Precise Orbit Determination for the GOCE Satellite Using GPS

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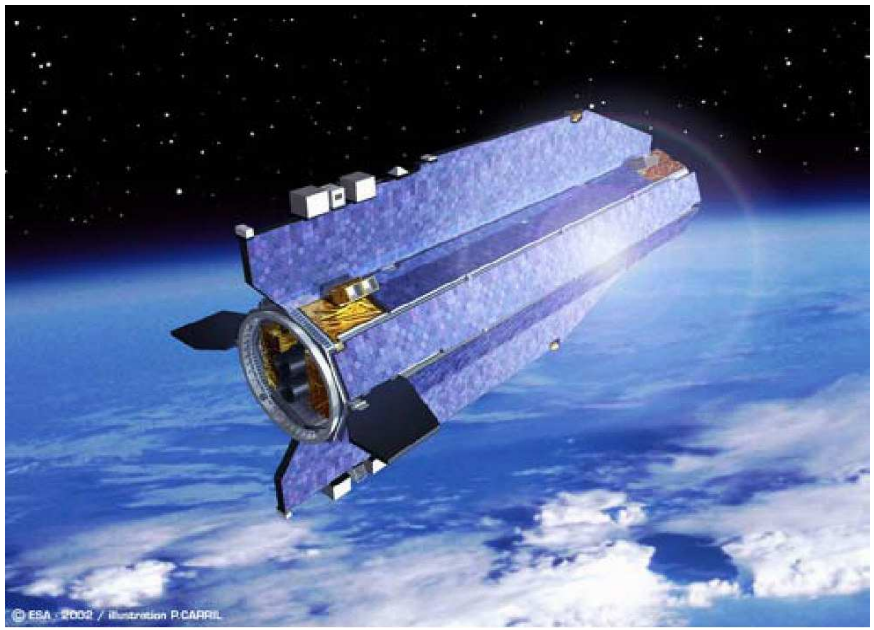
Outline

- GOCE Mission
- GOCE HPF (High-level Processing Facility)
- GOCE – Orbit Determination Procedures
- GRACE results
- 30-hours overlap processing
- Antenna characteristics
- Summary and Conclusions



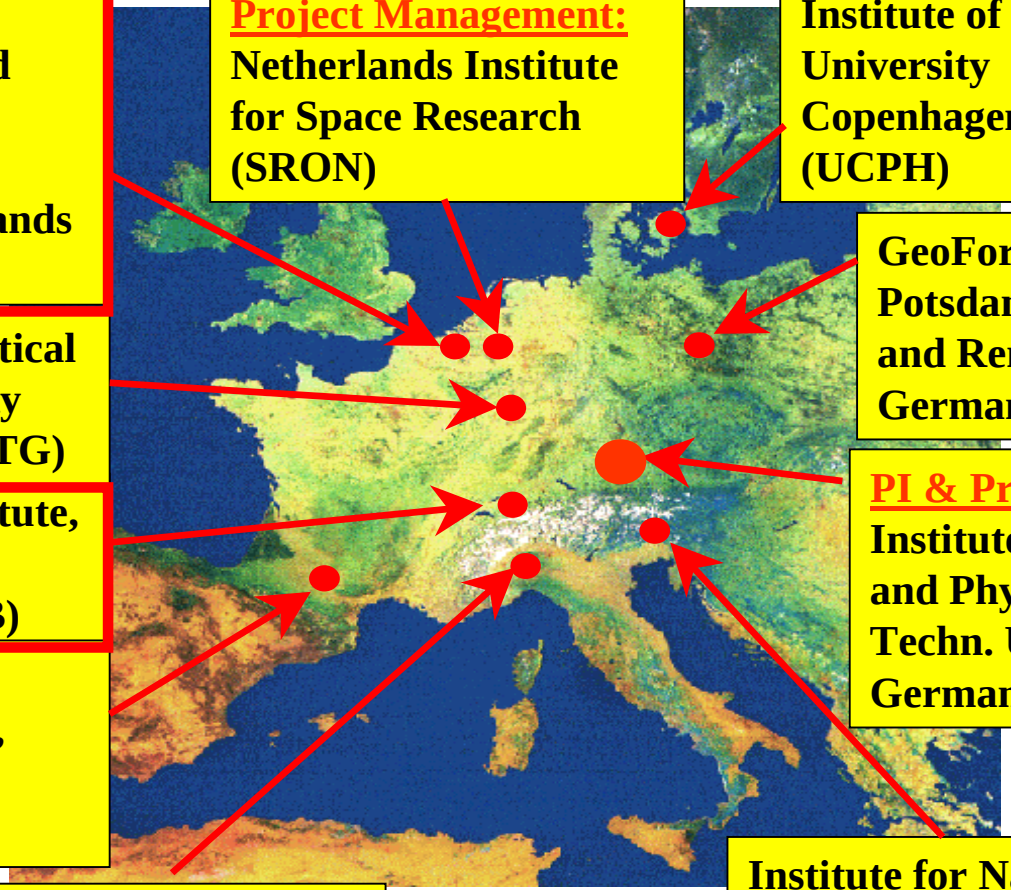
GOCE – Mission

- GOCE => Gravity field and steady-state Ocean Circulation Explorer
- Launch: Spring 2007
- Lifetime: 2 years (nominal 20 months, up to 30)
- Sun-synchronous orbit, close to terminator plane
- Altitude: ~ 250 km, Inclination: 96.5°
- Payloads:
  - Gradiometer (3 x 2 accelerometers)
  - GPS – receiver (12 channels)
  - Star cameras
  - Laser retro reflector (SLR)
  - Ion thruster (drag-free orbit)

GOCE – HPF Project

- GOCE – HPF (High Level Processing Facility)
- Project financed by ESA (European Space Agency)
- 10 European institutions => EGG-C (European GOCE Gravity – Consortium) => HPF team
- Processing of Level 1b data from the GOCE satellite:
  - GPS, gradiometer, attitude data
- Products (Level 2):
  - GOCE – orbits (Goal: 1 cm)
  - Calibrated gravity field gradients
  - Gravity field (1mGal (= 10^{-5} m/s^2))

Who is the HPF?



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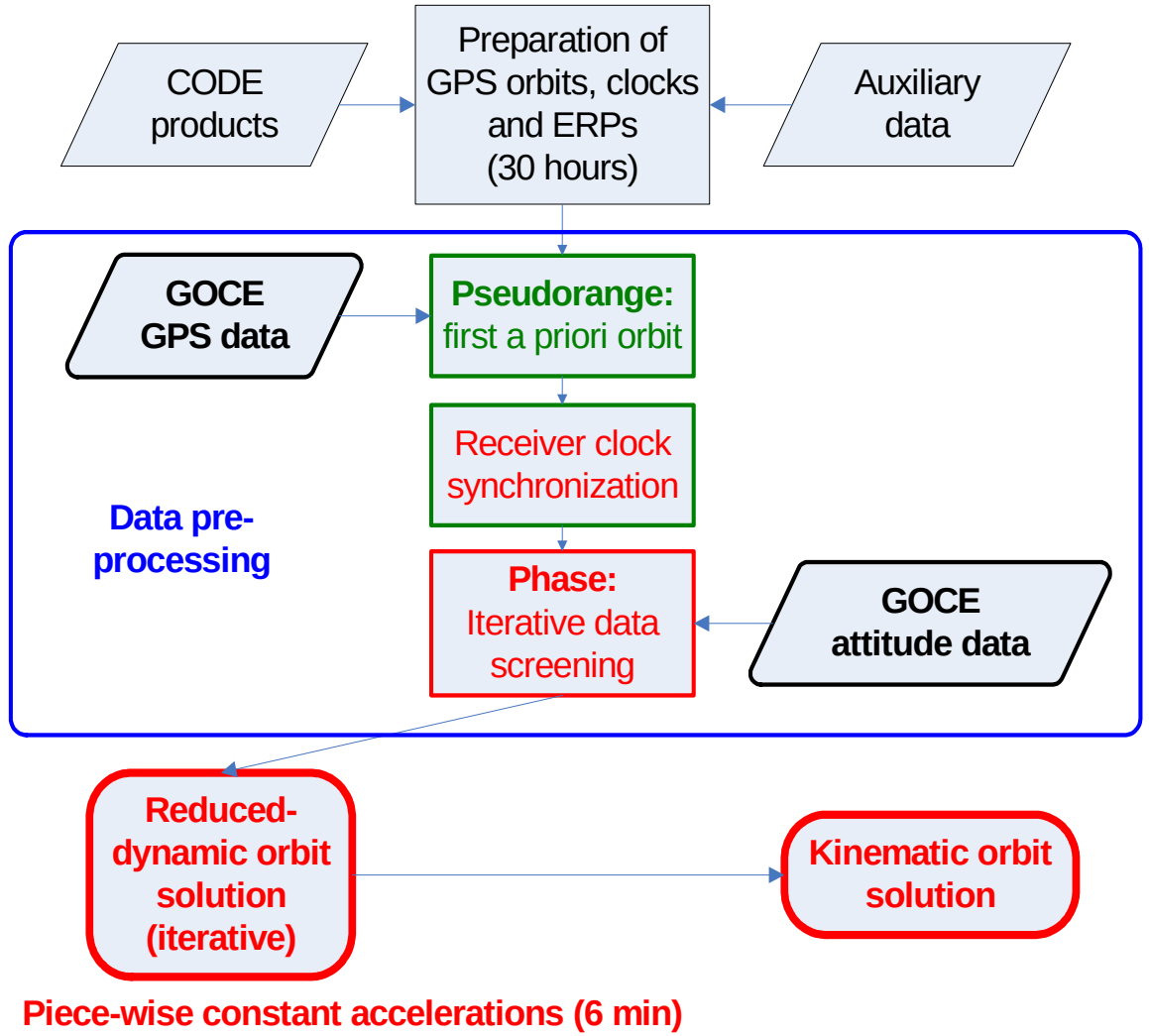
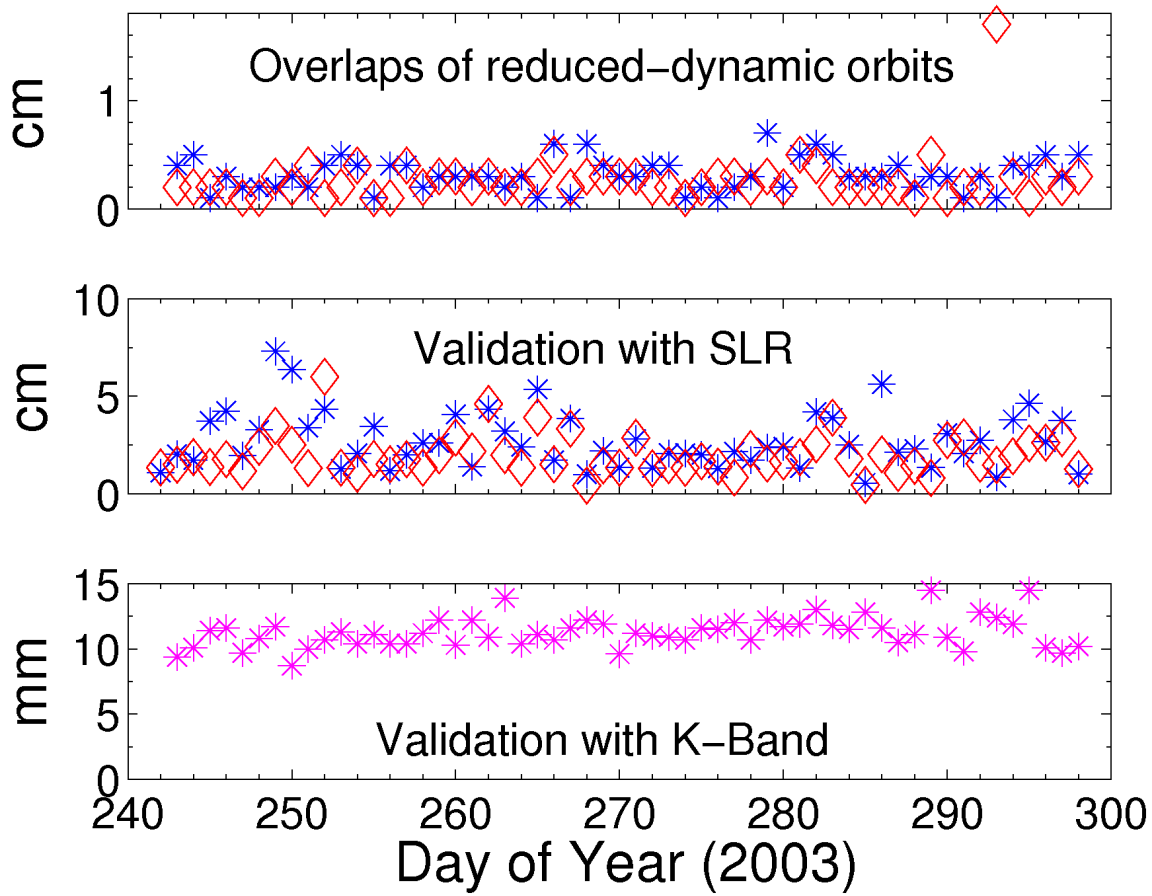
GOCE-Orbit Determination Procedures (1)

- Rapid Science Orbit (RSO) – done at DEOS in Delft:
  - IGS/CODE Rapid and Ultra-rapid products and IGS tracking data
  - Latency: 2 days, accuracy: < 0.5 m
  - Kinematic solution: zero-difference, 10 sec sampling
  - Reduced-dynamic solution: triple-differences, 10 sec sampling
  - ➢ Used for „Quicklook“ gravity field solutions
  - ➢ Data quality check and feedback to mission control
- Precise Science Orbit (PSO) – done at AIUB in Bern:
  - CODE Final products used
  - Densification of GPS clocks from 30 -> 5 seconds sampling
  - Latency: 2 weeks, required accuracy: 2 cm
  - Kinematic solution: zero-difference, 1 sec sampling
  - Reduced-dynamic solution: zero-difference, 10 sec sampling, piece-wise constant accelerations
  - ➢ Used for final GOCE gravity field solutions

GOCE-POD (2): PSO procedure

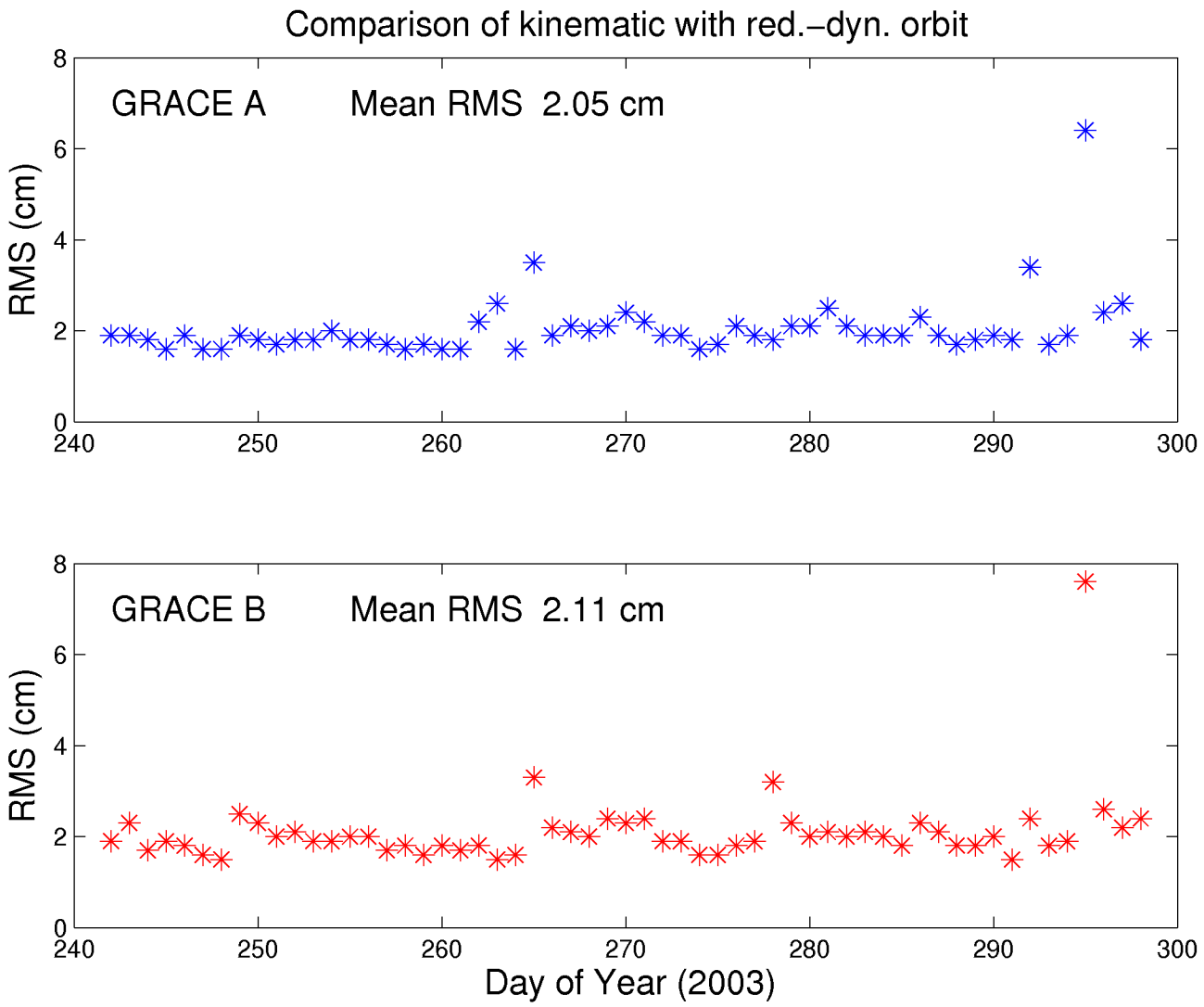


GRACE Results (1)



	Mean RMS (mm)	Offset (mm)
Overlaps of reduced–dynamic orbits	**A** 3.2 **B** 2.7	
Validation with SLR	**A** 27.1 **B** 19.8	-0.9 4.7
Validation with K–Band	**AB** 11.25	

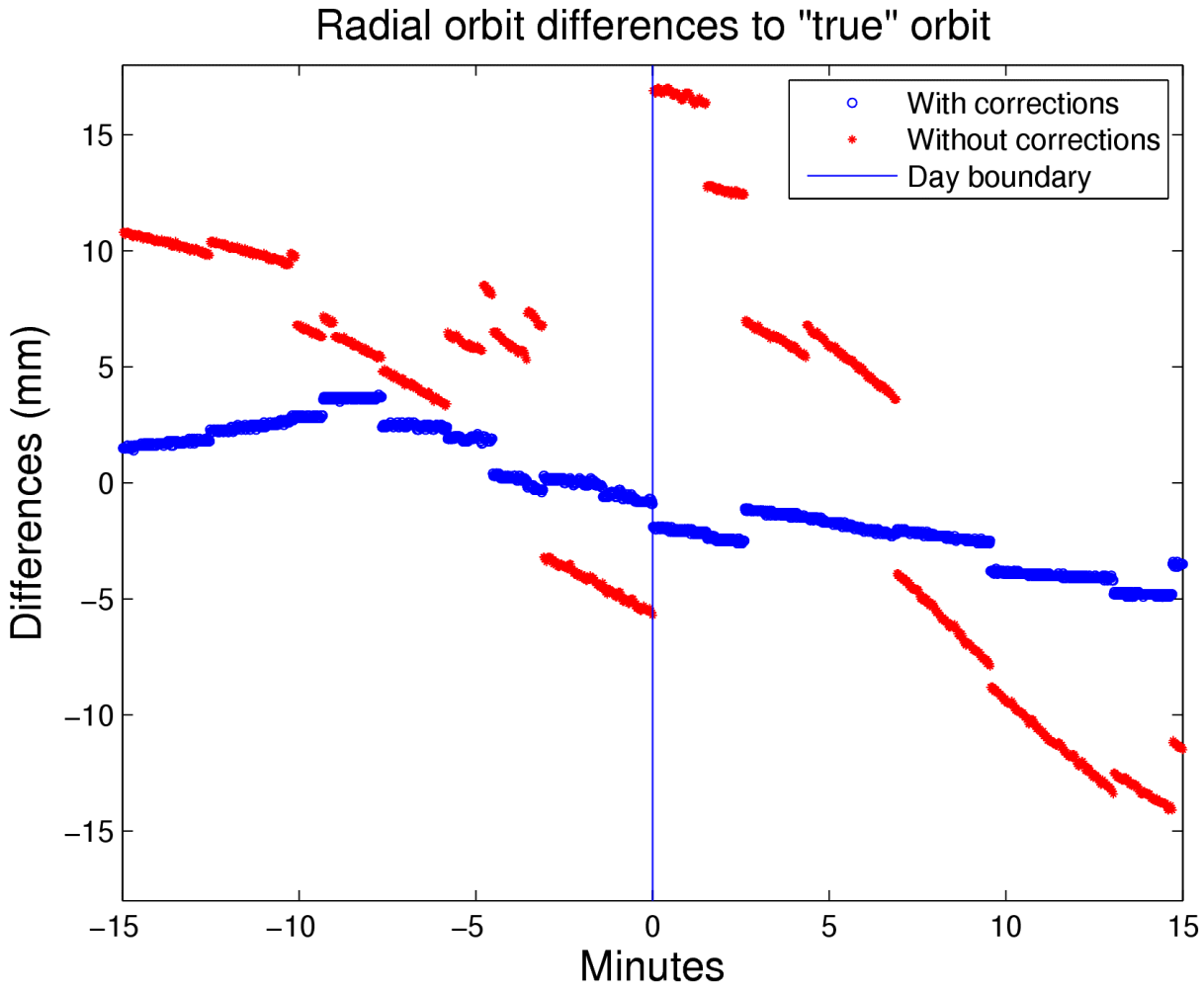
GRACE Results (2)



30-hours Orbit Overlap Processing (1)

- GPS orbits and clocks are results of 24-hours processing (CODE products)
  - Orbits have „jumps“ at day boundaries (few mm)
  - Clocks have „jumps“ (up to dm)
  - ➢ Inconsistent phase measurements at day boundary
  - ➢ New phase ambiguities for all measurements
  - ➢ Weaker solution
- Consistency for phase measurements at day boundaries:
  - Each satellite clock is corrected by the offset between the days.
  - The radial orbit offset for each satellite is corrected in the satellite clock.

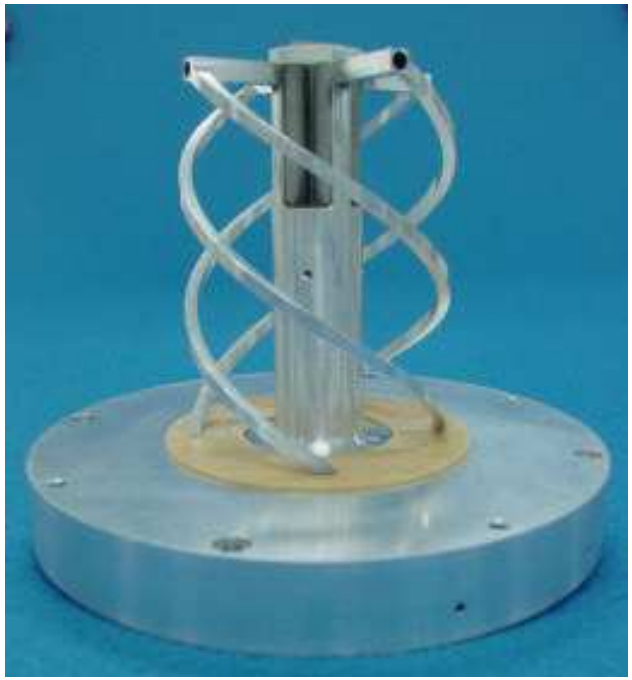
30-hours(2): Simulations, kinematic orbit



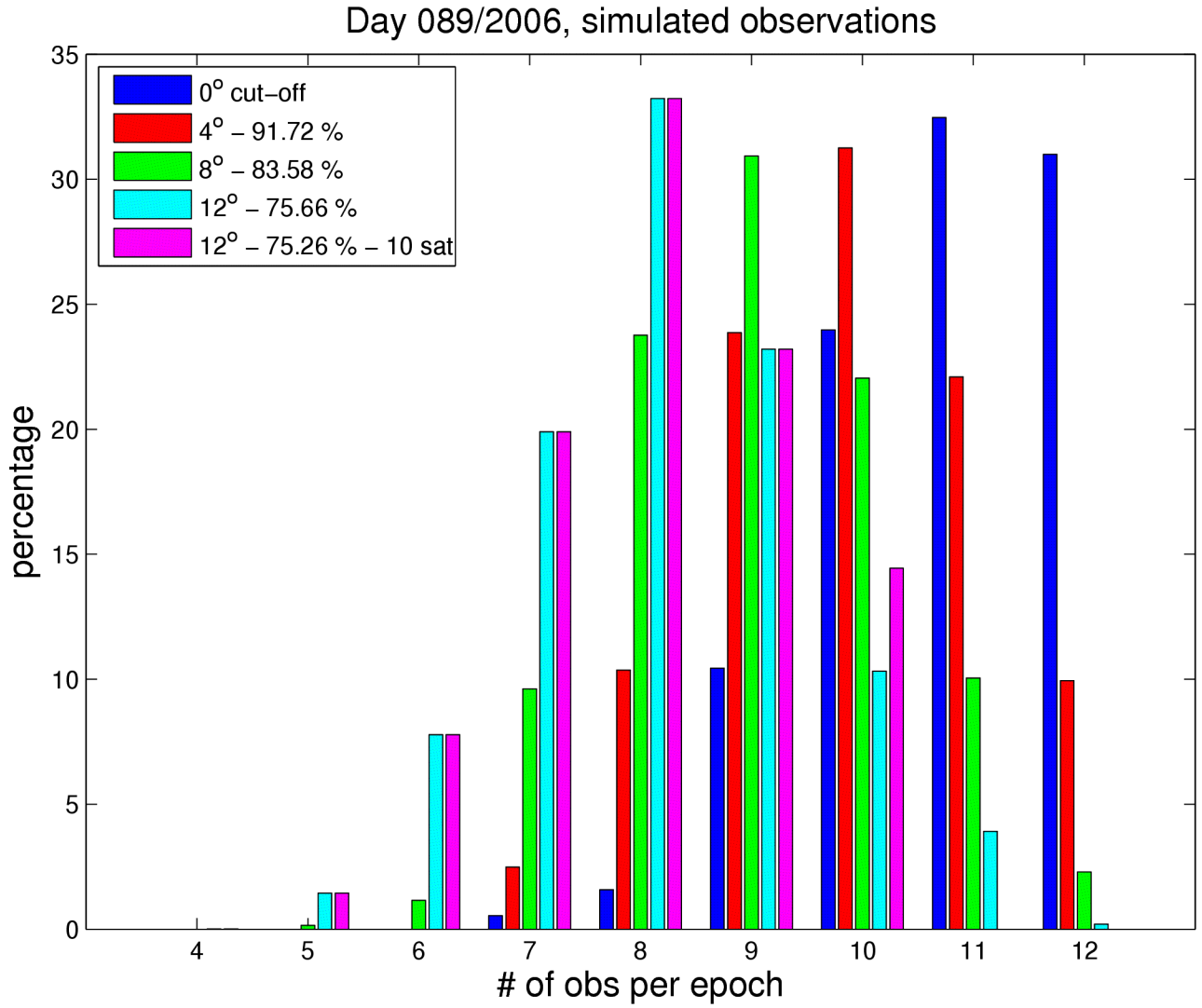
Antenna characteristics (1)

- Helix antenna
- For rising satellites L2 cannot be acquired at the horizon.
  - Effective cut-off will be between 8 and 12 degrees.

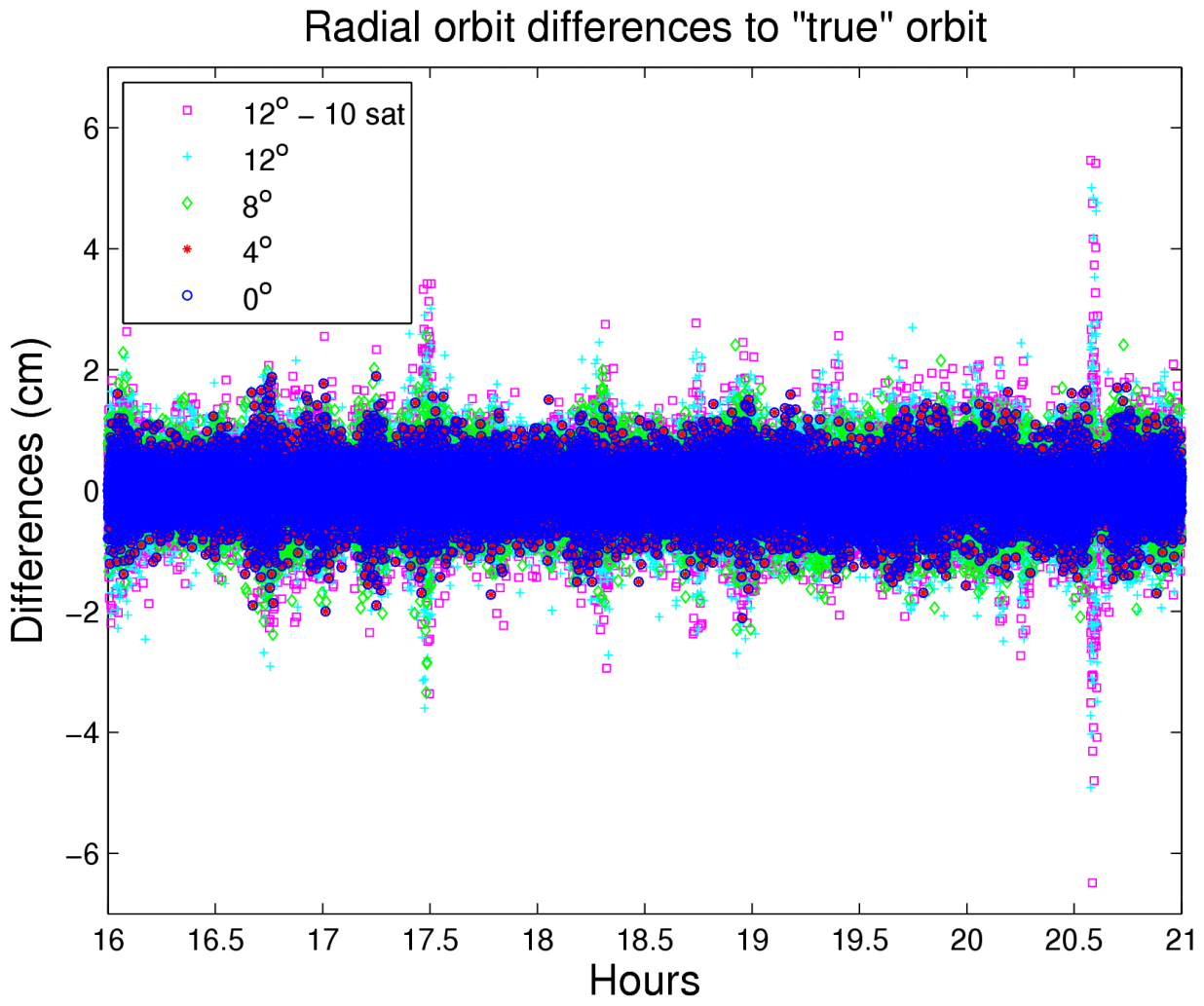
- Simulations:
  - 11 days of GOCE GPS observations
  - Noise: phase: 1 mm, pseudorange: 0.3 m
  - Five different sets:
    - 0° cut-off, 4°, 8°, 12°, 12° - 10 sat



Antenna characteristics (2): cut-off



Cut-off (3): Simulations, kinematic orbit



RMS

4 mm

4 mm

4 mm

3 mm

3 mm

Summary and Conclusions

- Precise orbit determination procedure for GOCE is realized in one processing flow.
- Overlap processing is done for quality and consistency checks.
- Simple GPS clock correction procedure has been developed to guarantee maximum consistency at day boundaries.
- Different antenna characteristic (cut-off angle) has impact on positioning accuracy (mainly at polar regions). It seems not to be critical except if several (>2) channels are missing or several (>2) observations per epoch are unusable.