Reviews

We thank the Reviewers for the careful and constructive comments. The suggestions and corrections have greatly improved the quality of this manuscript.

Referee 3

The paper focuses on studying dynamic ocean topography of the Greenland Sea. For this task the authors consider two alternative techniques based on satellite altimetry measurements of the sea surface height and ocean models. The peculiarities of applying satellite altimetry for the study region covered by the sea ice are considered and addressed by using an unsupervised waveform classification approach and the ALES+ retracking algorithm for SSH estimation. Overall, it has been demonstrated that combination of radar altimetry and the Finite Element Sea-ice Ocean Model techniques can lead to better understanding of the Greenland Sea dynamic topography. It is a well written paper worth publishing in the journal. However, I have got some comments that I would recommend the authors to addressing before publishing this manuscript.

Major comments:
3.1 Section 2.3.1 Sea-Ice/Water Discrimination starting p.5. The authors use annual altimetry data to compare with ocean model data. For Arctic regions the altimetry measurements can be affected by a seasonal sea-ice. The unsupervised classification technique is applied to discriminate altimeter waveforms from the open water, including leads, polynyas and Open Ocean (line 4, page 6). In late spring and summer time the sea-ice is covered by melt ponds – pools of melt water formed on the sea-ice (see, for example, NASA's 2014 MABEL campaign). It is not clear if the melt ponds can be discriminated by the proposed classification techniques and if the corresponding measurements were removed from further processing. Can the classification of altimeter waveforms be reliable in summer time? Please clarify and explain the possibility and extent to which melt ponds can affect the measurements of dynamic ocean topography of the Greenland Sea.

Actually, melt ponds can have a direct impact of the classification algorithm. In case of pulse-limited altimetry, also called conventional altimetry, there is no solution or classification algorithm to discriminate between open water between the sea-ice (leads) and open water on top of sea-ice (melt ponds) since the altimeter waveforms look more or less identical (specular returns). This can also be confirmed for example by Tilling et. al., 2018 and by Kwok et. al., 2018.
During summer, it could be possible that melt ponds distort the classification results. Melt ponds, which are assigned to the open water class can cause too short estimated altimeter ranges and consequently over-estimated sea surface and dynamic ocean topography heights.

We added following sentence to the end of Section 2.3.1. **"During sea-ice melt season, melt ponds, water bodies on top the sea-ice layer, can cause uncertainties in the computation of sea surface heights. Classification approaches solely based on radar waveforms from classical altimeters are not able to discriminate between measurements originating from melt ponds or leads at the sea surface level. In case of misclassification the estimated altimeter ranges will appear too short."**

Rachel L. Tilling, Andy Ridout, Andrew Shepherd, Estimating Arctic sea ice thickness and volume using CryoSat-2 radar altimeter data, Advances in Space Research, Volume 62, Issue 6, 2018

Kwok, R, et al. 2018. Relationship between specular returns in CryoSat-2 data, surface albedo, and Arctic summer minimum ice extent., Elem Sci Anth, 6: 53. DOI: https://doi.org/10.1525/elementa.311

Minor comments:

3.2 Line 5 on page 5 – replace "information are used" with "information is used"

We changed the text, accordingly.

3.3 Line 1 on page 6 – a Ref to K-medoids algorithm is missing

A reference was added.

Celebi, M.: Partitional Clustering Algorithms, EBL-Schweitzer, Springer International Publishing, https://doi.org/10.1007/978-3-319-09259-1, 2015.

3,4 Line 9 on page 7 – please specify the kernel size of a moving average filter

The kernel size of approx. 9.13 km was added to the text.

3.5 Line 5, page 8 – What method was used for interpolation of FESOM model data in time and space?

The nearest neighbor interpolation method, was added to text.

3.6 Line 10 on page 9 – replace "physical explained" with "physically explained"

We changed the text, accordingly.

3.7 Line 21, page 9 – can the reference be given for the applied harmonic fitting technique?

The harmonic fitting is just the application of the obtained coefficients to the cosine and sine function for the investigated time period. The mathematical background is given by a Harmonic Analysis and the Least-squares method. We added a reference.

Emery, William J., and Thomson, Richard E.. Data Analysis Methods in Physical Oceanography. Amsterdam: Elsevier Science & Technology, 2014.

3.8 Line 1, page 10 "...differences in the annual amplitudes" – can these phase differences be caused by model sampling issues?

Even if we can not exclude any influence of data sampling on phase estimation, we are confident that our comparison is free of such impacts. The reason is that for the comparison between model and observations exactly identical data sampling is used since the FESOM has been interpolated to the altimetry tracks and epochs. Thus, we are confident that these differences are not related to data sampling issues. The phase shift must be related to the data content (and not the data distribution), More information on causes for phase differences can be found in section 4 that has been updated taking into account comments from the other reviews.

3.9 Line 12, page 16 replace "significant noisier" with "significantly noisier". Please clarify why the altimeter DOT estimates are less reliable in sea-ice areas.

We changed the text. Please also see comment of Reviewer 1. Furthermore, we added a short explanation on the reasons. The sentence now reads:

"For satellite altimetry, the polar oceans are a challenging region, especially, when sea-ice is present. **In these areas, the returned radar echoes comprise signals from different surface reflectors such as different ice types and structures, melt ponds on ice, and open water. The challenge is to extract the valuable information on sea level while disregarding all other reflectors.** Even with the applications of a dedicated waveform classification and a special retracking, as performed here, DOT estimates in coastal and sea-ice areas are **significantly more noisy** than in open ocean."