of the moored observations. We find that the volume transport for the reduced C-GLORS resolution is in good agreement with the estimate obtained from full C-GLORS resolution (only 0.1 Sv smaller). When further reducing the resolution to half the observational resolution, the transport is significantly reduced. This implies two things: On the one hand, the discrepancies in the transport estimates (Table 1) are unlikely to stem from the different resolution of C-GLORS and OBS. On the other hand, one could infer that the spatial resolution of OBS is high enough to capture the transport, at least compared to a $1/4^\circ$ reanalysis. We conducted this analysis for Davis Strait, because the use of model data is smallest in this strait compared to the other gateways.

f. clarify if C-GLORSv7 are subsampled both in the horizontal and vertical to the observational ‘transport points’ or just in the horizontal direction. In the former case clarify further what horizontal length and vertical thickness each transport point represents (i.e. what kriging method was used). In the latter case please justify why subsampling was only used in the horizontal and not in the vertical direction for comparison with OBS;

Answer: As explained in our answers to d. and e., the reanalysis is not subsampled for the integrated transports (Tab.1 and Fig. 2). For the cross-section plots, we interpolate the OBS fields horizontally to match the higher resolution of C-GLORS, and similarly we interpolate C-GLORS in the vertical to meet the higher resolution of OBS. We will clarify this a bit better in the revised manuscript.

g. explain reasons for non-zero net integrated volume flux for the four Arctic gateways, including possible contributions from gaps between separate ‘lines’ evident especially

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at BSO;

Answer: The net integrated volume flux for the Arctic is not expected to be zero but close to 0.18 Sv due to the contribution from rivers and the net positive precipitation minus evaporation. The volume transport through each gateway is also not expected to be zero, but rather there is a net import or export of volume at each section.

h. expand the discussion of relative eddy contribution to total flux estimates based on C-GLORSv7, which is not eddy resolving for those high-latitude and shallow straits;

Answer: For this point we have to rely on recent publications with a higher spatial resolution than C-GLORSv7 ($1/4^\circ$, not eddy resolving) for a comparison for the effect of spatial eddies on the volume transports, as we cannot conduct such an analysis with our reanalysis product. Concerning temporal eddies (i.e. sub-monthly scale, transient eddies), those would only affect the temperature transports, which we will remove from the revised manuscript. For the net heat transport, we will include a quantification of the effect of transient (daily resolution) eddies on the total transport as estimated from C-GLORS (see also Fig S5 in the supplements).

i. discuss 'good/bad' agreement in comparison with observational flux estimates for different years than 2005-2006 as well as interannual variability of reported fluxes at different gates;

Answer: For this point we also need to rely on estimates published by other authors, because the OBS dataset is currently only available for the period 2005-2006.

j. explain how it is possible to increase volume flux by 0.6Sv between northern Baffin Bay and Davis Strait, when the combined Arctic-wide P-E+R+sea ice transport is 0.2Sv;

Answer: The Arctic wide net freshwater export cannot be directly compared to the Baffin Bay export, because evaporation compensates for some of the export terms (P, R, and ice). The larger export through Davis Strait compared to the CAA obtained in

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our study is in line with Curry et al. (2011). We can address this a bit more thoroughly in our revision.

k. address the discrepancy of the net volume flux estimate for Davis Strait between C-GLORSv7 / OBS and those from Curry et al. (2014) at 1.7Sv for 2005-2006;

Answer: We will have a closer look at this discrepancy for this particular year and include a discussion in our revision. Thank you for bringing this to our attention, as we were only comparing to the 2004-2010 average.

l. discuss the importance of mesoscale eddies, common in Fram Strait but 'missing' in C-GLORSv7, as well as the location of section in Fram Strait on estimates of northward/southward/net volume fluxes across this gate; also, as a follow-up to comment 2a above;

Answer: We will include a more detailed discussion on this topic (p. 8, line 10-30). We are not quite sure which comment the reviewer refers to ('comment 2a above') but from the context we think that the comment is 1h (eddy contribution).

m. address the contribution of the Norwegian Coastal Current (Skagseth et al. 2011) to the volume flux estimates at BSO, likely missing in both C-GLORSv7 and OBS, again as a follow-up to comment 2a above;

Answer: Thank you for raising this interesting point, we will include it in our revision. See comment 1h.

n. address comment 2a in case of Bering Strait;

Answer: See our answer to 1h.

o. compare volume flux estimates presented here against other published modeling results, including: Ilicak et al. (2016), Jahn et al. (2012); Kinney et al. (2014) and address comment 2a again.

Answer: Thank you for providing these references, we will include them in the

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manuscript.

2. Remove details and discussion of temperature transports / fluxes for individual gates, leave the Arctic heat divergence for the net zero volume flux and expend discussion of those estimates and associated uncertainties.

Answer: As stated in the beginning, we will remove this section from the manuscript and include a more detailed discussion on the Arctic net heat export and how it compares to estimates presented by other authors.

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