SPECTRAL ANALYSIS OF RESIDUAL GRACE AND GRACE-FO RANGE ACCELERATIONS

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A – ABSTRACT

GRACE and GRACE-FO K-band range-rate post-fit residuals obtained after a common estimation of monthly gravity field coefficients and ancillary satellite parameters represent a complex superposition of different effects. In this contribution, we analyze the component of the residuals that is related to geophysical effects. We low pass filter and differentiate range rate post fit residuals to obtain residual range accelerations. A spectral analysis of globally gridded residual range accelerations reveals unmodeled signal related to (ocean) tides and hydrology. The time series with approximately 100 millions of data records allows us to identify main periodic contributors in different bands. Diurnal and semi diurnal signal can be resolved on a 5x5 degree grid, while periods of 5 and 3 hours can be resolved on a 7.5x7.5 and 10x10 degree grid.

B – K-BAND POST-FIT RESIDUALS

We analyze GRACE and GRACE-FO K-band range-rate post-fit residuals covering the time span 2002-2022. The residuals are obtained as part of the gravity field recovery process of monthly solutions **[1]**. For orbit propagation (state-of-the-art) models were used, among them FES2014b **[2]** (ocean tides) and AOD1B-RL06 **[3]** (non-tidal atmosphere and ocean, atmospheric tides).

We define GRACE K-band post-fit range-rate residuals as follows:

$$\hat{\mathbf{v}} = \mathbf{A}_{\sim \mathrm{AB}}\,\hat{\mathbf{x}}_{\sim} + \mathbf{A}_{\oplus \mathrm{AB}}\,\hat{\mathbf{x}}_{\oplus} - \mathbf{l}_{\mathrm{AB}}$$

with $\hat{\mathbf{v}}$: estimated K-band range-rate post-fit residuals, $\mathbf{A}_{\sim \mathrm{AB}}$: design matrix of arc specific parameters, $\mathbf{A}_{\oplus \mathrm{AB}}$: design matrix of global parameters, $\hat{\mathbf{x}}_{\sim}$: estimated arc specific parameters (initial states, accelerometer bias, empirical parameters), $\hat{\mathbf{x}}_{\oplus}$: estimated global parameters (spherical harmonic coefficients, accelerometer scale matrices), and $\mathbf{l}_{\mathrm{AB}}$: reduced K-band range-rates.

C – SPECTRAL ANALYSIS OF POST-FIT RESIDUALS

1: Low pass filtering of post-fit range-rate residuals

2: Numerical differentiation of low pass filtered post-fit range-rate residuals

3: Assigning obtained residual range-rate accelerations to grid cells (→ D)

4: Lomb-Scargle periodogram of time series at each grid cell

5: Scanning each periodogram for amplitudes larger than 3 sigma

6: Plot all found amplitudes in a common plot as points (→ E)

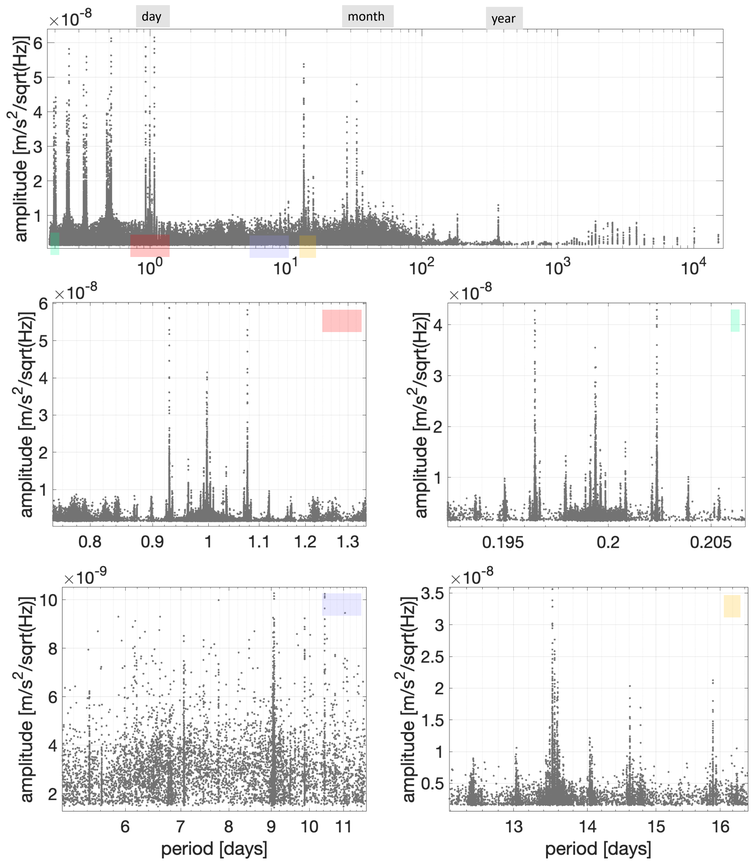
D – RESOLVABLE PERIOD

grid cell size [°]	limit [d]
1x1	10.6
2x2	3.4
3x3	1.3
4.5x4.5	0.6
5x5	0.5
7.5x7.5	0.2

The minimum resolvable period could be slightly improved by taking into account LRI observations of not-redundant epochs.

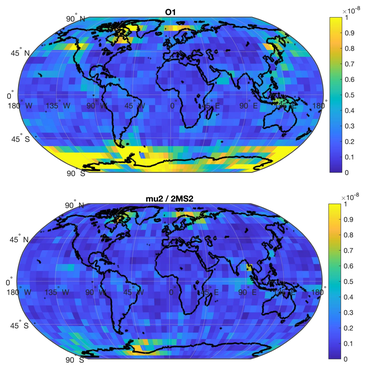
Considerable improvements could be achieved, if GRACE Level-1B sensor data would be available e.g. in a 1 seconds sampling instead of the provided 5 seconds.

E – AMPLITUDES > 3 SIGMA

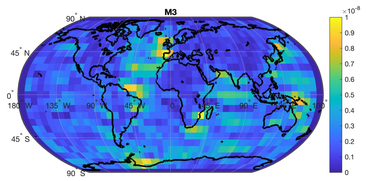


Upper panel: Amplitudes larger than 3 sigma in all grid cells (→ C). Spectral analysis was performed on 7.5°x7.5° gridded residual range accelerations. Detailed view in middle and bottom panels.

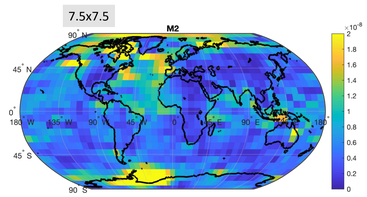
F – MAPS OF SELECTED TIDAL CONSTITUENTS

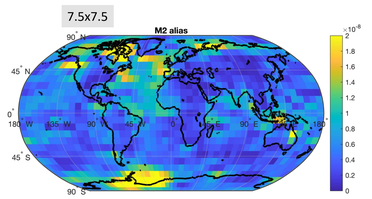


The plot with amplitudes larger 3 sigma (→ E) reveals hundreds of peaks and clustering bands (see E, lower panel left). A few exemplary amplitude maps can be seen in the following.

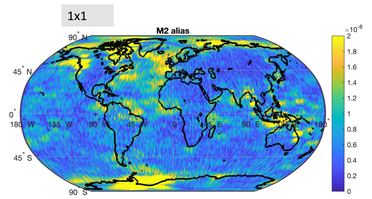


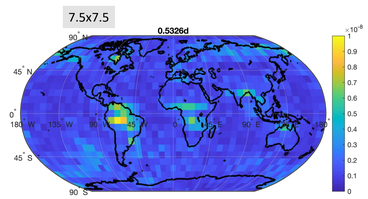
G – ALIASING

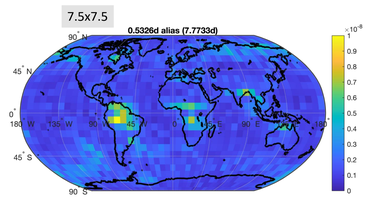




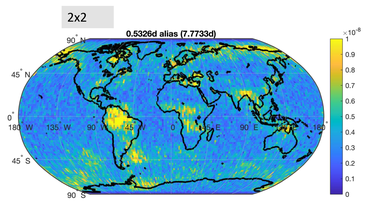
Several peaks are related via aliasing. Due to the larger periods of the aliases, the (tidal) signal can be resolved with a finer spatial resolution.







Most of the large peaks (see E) are related to ocean tides. Some of the peaks also show large amplitudes over major river basins. These amplitudes may indicate hydrological signal not captured by the spherical harmonic coefficients of the monthly gravity field solutions or possibly unmodeled contributions of the atmosphere.



H – CONCLUSIONS

A thorough analysis of K-band post-fit residuals can be useful for:

- Assessing the quality of background models including oceanic and atmospheric tidal and non-tidal contributions
- Evaluating admittance theory for ocean tide modeling
- Understanding aliasing in GRACE and GRACE-FO products
- Optimizing gravity field recovery processing strategies including parametrization and stochastic modeling
- Assessing tidal catalogues.

REFERENCES

[1] ***Koch, I. et al.*** **(2021):** Earth's Time-Variable Gravity from GRACE Follow-On K-Band Range-Rates and Pseudo-Observed Orbits, Remote Sensing, 13(9), 1766, doi.org/10.3390/rs13091766

[2] ***Lyard, F. H. et al.*** **(2021):** FES2014 global ocean tide atlas: design and performance, Ocean Science, 17(3), doi.org/10.5194/os-17-615-2021

[3] ***Dobslaw, H. et al.*** **(2017):** A new high-resolution model of non-tidal atmosphere and ocean mass variability for de-aliasing of satellite gravity observations: AOD1B RL06, Geophysical Journal International, 211(1), doi.org/10.1093/gji/ggx302

European Geosciences Union
General Assembly 2023
Vienna/Austria, 23-28 April

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