Orbit Determination of Low Earth Satellites at AIUB

IGS Workshop, ESOC,
Darmstadt, Germany,
May 8-12, 2006

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Introduction

The poster presents activities at the Astronomical Institute of the University of Bern (AIUB) in the field of precise orbit determination (POD) for Low Earth Orbiters (LEO) using the GPS. They are currently focused on the two GRACE satellites and range from general studies about reduced-dynamic and kinematic POD based on zero- and double-difference observations to the implementation and testing of the POD procedures in the framework of the High-Level Processing Facility (HPF) for ESA's upcoming GOCE mission.

GOCE HPF Project

AIUB is responsible for the Precise Science Orbit (PSO) determination of the GOCE satellite. The PSO includes a kinematic (1 sec) and a reduced-dynamic (10 sec) orbit solution. For this purpose a general zero-difference LEO POD procedure was developed which is also used for the GRACE processing presented on this poster.
GOCE observations will have 1-second data sampling. Studies showed that 5-second clock corrections (linearly interpolated to 1 sec) are needed to reach the expected accuracy.

High-Rate GPS Clock Corrections

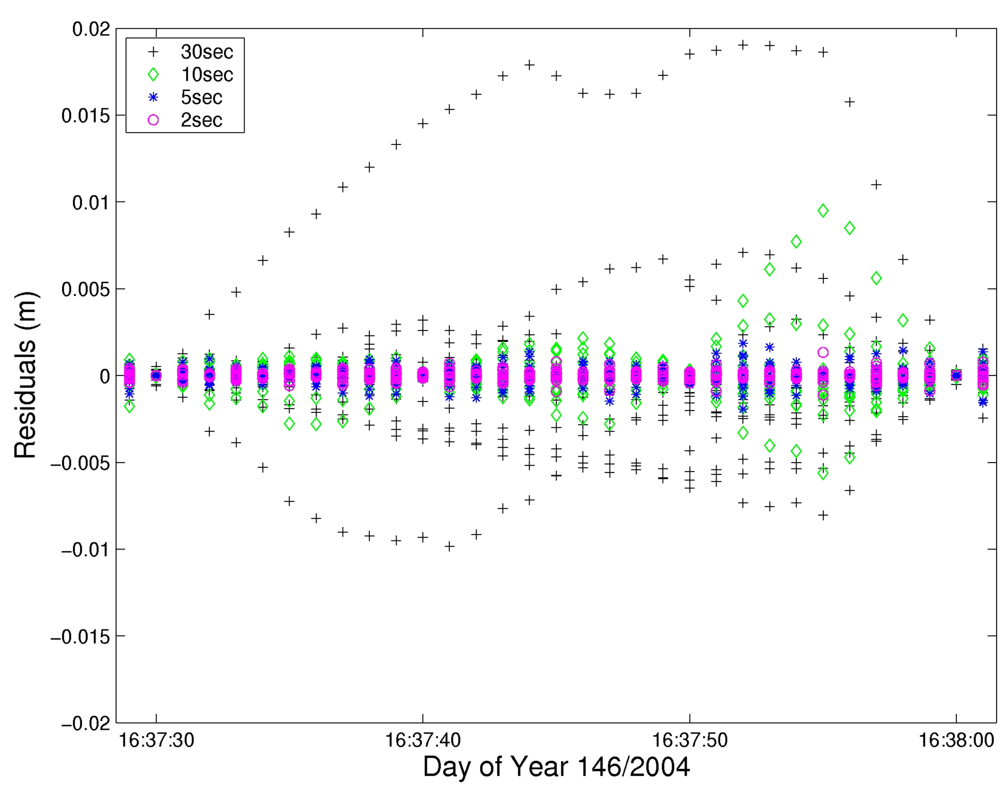

Figure 1: Residuals of error-free simulated phase observations (GRACE A) used for a kinematic point positioning solution [Svehla, 2004]. Four different solutions are computed using linearly interpolated 2-, 5-, 10-, and 30-second clock corrections. Residuals for solutions using 10- and 30-second clock corrections show significant signals. Therefore only interpolated 2- or 5-second clock corrections are usable. In order to minimize the computation time and storage requirements, 5-second GPS clock corrections are computed using phase-difference observations of the 1 Hz ground station network (available at IGS) and fixed on the official CODE 30-second clock corrections.

30-Hour Processing

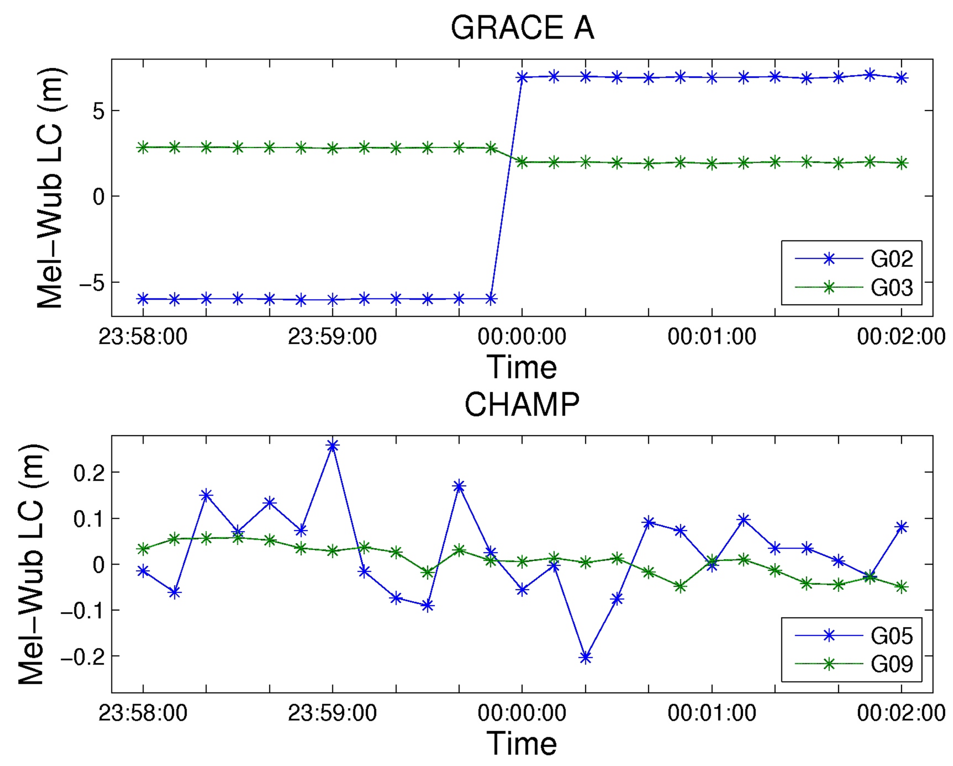

Figure 2: Melbourne-Wuebbena linear combination for two selected GPS satellites observed over midnight (= observation file boundary) from GRACE A (top) and CHAMP (bottom). Discontinuities seem to occur only for GPS observations from GRACE. Continuous phase observations over observation file boundaries are important if LEO arcs longer than 24 hours shall be generated, e.g., 30-hour arcs for GOCE. Kinematic, and to some extent also reduced-dynamic orbit solutions weaken if new phase ambiguities have to be set up for all GPS satellites at midnight.

GRACE Zero-Difference Reduced-Dynamic POD

This part of the poster presents GRACE A and B orbit solutions for the days 243/2003 to 363/2003 using different zero-difference GPS data samplings and orbital arclengths.

Solution A (red):
GPS data sampling: 10-second
Arclength: 30-hour reduced-dynamic orbit
Solution B (blue):
GPS data sampling: 30-second
Arclength: 30-hour reduced-dynamic orbit
Solution C (green):
GPS data sampling: 30-second
Arclength: 24-hour reduced-dynamic orbit

The reduced-dynamic POD methodology is based on 6-minute constant accelerations and is described in [Jäggi, 2006]. The gravity field model EIGEN-CG03C [Förste, 2005], attitude data from CSR, and GPS final orbit and high-rate clock information from CODE (see poster at this workshop) were the external sources for POD.

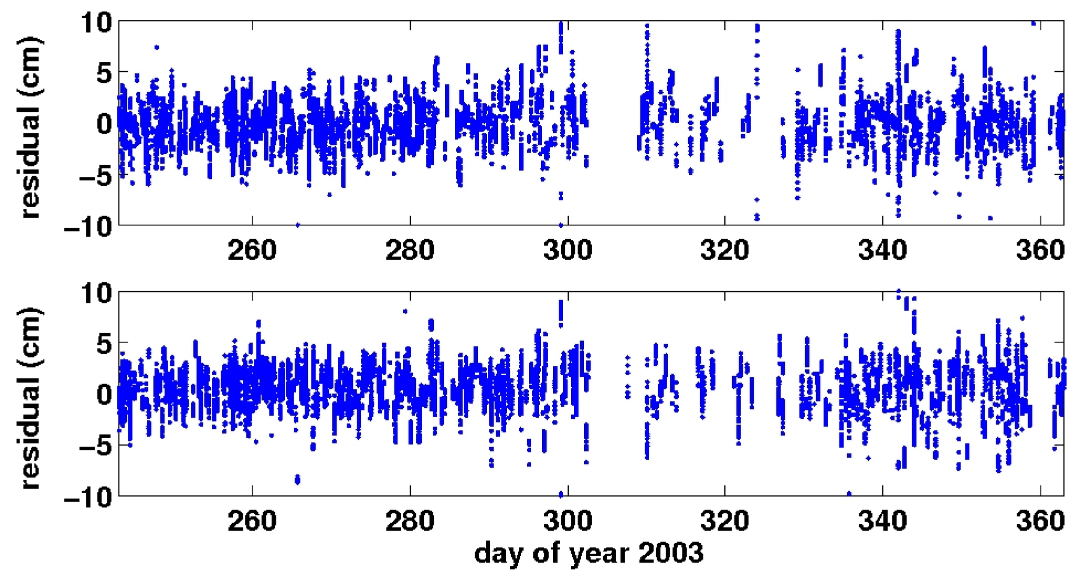

Figure 4: Residuals computed from a total of 20 SLR stations to the GRACE standard solutions B. The overall RMS for GRACE A (top) and GRACE B (bottom) is 2.50 cm and 2.30 cm, respectively, which is slightly better than 2.66 cm and 2.36 cm for solutions A. A small degradation of the SLR results may be recognized for the second half of the validation period despite the occasionally sparse SLR tracking (several days remained completely unobserved after day 300).

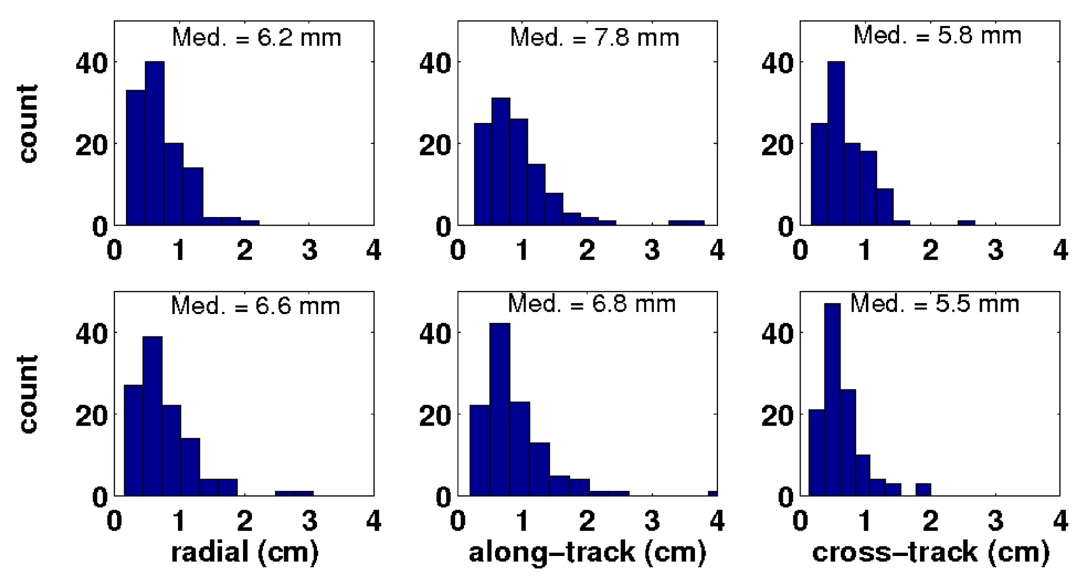

Figure 6: Histogramms of the RMS errors per day of the full 6-hour orbital overlaps of the solutions B for GRACE A (top) and GRACE B (bottom). The statistics is dominated by "edge-effects" of the first and last hour of each overlapping period. Analysis of the central 4-hours yields median values of 1.7 mm, 3.3 mm, and 3.8 mm for GRACE A, and 1.4 mm, 2.9 mm, and 3.4 mm for GRACE B, which is an estimate of the orbit consistency in the radial, along-track, and cross-track directions.

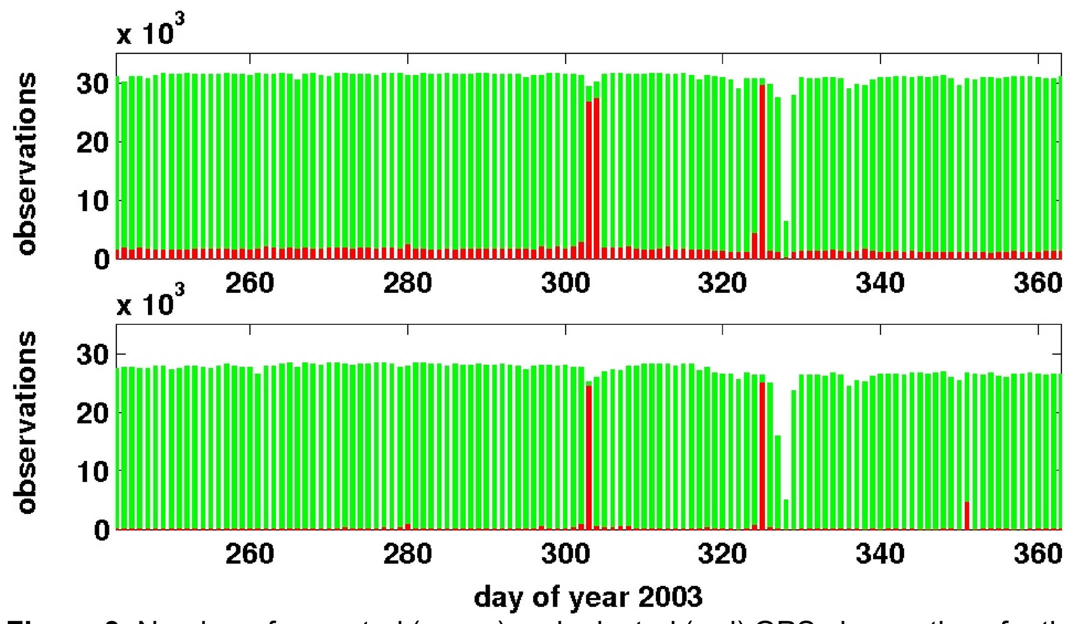

Figure 3: Number of accepted (green) and rejected (red) GPS observations for the standard solutions B for GRACE A (top) and GRACE B (bottom). Similar patterns result for the solutions A with a slightly reduced tracking performance for the second half of the analyzed period including a few problematic days (left out in the validation plots). It needs to be further investigated whether the worse validation results for the second half of the analyzed period can be attributed to this reduced performance.

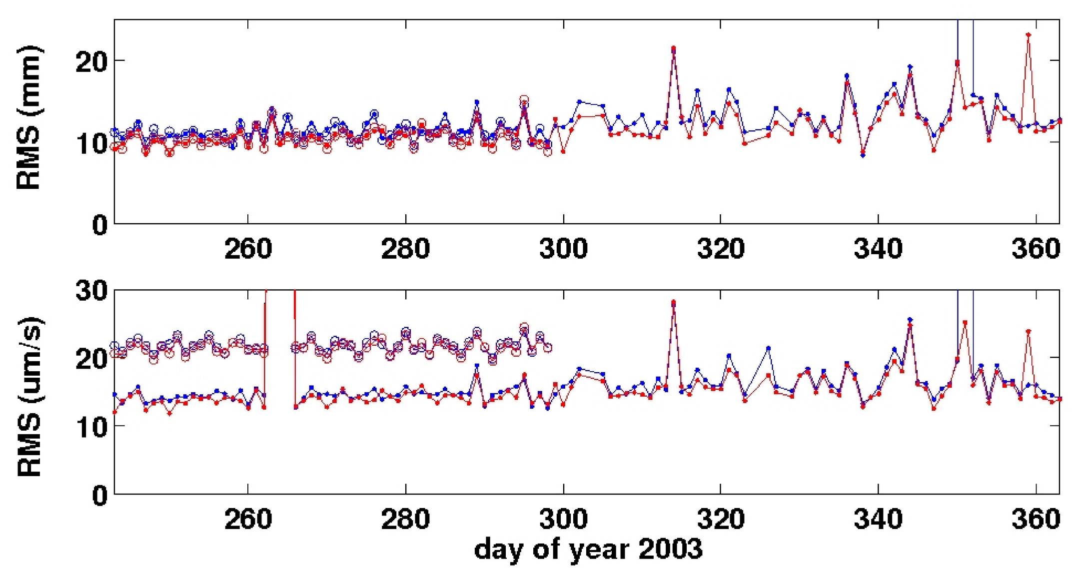

Figure 5: K-band range (top) and range-rate (bottom) RMS errors per day for the GRACE standard solutions B and the solutions A, which perform very well for the first half of the validation period. The overall RMS is 12.4 mm and 11.6 mm, and 15.8 um/s and 15.2 um/s, respectively, i.e., slightly better for solutions A. Orbit solutions with the gravity field model EIGEN-2 [Reigber, 2003] (circles) show significantly increased range-rate residuals (bottom), but almost the same range residuals (top).

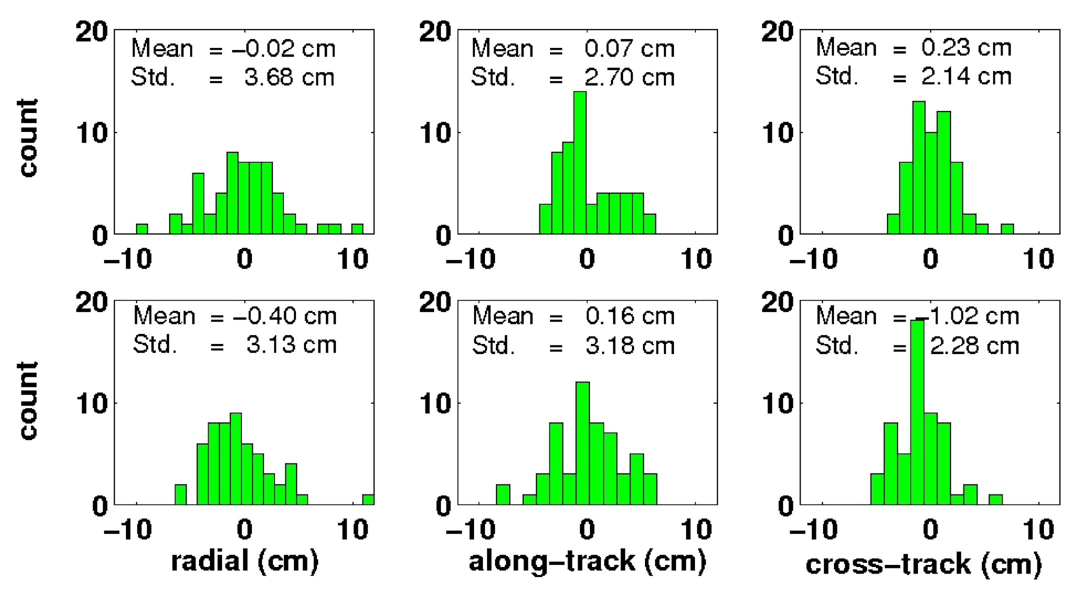

Figure 7: Histogramms of the orbital overlaps at the day boundary epochs for the 24h arcs of the solutions C for GRACE A (top) and GRACE B (bottom). The statistics provides pessimistic estimates of the orbital errors in the radial, along-track, and cross-track directions. Observe that solutions C were computed for days 243-298 only, which makes the statistics rather incomplete. More data needs to be analyzed to decide, e.g., whether the cross-track mean for GRACE B is systematic.

GRACE Double Difference Reduced-Dynamic POD

This part of the poster presents GRACE A and B orbit solutions with 24-hour orbital arclength for the days 243/2003 to 256/2003 using 30-second double-difference GPS data. 50 well selected IGS ground stations were used to form the Ground-Space (GS) baselines (coordinate and troposphere solutions were introduced as known from CODE).

Float Solution D (black), E (cyan):
Baselines GS-A and GS-B (D), or GS-A and A-B (E)
Fixed Solution F (magenta):
Like solution E, but fixed space-baseline ambiguities

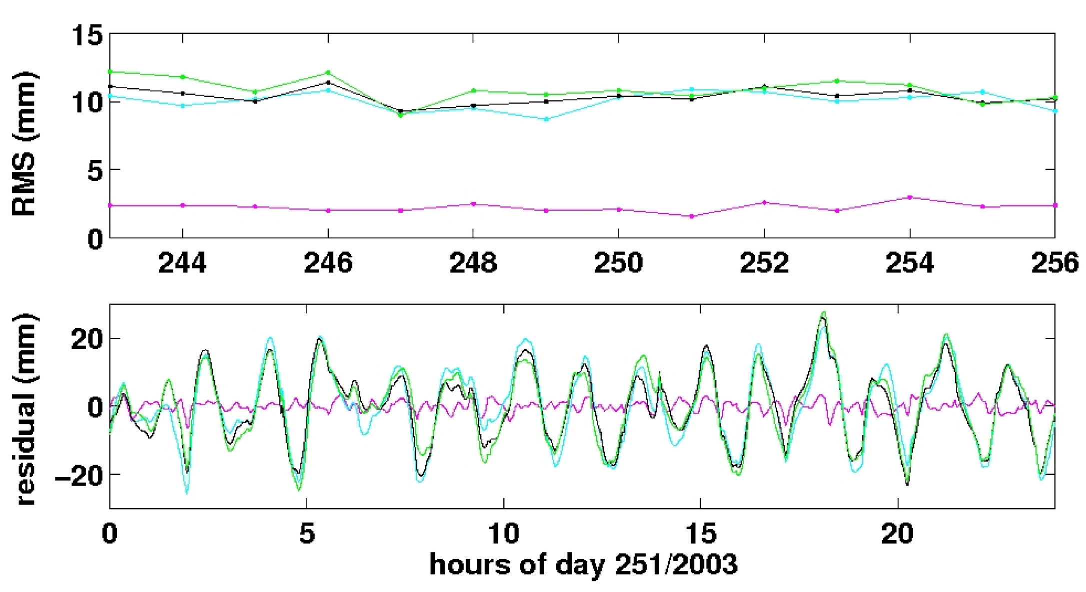

Figure 8: K-band range RMS errors per day for the GRACE solutions C, D, E, and F (top). The overall RMS over the 14-day period is 10.9 mm (C), 10.4 mm (D), 10.1 mm (E), and 2.3 mm (F). The significant impact of the fixed narrow-lane ambiguities (89.8% for the 14-day period) of the space-baseline on the "relative orbits" of the two GRACE satellites can be easily recognized on the individual time series of the K-band range residuals, as shown, e.g., for day 251 (bottom).

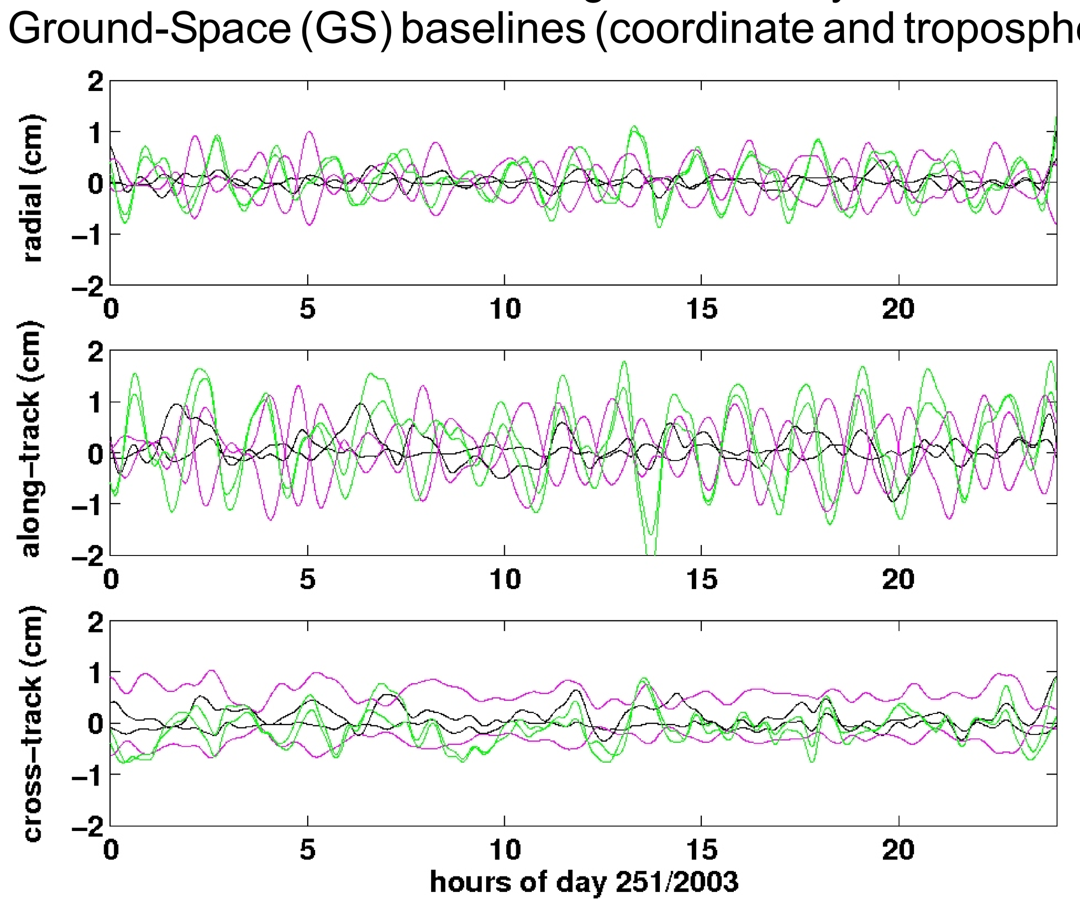

Figure 9: Orbit differences for day 251 for the GRACE solutions C, D, and F w.r.t. the solution E in the radial (top), along-track (middle), and cross-track (bottom) direction. The ambiguity-float solutions D and E do not differ by more than a few millimeters (for GRACE A), but the GRACE orbits of the ambiguity-fixed solution F show a distinct, anti-correlated pattern (oscillation in radial and along-track, shift in cross-track) with sizeable amplitude w.r.t. the orbits from solution E.

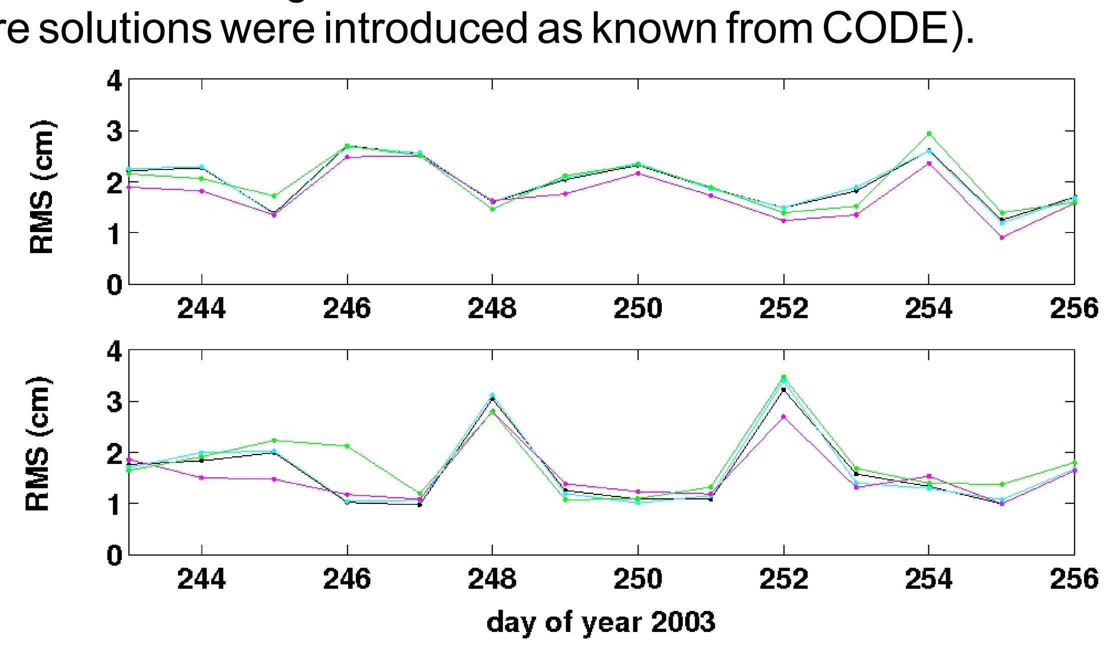

Figure 10: SLR RMS errors per day to the GRACE solutions C, D, E, and F for GRACE A (top) and GRACE B (bottom). The overall RMS over the 14-day period is:
GRACE A: 2.08 cm (C), 2.09 cm (D), 2.10 cm (E), 1.89 cm (F),
GRACE B: 1.77 cm (C), 1.68 cm (D), 1.70 cm (E), 1.61 cm (F).
Ambiguity fixing on the space-baseline seems thus to have a very small, positiv impact on the "absolute" orbits of the two GRACE satellites.

References

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Reigber C, Schwintzer P, Neumayer KH, Barthelmes F, König R, Förste C, Balmino G, Biancale R, Lemoine JM, Loyer S, Bruinsma S, Perosanz F, Fayard T (2003), *The CHAMP-only Earth Gravity Field Model EIGEN-2*, Adv Space Res 31(8): 1883-1888
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