GFR processing standards at IfE

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GRACE-SIGMA

- New compact software package for gravity field recovery from GRACE sensor data
- Implemented in MATLAB from scratch [M. Naeimi et al., 2018]
- Competitive run time
- Variational equations approach
GFR overview

[Afterimage of a diagram depicting the GFR overview with steps such as GPS orbit, Star Camera, Acc. data, K-Band ranging, LRI, Frame transformations, Orbit integration, STM integration, SM integration, Reduced observations, Reference observations, Par. Estimation, C_{nm}, S_{nm}, Quality assessment, Numerical integration, - Planet tides, - Ocean tides, - Solid Earth tides, - Pole tides, - De-aliasing, - Rel. effects, - Atm. Tides, - J2, Sun/Moon, - etc, Background force modeling, GRACE data pre-analysis, [Naeimi et al., 2018]]
Variational equations approach

\[ \dot{\rho}_o = \dot{\rho}_{\text{ref}} + \frac{\partial \dot{\rho}_{\text{ref}}}{\partial u} \delta u \]

\[ \dot{\rho}_o - \dot{\rho}_{\text{ref}} = \frac{\partial \dot{\rho}_{\text{ref}}}{\partial u} \delta u \]

Important aspects:

- Numerical integration
- Force modeling
- Adjustment strategy
Numerical integration

- Modified Gauss-Jackson integrator
- Without correction step (contribution to the position vector below 1E-12 m)
- Multistep integration method (→ RK4 for initialization)
- Vectorized computation of ephemerides, STM and SM

More information:

# Force modeling

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<th>Effect</th>
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Force modeling

- In order to decrease the computational time, the major part of the force effects is calculated once using the L1B reduced dynamic orbits.
- During orbit improvement these effects are not re-computed.
- Only accelerations due to the geopotential and non-gravitational accelerations are evaluated every iteration.
Adjustment strategy

1. Pre-adjustment

Estimated parameters:
- Initial state vectors
- Accelerometer biases

2. Main adjustment

Estimated parameters:
- Initial state vectors
- Accelerometer biases
- Empirical KBR parameters
- Spherical harmonics

3 it.

1 it.
Stochastic modeling

- Orbit (30 sec) + KBRR (5 sec) KBRR (5 sec)
- $1E-02$ m $1E-07$ m/s $\sigma_{KBRR} = 1E-07$ m/s

- Relative weighting of normal matrices

$1 \times$ NEQ orbit

$1E10 \times$ NEQ KBRR
Arcwise NEQ stacking
Arcwise NEQ stacking
Arcwise NEQ stacking
Arcwise NEQ stacking

![Graph showing degree standard deviation over degree for different time spans (3h, 3d, 10d). The graph compares Signal GIF48 and Formal error GIF48.](image)
Arcwise NEQ stacking
Arcwise NEQ stacking

![Graph showing arcwise NEQ stacking with different time intervals: 3h, 3d, 10d, 20d, and 31d. The y-axis represents degree standard deviation, and the x-axis represents degree. The graph compares Signal GIF48 and Formal error GIF48.]
Arcwise NEQ stacking

No regularization
Published solutions

- First batch of spherical harmonics using the presented strategy for the period 2003-2009 can be found on IfE and also on ICGEM website
Exemplary EWHs (2008)

- Gauss filter (350 km)
- C20: TN SLR values
Exemplary EWHs (2008)

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Comparison of degree standard deviations (2003-2009)

- Results are in a good agreement with GFZ, CSR and JPL solutions
EWH Greenland (2003-2009)

- Gauss filter (350 km)
- C20: TN SLR values
EWH Amazonas (2003-2009)

- Gauss filter (350 km)
- C20: TN SLR values
Future plans

- **Force models**: atmospheric tides, AOD1B RL06, FES2014, dynamic empiric parameters
- **Parametrization**: arc length, scale factors
- **Data**: L1B RL06
- Range rate residuals analysis
- Code extending for GRACE-FO
References

- **Case et al. (2010):** GRACE level 1B data product user handbook (JPL D-22027), Technical report.

- **Naeimi et al. (2018):** IfE monthly gravity field solutions using the variational equations, EGU 2018, Vienna.


- **Petit and Luzum (2010):** IERS Conventions (2010), IERS technical note 36, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main.

- **Ries et al. (2011):** Mean background gravity fields for GRACE processing, GRACE Science Team Meeting Austin, TX, August 8-10.

- **Rieser et al. (2012):** The ocean tide model EOT11a in spherical harmonics representation, Technical report.

Thank you for your attention!