Ocean Sci. Discuss., 9, C843–C849, 2012
www.ocean-sci-discuss.net/9/C843/2012/

Ocean Science Discussions

Interactive comment on "Evaluation of Release-05 GRACE time-variable gravity coefficients over the Ocean" *by* D. P. Chambers and J. A. Bonin

D. P. Chambers and J. A. Bonin

dchambers@marine.usf.edu

Received and published: 10 August 2012

Thank you for your comments. We will review them briefly below and then give our response. Regards, Don & Jenni

1. "In addition to the de-striping method originally devised by Swenson and Wahr (2006), a number of alternative filtering approaches have been published during the last years that all attempt to reduce the systematic meridional stripes in the GRACE fields. For example, Kusche (2007) devised a Tychonow regularization-like method that can be applied to the GRACE Level-2 gravity fields during post-processing. The method directly relies on the error covariance information provided by the processing centers and therefore avoids any ad-hoc tuning efforts as discussed in your section 4. Since the method by Kusche has been made available to a number of groups world- wide

and has shown to work favourably for both ocean and continental applications (i.e., no signal reduction in higher latitudes), I suggest to consider it also for the analyses presented here."

Reply: Besides the Kusche (2007) filter, we know of at least 3 other methods (Wouters and Schrama, 2007; Davis et al., 2008; Boening et al., 2008) that have been utilized in the literature to de-stripe data. The goal of this paper is to show the improvement of RL05 data compared to RL04 using a consistent post-processing scheme. Therefore, we have selected the method we are familiar with, and perhaps more importantly, the only one that is used to create gridded data that is publicly distributed, updated regularly, and widely used by a larger scientific community. The quantification of improvement should not change depending on what post-processing scheme is applied. Thus, we feel that using a single approach throughout the analysis is adequate and we will not be adding evaluations using other de-striping algorithms. While it would be interesting to work with all the authors of de-striping algorithms to evaluate them in a consistent manner in the future, such a study would be more fitting as a separate paper.

Boening, C., Timmermann, R., Macrander, A., Schröter, J, 2008. A pattern-filtering method for the determination of ocean bottom pressure anomalies from GRACE solutions, Geophys. Res. Letts, 35, L18611, doi:10.1029/2008GL034974. Davis, J.L., Tamisiea, M.E., Elósegui, P., Mitrovica, J.X., Hill, E.M., 2008. A statistical filtering approach for Gravity Recovery and Climate Experiment (GRACE) gravity data, J. Geophys. Res., 113, B04410, doi:10.1029/2007JB005043. Wouters, B., Schrama E.J.O., 2007. Improved accuracy of GRACE gravity solutions through empirical orthogonal function filtering of spherical harmonics, Geophys. Res. Lett., 34, L23711, doi:10.1029/2007GL032098.

2. "The errors of JPL_ECCO and OMCT are certainly not uncorrelated, since both models share a number of common bits of information (e.g., primitive equations including Boussinesq and hydrostatic approximations are used, spatial resolution is compa-

OSD

9, C843–C849, 2012

rable, atmospheric forcing is essentially based on identical meteorological observations that were assimilated into NWP models). Those correlations are primarily responsible for your apparently negative errors that finally led to the rather crooked blending of sigma_E-A into the final error maps. I suggest eighter to remove this error assessment section completely, or at least replace the apparent negative errors by NaN values in the plots in order to make clear where this error assessment method obviously fails. In any case, the assumption of uncorrelated errors needs to be emphazised and critically discussed."

Reply: While it is true that JPL_ECCO and OMCT do share some common background physics that could lead to common errors, there are clearly enough differences to lead to large differences in the high latitudes, or else the calculation would not lead to the large positive values it does in these areas (e.g., Figure 9). First, one is data-assimilating, the other is not. Second, the differences in the output from the NWP models is quite large, again indicating different forcing. Finally, the resolutions and parameterization of small-scale features like eddies are sufficiently different to again lead to uncorrelated differences.

It is true that these differences are smaller in the tropics where the full signal size is also smaller, which is why we had the negative numbers. However, we still feel it is more appropriate to put in an estimate of the error based on the model differences in these regions, rather than to put in NaN values and give no error estimate at all. Note that for the GRACE error assessment, we actually replace with the difference between GRACE and JPL_ECCO, which is an upper bound. We realize that this was not made clear in the original text. To address this concern, however, we have revised the text somewhat to discuss the fact that there are some correlated errors between the models (especially in the tropics) and to emphasize that where the computation breaks down we put in an upper bound for the GRACE uncertainty. We have included the following sentences after Equation (2) in the revised text (formerly, Equation (1)):

“The two models share some common heritage, in the form of the starting primitive equations, and so will have some common errors. This means that the assumptions underlying Equation (2) are not strictly valid. However there are substantial differences in the models, such as the fact that JPL_ECCO assimilates data while AOD is simply a forced run, the winds, heat and freshwater fluxes come from two very different numerical weather prediction models, and parameterization of smaller-scale features (eddies, bathymetry) are different. Thus, we believe that the differences are far larger than the potential common errors, and that Equation (2) is a reasonable approximation to computing a better standard error in the GRACE maps then simply using the difference between GRACE and any one model, since this assumes no error in the model. The largest differences between the models are found in shallow waters and at high latitudes, while the smallest differences are found in the tropics where there are no significant OBP variations. The small difference in the tropics means that the computation of either εA or εE sometimes results in a negative sign. When this happens, we assume uncertainty is σE-A (the difference between the models), which is an upper bound of the uncertainty, as it assumes one model has no error. The computation for εG does not suffer from this problem, but when the value of εA or εE is replaced, we also replace the value of εG computed in Equation (2) with σG-E (the difference between GRACE and JPL_ECCO), which again represents an upper bound of the error. This occurs in less than 5% of the grids, all in the tropics.

3. "C_20 coefficients of RL05 were found to be much more consistent with SLR then before, a replacement of those coefficients does not appear to be necessary anymore. Your suggestion on this issue might be valuable for the paper."

Reply: This is only true for the GFZ solutions, likely due to the fact GFZ uses a background time-variable model based on RL04 coefficients where the C20 value had been replaced. The JPL and CSR C20 time-series still are quite different from the SLR time-series. We found no statistically significant difference between replacing the GFZ coefficient and not replacing it, so replaced to be consistent. We have revised the first paragraph in Section 3 to read:

OSD

9, C843–C849, 2012

Interactive Comment

“The new RL05 coefficients were initially processed exactly as the RL04 coefficients described in Section 2, with the exception that the geocenter estimates are based on RL05 GRACE gravity data combined with RL05 Atmosphere-Ocean Dealiasing (AOD) OBP from the GAD files using the method described in Swenson et al. (2008). The C2,0 coefficients in the GFZ_RL05 solutions are considerably closer to the SLR estimates than either the CSR_RL05 or JPL_RL05 solutions, likely because GFZ uses a background time-variable gravity model based on RL04 coefficients where the C2,0 value had been replaced with that from SLR. We tested statistics with and without replacing the C2,0 coefficient in the GFZ_RL05 data, and found they were not significantly better. Since replacing the C2,0 coefficient is still required for CSR_RL05 and JPL_RL05, we chose to replace the coefficient for consistency.”

4. "From my understanding, the method has been developed by Swenson and Wahr (2006), whereas Chambers (2006) only suggested to slightly modify the way the filtering coefficients are obtained. Calling this an ’algorithm development’ is certainly an overstatement."

Reply: We have changed the sentence from:

“In Chambers (2006), we developed an algorithm to reduce these stripes caused by the correlated error and tested this on RL02 data.”

To

“In Chambers (2006), we modified the algorithm proposed to Swenson and Wahr (2006) to make it more applicable to the longer-wavelength, small amplitude OBP variations and tested it on RL02 data.”

5. "There are substantial differences among OMCT RL04 and RL05, but those where not implemented to "correct obvious deficiencies", which where not so obvious only some time ago. Instead, since OMCT RL04 is based on a model version that were not changed since 2006, RL05 incorporates improvements from both an increased spatial

resolution as well as various changes in parametrizations obtained from validating the model against a number of data-sets not available in current quantities before 2006. RL05 can be therefore seen as an evolution of RL04, not simply a version that has been bugfixed as it might be anticipated by your formulation."

Reply: This was a poor choice of wording in the original draft. We have changed that sentence to:

“There are significant differences between the RL04 version of the OMCT model and the RL05 version, mainly to improve resolution and incorporate changes in parameterization that allowed better matches with in situ observations not available when the original version was held fixed for GRACE processing. One aspect that has improved is the high-frequency variability, which is important for de-aliasing. The RL04 version has been shown to have significant deficiencies at periods less than a month in two recent studies (Bonin and Chambers, 2011; Quinn and Ponte, 2011; 2012).”

6. "It might be worth to investigate reasons for this discrepancy in the Arctic. Are there differences in the tide models applied by the different centers?"

Reply: Since submitting the first version , we have investigated this further and have discovered that GFZ did use a different tide model, with substantial differences in the Arctic. We suspect this may be the cause, but cannot prove it. We have added the following statement:

“One major difference between the CSR, JPL, and GFZ processing is the use of background ocean tide models. CSR and JPL use the GOT4.8 model, while GFZ uses the EOT11a version. This may be the source of the difference, and should be investigated further by the processing centers.”

7. "The errors are certainly not "well-behaved" in a mathematical sense. Please reformulate."

Reply: This was addressed under our response to Comment 2.

8. "The comparisons shown here might only be used as an indicator of the reliability of monthly mean bottom pressure fields. It should be made clear that overestimating the monthly mean in OMCT RL05 (with respect to an assimilated ocean model) does not necessarily imply a poor prediction of sub-monthly variability, which is effectively important for sucessful de-aliasing. This might be assessed wrt. daily satellite altimetry maps as done in your previous work, but it is certainly not the scope of this study."

Reply: This is a good point. We have added the following statement to clarify this:

“The uncertainty at high latitudes where OBP variability is large, especially in the Southern Ocean, is approximately the same in the GRACE maps as it is estimated to be in the JPL_ECCO model. Both are significantly smaller than the estimated uncertainty in the AOD model in regions of high OBP variability. We note that this applies only for the monthly and longer periods, and the same problem may not be seen in the AOD model at periods shorter than a month. This would require additional testing, which is beyond the scope of this discussion.”

Interactive comment on Ocean Sci. Discuss., 9, 2187, 2012.