Global Gravity Field Determination from Future Satellite-Gravimetric Missions analysed by IGG and GFZ

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Outline

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- Models used for the simulations
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Simulated mission configurations

- **GRACE** ($\rho_x = 220$ km)
- **(Alternative) GRACE-FO** ($\rho_{x,y} = 220/25$ km)
- **Cartwheel** ($\rho_{x,z} = 100/50$ km)

- **3 Pendulum formations**
  - Pendulum ($\rho_{x,y} = 96/43$ km)
  - Pendulum V1 ($\rho_{x,y} = 166/166$ km)
  - Pendulum V2 ($\rho_{x,y} = 83/83$ km)

- **Helix** ($\rho_{x,y,z} = 50/150$ km)
- **Bender** ($\rho_x = 100$ km)

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• 7 possible future missions are investigated plus GRACE as reference

• 6 missions were treated as drag-free but for GRACE and GRACE-FO non conservative forces were considered.

• It was decided that GFZ will provide IGG with orbits, SST data, accelerometer and star-trackers data.

• The simulation period was set to 32 days corresponding to the repeat cycle for an altitude of 335km.

• The integration step-size was set to 5 seconds

• GFZ-EPOS and IGG-GROOPS softwares have been used to estimate the gravity field solutions (up to d/o 120)
Models used for the simulations

- Static gravity field model EIGEN-GL04C
- Time-variable background model AOHIS ESA Model Version 2
- Ocean tides model EOT08a (Q1,O1,P1,K1,M2,N2,K2,S2) up to 50x50
- Planetary ephemerides: DE405 (only Sun and Moon)
- Permanent tide: C20 from EIGEN-GL04C
- Models for non-gravitational forces (transformed to acc. data)
  - air drag, solar radiation pressure, albedo.
  - no precession, no nutation, no polar motion
- Simple Earth rotation only by
  \[ \theta = 2 \pi \left(0.7790572732640 + 1.00273781191135448 \right) \text{ (MJDUTC-51544.5)} \]
  - no Earth tides model, no pole and ocean tide models,
  - no relativity
• Simulated Data:
  • SST range-rate observations
  • GPS to LEO satellites observations (code + phase)
  • Accelerometer data for the non-drag free missions
  • Star-trackers data

• Simulated Errors :
  • SST observations: colored noise from ife-iFR
  • Accelerometer data: colored noise from ife-iFR
  • No orbit error was introduced
The GFZ simulations are based on the GFZ EPOS software:

- Package operated with a symmetric Adams-Cowell integrator of order seven
- Using the full dynamical approach

The IGG simulations are made with the IGG GROOPS software:

- Package procedure is based on the solution of Newton’s equation as
- Solution of a boundary value problem (Fredholm integral equation of the second kind).
- 35 minutes arcs are used to compute observation equations and normal equations
Results in the spectral domain

Different error influences on (alternative) GRACE-FO (GFZ-EPOS)
Results in the spectral domain

Comparison of the Results between IGG and GFZ

Agreement of current results by 120x120
Results in the spectral domain

IGG Results – Spectral domain

- EIGEN-GL04C
- AOHIS-mean (03.2004)

Legend:
- Meas. + Model error
- GRACE ref.
- GRACE-FO
- Pendulum
- Cartwheel
- Helix
- In-line Bender
- Ch. Pendulum V1
- Ch. Pendulum V2

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Results in the spatial domain

IGG-GROOPS
GRACE reference (min. = -209.18, max. = 216.67, RMS = 43.605) GRACE Follow-on (min. = -37.766, max. = 38.096, RMS = 5.14023)

Pendulum (min. = -7.64898, max. = 9.59605, RMS = 1.06742)
Cartwheel (min. = -7.1101, max. = 8.2586, RMS = 0.82904)

Helix (min. = -3.58067, max. = 4.01495, RMS = 0.53023)
In-line Bender (min. = -2.2631, max. = 2.2576, RMS = 0.30911)

Ch. Pendulum V1 (min. = -2.45107, max. = 1.1918, RMS = 0.2929)
Ch. Pendulum V2 (min. = -1.6051, max. = 1.3775, RMS = 0.25468)

GFZ-EPOS
GRACE reference (min. = -542.19, max. = 600.05, RMS = 114.026) GRACE Follow-on (min. = -29.9603, max. = 33.2638, RMS = 4.8268)

Pendulum (min. = -11.3675, max. = 9.6287, RMS = 1.3419)
Cartwheel (min. = -6.1096, max. = 6.2665, RMS = 0.7637)

Helix (min. = -3.2281, max. = 3.0341, RMS = 0.5728)
In-line Bender (min. = -4.1122, max. = 4.0198, RMS = 0.6198)

Ch. Pendulum V1 (min. = -3.4138, max. = 4.1196, RMS = 0.7948)
Ch. Pendulum V2 (min. = -1.7105, max. = 3.0416, RMS = 0.5001)
Summary

- Within the frame of future gravity missions project, 8 Basic-formations are investigated.

- Full-scale mission are carried out using two different softwares of GFZ (EPOS) and IGG (GROOPS).

- Generally good agreement in the spectral domain between the EPOS and GROOPS solutions but for a few missions (GRACE, Bender) some discrepancies for d/o > 90.

- It has been found that the aliasing effects are so far the main problem that future missions will face, especially for the GRACE Follow-on configuration.

- Simulations show obvious potential improvements for the (alternative) GRACE-FO formation w.r.t. the GRACE reference.

- Most promising for a future gravity mission (2020+) seems the Bender constellation.
Thank you for your attention