Response to Referee 2:

We are greatly appreciative of your comments and constructive suggestions which are quite important to further improve our paper from quality to scientific dissemination. In the following text, we will answer all the questions or comments (in italic with black color) one by one with the blue color.

This article presents the impact of satellite sea surface salinity assimilation on an Artic coupled ocean and ice system. Different version of SSS maps derived from SMOS observations in the Arctic are tested. Results show significant impact depending on the region and the product version. In situ observations from different campaigns are used to assess if those changes correspond to improvement or degradation toward the real state of the ocean. They allow to demonstrate the globally positive impact of the assimilation of the latest version compared to the previous one and the simulation without SSS data assimilation. The impact of SMOS SSS data assimilation is also assessed on a more climate- oriented diagnostic, the Fresh Water Content north of 70°N.

This article is well introduced with a clear description of the data and assimilation system used. The results are clearly and rigorously analyzed. The article is original since it shows the benefit of assimilating very recent satellite Sea Surface Salinity product dedicated to the Arctic to constrain a coupled ocean and ice system. Few satellite SSS impact studies were conducted in other regions but not in the Arctic, at my knowledge. I addition, until very recently, the accuracy of such satellite product did not allow their assimilation into ocean forecasting system in the Artic. The perspectives from this study are important. It shows that today Arctic satellite SSS product can be used to monitor and constrain operational system toward more realistic representation of the SSS in the Artic, where in situ salinity observations are sparse. I would recommend the publication of this article after minor revisions.

General comments

I would suggest showing maps of the different SSS satellite products for August and September to complement figure 3 (model fields). This will highlight differences between the product versions and between the different experiments presented in figure 3. It may also help to understand the differences in the increments in the ESS, LS and KS regions shown in figure 8. Since the increments (figure 8) are quite different in regions where no in situ data allows to evaluate their realism, it may be interesting to compare them to the mean SMOS

innovations to see if it can explain the increment differences in expv2 and expv3. As it is difficult to see the SSS differences between the different experiments and the observations when looking at the absolute fields, showing maps of differences may be more efficient to illustrate the results.

-**A**: Yes, the monthly mean for Aug. and Sep. from the two products will be interesting as the reference for understanding the results in Fig. 3 and Fig. 8 as well.

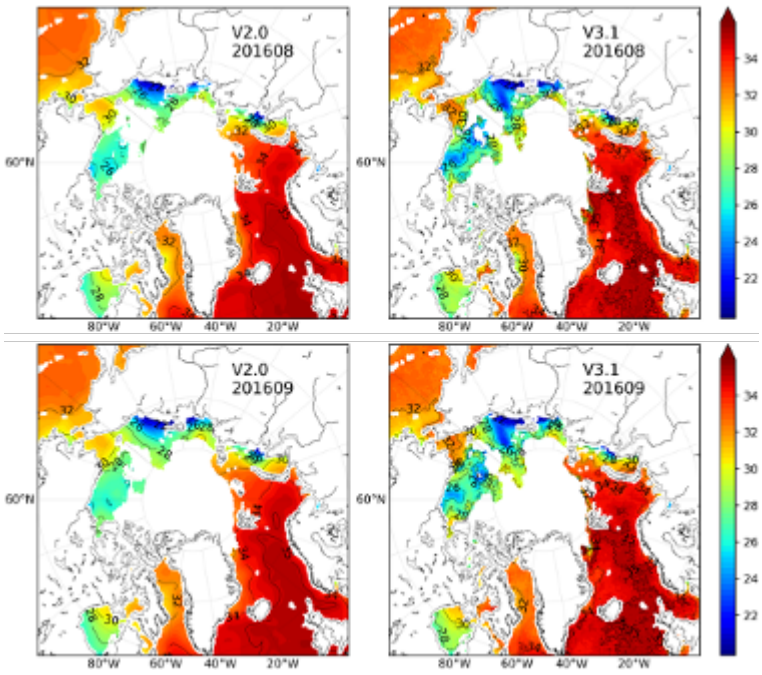

Fig. A1 Monthly SSS of Aug (top line) and Sep (bottom line) in 2016 from SMOS products of BEC V2.0 (left) and V3.1 (right). Note: the solid isolines of SSS are 22, 26, 28, 30, 32,34, and 35 PSU.

In addition, Fig. 8 has been carefully considered and is partially replaced by the SSS difference between ExpV2/ExpV3 and Exp0 in the revision.

In many regions, the model salinity shows less variation than the in situ observations (scatterplots), even if it is still improved with assimilation. For the Chukchi Sea, it is attributed to the climatology relaxation, but do you have any possible explanations for the other regions?

-**A**: The model salinity also used the relaxation to constrain the possible model drift as stated in Section 2.1: “At all lateral boundaries, the temperature and salinity stratifications are relaxed to a climatology combining version 2.0 of WAO2013 and version 3.0 of PHC with a 20-grid cells buffer zone. To avoid a potential model drift, the surface salinity is relaxed to

the combined climatology as mentioned above, with a 30-day timescale, but the relaxation is suppressed wherever the difference from climatology exceeds 0.5 psu to avoid the artificial formation of stable surface freshwater layers."

Overall, the model has less variability in salinity than the observations. One of the intrinsic reasons is that the resolution of the model itself is too coarse to be representative of in situ observations.

In few places in the article, regions are referred with "S number" that may be removed completely with just the use of the acronyms presented in figure 1.

-**A**: Thanks. It will be a good suggestion for well understanding.

Line by line comments :

l.21: Sea ice melt contributes freshwater: missing words?
-A: There is no missing.

l.119: Can you confirm that "the relaxation is turned off wherever the difference from climatology exceeds 0.5 psu." And not the opposite?
-A: Thanks for this comment. It is changed into "the relaxation is suppressed wherever the difference from climatology exceeds 0.5 psu to avoid the artificial formation of stable surface freshwater layers. "

L160: "observation" error: can you give a range for the errors attributed to the different versions? l.230: the root is missing.
-A: The observation error varied in a range of 0.8-1.0 psu as Fig. 3 shows. The missing root is corrected and identical to Eq. 5. For instance, the Eqs. 4 and 5 will be corrected as:

$$Bias = \frac{1}{\sum_{i=1}^{N} O_i} \sum_{i=1}^{N} \sum_{1}^{O_i} (H\bar{\boldsymbol{X}}_i - \boldsymbol{y}_i) \quad (4),$$

$$RMSD = \sqrt{\frac{1}{\sum_{i=1}^{N} O_i} \sum_{i=1}^{N} \sum_{1}^{O_i} (H\bar{\boldsymbol{X}}_i - \boldsymbol{y}_i)^2} \quad (5),$$

Where *i* is the *i*th day, O_i represents the number of observations on this day, and N represents the total number of days depending on the source of observations. Then Xi represents the model daily average at the observation time as the ensemble mean of 100

model members. *H* is an operator to extract the SSS simulation from the model at the observed location.

l.239: The beginning of the sentence is in italic letters.

-A: It is corrected.

L.257: Adding the SMOS "equivalent maps" may help to interpret the differences between the different experiments. Does those differences follow the product differences or "remote differences" exist?

-A: Yes, as you comment it could be a good idea to add these maps. The middle and bottom panels in this figure will show the SSS differences in August and September 2016 between the SSS assimilation runs and the control run as follows:

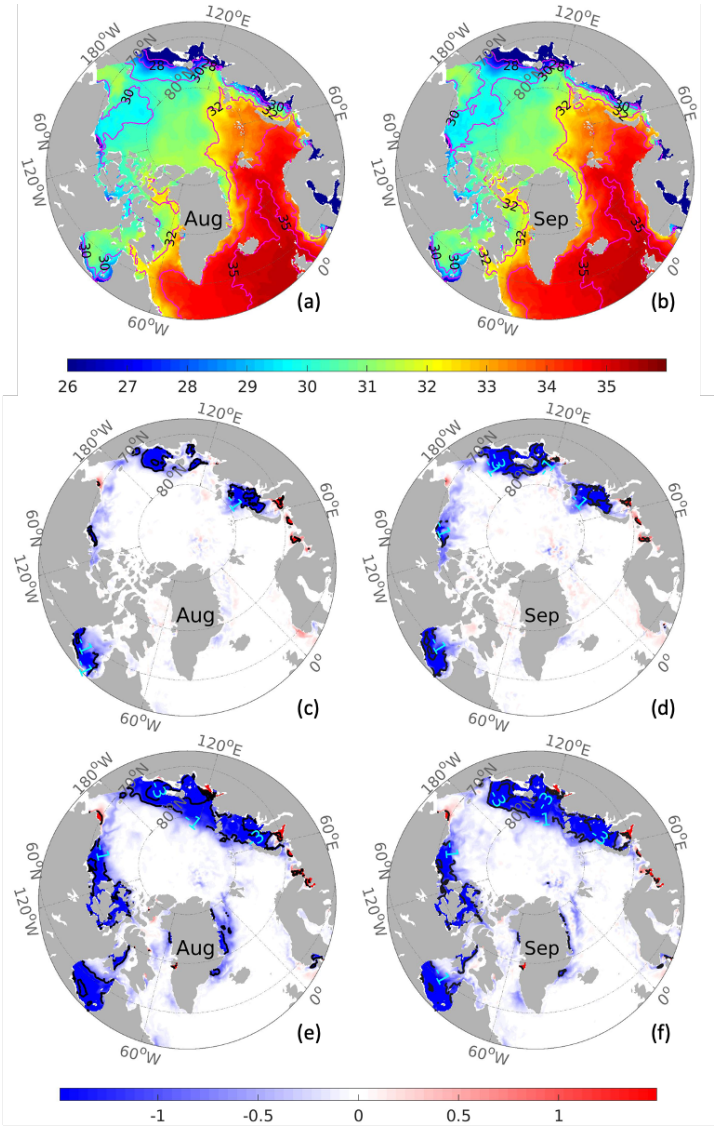

Fig. A2 Top: Monthly simulated SSS (unit: psu) from Exp0 in August (left column) and September 2016. The black isolines indicate the 26, 28, 30, 32, 34, and 35 psu isolines. **Middle and bottom**: the monthly SSS differences in ExpV2 (middle line) and ExpV3 (bottom line) with respect to that in Exp0. The black lines are -3, -1, 1, and 3 psu for SSS.

l.267: "On the European side of the Arctic, the characteristics of the saline Atlantic water are very similar in all the three runs. This is an indication that the model ensemble has a lower standard deviation of SSS." Could it be also due to smaller innovations/higher observation error in those regions?

-A: At least by deriving the pure radiometric error it does not appear that the original SSS field has a higher error in the region (figure from technical note doi.org/10.13140/RG.2.2.12195.58401

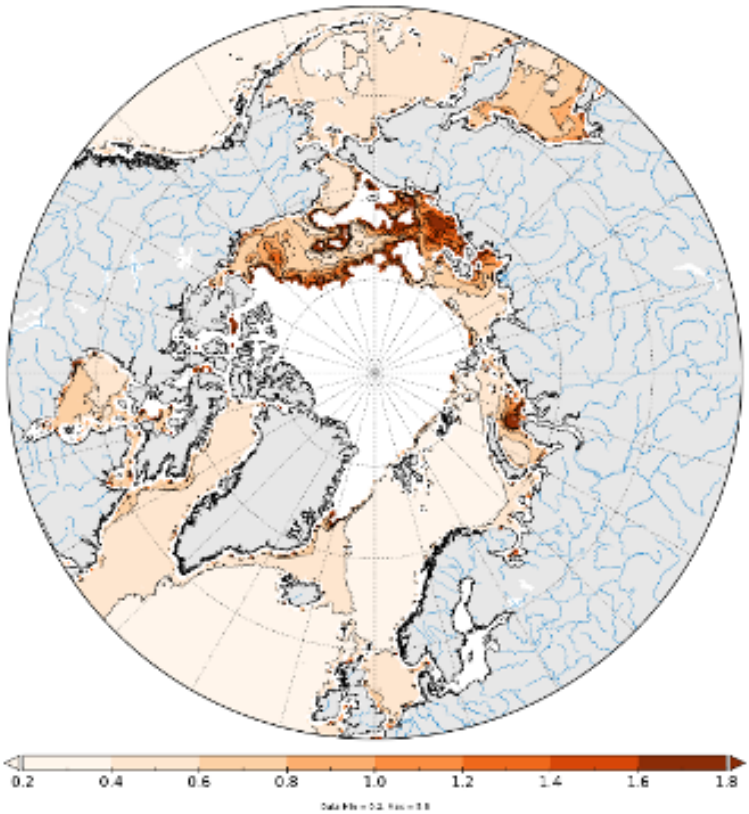

Figure 33: Salinity error derived from the radiometric error. Arctic+ v3.1 map of the period August 11-19, 2012.

However, the SSS gradients are much smaller in the Nordic Seas than in the Central Arctic: 34.9 and 35 psu belong to different water masses so the effective precision could be much higher.

l.408: the acronym FWCL is not defined.

-A: They are corrected by “FWC”.

l.476: S5 and S6 regions are mentioned but only appear in table 2 and not in figure 7.

-A: These kinds of statements about S5 and S6 are deleted for easy understanding.

l.492: S1 is mentioned for Figure 1 but do not appear on it.

-A: It is deleted the same as the above-mentioned.

l.496: though DA -> through DA?

-A: Right, it is corrected.

l.510: I suggest to replace S6 with BB.

-A: Right, we skip all the S? names.

L.532: Space to remove between copernicus. and eu.

-A: Thanks, it is corrected.

L.540: Space to add between Competing and interests.

-A: It is corrected.

l.544: The “link” to PO.DAAC does not work in the pdf, or it appears in blue as a link but is not.

-A: Thanks for this finding. It is corrected.

l.594: the correct link is: https://doi.org/10.5670/oceanog.2016.100

-A: It is corrected.