Error modeling validation of GRACE gravity data

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Introduction

The efforts to understand the error content of the GRACE (Gravity Recovery and Climate Experiment) observations continue for further improvement of gravity field models and preparation of GRACE-Follow On data processing setup.

• To identify un-modelling errors, a carefully inspection of the range rate post-fit residuals from the ITSG-Grace2016 gravity model [1], is performed in the spatial, temporal and frequency domain. This investigation indicates systematic errors due to eclipse crossings in frequency range of 3 to 10mHz.
• From gravity field modeling point of view, eclipse crossing errors can be interpreted as a temporary bias term on the range rate measurements.
• Depending on the month under study, co-estimation of this calibration parameter in the ITSG-Grace2018 [2] scheme for the available level-1B (RL03) data improves the solution up to 3% RMS over the oceans.

Gravity field recovery from GRACE observations

Linear system model

\[ \mathbf{I} = \mathbf{A} x = \mathbf{e} = \mathbf{N}(x, \mathbf{e}) \]

Parameter estimation

\[ \hat{\mathbf{x}} = (\mathbf{A}^T \mathbf{A})^{-1} \mathbf{A}^T \mathbf{e} \]

Postfit residuals

\[ \hat{\mathbf{e}} = \mathbf{A} \hat{\mathbf{x}} - \mathbf{f} \]

Systematic errors

• Long term errors in frequency band 3-10mHz cannot be described stochastically nor corrected before gravity field recovery, affecting both residuals and gravity parameters.

Fig. 1: Filtered residuals in 3-10 mHz band with respect to GRACE-A (left) argument of latitude (right) ground-track (May 2004).

Fig. 2: Temporal geoid height variations w.r.t GOCC05s static model from (left) ITSG-Grace2016 (right) Official GRACE solutions CSR RL05 (May 2004).

Fig. 3: Temporal bias function in time domain, compared to filtered residuals.

Fig. 4: Mission eclipse transit w.r.t. GRACE-A argument of latitude.

Fig. 5: Filtered residuals w.r.t. GRACE-A argument of latitude.

Fig. 6: Filtered residuals w.r.t. GRACE-A argument of latitude.

Fig. 7: Degree variances w.r.t. GOCC06s static model.

Fig. 8: PSD of the range rate residuals of (left) November and (right) December 2008.

Error modeling

• Approach: Estimate the calibration parameter b within the framework of LS adjustment.

\[ \mathbf{e} = \mathbf{B}(\mathbf{b}) + \mathbf{e}_c + \mathbf{e}_s = \mathbf{N}(\mathbf{x}, \mathbf{e}) \]

\[ \mathbf{L} = \mathbf{A} \mathbf{x} + \mathbf{B}(\mathbf{b}) + \mathbf{e}_c \]

\[ \mathbf{L} = \mathbf{A} [\mathbf{b}] + \mathbf{e}_c + \mathbf{e}_s \]

• Temporal bias \( \mathbf{B}(\mathbf{b}) \): Impulse signals at transit phase + GRACE low pass filter

Characteristics of errors

• \( \Delta \mathbf{b} = 0 \): Errors occurrence.
• Two swap maneuvers in December 2005 and July 2014.
• Before December 2005 and after July 2014: GRACE-A is the leading satellite, \( \Delta \mathbf{b} < 0 \); the pair are entering the shadow.
• Between December 2005 and July 2014: GRACE-B is the leading satellite, \( \Delta \mathbf{b} > 0 \); the pair are entering the sunlight.

Fig. 9: Degree variances w.r.t. GOCC06s static model.

Outlook

• More studies are needed to define specific cause of the systematic errors.
• The implemented approach improves the gravity field solutions, but could be far from an optimal approach. For an optimal modeling, dynamic motion of the satellites and a more realistic eclipse model (e.g. with atmosphere model and the Earth’s oblateness) should be considered.

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References


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