Global Ocean Tides from GRACE Satellite Accelerations

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Introduction

GRACE measures gravity fluctuations using two satellites in the same low-earth orbit. One satellite is ∼ 220 km ahead of the other, and the two satellites are connected by a microwave ranging system that continuously measures their relative separation distance. Because the first satellite is ahead of the second, it's affected by differences in local gravity before the second satellite. This delay can be used to deduce the underlying gravity variations. Many GRACE projects describe these gravity variations using spherical harmonics, but we chose to use mass concentrations (or "mascons") to parameterize variations in local gravity. More information is available in [1].

Conclusions

1. The mascon fields have much larger tide amplitudes in the ocean than on land, and are mostly larger where FES2004 is also larger.
2. Two independent solutions (each using 4.5 years of GRACE data) are subtracted to provide another estimate of the uncertainty in the inversions which agrees with the land tide estimate.
3. Two semi-independent methods are used to optimize the regularization parameter for each tide. Verification acceleration residual minimization suggests that 230km mascons allow for a better solution than 400km mascons. L-curve analysis for K1 suggests that adding weak regularization decreases the residuals of accelerations used in the inversion, which shouldn't be possible. This is currently under investigation.

The source code is available at

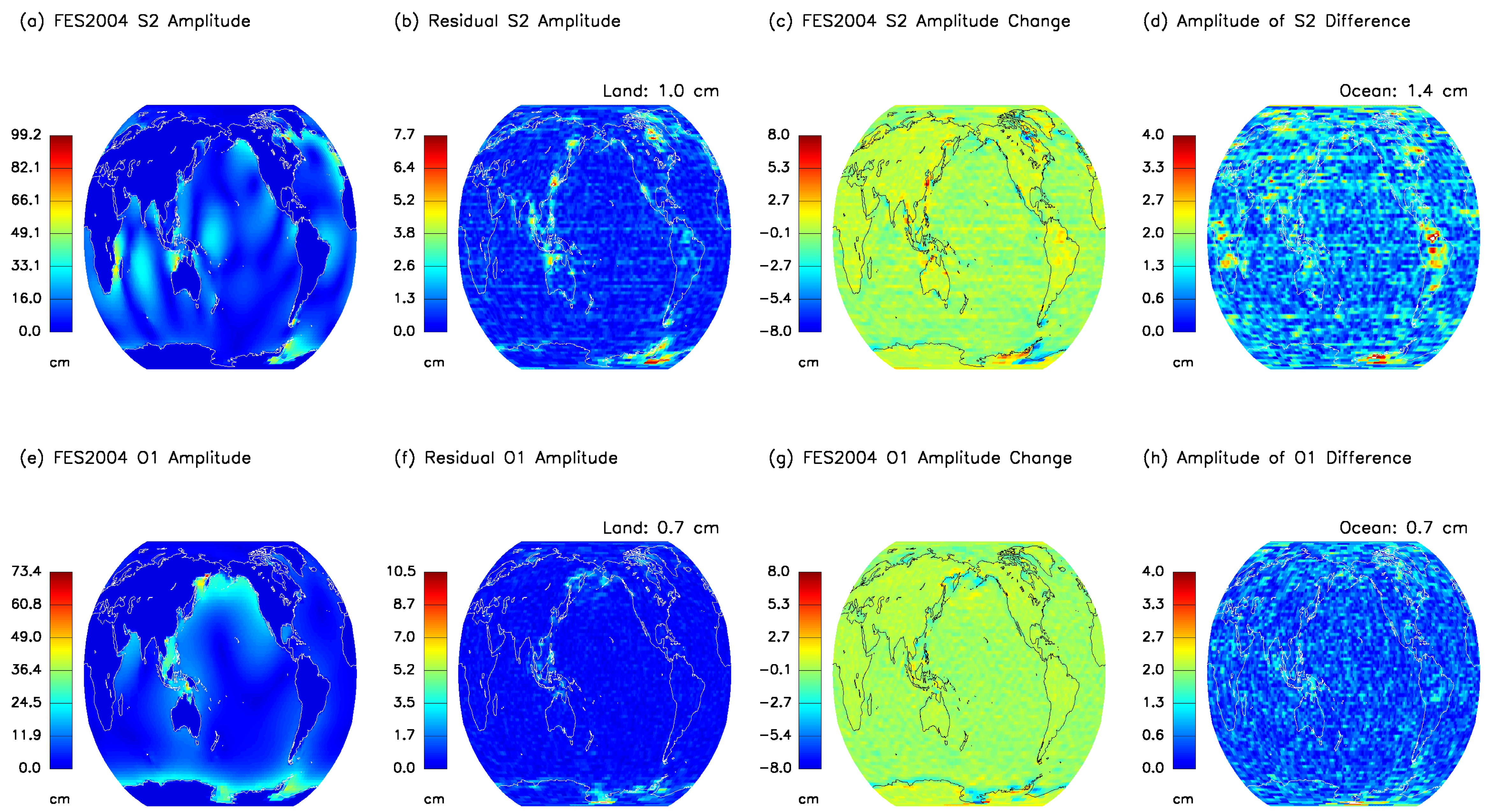
`http://bryankillett.com`

References

1. Killett, B., J. Wahr, S. Desai, D. Yuan, and M. Watkins (2011), Arctic Ocean tides from GRACE satellite accelerations, J. Geophys. Res., 116, C11005, doi:10.1029/2011JC007111
2. Hansen, P.C., (1999), The L-curve and its use in the numerical treatment of inverse problems

Tidal Residuals

9 years of GRACE inter-satellite accelerations are inverted to solve for corrections (b and f) to the FES2004 tide model (a and e). The average tide amplitudes on land are shown for each correction. Amplitudes and phases for S2 (top row) and O1 (bottom row) are solved separately; each inversion also estimates the annual cycle and secular trend. Next, the corrections are added to FES2004 to show the change in FES2004 amplitude (c and g), which accounts for the phases between FES2004 and the corrections. Finally, the GRACE accelerations are split in two 4.5 year segments, each is inverted for tides separately, then those solutions are subtracted to obtain uncertainty estimates (d and h). Note that the average ocean amplitudes in these uncertainty estimates agree with the land tide uncertainty estimates.



Regularization Parameter

Tikhonov regularization (damping) is applied during the inversion of GRACE data; larger values of the parameter lambda produce a smoother solution. The residual of "verification" accelerations NOT used in the inversion is plotted vs. lambda for M2 (a) and K1 (b), for mascons spaced at 400/230/100 km. Notice that M2 and K1 have different optimal lambdas. For M2, decreasing the mascon spacing reveals a deeper, sharper minimum which occurs at a smaller value of lambda.

Next, the solution norm is plotted vs. the residual of accelerations that WERE used in the inversion to produce L-curve plots for M2 (c) and K1 (d). The value of lambda is printed next to each point. L-curve plots are used to optimize lambda because regularization is a trade-off between a noisy solution (large norm) and an overly smoothed solution (large residual). The K1 L-curve is puzzling, because adding regularization shouldn't decrease the residual [2].