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

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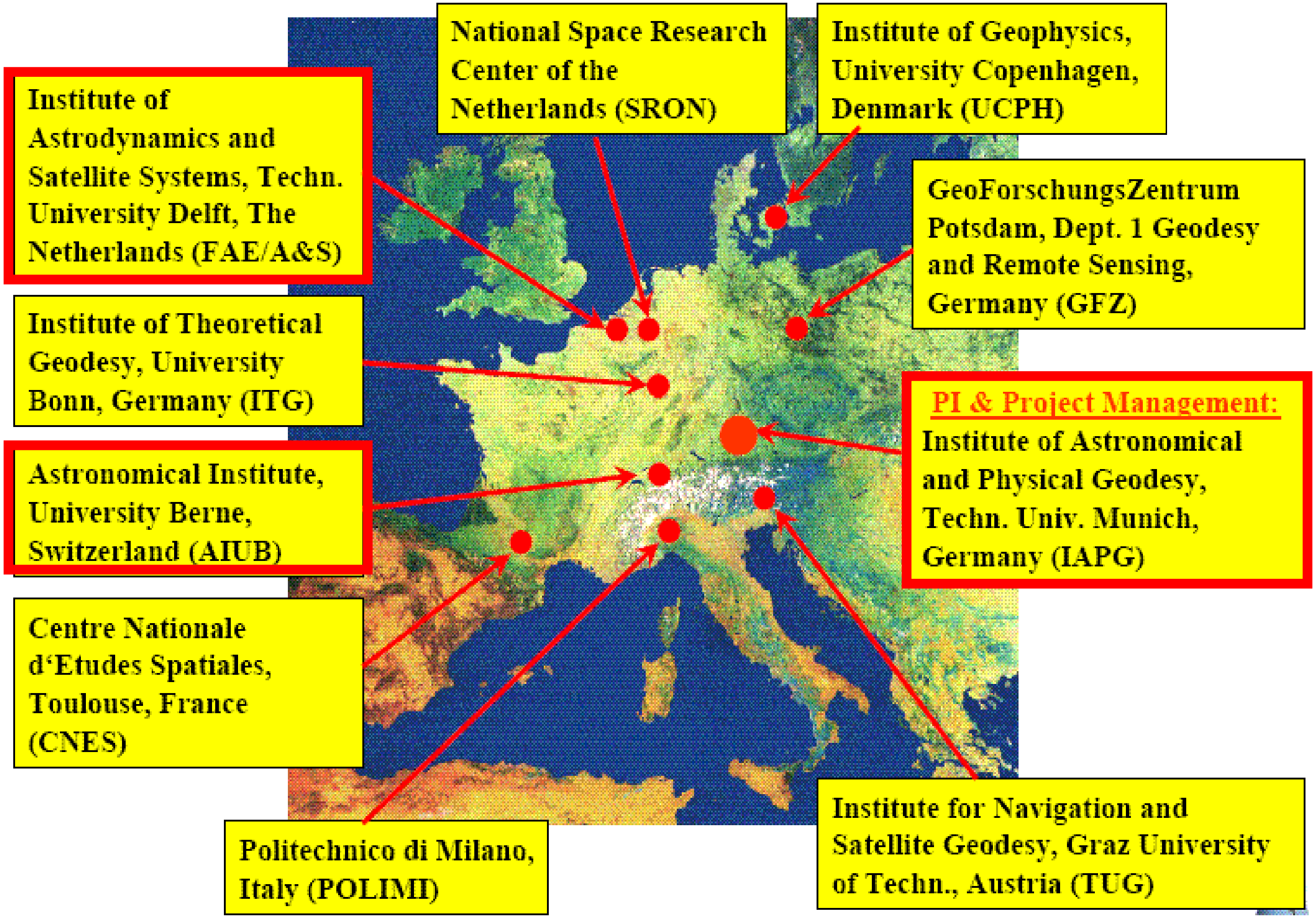
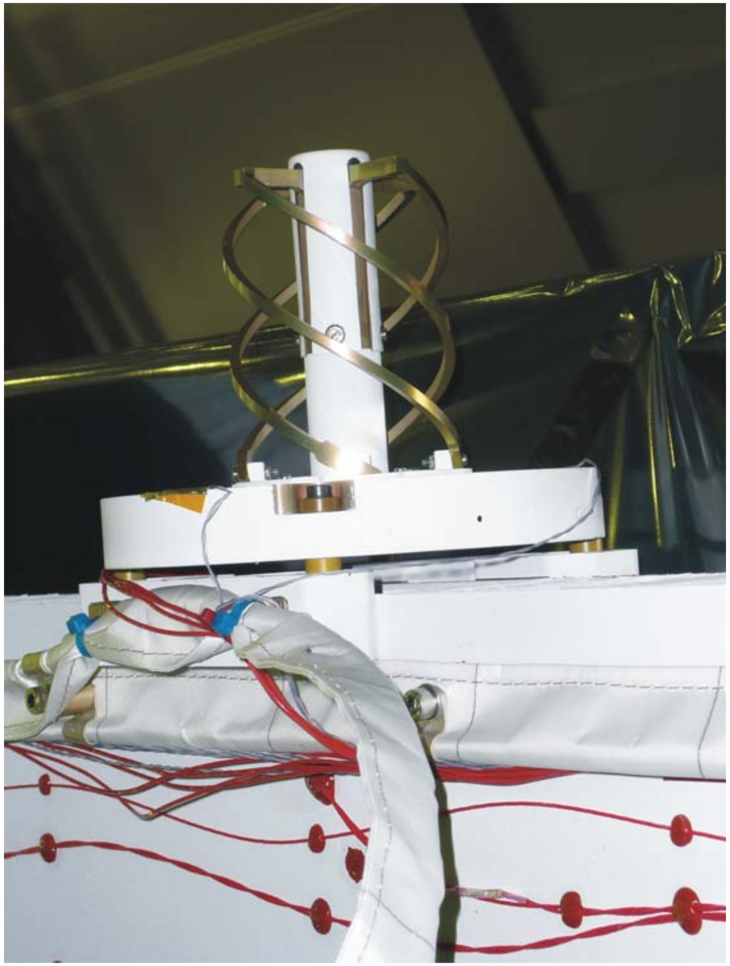
GOCE-HPF: Orbit groups



Responsibilities:

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

GOCE Precise Science Orbits



GOCE instruments data used:

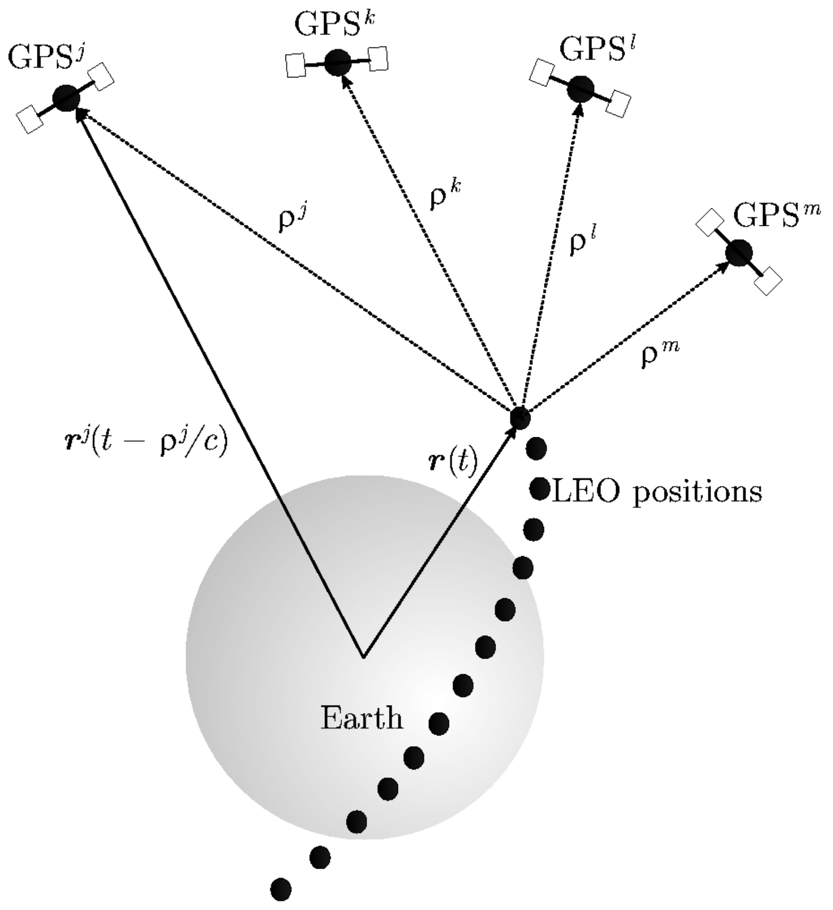
- 1 Hz GPS data of highest quality
- Star tracker measurements

⇒ Precise Science Orbit product

PSO is a Level 2 product consisting of two different orbit solutions:

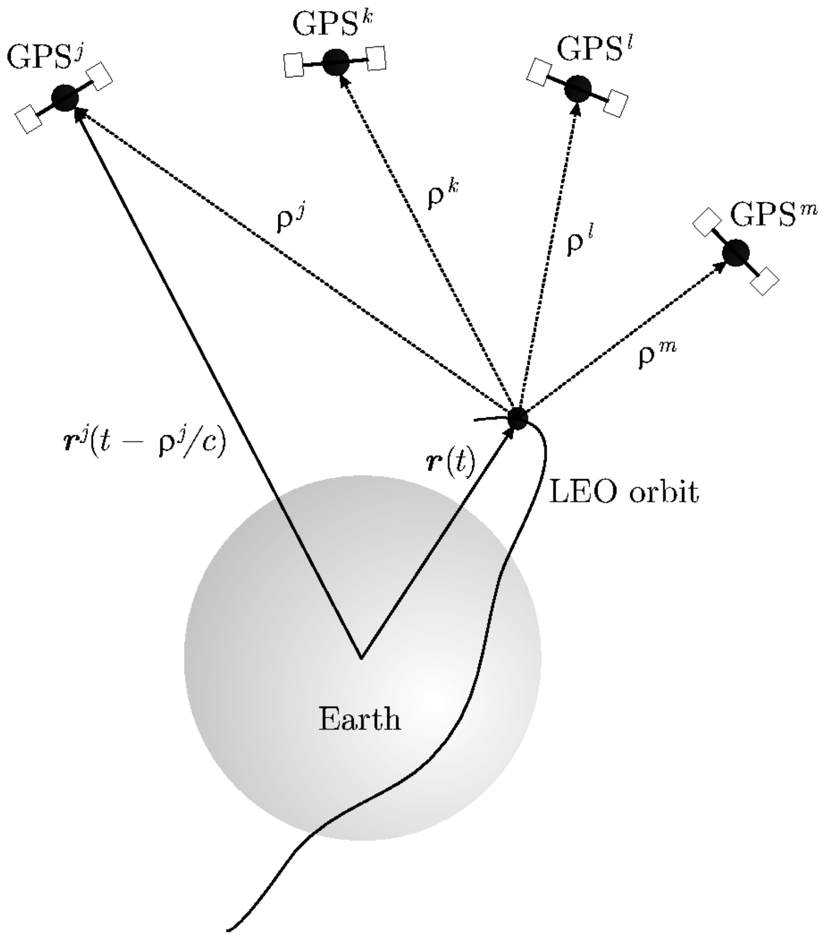
- Kinematic
- Reduced-dynamic

Kinematic orbit representation



- 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

Reduced-dynamic orbit representation



- Satellite trajectory is a particular solution of the equation of motion defined by the force models used.

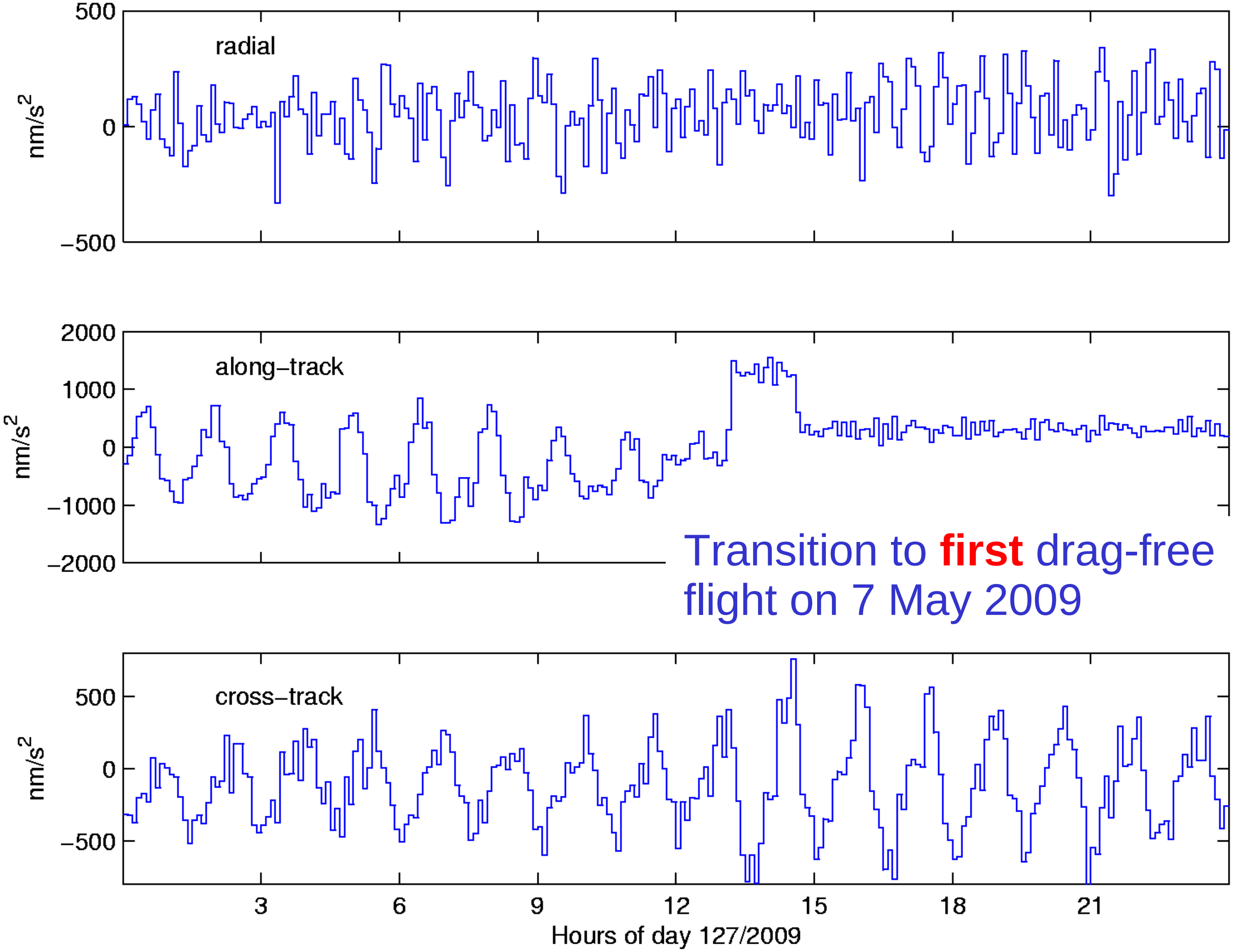
  The strength of the force models is **reduced,** to some extent, by additional empirical parameters.

- 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**

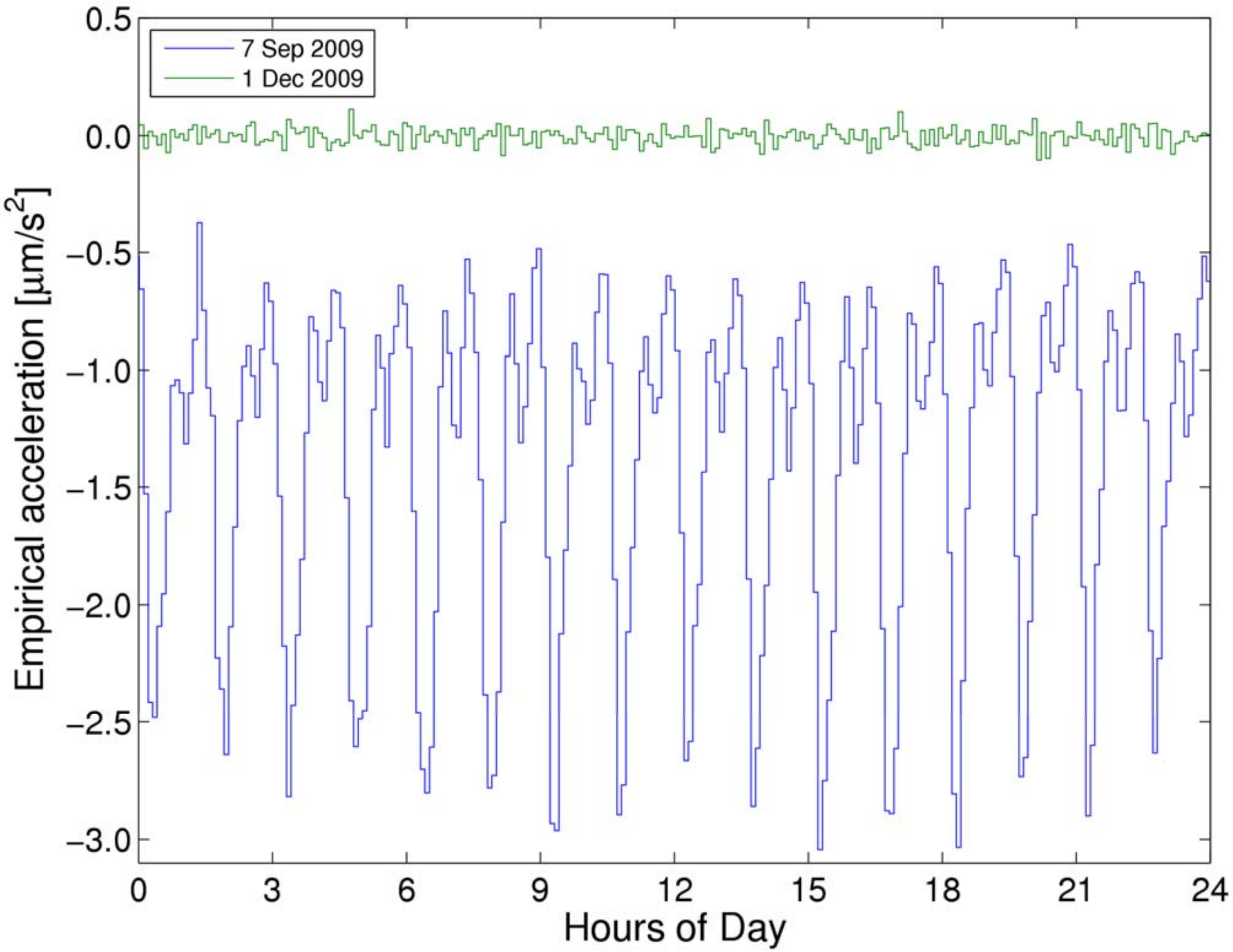
Special GOCE characteristic: Drag-free flight

Empirical accelerations from reduced-dynamic orbit determination



Transition to **first** drag-free flight on 7 May 2009

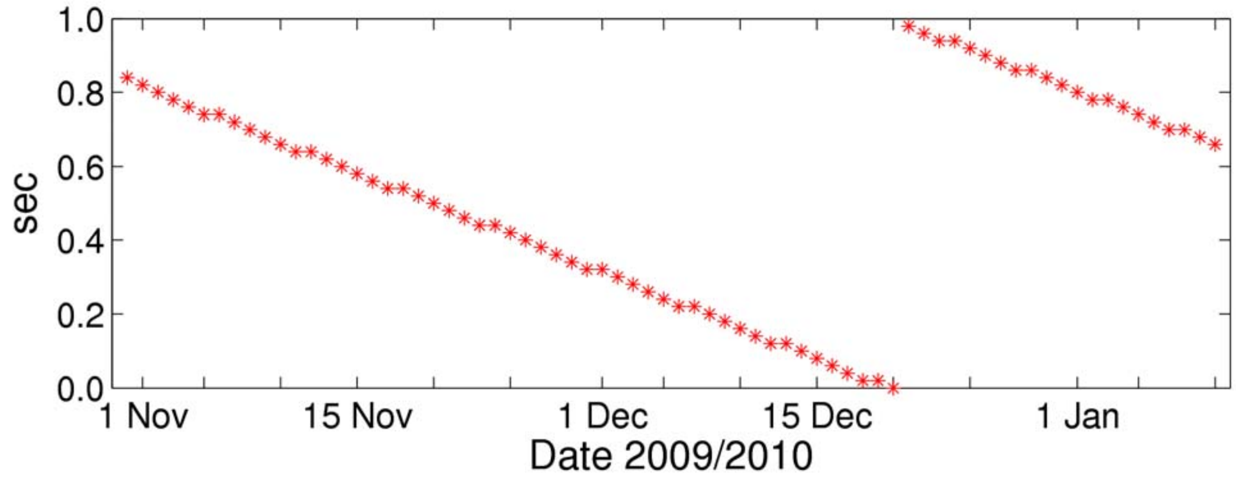
Special GOCE characteristic: Drag-free flight



- 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

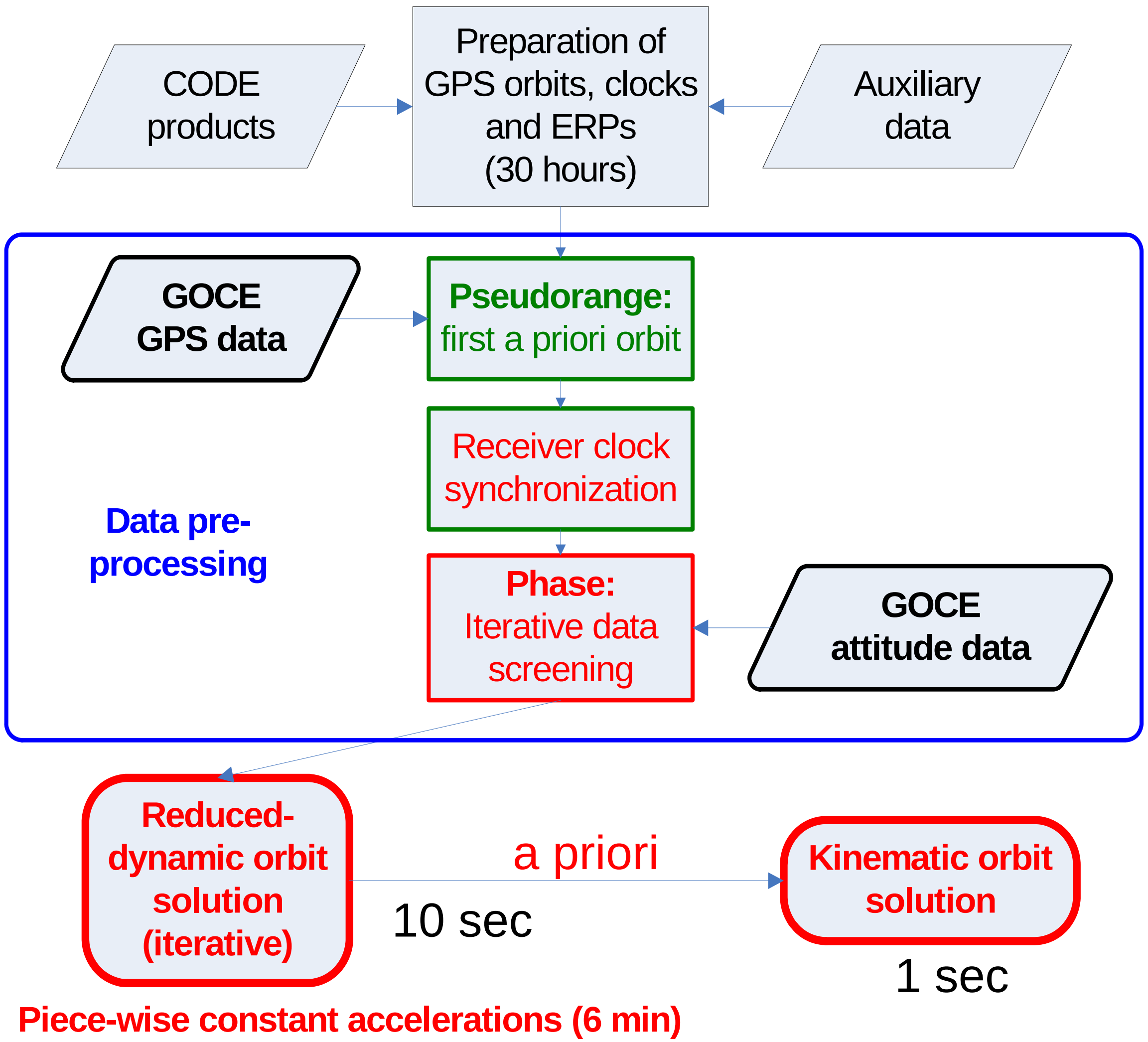
Fractional offsets of observation epochs at midnight (from RINEX)



- 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

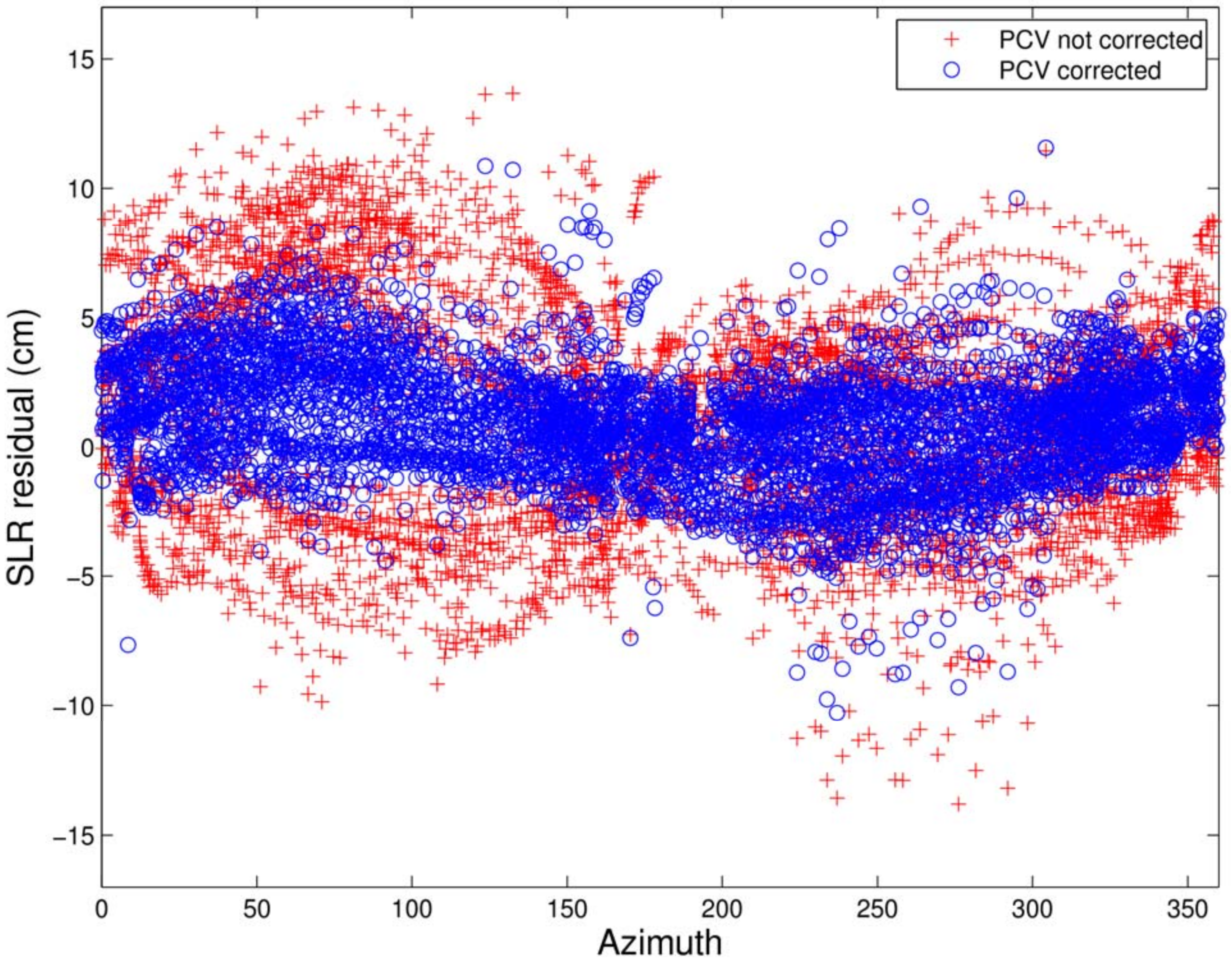


- Tailored version of Bernese GPS Software used
- Un-differenced processing
- 30 h batches

  => 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

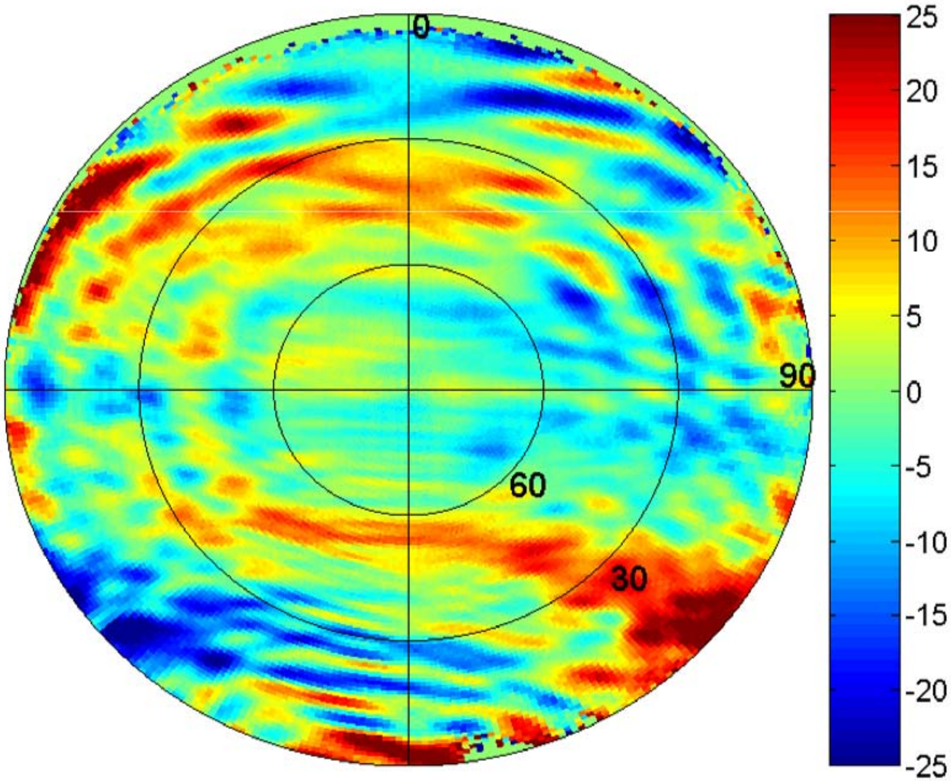
  => on average **only** 0.5% positions missing

GOCE PSO procedure: Improvements



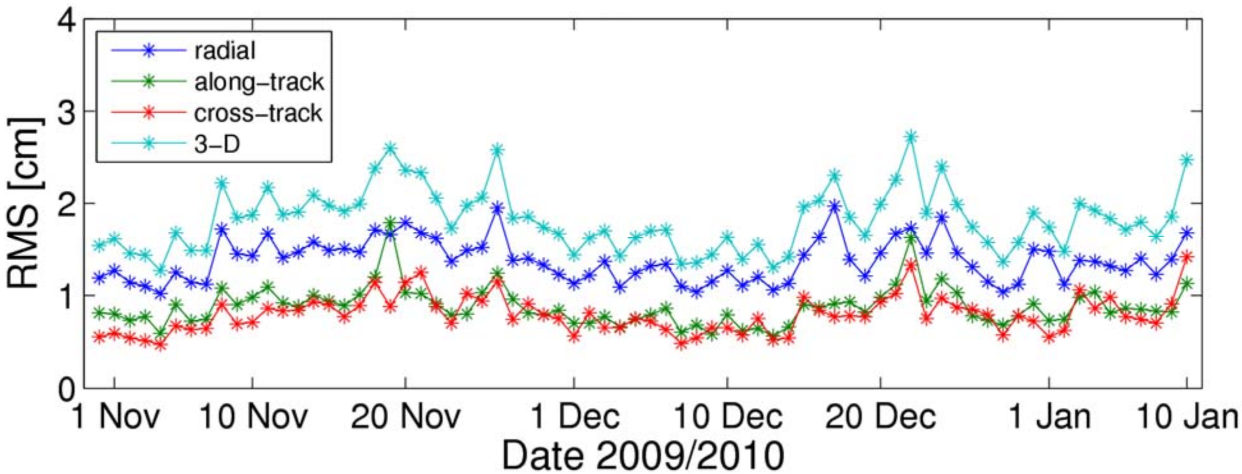
- GOCE SLR residuals as a function of the azimuth of the SLR stations
- Significant improvement of SLR residuals due to use of the PCV map

GOCE PSO procedure: PCV map



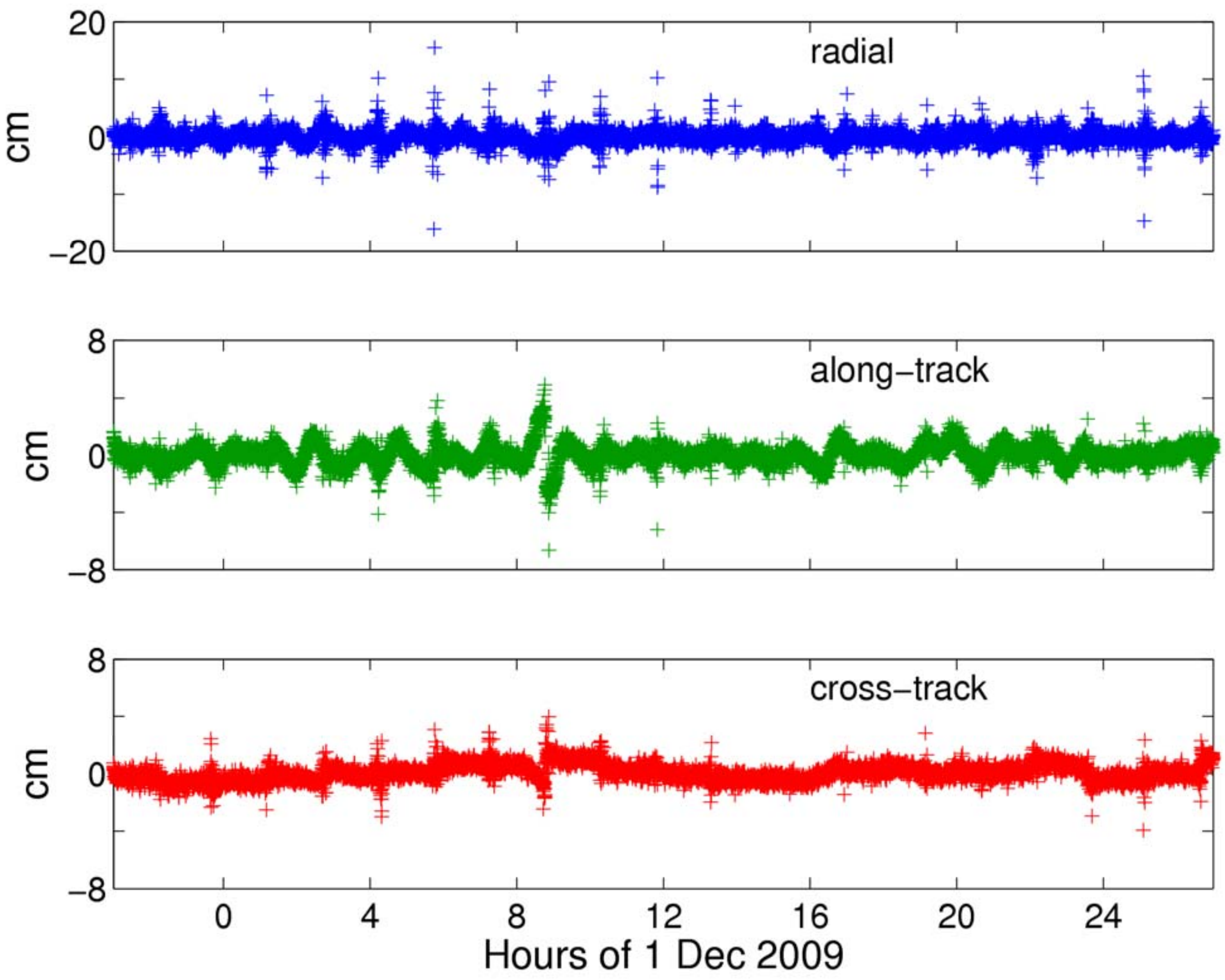
- Azimuth-elevation diagram of antenna PCVs [mm] – ionosphere-free linear combination
- Azimuth of 0º => flight direction
- 154 days of data used for the generation of the PCV map

PSO: Comparison reduced-dynamic ⇔ kinematic orbits



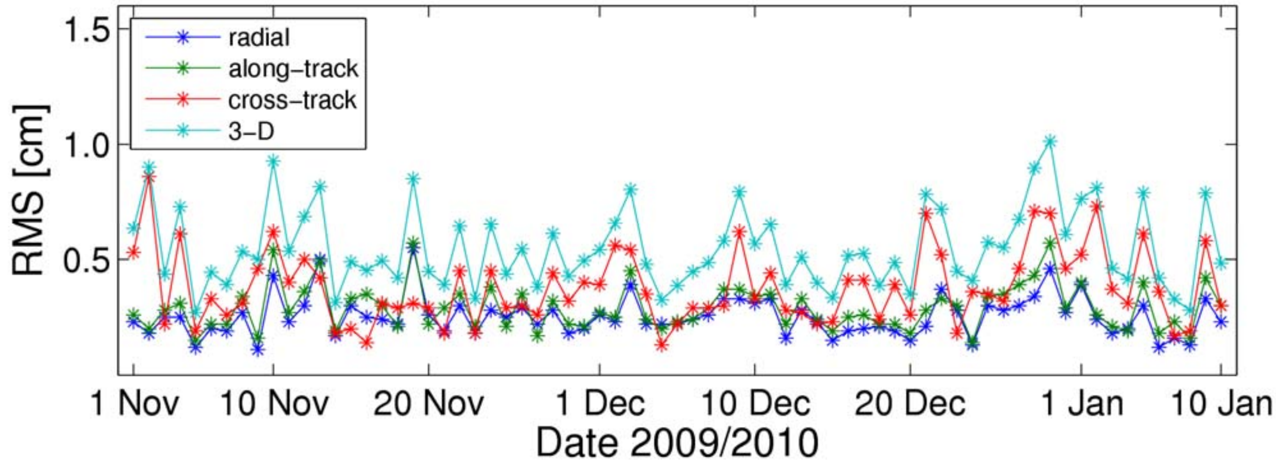
- Orbit differences between reduced-dynamic and kinematic PSO solutions
- Orbit differences > 1 m removed (only 60 positions for the whole period)
- Consistency of reduced-dynamic and kinematic PSO is at 2 cm level
  => mean 3D-RMS 1.82 cm

PSO: Comparison reduced-dynamic ⇔ kinematic orbits



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

PSO: Overlaps reduced-dynamic orbits

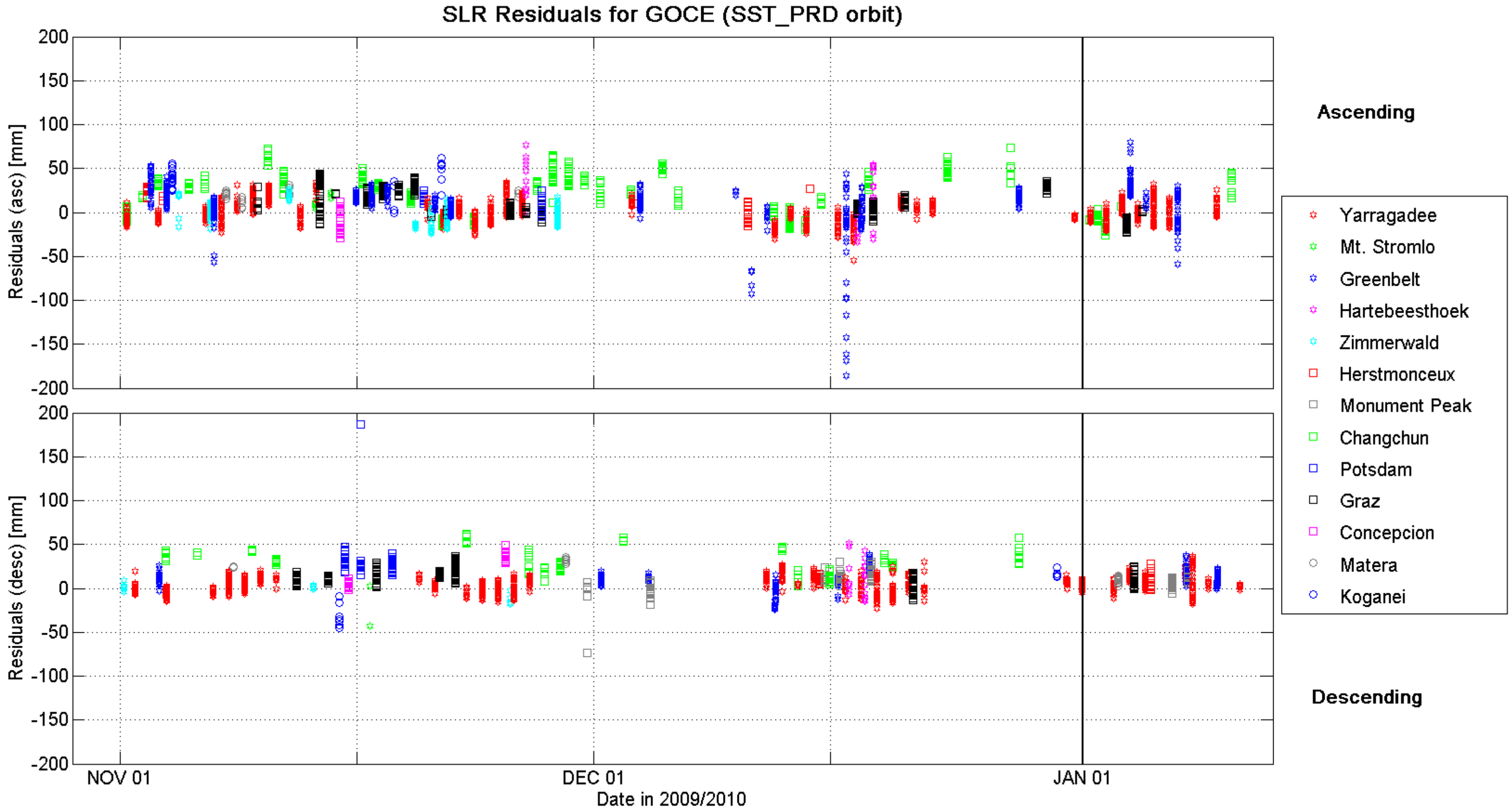


- 5 h overlaps (21:30 – 02:30)
- Mean 3D-RMS: 0.55 cm

Orbit validation with SLR

Reduced-dynamic orbit

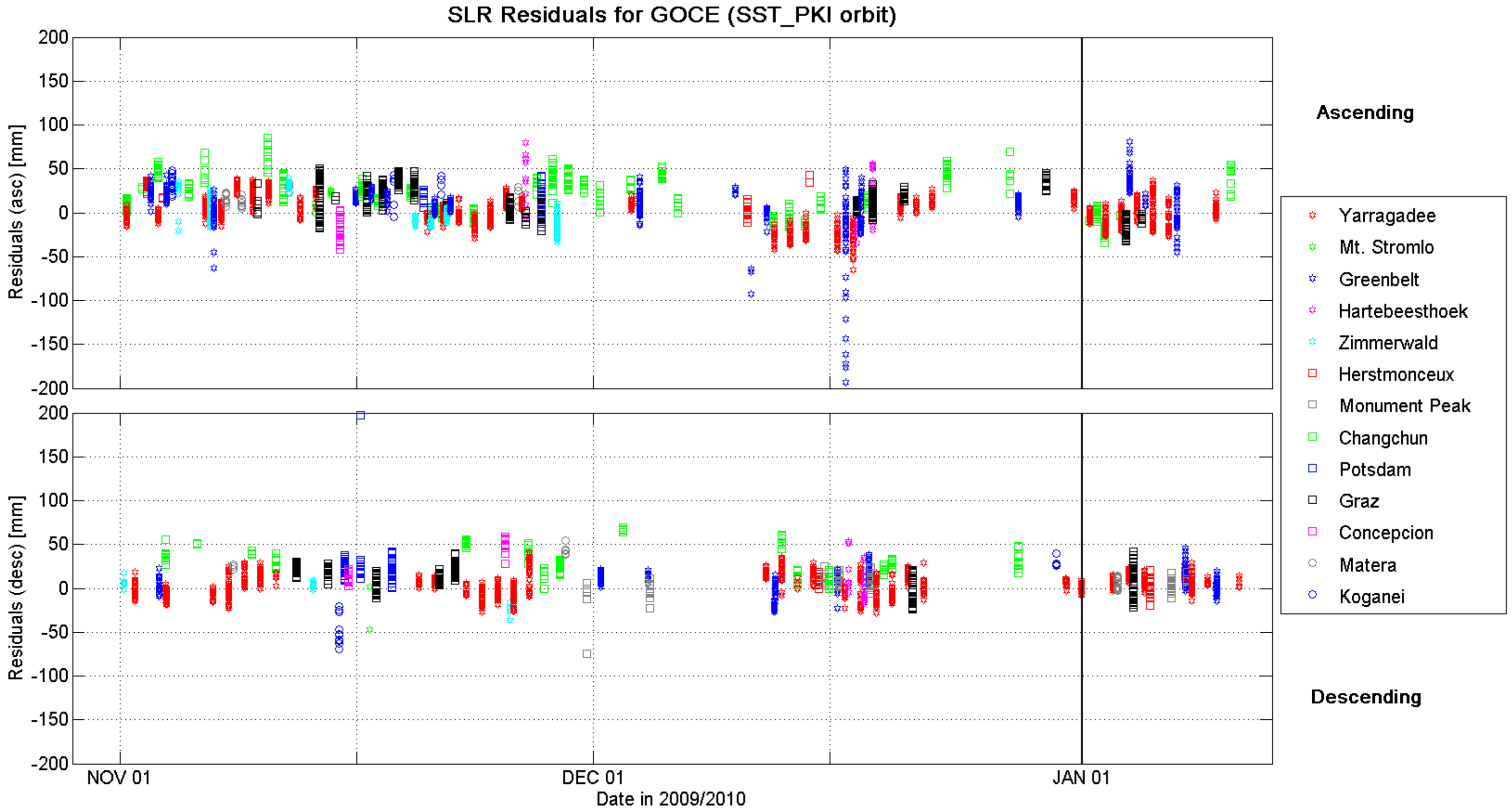
Mean: 0.88 cm, RMS: 2.05 cm



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