Response to Referee #1 on *"Accuracy of the Mean Sea Level Continuous record with future altimetric missions: Jason-3 vs. Sentinel-3a"* by L. Zawadzki and M. Ablain, received and published the 22nd September 2015

Thank you for your very interesting review of our paper. Please find below our answers in red with the corresponding modifications. In the modifications, I refer to the lines in the version you reviewed, not the new one.

Major comments:

1. This work has a basic contradiction in its approach to estimating the bias error between two satellite missions that should be addressed. An assumption appears to be made that the bias error can be estimated by constructing simulated data that has natural variability taken from an ocean model combined random errors the errors from the Jason-1/Jason-2 cal/val phase. Experience in error sources from altimeter missions would suggest that the errors are not simply random errors, but are often geographically-correlated. The actual errors are a combination of once-per-revolution and other orbit determination errors, drifts and sudden offsets in the wet troposphere correction, tracker errors and biases from non-ocean like surfaces, etc. The authors implicitly acknowledge that there are geographical biases, by estimating the bias error for a region, implying that the regional bias is potentially different from the global bias. However, their simulated data does not adequately reflect geographically-correlated errors. My guess is that is why the simulated errors are lower than the results from Jason-1/2 and Envisat. I feel that these results are flawed by considering only errors that are temporally-correlated.

> **Response 1:**
> The methodology does not, indeed, take into account potential POD errors, drift and offsets in the radiometer measurements. I thoroughly agree with this: these errors would increase the relative bias uncertainties (RBU) for both J2/J3 and J2/S3a cases. However, adding them to our simulation would be both very difficult (and thus very controversial) and, I think, pessimistic because the biases are estimated over 9 cycles only.
> I could not agree more that these errors are most probably present between J1 and Envisat, but also J1/J2 which certainly explains why the simulated errors are lower than the results from real altimetric series. Moreover, the J1/Envisat time period we had to take for our estimation is about 120 cycles (shifting iteratively a 9-cycle window with a 10-day subcycle for Envisat), which is a lot larger than the 9-cycle time period considered in the simulations.
> As for the geographically-correlated errors, I am not sure I understand your point: the relative biases are computed using the cycle-per-cycle Global (or at basin scale) Mean Sea Level so the geographically-correlated errors have already been averaged in the pre-process. We then add correlated noises to these time-series and not along-track if these was unclear (but I agree that the methodology part needs clarifications).

Modification 1: (Page 1516. Lines 16-17)

…strongly impact the results and should be designed carefully. The correlated noise does not take into account possible drift or offsets in the radiometer measurements that would increase the uncertainty, mostly because even though these events may potentially happen, it would be a pessimistic assumption. An estimate of the relative bias is computed from the simulated MSL series over 9 cycles.

2. The methodology section could be clearer in several sections. Many of the details about the methodology appear in a report (Zawadzki and M. Ablain 2014) that does not appear to have been peer reviewed. More of the details of the construction of the synthetic data that are included in the appendix of that report should appear somewhere in this paper.

Response 2:

I agree: I worked on it. It was also a request from 2nd referee. I Hope this is clearer now.

Modifications 2:

(Page 1515 Line 12)

The calibration phase between Jason-2 and Jason-3 allows us to make the reasonable assumption that the impact of oceanic variability sampling on each MSL series is negligible because both altimeters measure the same ocean at almost the same time (less than 1 minute) with respect to the MSL record temporal resolution (about 10 days).

(Page 1516 Line 2)

which – in this paper – are considered identical during the calibration phase

(Page 1516. Lines 12-13)

Firstly, the variances of Jason-1, Jason-2 and Envisat "real" GMSL time series were estimated. Secondly, a spectral analysis of Jason-1, Jason-2 and Envisat GMSL time series was performed. The noise was then tuned so that the variance and correlation period of the simulated GMSL time series are consistent with these analysis, see Tab. 1. It is however worth noting that its characteristics strongly impact the results and should be designed carefully

3. With the North Atlantic, the authors have chosen a particularly challenging region to estimate a regional bias error. The basin is relatively small and as they acknowledge, it is dominated by mesoscale variability. If the bias were truly a constant in the region, it would be more effective to either mask out the mesoscale portions or downweight them, which should reduce the bias error.

Response 3:

This is a very legitimate comment. If we had taken a region in the Pacific for example, the RBU would probably be smaller. It was actually the whole point to take a region of high mesoscale variability in order to estimate an "upper bound" of the RBU at basin scale. We also tried the Indian ocean and the results suggested a similar uncertainty (9mm) but it is probably due to the ACC. I mitigated our results by better explaining this choice and its consequences.

Modification 3: (Page 1517. Line 25)

Thus, we adapted the methods for the global scale to refine the analyses at the regional scale with a focus on North Atlantic Basin. This region is dominated by mesoscale variability and is thus a challenging choice because it will increase both components of the relative bias uncertainty. The intention here was to estimate an "upper bound" of the uncertainty, but results could be more mitigated in other basins (e.g. East Pacific). However, because of this variability, the correlated noise used for this specific region is also more difficult to design, see **Erreur ! Source du renvoi introuvable.**.

4. The paper should address the impact of errors in the current mean sea surface models on mean sea level measurements made by Sentinel-3A initially on the new ground track. Deviations of from the nominal track will sample areas where the mean sea surface has not been measured before. The authors can cite results from the Jason-1 geodetic phase, which sampled a new ground track. While the mean sea surface along S3A's ground track will eventually be well-determined, this could increase the error in including S3A in the climate record. This paper does not include these errors in the simulation of determining the Jason-2/S3A bias.

Response 4:
Very good point, this will definitely have an impact at first! It is actually more an error than an uncertainty: we will be able to correct it when a consistent MSS (assimilating S3A measurements) will be derived. The uncertainties I computed in this study can however not be corrected. Therefore, I do agree that this problem should be mentioned, but I do not think too much effort should be spent on this matter in the paper.

The lack of S3a measurements in the MSS solution will lead to a rise of the MSL variance for each cycle. Some results presented in a poster at last OSTST (Roinard et al., 2015) show that the SLA variance of Jason-1 was raised by 0.5 cm² globally after it changed orbit.

According to our MSS experts, this is a problem that is currently being explored (for example when SARAL left its nominal ground-track for a while) but not much has been done yet in the literature to measure this impact in general.

Basically, everything happens as if the S3a MSL quality was lower than J2's, which is indeed not consistent with our working hypothesis.

Quick test: I interpolated the error of the CNES/CLS MSS (given by the optimal interpolation) on Jason-2, Envisat and Sentinel-3a ground-tracks. Envisat and Jason-2 were integrated in the MSS solution, therefore the MSS error is locally between 0 cm and 1.5 cm (except at very high latitudes) and the global RMS is about 1 cm. For S3a, the local MSS error is between 0 cm (for some tracks) and 5 cm and the global RMS is about 2.6 cm.

Modification 4:

The reader's attention is being drawn to the fact that this hypothesis does not take into account the impact of the Mean Sea Surface (MSS) model. Indeed, the error budget must take into account the quality of the MSS model over the mission ground-tracks. However, Sentinel-3a is on a new orbit that has never been repetitively sampled. Thus, as long as the MSS model is not reprocessed with Sentinel-3a measurements, the impact in its error budget will be larger than in Jason-2 and Jason-3's, see (Dorandeu et al., 2004). In this paper, we did not take this temporary error into account and made the hypothesis of similar error budgets to focus on the impact of the new Sentinel-3a ground track on MSL trends.

5. It is not clear what the length of the Sentinel-3A/Jason-2 overlap period was assumed to be. Also, in constructing the Sentinel-3A/Jason-2 bias differences, it is not clear what time sampling was used. The ~10-day Jason-2 cycle? The Sentinel-3A 27-day cycle?

Response 5:
Indeed, my mistake!

Modification 5: (Page 1517. Line 13)
For this, their respective simulated MSL series are compared without addition of high frequency correlated noises simulating SSH errors: the set of relative bias estimations is only computed by changing the common period. Since Jason-2 and Sentinel-3a have different repetitivity cycles (about 10 days for Jason-2 and 27 days for Sentinel-3a), a 10-day subcycle is used for Sentinel-3a GMSL series. The relative bias is again estimated over 9 cycles. In the case of the second component,…

Minor comments:

page 1512, line 16: Reword "would prevent from meeting climate users requirements" to "would not meet climate users requirements".

page 1513, line 10: Better references for the GMSL time series are: GSFC (http://climate.nasa.gov/vital-signs/sea-level/) and NOAA (http://www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/)

page 1513, line 11: Change "orbits" to "orbit".

page 1513, line 12-13: The calibration phases were 20 cycles or 200 days, which is slightly less than 7 months rather than 9 months.

page 1513, line 14: "a few seconds apart" implies that the separation times were <5 seconds. T/P and Jason-1 were separated by about 71 seconds and Jason-1 and Jason-2 were separated by an average of 55 seconds. It would be more accurate to a say "about 1 minute apart".

page 1513, line 26: Update the expected launch date of Jason-3.

page 1513, line 28: 7 months rather than 9 months

Page 1516: In several places in the draft "Noises were", "noises have", etc. should be "noise was" or "noise has", etc. "theses noises" should be "this noise".

Response : OK, everything taken into account