Authors' replies to
Editor Comment on essd-2022-111

Editor comment on "Sea surface height anomaly and geostrophic current velocity from altimetry measurements over the Arctic Ocean (2011–2020)" by Francesca Doglioni et al., Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2022-111-RC2, 2022

The paper can only be accepted after a major revision of the entire content. In particular I would like to emphasize the fact that satellite data must be validated by in situ data. As noted by one referee, there is only one point of verification: too little to ensure the validity of the results over the entire area under study. The methodology must be better explained and the advantages emphasized more precisely. Last thing: the spatial resolution. Considering the criticisms of the referees. Authors are allowed to review their manuscript which will undergo further re-evaluation

We thank the editor for the opportunity to revise our work, which allowed us to improve the clarity of the manuscript itself and substantially extend the dataset validation. We have responded to all of the criticisms highlighted above. In the following, we give a brief overview over the modifications we implemented accordingly. Further details can be found in our replies to the referees.

1. Improved information on data quality

The main concern expressed by the two referees, and supported by your above comment, regards the data quality and validation. Specifically, the referees asked to include more information about the quality of the source data used to generate the maps, and to extend the validation of the final monthly maps.

To provide more information on the quality of the source data (AWI and RADS), we acted in two directions:

<u>Modification 1.1</u>: We provided in Fig 3 an overview of the AWI and RADS data density (number of data points per 100 km^2) and statistics accompanying the source data, which was commented in section 4.2.3;

<u>Modification 1.2</u>: We added the merged ice-covered and open-ocean along-track data, as processed in this work, to the final data file deposited in the data archive PANGAEA.

In this way we now provide clearer information on the quality of the source data in a 2-stage way, particularly addressing the comment by Referee#2 who mentioned that only one single satellite profile was shown. The manuscript is thus much improved in terms of transparency regarding the quality of the source data. Readers, who want a general overview of the source data characteristics will find this addressed by modification 1.1. Readers who prefer to carry out their own in-depth assessment, will be able to do this building on modification 1.2.

2. Validation

To improve the validation of the final monthly sea level maps, we extended the quality assessment of our gridded sea surface height and geostrophic velocity fields as follows.

Modification 2.1: the validation now includes mooring data in the Beaufort gyre (deep basin in the western Arctic). Sea surface height was compared to data from moorings part of the Beaufort Gyre Exploration Program (BGEP[1]). Geostrophic velocity was compared to velocity data from the BGEP moorings.

Modification 2.2: the validation now includes mooring data in Chukchi Sea (shelf region in the western Arctic). Geostrophic velocity was compared to velocity data from two moorings in the Chukchi Sea.

Modification 2.3: Validation of sea surface heigh fields now include basin scale, monthly comparisons to hydrographic profiles from the central Arctic basins.

With these modifications our validation includes both the eastern and western Arctic circulation regimes, the central Arctic Ocean, Arctic shelf seas and the main exchange gateways of the Arctic. The extension of the validation is a huge effort, and we argue, that all major aspects of the Arctic Ocean circulation are included now. Overall, the extended validation is consistent with our previous results, showing that the correlation with in-situ data is significant where variability on seasonal and longer time scales is present, while it is reduced in presence of intense eddy activity.

3. Better explanation and advantages of methodology, including the dataset resolution

The methodology used to process the in-situ data was revised and improved, furthermore differences / advantages of our methodology to previous approaches were pointed out, following comments from both referees.

Modification 3.1: We checked the processing of in-situ data for possible errors or approximations, which could lower the correlation between in-situ and altimetry data (see especially our replies to comments from Referee#1). This revision was indeed helpful to support the reliability of the in-situ sea surface height estimates. After the revision, the correlation coefficients between altimetry- and in-situ- sea surface height actually improved at all comparison sites, now ranging from 0.5 to 0.9.

Modification 3.2:
In our manuscript discussion we described more explicitly the differences and advantages of our work with respect to what done in Armitage et al. (2016) to derive to CPOM DOT: in section 6.1, we clarify the methodological steps in which the processing of our dataset differs from the CPOM DOT; in section 6.3, we discuss the spatial and temporal resolution of our dataset. The advantages of our work are briefly summarized in the following.

- We used an active approach to filter out unresolved high frequency ocean variability from the along-track satellite data: *i)* we demonstrated the improvement in the correction provided by more recent models for wind- and tide-related variability (i.e., DAC versus IB and FES2014 versus FES2004), and finally applied those; *ii)* we derived the monthly maps as averages of the following four weekly interpolated maps. Through this two-steps approach, we also provided: an overview of Arctic sea-level-variability at sub-monthly timescales; an estimate of the contribution of this variability to the error on the monthly means.

- We used an interpolation radius of 50 km to grid our SLA fields, shorter than the smoothing radius of 100 km used for the CPOM DOT. Given that the solution provided by the DIVA gridding method is derived from a continuous equation, this scale is the one that impacts the effective resolution of the dataset, independently from the resolution of the output grid. Therefore, the resolution is improved with respect to the CPOM DOT.

- The analysis and validation of the realism in the spatial and temporal patterns of our dataset is extended with respect to the work done by Armitage et al. 2016 and 2017. This improvement consists of:

  1. <u>Extended number of regions and dynamical regimes covered by the validation</u>: sea surface height is compared to data from 5 moorings in the Fram Strait, Eurasian Basin and Beaufort Sea and more than 3000 hydrographic profiles distributed across the Amerasian basin, the Eurasian Basin and in the Fram Strait; geostrophic velocity is validated based on data from a total of 19 moorings from the Fram Strait, Eurasian Arctic, Beaufort Gyre and Chukchi Sea.

  2. <u>More in-depth analysis of spatial and temporal patterns in velocity fields</u> (see results in section 5.2.2b and discussion in section 6.3):

     - Regarding the spatial resolution, our results show that the geostrophic velocity can capture transitions from strong to weak mean flow on scales roughly exceeding 50 km, which is consistent with the underlying smoothing of the altimeter data using a 50 km scale;
     - Regarding the temporal resolution, we find that altimetry and in-situ velocity agree best in regions where the flow is dominated by steady currents, with dominant variability at seasonal and longer time scales. Within these regions, correlation coefficients are highest when data are averaged over a cross-flow distance of about 50 km.

     Consistently with the resolution set for our dataset in phase of interpolation, as a result of our validation we show to be able to resolve temporal variability of flow speed of the West Spitzbergen Current when spatially averaged over a 50 km, a narrow but important pathway for Atlantic Water into the Arctic. On the contrary, it is mentioned among the results of Armitage et al. (2017) that the smoothing applied to the CPOM DOT prevents properly resolving this current.

3. Evaluation of currents seasonality by literature review: In sections 5.3 and 6.4 we provide an overview of the seasonality emerging from our dataset and how that compares to literature results. This is indeed an added value to the direct comparison, as it shows the consistency of our results with previously published results, and highlights the usefulness of the dataset for studies of large-scale Arctic Ocean circulation.

References:

[1]Beaufort Gyre Exploration Program: https://www2.whoi.edu/site/beaufortgyre/

Armitage, T. W. K., S. Bacon, A. L. Ridout, S. F. Thomas, Y. Aksenov, and D. J. Wingham, 2016: Arctic sea surface height variability and change from satellite radar altimetry and GRACE, 2003-2014. *Journal of Geophysical Research: Oceans*, **121**, 4303–4322, https://doi.org/10.1002/2015jc011579

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