Precise Science Orbits for the GOCE Satellite – Aiming at the cm-level

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GOCE-HPF: Orbit groups

Responsibilities:

- DEOS => RSO (Rapid Science Orbit)
- AIUB => PSO (Precise Science Orbit)
- IAPG => Validation
GOCE Precise Science Orbits

GOCE instruments data used:
- 1 Hz GPS data of highest quality
- Star tracker measurements

⇒ Precise Science Orbit product

PSO is a Level 2 product consisting of two different orbit solutions:
- Kinematic
- Reduced-dynamic
A kinematic orbit is an ephemeris at **discrete** measurement epochs.

Kinematic positions are **fully independent** of the force models used for LEO orbit determination.

Kinematic orbits are well suited for gravity field recovery of the long-wavelength part.
• Satellite trajectory is a particular solution of the equation of motion defined by the force models used. The strength of the force models is reduced, to some extent, by additional empirical parameters.

• Reduced-dynamic orbits heavily depend on the force models used, e.g., on the gravity field model (solving the equation of motion)

• Reduced-dynamic orbits are well suited to compute LEO orbits of highest quality
Special GOCE characteristic: Drag-free flight

Empirical accelerations from reduced-dynamic orbit determination

Transition to first drag-free flight on 7 May 2009
Special GOCE characteristic: Drag-free flight

- Non-gravitational forces in along-track direction are compensated by the IPA (Ion Propulsion Assembly)
- Empirical accelerations from reduced-dynamic orbit determination illustrate the effect
Special GOCE characteristics: Observation epochs

- Internal clock is not steered to integer seconds
- This is no problem for the GPS data processing but

=> resulting kinematic positions are not truly equidistant
GOCE PSO procedure

- Tailored version of Bernese GPS Software used
- Un-differenced processing
- 30 h batches
  => overlaps
- CODE final products
- Consequent use of antenna phase center variation (PCV) map
- Final kinematic positions are only accepted, if five or more simultaneous observations were available
  => on average only 0.5% positions missing

Data preprocessing

- Preparation of GPS orbits, clocks and ERPs (30 hours)
- Auxiliary data

GOCE GPS data

- Pseudorange: first a priori orbit
- Receiver clock synchronization
- Phase: Iterative data screening

CODE products

- Redundant-dynamic orbit solution (iterative) 10 sec
- Kinematic orbit solution 1 sec

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GOCE PSO procedure: Improvements

- GOCE SLR residuals as a function of the azimuth of the SLR stations
- Significant improvement of SLR residuals due to use of the PCV map
GOCE PSO procedure: PCV map

- Azimuth-elevation diagram of antenna PCVs [mm] – ionosphere-free linear combination
- Azimuth of 0° => flight direction
- 154 days of data used for the generation of the PCV map
PSO: Comparison reduced-dynamic ⇔ kinematic orbits

- Orbit differences between reduced-dynamic and kinematic PSO solutions
- Orbit differences > 1 m removed (only 60 positions for the whole period)
- Consistency of reduced-dynamic and kinematic PSO is at 2 cm level
  => mean 3D-RMS 1.82 cm
PSO: Comparison reduced-dynamic $\Leftrightarrow$ kinematic orbits

Typical example for orbit differences between reduced-dynamic and kinematic PSO
PSO: Overlaps reduced-dynamic orbits

- 5 h overlaps (21:30 – 02:30)
- Mean 3D-RMS: 0.55 cm
Orbit validation with SLR

Reduced-dynamic orbit

Mean: 0.88 cm, RMS: 2.05 cm
Orbit validation with SLR

Kinematic orbit

Mean: 0.88 cm, RMS: 2.23 cm
Summary

- GOCE PSO product consists of a kinematic and a reduced-dynamic orbit solution
- Both orbits are computed in one and the same processing chain
- Use of PCV map led to a significant improvement of the PSO product
- Validation with independent SLR measurements shows that precision requirements of 2 cm are amply met by the PSO