Issues of GOCE SSTI processing

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Introduction

ESA's first Earth Explorer Core Mission GOCE is equipped with a 12-channel dual-frequency Lagrange GPS receiver. The GPS data are primarily used for precise orbit determination of the satellite and the derivation of the long wavelength part of the Earth's gravity field. The Precise Science Orbits (PSO) derived from the almost continuous 1 Hz GPS data series meet the mission accuracy requirement of 2 cm.

The GOCE PSOs are, however, of slightly reduced quality over the polar regions. This is particularly important and evident for kinematic positions, where an inferior quality directly maps into subsequent gravity field solutions. The root-cause for the degradation is not yet fully understood, a direct correlation with more frequent L2 tracking losses occurring near the geomagnetic poles could not yet be clearly demonstrated.

Possible interactors are the observation geometry, which is slightly worse near the poles, and the ionosphere that is coupled with solar activity and the magnetic field of the Earth. We show correlations with these interactors and present the state of findings.

Method of analysis: To assess the orbit accuracy, the GPS phase residuals of the routinely processed reduced dynamic PSO are studied. The RMS of the residuals is related to the number of available observations, their quality and geometry. Gaps occur due to signal losses (either L1 or L2) and due to data screening because of bad signal to noise ratio or too little observations per epoch. To separate antenna specific issues from atmospheric influences, the RMS as well as the number of observations and the number of gaps is plotted in different coordinate systems (earth fixed (φ/λ), antenna fixed (Az/Ele) or related to the direction of the sun (u/β)).

U/β-plane (fig. 1): The u/β-plane visualizes the directional influence of the sun. The β-angle varies slowly with time between 59° and 90°, shown is the period from doy 62 to doy 171, 2010. The distribution of observations is very homogeneous (more observations only when β is turning). Gaps occur mainly near the poles (u~90°, 270°), the RMS is degraded near the poles and at the magnetic equator. There is a seasonal influence visible near the south pole in the RMS-plot. The increase in gaps around β=67.2° corresponds to a degradation after doy 121, probably due to a magnetic storm around this date.

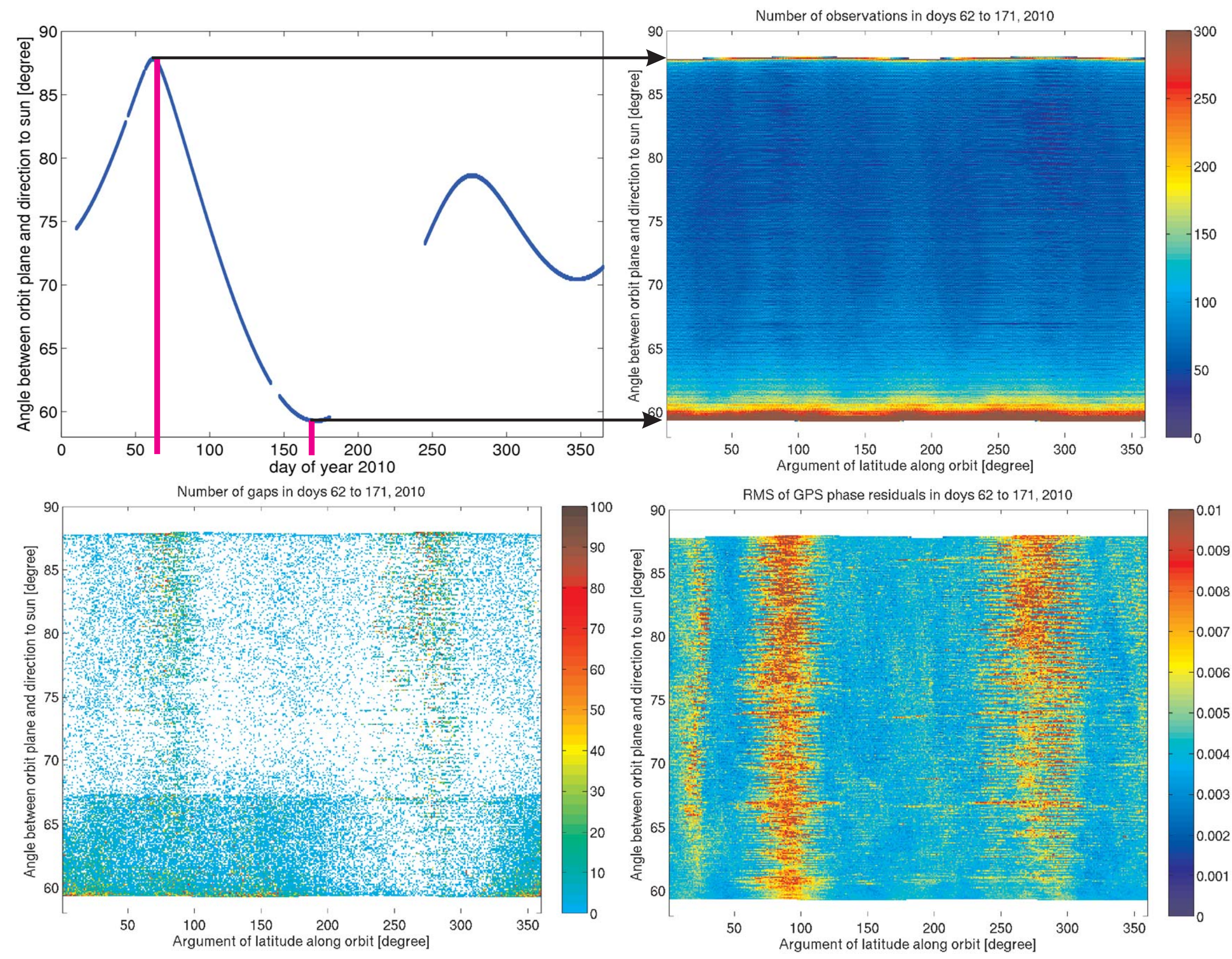
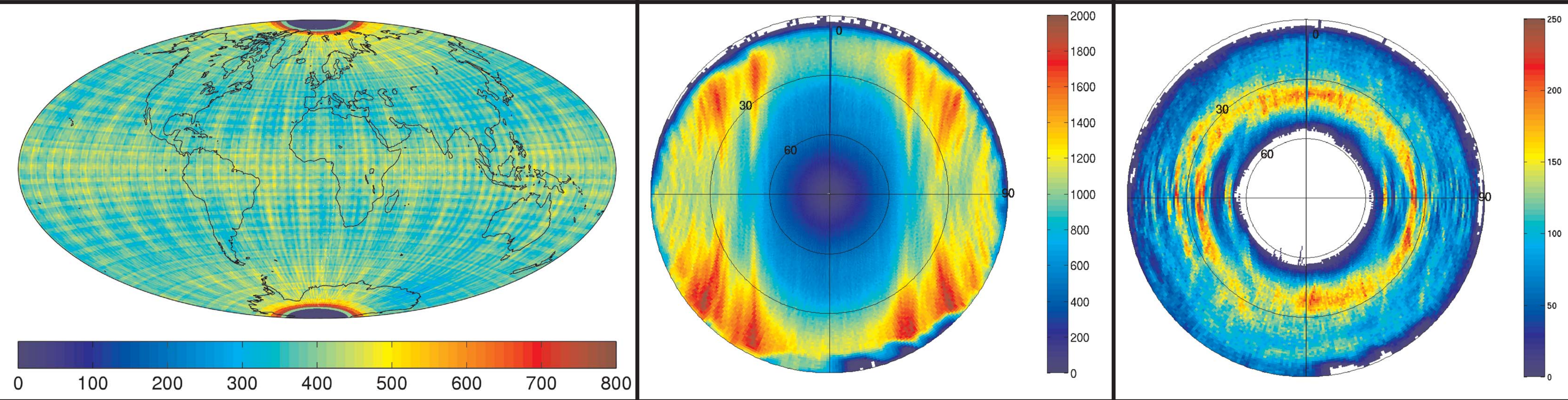


Fig. 1a-d: β-angle in 2010, observations, gaps and orbit quality in u/β-plane.

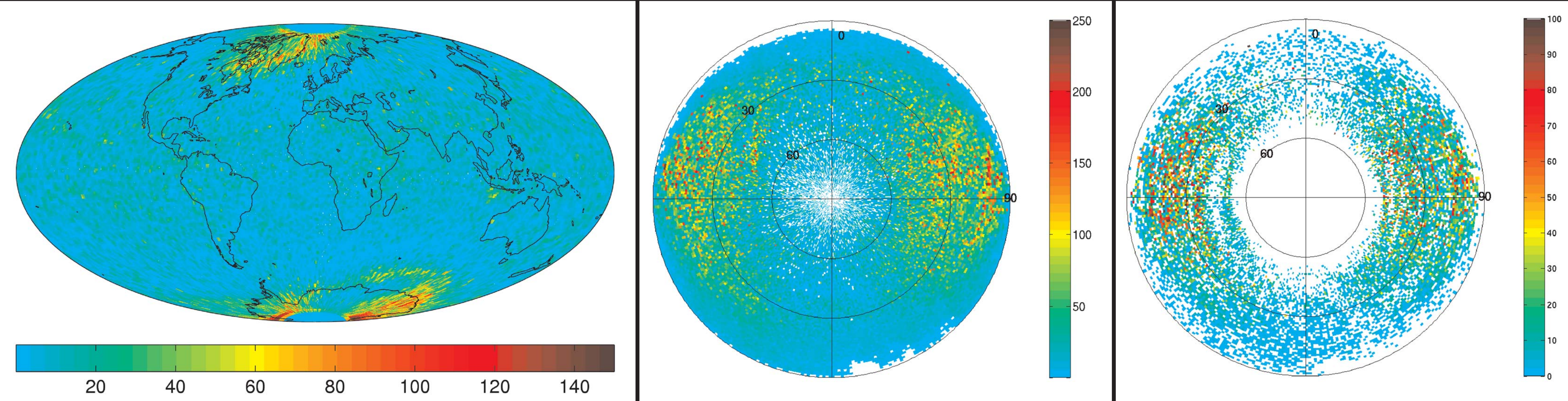
	Earth fixed (φ,λ)	Antenna fixed (Az, Ele), |φ|<80°	Antenna fixed (Az,Ele), |φ|>80°	What do we learn?

Number of observations



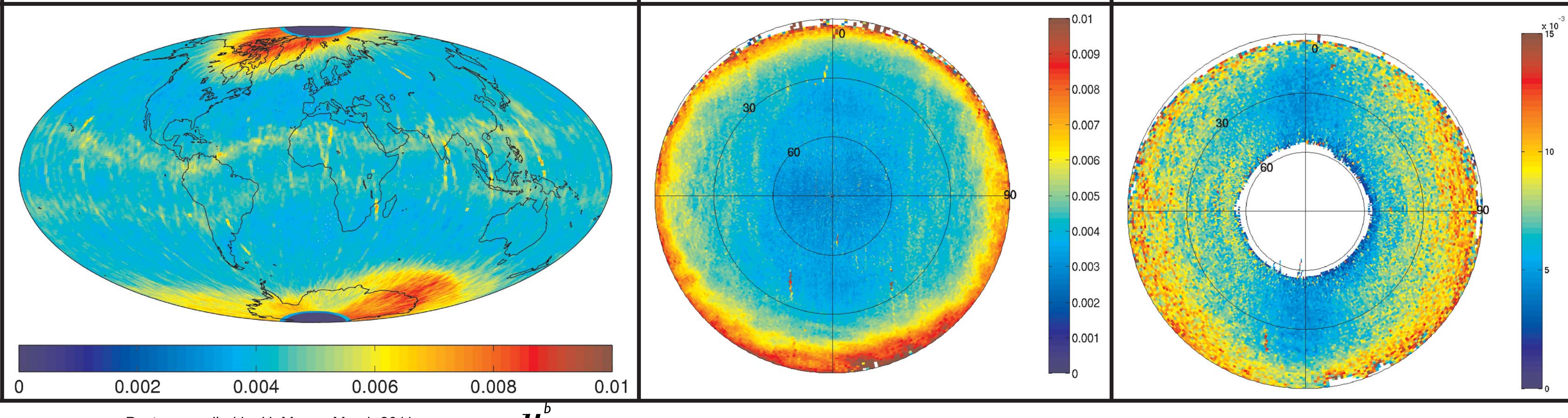
- The distribution of GPS observations is uniform in longitude but varies with latitude; density is highest near the polar gaps, due to the dense ground tracks.
- There are less observations in zenith direction (due to the rapid pass), the number of observations is not symmetric due to antenna characteristics.
- Close to the poles the distribution is nearly azimuth independent; most acquisitions at medium elevations, no observations above ~55° (due to orbit geometry of GPS satellites).
- Little observations at low elevations due to antenna limitations and atmosphere issues.

Number of gaps



- Most gaps occur near the magnetic poles, but they are not uniformly distributed. There seems to be a correlation to ionospheric scintillations.
- In the skyplot most gaps occur in cross track direction, this is especially true for high latitudes.
- The accumulation of gaps in cross track is not directly correlated to the number of observations.
- Gaps occur from low to medium elevations; the lack of gaps at high elevations may be partially explained by the generally small amount of observations near zenith.
- The accumulation of L2-losses at lowest elevations (see fig. 2) is not really visible in the distribution of gaps in the phase residuals.

RMS of residuals [m]



- The RMS of the orbit fit is significantly degraded near the magnetic poles and shows some correlation with the magnetic equator.
- In the antenna fixed system mainly low elevations are affected, in particular in the rear of the satellite.
- Near the poles mainly low elevations in cross track direction are degraded. There seems to be a slight asymmetry that favors azimuths from 0° to 180°.
- While the global distribution of gaps seems to be highly correlated with orbit quality, this correlation gets lost in the skyplot, where elevation dependence is more pronounced.

L2-Losses in the skyplot: The skyplot is an antenna fixed system. The azimuth of the observation is counted clockwise (flight direction to the top of the plot), the elevation of the observations is 0° at the outer border, 90° in the center of the plot. L2-losses occur mainly at low elevations in cross track direction. There exist sharply distinguished maxima around Az=270°, some less striking features between Az=80° and 125° and close to Az=180°. These accumulations of gaps in a few places suggest "blind spots" of the GPS receiver antenna. In fig. 3 it is shown, that some of them may also be due to correlations with the ionosphere.

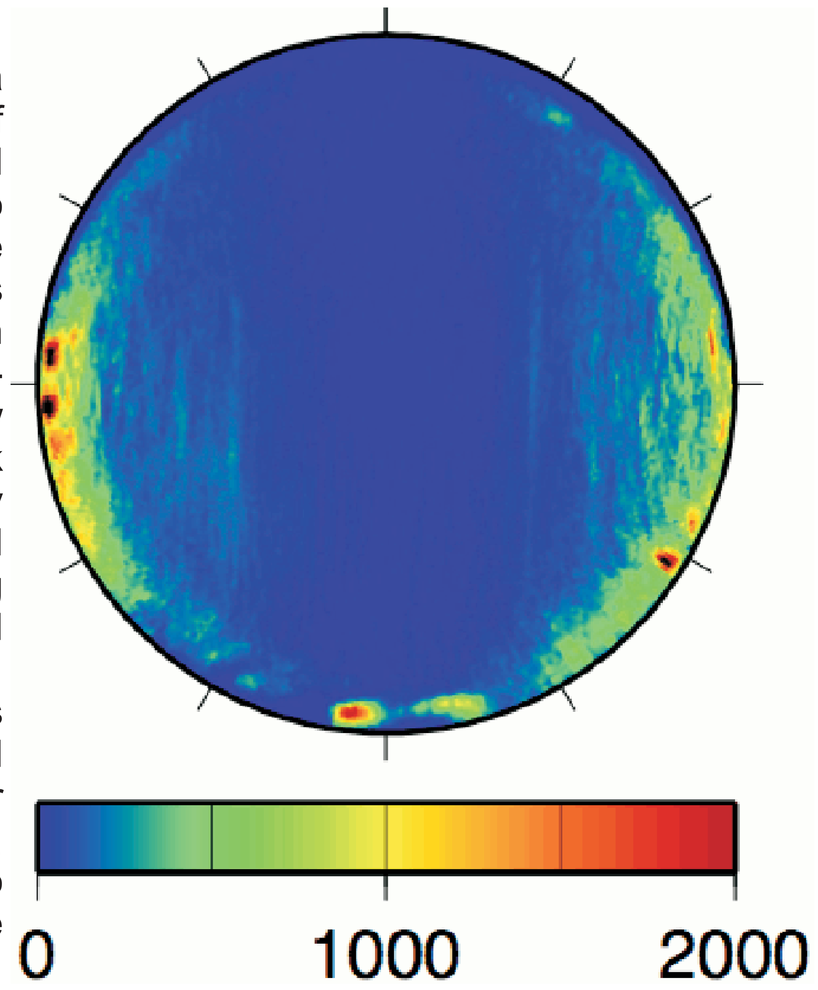


Fig. 2: L2-losses in the middle of a pass, extracted directly from the RINEX observation files.

Where is the sun: GOCE follows a dusk-dawn orbit. As a consequence, the sun is relative to the GPS antenna always at a low (or negative) elevation to the left. More precisely, the sun's track on the skyplot is a circle around Az=270° and Ele=0° with a radius corresponding roughly to 90°-β. In fig. 3a the RMS of the residuals from doy 62 to 171, 2010 is mapped to the corresponding location of the sun. In fig. 3b the number of observations at |φ|>80° are mapped in the same way. Figures 3c and 3d show the results for doy 278 to 347. As already shown, the orbit quality is worse near the poles. It may be noted, that most L2-losses (fig. 2) occur at low elevations in the direction of the sun, when GOCE passes a pole. This points again to trouble with the ionosphere.

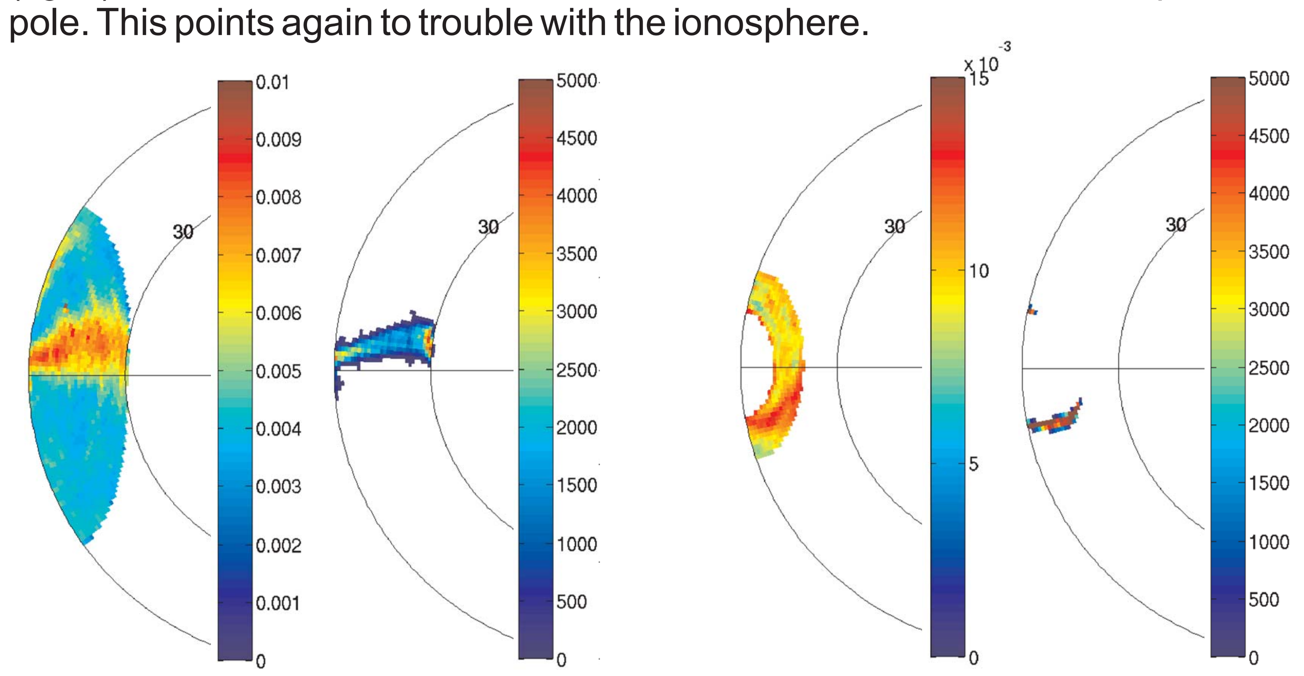


Fig. 3a-d: RMS [m] and number of observations near pole during doy 62 to 171 (left) and doy 278 to 347 (right), mapped to position of sun.

Conclusion:

All analyses point to an influence of the ionosphere on the signal reception of the GPS antenna onboard GOCE. The ionosphere interacts with the magnetosphere and is heated by the sun. Signal reception is degraded at low elevations (long travel time through ionosphere) near magnetic equator and poles in the direction of the sun (where the ionosphere is heated most). L2-losses to the right and the rear of the satellite may be antenna specific (to be verified).

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