Ocean Sci. Discuss.,
doi:10.5194/os-2016-104-AC3, 2017

Ocean Science Discussions
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EGU

Interactive comment on "Assessing the impact of multiple altimeter missions and Argo in a global eddy permitting data assimilation system" *by* Simon Verrier et al.

Simon Verrier et al.

simon.verrier@mercator-ocean.fr

Received and published: 31 May 2017

The reviewer made some comments about our study and the associated manuscript. We are thankful for the time and the energy spent to address these comments. The following will answer one by one the comments and questions that have been raised up from the first version of the manuscript.

"Description and explanation of Methods. The authors did not give a clear descriptions of the data assimilation system used in the study. For example, different assimilation window has large impact on the data assimilation results, which is directly related to the observation selections and the disturbed frequency of AR by data assimilation. In this study both observations and anomalies ensemble are different from the Lellouche et

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al., 2013, why you still used the 7-day time window? Further, Authors used the anomalies constructing method similar to the other studies with EnOI method like Oke et al. (2008). This kinds of method needs large member of samples. How it can save the computation cost compared to the 'EOF' methods in SAM2? How many members have been used? How to select these members? How about the localization? Observation errors covariance? What is the control variables? And so on... All these are related to your OSSE results, authors should give a clear descriptions."

- Concerning the assimilation scheme we used, the SAM2 description will be filled out in the manuscript. We kept the setup of the assimilation scheme as it is in the operational system and described in Lellouche et al. 2013 except for the representativity errors we did not take into account here, the assimilation of the full SSH signal and not only the SLA and the uniform observing error covariance matrix (3 cm in RMS).Control variables are the Sea Level, Zonal and Meridional speeds, Temperature and Salinity.Yes, the method is closed to the EnOI used by Oke et al. (2008). SAM2 does not used EOF but a fixed basis of model anomalies is pre-computed. It saves calculation time compared to a classical evolutive filter method. We have used 349 members in a fixed pre-computed basis and their selection and localization are explained in Lellouche et al. 2013. Our filter is not evolutive in the way that error is not propagated by the model. The anomaly basis changed at each analysis cycle : they follow the global model climatology. Analyses results are given for the 7 days of the cycles and forecasts results are given only for th 7th (last) day of the cycle (one forecast is made each 7 days).

"Experiment design. The paper discuss both the impact of Sat 1.2.3 and Argo observation systems on data assimilation system. The derived Argo observation effect to the AR results is shown. The corresponding experiment is deigned by assimilating Argo alone or both Argo and satellites? Please clarify it and supply another corresponding experiment. Further, Authors show the three experiments with one (Jason-2), two (Envisat and Jason-2) and three (Jason-1, Envisat and Jason-2) assimilated satellite data

sets. The other experiments and analysis with single or combined sat. dataset are also need to be addressed."

- This comment deals with experiments design. We chose to not compute a simulation assimilating only Argo since the subject of the study deals with increasing altimetry observations and the complementarity of Argo observations with altimetry, we made that clearer in the introduction. Moreover, experiment design is specified in Table 1. We only computed the experiment assimilating Argo observations and the 3 altimeters data as we found that changing the number of satellites did not change much the T,S error profiles (fig. 13).

"Salinity is not improved too much in AR experiments related to the temperature field. The improvements of salinity among three AR experiments (Fig .13) are very small. Why? Is it caused by poor T-S background error covariance ?The reasons need to be clearly discussed."

- This comment is about how well sub surface temperature is improved by assimilating altimetry observations compared to salinity. Except in the Gulf Stream, salinity is not significantly improved when assimilating altimetry data. It is because in the system, sea level errors are well correlated to upper temperature errors and less to salinity's through the model covariance error matrix. We modified the end of the second paragraph p7 like this: "As density variations are mainly correlated to temperature variations and less salinity variations in most of the ocean regions, this explains why assimilating altimeter data improves more the representation of the temperature fields (e.g. Guinehut et al., 2012)." T/S relationship is in fact embedded in the background error covariance matrix built from a free model long simulation. Though T and S variations are linked to the density through the density equation used in the ocean model (here NEMO, using the UNESCO density equation). Temperature changes have a much larger effect on density than salinity changes in most of ocean regions. The SSH is changed by density changes through the steric effect.

“The study is mainly focus on the overall impact of assimilating Sat.123 and Argo. The evolution of impact is also interested for the T,S,U,V in time.”

- This suggestion is about time evolution of the error. Because we did not want to put too many figures, we only selected profiles and not time evolutions. In both point of view, results lead to the same conclusions. Error on observed variables decreases during the first 6 months (on average) and then keep a constant level. Non observed variables errors are gradually reduce with time but slower than the seal level errors, in many places those errors do not reach a constant value after the almost one year of assimilation.

“The impact of Argo on the SL also need to be addressed. Perhaps forecast errors in SL might reduce?”

- The reviewer suggests to assess the impact of Argo observation on SL scores but we did not show it because it is not significant. We add this information in the manuscript (Last lines of the 4th part).

“fig3. The Global MSE of SL is fast reduced during the first or two month and then keep small variability. And you explain it “The system constrained by the 1/12 âŮę simulated SSH observations converges toward a stable state in 2 to 3 months” Why these happened? Because of the observations coverage or initial conditions or other reasons???”

- The reviewer ask for more explanation concerning the error reduction in time as it can be seen in the figure 3. As long as the observing errors is a fixed at 3cm, only the differences between the initial states at each cycle of the OSSEs and the NR explains the convergence. The fact that we assimilate more observations make this convergence stronger.

“p2 As a following of Turpin et al. (2016), it seems to not true in the beginning of the manuscript : “Analysing the impact of altimetry and Argo in a global data assimilation

system through OSSEs has, to our knowledge, not been carried out at least in recent years""

- Here we address the problem with OSSEs and not OSEs that have been done extensively in recent years.

"The OSSEs is from January 7, 2009 to end of 2009. So it is not the 1-year OSSEs. Please correct it."

- For this point we corrected it in "almost one year".

"p2 Line 7, "results for existing observing systems must be consistent with those derived from OSSEs.", why must be consistent?"

- This comment address the fact that if OSSEs and OSEs do not show the same results it implies that OSSEs are not correctly calibrated. Here the goal is to study how a system close to the operational one works in an ideal case. Thus the errors of our OSSEs need to be close to the error of the OSEs when assimilating real observations.

"p3 "...within the upper 100m and with 1m resolution at surface up to 450 m at the bottom...", make it clearly"

- The reviewer suggests to clarify the vertical size of the grid. m The vertical resolution increases from 1 m for the surface layer to 450 m at 5000 m depth. We changed it in the manuscript.

"p3 Line 20. "... our best estimation ...", How about other setup of NEMO or other models, observation. Why you say it is the best one..."

- The NEMO at 1/12° of resolution is at the state of the art in term of high resolution oceanconfiguration. Comparison with other high resolution model such as HYCOM were conducted and shows globally the same level of quality. Those simulations are very realistic. In fact the free model estimations are not the best for the surface and subsurface ocean variability. The best are the analysis that includes both model and

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observation information. So we remove the word “best” and replace it by “good”.

“p5 Line 11 “The error level of the analysis with one altimeter is close to the forecast error level when two or three altimeter data sets are assimilated.”. why? One altimeter doesn’t work in you AR experiment? Please explain it.”

- This comment is misunderstanding that if analysis error with one satellite is close to the forecast error with 2 satellites do not mean that the one satellite simulation does not “work. For each data assimilation experiment, the analysis error is lower than the forecast error showing the benefit of the data assimilation. It happens that the forecast error level with two assimilated altimeters is close to the analysis error level with one altimeter. We do not have explanation on the reason why.

“p.5 Line 8-9, make it clearly. Why you compare the Sat2 to Sat1 and Sat3 to Sat2, not Sat3 to Sat1?”

- We do not compare Sat3 to Sat1 because we assess the improvements brought by each new altimeter and do not want to add more figures.

And we finally changed the unit in Fig2.

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