Interactive comment on "First evaluation of MyOcean altimetric data in the Arctic Ocean" by Y. Cheng et al.

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We sincerely appreciate the reviewer's comments and suggestions on our manuscript which were very constructive. Below you will find our detailed responses on how we are currently improving the scientific quality of the manuscript. Generally, the description of the methods and the statistical significance of the results improved significantly (and we admit that it was quite poor in the first version).

(1)My first concern deals with the statistically significance of some results. Including other metrics and computations would add robustness (see below for more details).
Please see answers to specific comment 4.

(2)Second, some relevant information on the new product is missing and it should be given.
We agree and the related information will be added in the revised manuscript. The MyOcean regional Arctic Sea level product is an improvement over the DUACS Version 3 gridded global sea level product by improving the following steps:
Updated the Mean Sea Surface (MSS) with DTU10 MSS (Andersen and Knudsen, 2009).
Updated the ocean tide model with the TPXO7.2 global ocean tide model (Egbert and Erofeeva, 2002).
Increased the spatial resolution from 0.25°×0.25° to 0.125°×0.125°.
Lowering the along-track Lanczos filtering to a cut-off wavelength of 35 km. We are not aware if any update to the editing and retracking have been performed.

Currently the new MyOcean regional Arctic sea level product have not been released as an official MyOcean product, but it is foreseen that this will be part of MyOcean2.

(3)Third, I found the article too basic, more in line with a technical report rather than a scientific paper.
We acknowledge that the original manuscript was written in great haste to meet the submission deadline. As a consequence the original paper was not mature enough and consequently the paper lacked adequately quality. Taking into account the constructive comments from the reviewers, we are revising the results and paper and updating the scientific quality of the paper substantially and documenting the products and methods adequately over the past month. The revision will provide substantially scientific improvement and with the importance of the subject and we feel that it will be an important contribution to the MyOcean Special issue of Ocean Science.

(4)Fourth, I am not sure this MyOcean product has been specifically designed for sea level trends. I have the impression that the main target was to improve correct representation mesoscale features as well as to enhance the data coverage close to the coast (in areas covered by ice during an important part of the year). This should be clarified and eventually corrected.

The MyOcean regional Arctic sea level product not designed for sea level trend. We decided to remove the section of sea level trend and put more focus on the inter-annual signal which is also the focus of the MyOcean project and where the new MyOcean regional altimetric data was supposed to be improved.

(5)And finally, the authors need to do a major effort to expand the evaluation of the new product,

To make statistics more robust and reliable, a secondary model was introduced to provide an idea about the quality of the SODA model used for comparison of the altimetric products. The MyOcean GLORYS2V1 (available from http://www.myocean.eu/) reanalysis model (1993-2009) was introduced and also used to compare with altimetry data sets. The model assimilated altimetric sea level anomaly, sea surface temperature, and salinity in situ profiles. We mainly focus on the comparison of annual, interannual and intra-annual signals derived from tide gauge (model reanalysis) with that from altimetric data.

For example, power spectra analysis,
However, due to the substantial data gaps in altimetry and tide gauge data, we could only perform the PSD analysis at very few tide gauge locations. We selected data close to Andenes (located on the Norwegian coast) and Ammassalik (located on the east coast of the Greenland) where there are continuous altimetry and tide gauge observations to perform PSD analysis. The results show the similar PSD patterns from different altimetry sea level products and this was also added to the revised version of the manuscript. The seasonal cycle is the major signal in both altimetry and tide gauge observations and lower PSD presented in altimetry observations which will also be discussed.

And mean eddy kinetic energy estimation, as well as comparison with independent data such as drifters or other sources of remote sensing (e.g. SST).

In the present study, we mainly focus on the sea level variations up to inter-annual time sales. Due to the limitation of independent data, we decided not to use these in order to limit the paper and keep it focused on sea level variation. Introducing drifters (like from the Global Drifter Program) will be importance once more drifters become available in the Arctic Ocean.

Answers to specific comments:
1. Introduction: I do not think RADS data can be considered as fully independent as it is also altimetric data.
1. We agree with that it is not fully independent data set. The word ‘independent’ will be deleted in the revised manuscript.

2. Data Set: many details on the new MyOcean V2p products are missing. It is not clear who has developed this product. If the authors have done so, this needs to be stated.
2. As mentioned in response to main comment 2, more details will be given in revised manuscript. The Arctic sea level product was not developed by the authors. In the frame of MyOcean project, the development of Arctic regional sea level product have been developed by CLS (Collecte Localisation Satellites)

Please provide information on:
Editing criteria - *Tidal model and other geophysical corrections* - *Retracking – Along track data filtering and sub-sampling* - *Spatial and temporal correlation scale of the objective analysis scheme* - *Error budget (instrumental and long-wavelength error correction)*

The main improvements in the MyOcean regional Arctic sea level product relative to the DUACS global product are given in response to main comment 2. The MyOcean data set was developed as an update to the DUACS sea level products. Editing criteria/corrections/retracking/interpolation method can be referred to DUACS products handbook.
Unfortunately, the error budget of the product is not available for us, but we introduced errors on the tide gauge observations to investigate if altimetry and tide gauges matched within the uncertainty of the tide gauges.
Currently the new MyOcean regional Arctic sea level product has not been released as an official MyOcean product.

3. Data Set -SODA reanalysis: A sentence on the reliability of SODA sea level trends would be acknowledged.

3. It is generally very hard to get models for the Arcitc Ocean that covers the entire satellite era. SODA model has been used for past sea level reconstruction (e.g., Berge-Nguyen et al., 2008; Meyssignac et al., 2012), we agreed with that the availability of the model in climate scales over the Arctic Ocean maybe constrained by the lack of the in situ measurement and we will describe this limitation. Also we introduced the alternative GLORYS model to investigate the consistency among models in this region.
We removed the sea level trend sub-section in revised manuscript for the reasons mentioned in response to main comment 4.

I do not have any objection against using SODA although it would have been nice comparing also with other MyOcean reanalysis (e.g. GLORYS).

We appreciate this suggestion and introduced the GLORYS reanalysis into the comparison. More on the description of the model is found under main comment 5. The comparisons of annual signal (amplitude and phase) derived from tide gauge data, altimetric data and model reanalysis show the higher reliability of GLORYS2v1 reanalysis than SODA in the Arctic Ocean.

4. Results - Sea Level Variance: 'The MyOcean data set clearly has higher zonally averaged SLA variance, particularly along the coastal regions and around the Queen Elizabeth Islands, which means the quality of the data set is even worse over these regions'. This is not necessary true and needs to be justified. If the new product has shorter spatial and temporal scales (as I guess it may have given the higher resolution grid) it is expected that the variance is going to be higher than the standard product but this does not mean that the quality of the data is worse. This should be validated against independent data.
We agreed that we might have drawn the wrong conclusion in the first version of the paper. The higher sea level variance over some coastal regions is reasonable due to higher spatial resolution of the new Arctic sea level product and the less filtering (35 km vs 60 km).

In order to perform a validation against independent data, the tide gauge data and GLORYS reanalysis derived annual signal are used for the validation. The average RSS (Root Sum of Squares difference taking into account amplitude and phase errors) for all tide gauges and for the altimetric products is between 5 and 6 cm compared with and averaged amplitude of 8 cm of the annual signal which indicate that the data and tide gauges are still far from each other and which calls for much more research in this region. It should be noted that the difference could have two causes. In several places the gauges are situated in rivers which mean that they are more representative of the river flow than the Arctic Sea level. Secondly the altimetric products are still suffering from a high level of noise. However, we demonstrate that in terms of annual signal the new MyOcean product corresponds closer to tide gauges.

We also provide the standard deviation of inter-annual signal derived from tide gauge and altimetric data. The inter-annual signal are under estimated from altimetric data and the new Arctic sea level product fit in-situ measurements better and with lower RMSd of the inter-annual signal.

And also I recommend to perform an estimation of the statistically significance (e.g. confidence intervals) of the variance differences between different products. Power spectra analysis, rms differences between the different products and/or eddy kinetic energy estimates would also provide additional interesting information.

Computing variance differences between different products is not straight forward as the altimeter data are weekly and the models are monthly. Furthermore the tide gauges are either hourly or monthly. As a consequence we provided the sea level variance difference between the altimetry sea level products as well as comparison with weekly averaged tide gauges in a new table. Due to the fact that all data have large temporal voids a PSD analysis could only be performed at two out of 70 tide gauge locations. More discussion will be given in the revised manuscript.

5. Results - Intra-annual sea level signal: some details on the estimation of the intraannual variability are missing. Are the seasonal cycle and interannual variability removed?

We updated the text and detailed how the seasonal and inter-annual signals are removed (i.e., Volkov et al., 2007). Furthermore we have detailed the determined coefficient (percentage of the total sea level variance) of the intra-annual signal. This is done for the various data sets. Finally comparisons with variance at several tide gauges are presented.

6. Results – Figure 5: I would suggest plotting the temporal series of tide gauge and altimetry (DUACS and MyOcean) interpolated at the tide gauge location only, rather than computing the spatial variability of the temporal correlation.

From the spatial variability of the temporal correlation, we can see that the correlation coefficient between the two type data sets depend on the distance between tide gauge and the altimetry observations. The location of the highest correlation coefficient is generally not identical to the closest normal point to the tide gauge (Valladeau and Ablain, 2011). Consequently it is only in-frequently interesting to investigate the temporal time series of the tide gauge and altimetry at the closest point as the local agreement might be different to the regional agreement due to local effects and errors in altimetry close to the coast from i.e. retracking and bad corrections (typically tides, wet troposphere). Hence we find that provided the spatial variability of the temporal correlation is a better measure of how representative sea level variations at the tide gauges are away from the gauge.

7. Results - Annual signal: Please, give more information on how the annual cycle is estimated. Add errors.

We have updated the text to explain that the annual signal (amplitude and phase) is determined using a four parameter least square estimation of the mean, the cosine and sine to the annual signal and the linear trend.

As no errors were available for the altimetric products, we decided to assign error to the tide gauge observations to investigate if tide gauge and altimetry corresponds within this error estimate or to study what a realistic error level on the altimetric products should be. Assuming a sea level error of 1 cm for monthly tide gauge observations (Proshutinsky et al., 2004; 2007; Jevrejeva et al., 2006), leads to an average amplitude error for the determined annual signal of 0.15 cm. This number is shown to be far smaller than the difference between nearly all gauges and the annual signal from satellite altimetry, even taking into account a typical interpolation error of 0.3 cm (Volkov and Pujol, 2012).

8. Results - Inter-Annual signal: Same comments as above. How are the trends estimated? Estimate statistical errors. Is this product suitable for trends?

The interannual signal was estimated by a running mean over 53 weekly altimeter measurements (Volkov et al., 2007).

The trends are estimated with the least square method mentioned above. For the reasons mentioned in response to main comment 4, the section about sea level trend will be removed. Particularly as we are not sure the new Arctic regional sea level product is suitable for trends in the Arctic Ocean or not.

9. Summary: the summary and conclusions are based on very poor statistics. This definitely needs to be expanded by including a more complete evaluation including other metrics.

We acknowledge that the summary and conclusions were based on very poor statistics in original paper. Taking into account the constructive comments, substantial effort has been devoted to update and ensure the robustness and reliability of the statistics over the past month and the revision will provide substantially scientific improvement.
The error of in-situ and altimetry comparison is discussed (e.g., response to comments 4 and 7). The discussion on sea level variance difference between altimetry products are added in revised manuscript. The PSD analysis were performed and discussed in revised manuscript (response to main comment 5). As a complement, the GLORYS2V1 reanalysis has been involved for the comparison. More discussion is given on the comparisons of annual, interannual and intra-annual signals derived from altimetric data sets with that from independent data sets.

10. References: the list of references clearly lacks of many relevant studies closely linked to the topic of this manuscript.

10. A more careful literature study confirmed this and we acknowledge that more related literatures would be included. A few of these are shown below as they are directly relevant to the answers of the questions posed here.

Some references to the answers

Volkov, D. L., Pujol, M.-I. (2012). Quality assessment of a satellite altimetry data product in the Nordic, Barents, and Kara seas. Journal of Geophysical Research, 117(C3), 1-18. doi:10.1029/2011JC007557.

Volkov, D. L., Larnicol, G., Dorandeu, J. 2007. Improving the quality of satellite altimetry data over continental shelves. Journal of Geophysical Research. doi:10.1029/2006JC003765

Valladeau, G., Ablain, M. (2011). Validation of altimetric data by comparison with tide gauge measurements. Altimeter/in-situ validation activities synthesis report for 2010 CLS.DOS/NT/10-289. P9.
Mork, K. A., Skagseth, O. (2005), Annual sea surface height variability in the Nordic seas, in The Nordic Seas: An Integrated Perspective, Geophys. Monogr. Ser., vol. 158, edited by H. Drange et al., pp. 51–64, AGU,Washington, D. C., doi:10.1029/158GM05.