GOCE SSTI Performance

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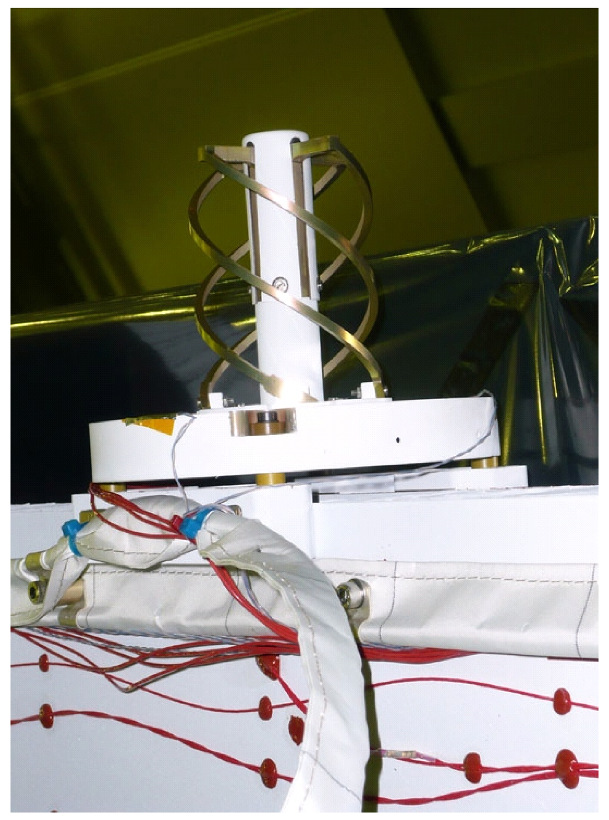
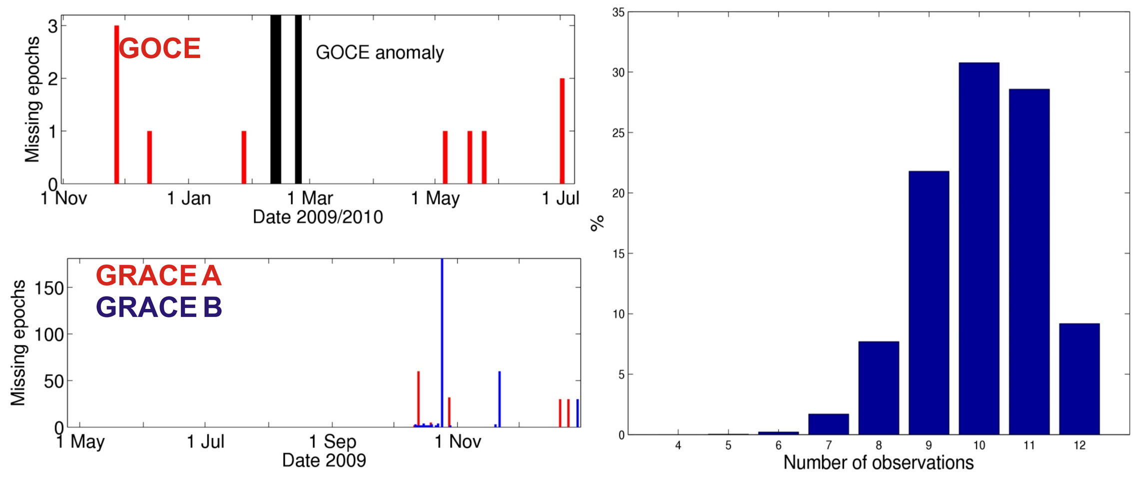
Introduction



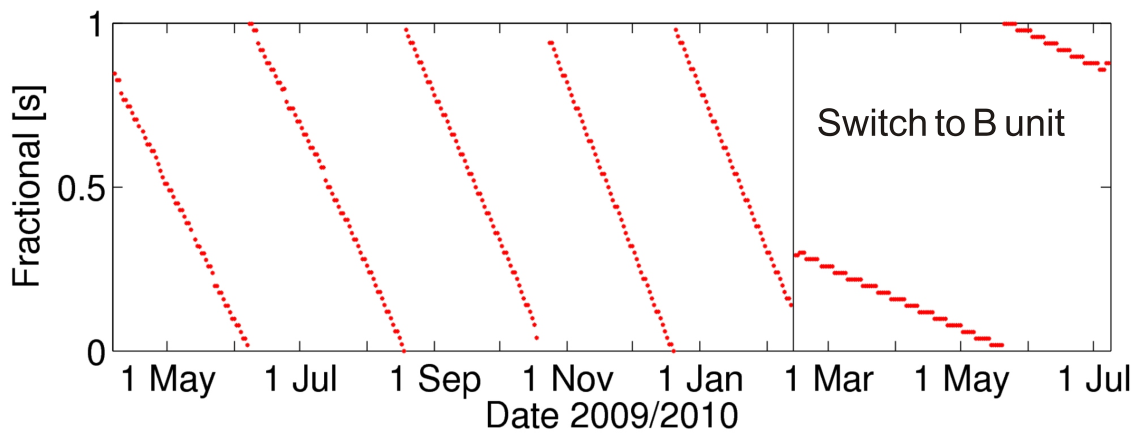
The GOCE (Gravity field and steady-state Ocean Circulation Explorer) satellite has been launched on March 17, 2009 from Plesetsk, Russia. The satellite is now in orbit for more than 18 months.
The mission is equipped with a Satellite-to-Satellite Tracking Instrument (SSTI) consisting of a 12-channel dual-frequency Lagrange GPS receiver connected to a helix antenna.
The quality and performance of this completely new spaceborne GPS tracking system is assessed.

Data availability

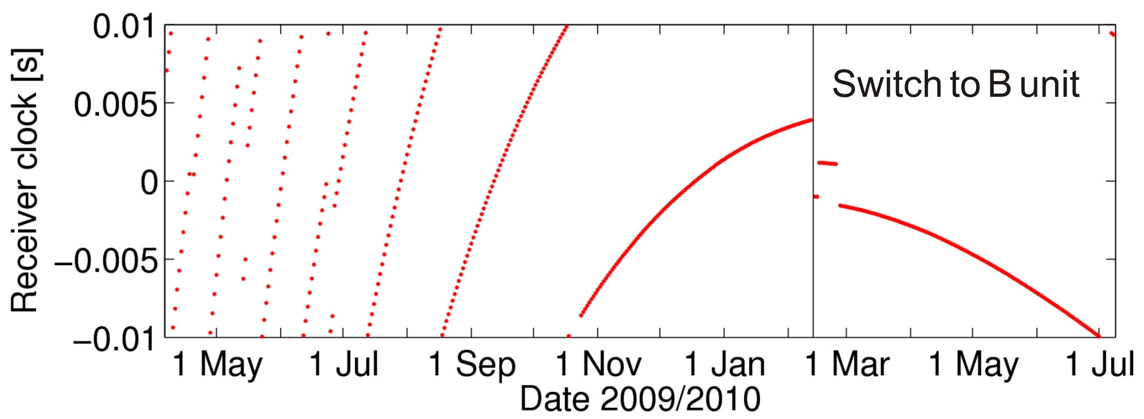


Left, top:The GOCE 1 Hz GPS data are almost continuous and only very few observation epochs are missing (1 bar/day). Bottom: Missing epochs (10 s !!) for GRACE A / B. **Right:** The percentages of the number of tracked satellites per epoch are shown for a typical day (November 6, 2009). For two thirds of the epochs ten or more observations are available.

Observation epochs and receiver clock

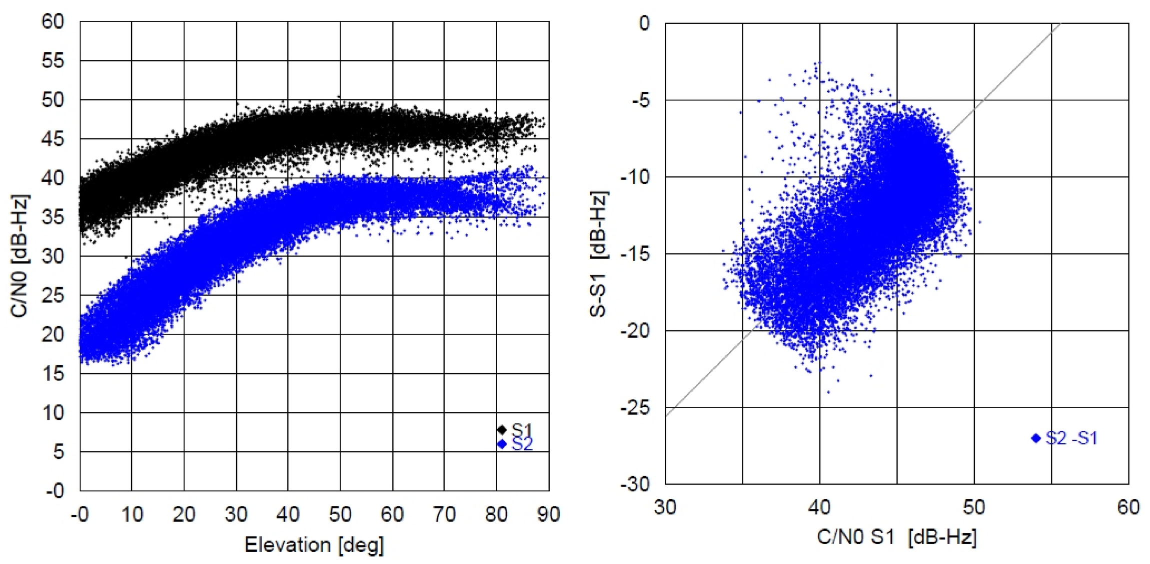


The internal clock is not steered to integer seconds and the observation epochs have, therefore, fractional offsets (shown at the midnight epochs). These fractional offsets stayed constant for about 25-27h and then jumped by 20ms. This behaviour changed after the switch to the redundant onboard computer B mid of Feb 2010. The time interval for a constant fractional offset is extended to 5-6 days.

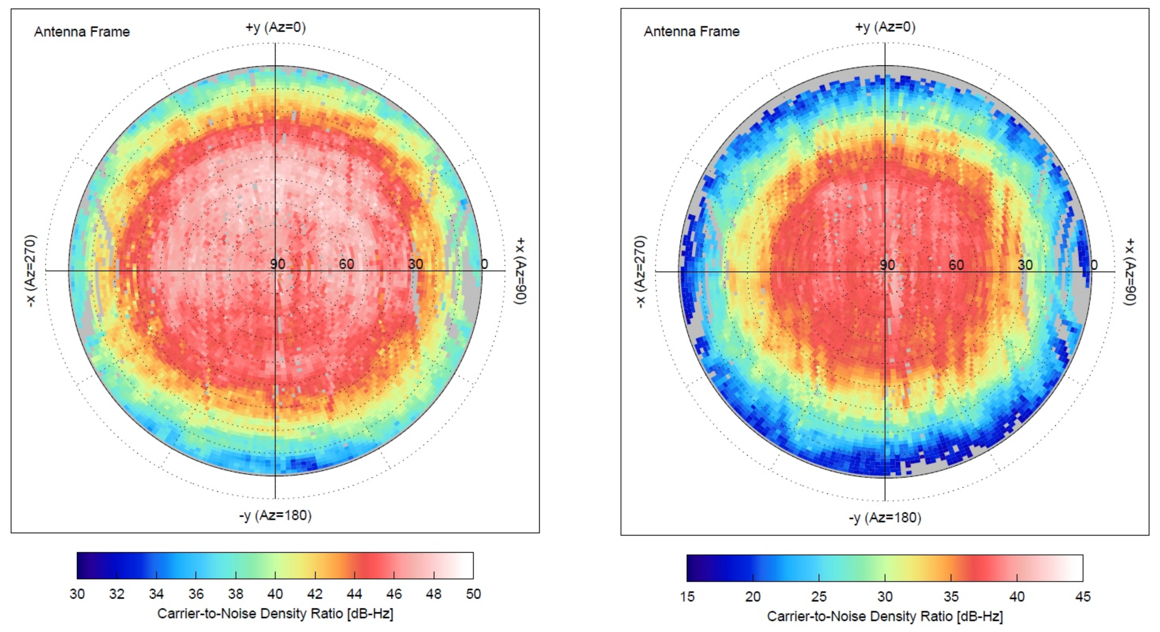


The receiver clock (shown at the midnight epochs) varies between -0.01s and +0.01s. The variations from one day to the next have been larger at the beginning of the mission.

Carrier-to-noise / semi-codeless tracking

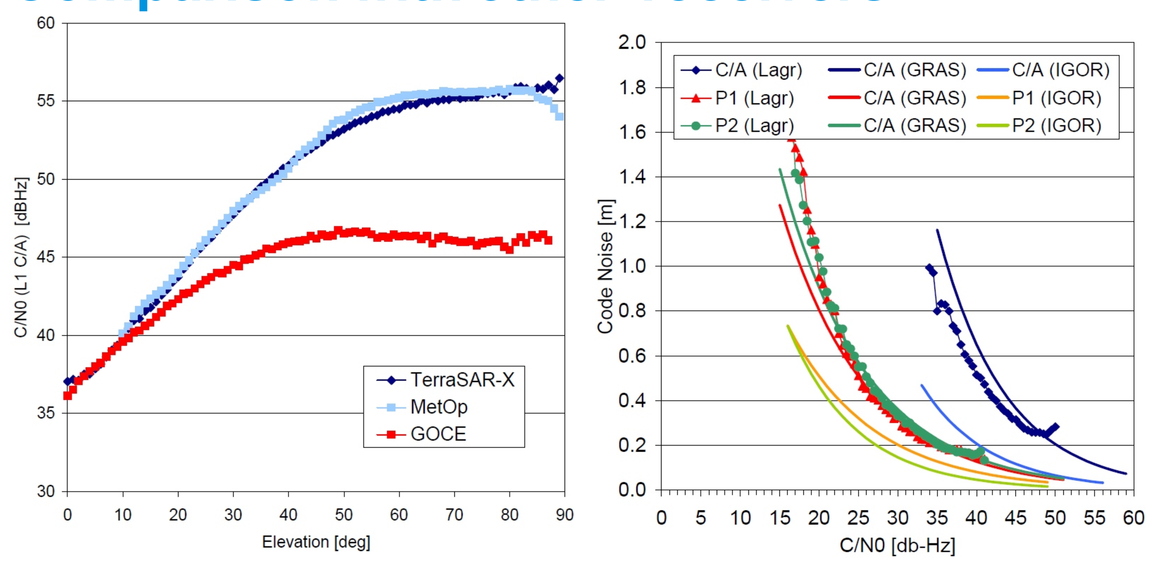


Left: Variation of carrier-to-noise-density-ratio for L1 C/A-code tracking (S1) and semi-codeless L2 P(Y)-code tracking (S2) for GOCE main SSTI antenna (DOY 2009/342). The helix antenna diagram exhibits a slight sensitivity decrease near zenith and the maximum C/N0 is achieved near elevations of about 50°. Semi-codeless measurements are only performed down to a lower C/N0 threshold of about 17 dB-Hz. **Right:** Semi-codeless tracking losses for L2 P(Y) tracking. The S2-S1 values are in close accord with the Z-tracking theory and GPS signal levels when assuming a slightly higher antenna gain in the L2 band as compared to the L1 band.



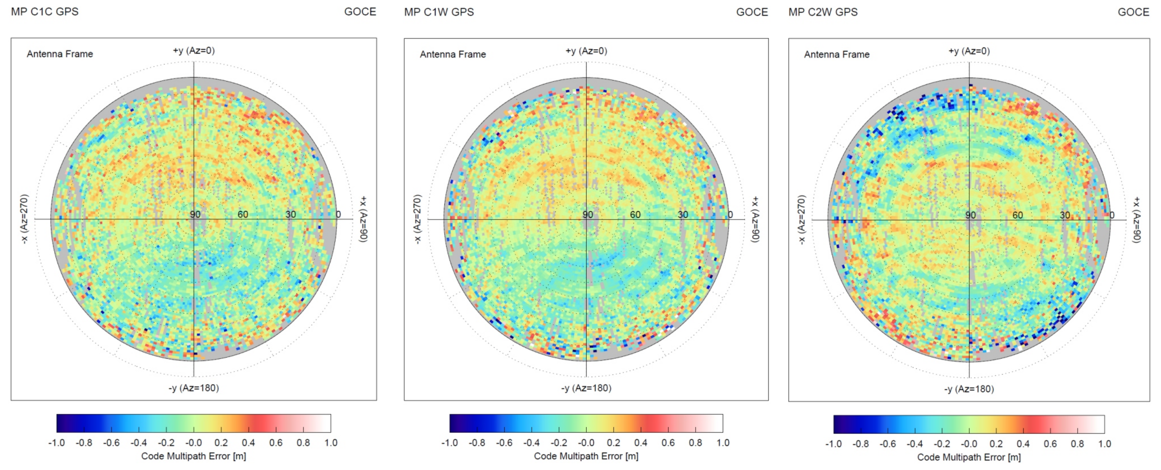
The variation of the carrier-to-noise-density-ratio (C/N0) for L1 C/A code tracking (**left**) and L2 P(Y)-code tracking (**right**) as a function of azimuth and elevation in the antenna diagram indicates a slightly higher L1 antenna gain in the forward direction. The flight direction corresponds to Az=0°.

Comparison with other receivers



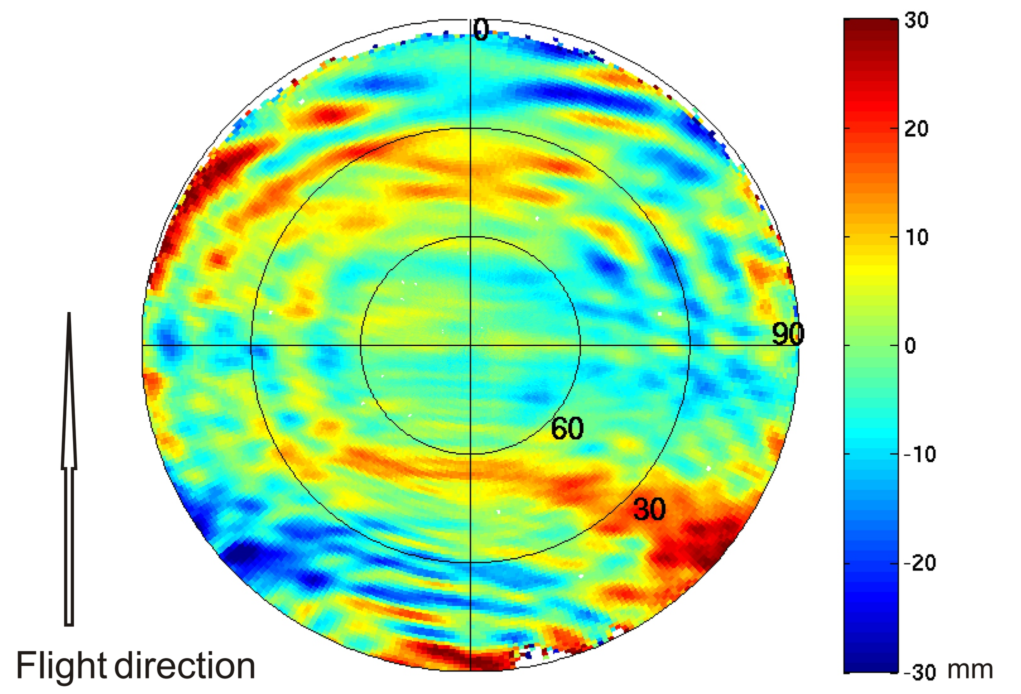
Left: A comparison of L1 C/N0 values for the TerraSAR-X (IGOR receiver), MetOp (GRAS instrument) and GOCE (Lagrange receiver) indicates a notably lower L1 gain of the helix antenna on GOCE as compared to the antennas employed on the other missions.
Right: Comparison of code noise for L1 C/A and L1/L2 P(Y) tracking for the Lagrange receiver on GOCE with the IGOR receiver on TerraSAR-X as well as the GRAS instrument on MetOp-A. The GRAS and Lagrange receivers exhibit a closely similar variation of code tracking noise versus C/N0, which indicates an almost identical choice of the respective tracking loop bandwidths.

Code multipath errors



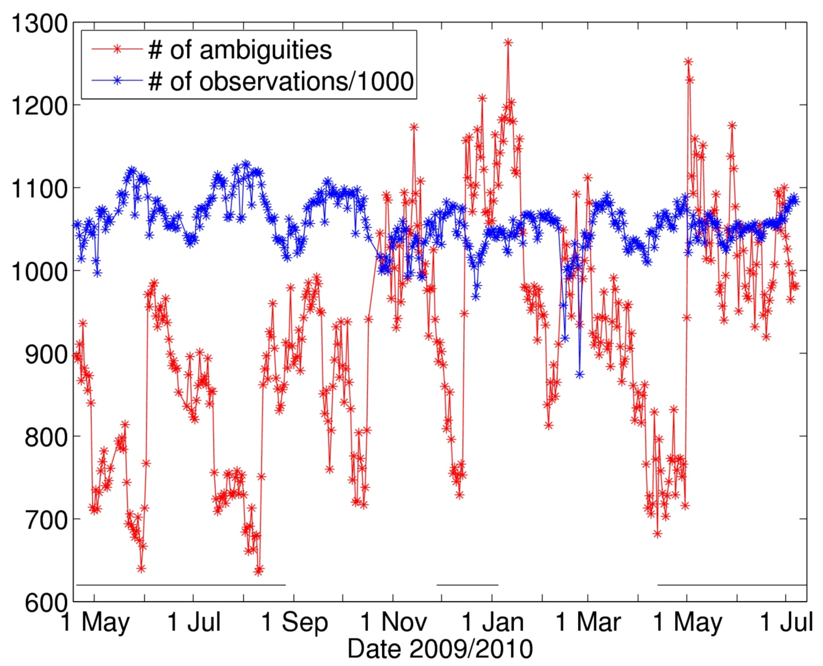
Code multipath errors for L1 C/A (**left**), L1 P(Y) (**center**) and L2 P(Y) tracking (**right**). The plots indicate the presence of moderate (<0.5 m peak error) multipath errors which are presumably caused by diffraction in the near-field of the antenna. For L1, a notable forward/backward asymmetry can, furthermore, be recognized, which might introduce systematic along-track positioning errors in code-based orbit determination.

Antenna phase center variations



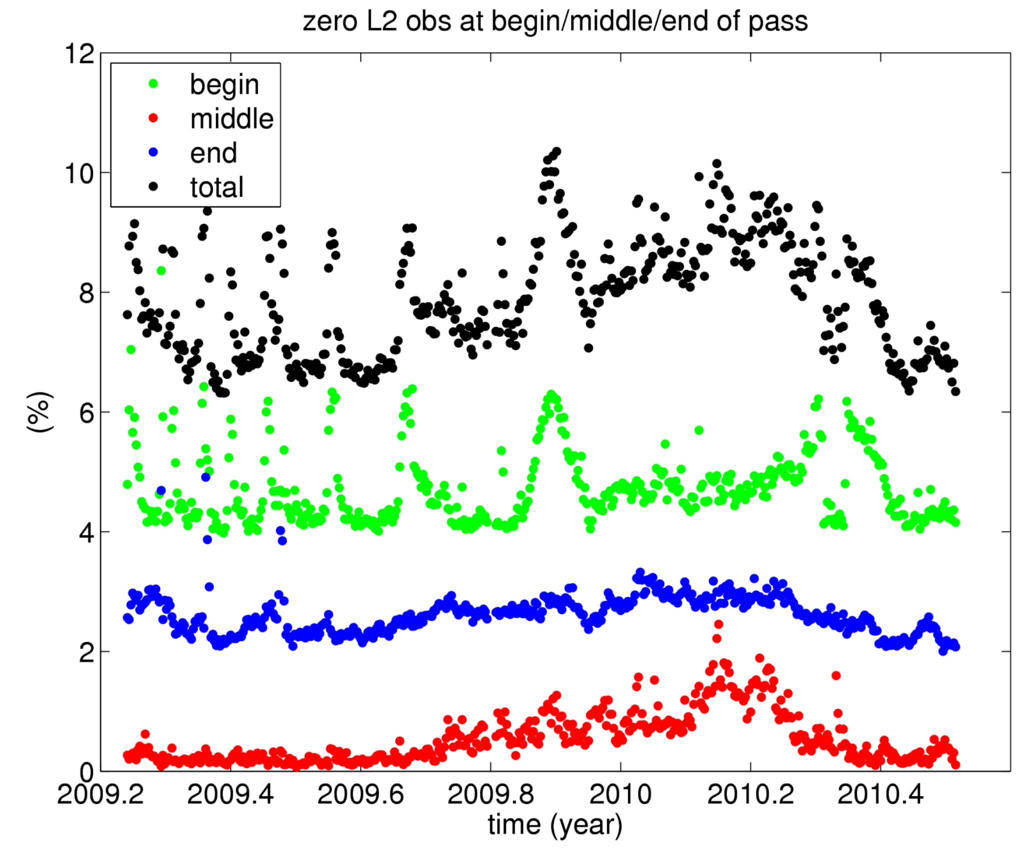
The empirically derived phase center variations (PCVs) of the main SSTI antenna show systematics up to several cm's. The carrier phase observations have to be corrected for the PCVs in the PSO (Precise Science Orbit) processing to achieve the required orbit accuracy.

Data processing

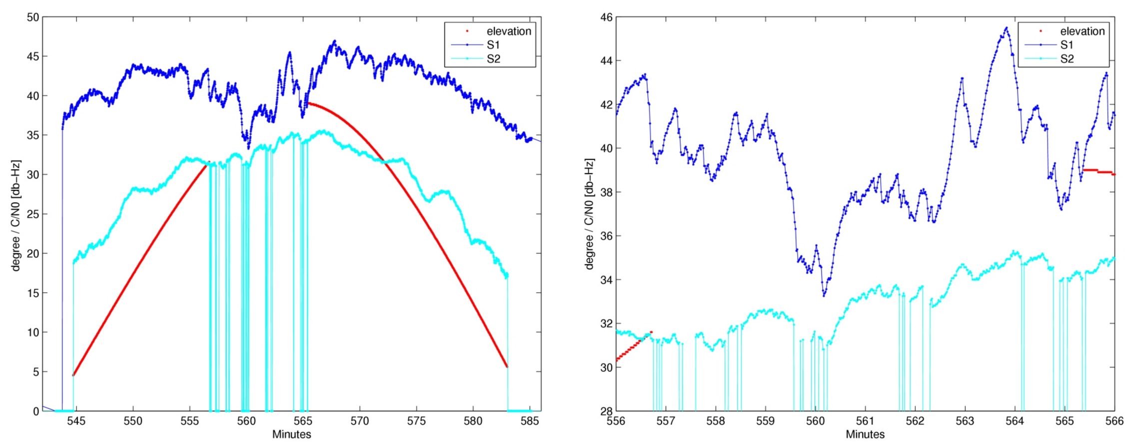


The number of phase ambiguity parameters set up per orbital arc in the PSO processing varies heavily. The variations are not related to the different number of observations used in the processing. At least one phase ambiguity parameter is set up for one GPS satellite pass. An additional ambiguity per pass is necessary, if a cycle slip or a data gap occurs. A direct correlation to the varying number of L2 tracking losses (see next column) could not be found. The causes of the sudden changes on subsequent days are not yet understood.

L2 tracking issues



Missing (zero) L2 observations at begin and end of a GPS satellite pass are normal due to receiver tracking technology and the lower carrier-to-noise ratio. The sometimes quite large number of missing L2 observations in the middle of a satellite pass are, however, not yet understood. The variations in time cannot be explained as well as the geographical accumulation at the polar regions/near the magnetic poles (not shown here) could not yet be correlated to physical phenomena, e.g., increase of the ionospheric disturbances due to the solar cycle.



A typical image of the C/N0 values is shown in case of missing L2 observations (C/N0 (L2)= 0) in the middle of a satellite pass. The elevation shows that the missing observations occur near the highest elevation of the satellite pass. The different behavior of the C/N0 values as well as the different noise on the two frequencies are not yet understood and need further investigations.
Nevertheless, these missing L2 observations do not have significant impact on the data processing and the corresponding orbit determination results.

Summary

The GOCE Lagrange receiver is a state-of-the-art GPS tracking instrument, which delivers an almost continuous 1 Hz data series. The helix antenna has a significantly lower L1 gain compared to different antennas on other missions. Code multipath errors are moderate. The PCVs show systematics up to several cm's.
The heavily varying number of phase ambiguities in the data processing and missing L2 observations in the middle of satellite passes are open issues, which have to be further investigated to fully understand and assess the performance of the GOCE SSTI.

References

Bock H., Jäggi A., Meyer U. et al.(2010) GPS-derived orbits for the GOCE satellite, submitted to Journal of Geodesy
Bock H., Jäggi A., Meyer U. et al.(2010) Impact of GPS antenna phase center variations on precise orbits of the GOCE satellite, submitted to Advances in Space Research

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