Dependency of Geodynamic Parameters on GNSS Constellation

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Introduction

The time series of the daily geocenter Z coordinate (G_Z) and the Earth Rotation Parameters (ERPs) differ significantly between GPS-only, GLONASS-only and combined GPS/GLONASS solutions (Meindl et al. 2013). To some extent this is explained by deficiencies in the empirical solar radiation pressure model (Arnold et al. 2015). Other reasons for these differences may be the number of satellites, the number of orbital planes or the inclinations of the orbital planes which is different between the different Global Navigation Satellite System (GNSS). In this analysis we examine the influence of the number of orbital planes.

The understanding of the relation between satellite constellation and resulting geophysical/geodetic parameters is important because systems under development (Galileo and MEO-constellation of BeiDou) consist only of three orbital planes. If this turns out to be a disadvantage with respect to GPS with its six orbital planes it is a valuable information when these systems will be operationally included in multi-GNSS processings.

Generating the Solutions

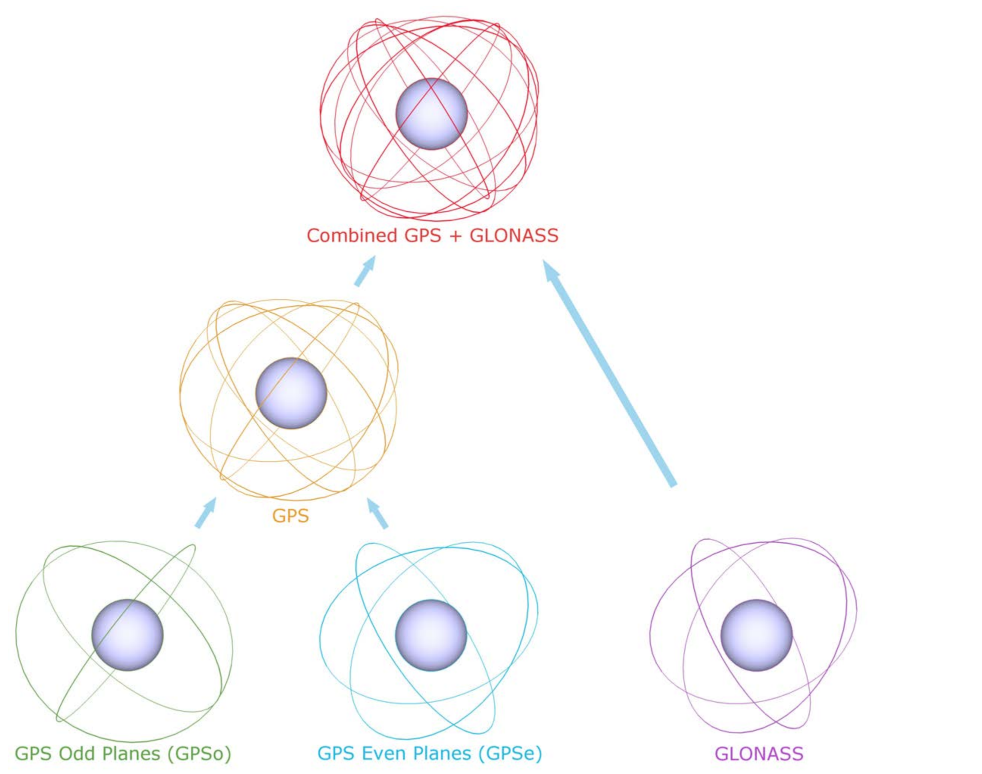

Figure 1: GNSS constellations used to determine G_Z and ERPs. The GPS constellation is divided into two sub-constellations with the same amount of orbital planes as the GLONASS constellation (3 planes).

We establish one set of normal equations (NEQs), with plane specific ERPs and satellite specific geocenter coordinates (GCC). This set of NEQs is then solved three different times. Within each solution ERPs and geocenter coordinates are combined for different GNSS constellations (Tab. 1).

In the first solution of the set of NEQs all plane and satellite specific ERPs and GCC are combined to generate a combined GPS/GLONASS solution. In the second solution the parameters are combined per GNSS to generate a GPS and a GLONASS solution. In the third solution the parameters for two GPS sub-constellations (GPSo and GPSe) and for GLONASS are combined. The two GPS sub-constellations are obtained by splitting the GPS constellation into two groups of three orbital planes each, where the planes within each group are separated by 120 degrees in the equator (Fig. 1). The sub-constellations thus resemble the GLONASS constellation which is also based on three orbital planes. The finally computed constellation specific daily ERPs and GCC are analyzed for systematic differences and their spectral behavior is inspected.

The 1-day solutions contain the same observations as those collected in the years 2012-2014 by the global station network (>250 stations) of the International GNSS Service (IGS) that are analyzed routinely by the Center for Orbit Determination in Europe (CODE) analysis center of the IGS. The analysis was done with the *Bernese GNSS Software* using the up-to-date Empirical CODE Orbit Model ECOM (Arnold et al. 2015).

Table 1: Combination level of ERPs and GCC.

	GPS/GLO	GPS	GLO	GPSo	GPSe
Solution 1	✓				
Solution 2		✓	✓		
Solution 3			✓	✓	✓

Each solution of the NEQs has general (and not constellation specific) clock parameters and troposphere parameters. These parameters vary between the solutions because of the different parametrisations of the ERPs and GCC. To verify the consistency between the different solutions of the NEQ set, we show that the station coordinates of different solutions do not differ by more than ~0.5 mm (Fig. 2). By applying a Helmert transformation between the different coordinate sets no Helmert parameter showed a significant contribution, excluding any systematic differences.

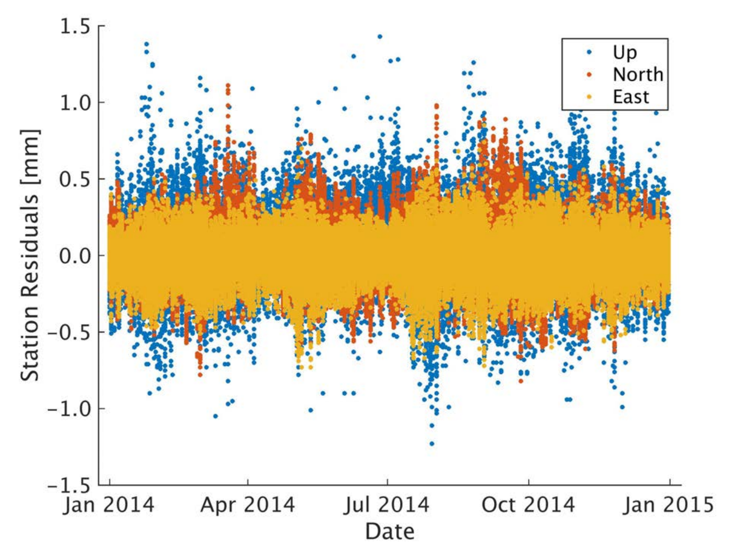

Figure 2: Direct differences between the station coordinates of solution 1 and 2 (Tab. 1). The differences in the north, east and up directions for all stations are plotted at each day of the year 2014. The differences between other solutions are in the same order.

Geocenter Coordinates

The periodic variations of G_Z in the GLONASS series are significantly larger than the one for the two GPS sub-constellations, even though the systems have the same amount of orbital planes as GLONASS (Fig. 3-4). The number of planes in the constellation seems to have no impact on G_Z. A considerably higher formal error of G_Z for GLONASS (Fig. 5) suggests that the main reason for the large variations is due to the higher inclination i of the orbital planes of the GLONASS satellites (and thus correlations with solar radiation pressure model parameters, Meindl et al. 2013).

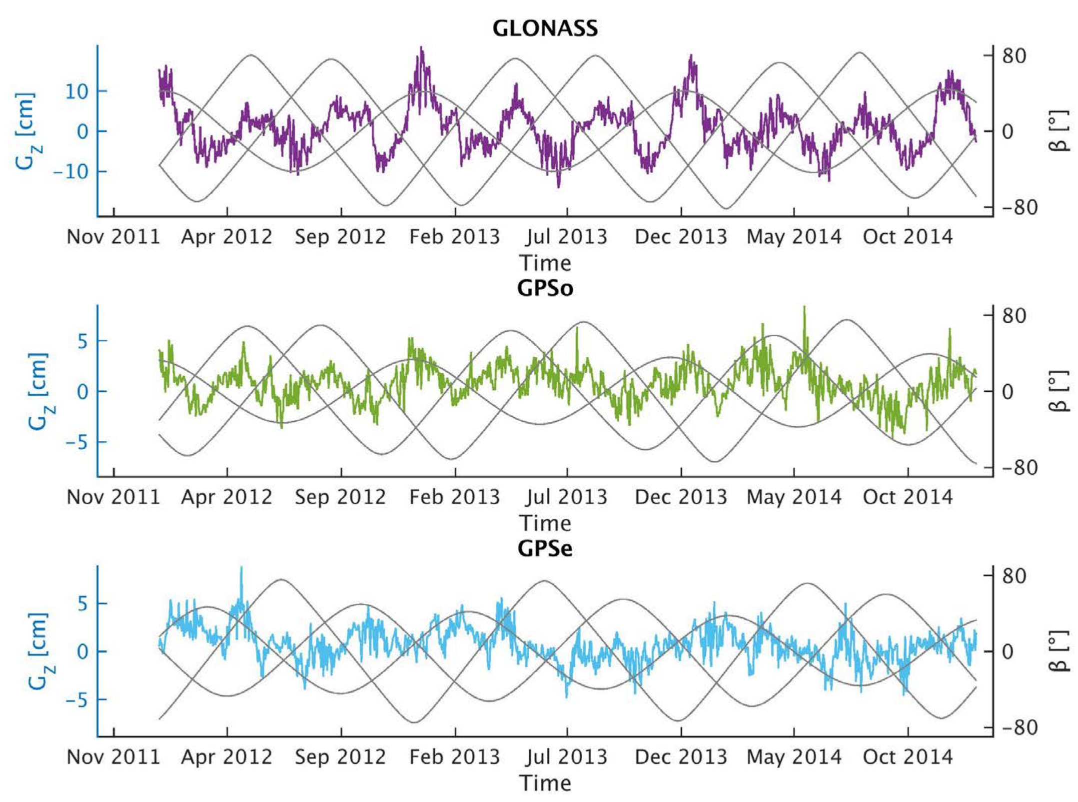

Figure 3: Time series of the geocenter Z coordinate and the elevation β of the Sun above the orbital planes of GLONASS, GPSo and GPSe.

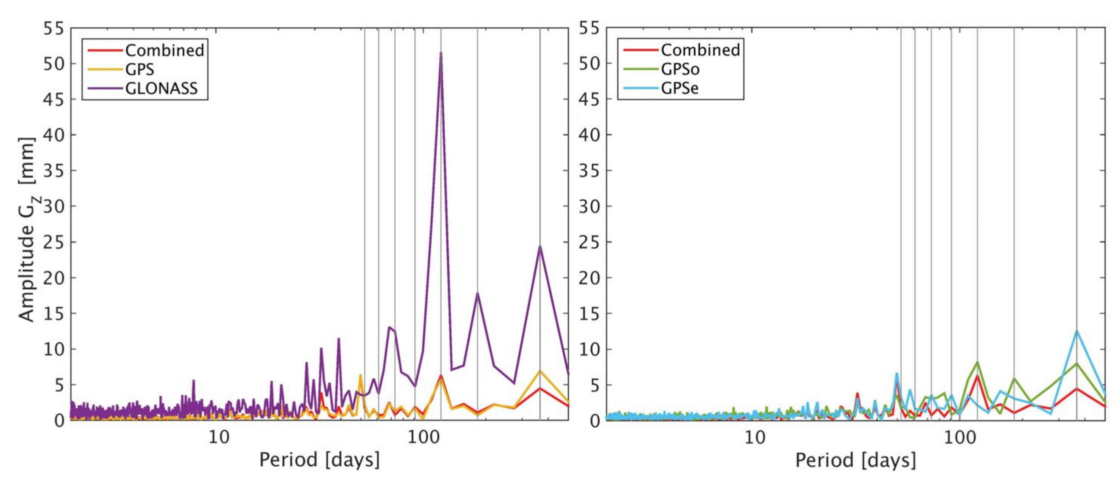

Figure 4: Amplitude spectra of the geocenter Z coordinate time series for all constellations. The grey lines mark the annual, semi-annual etc. periods. GLONASS has a strong periodicity at 1/3 year.

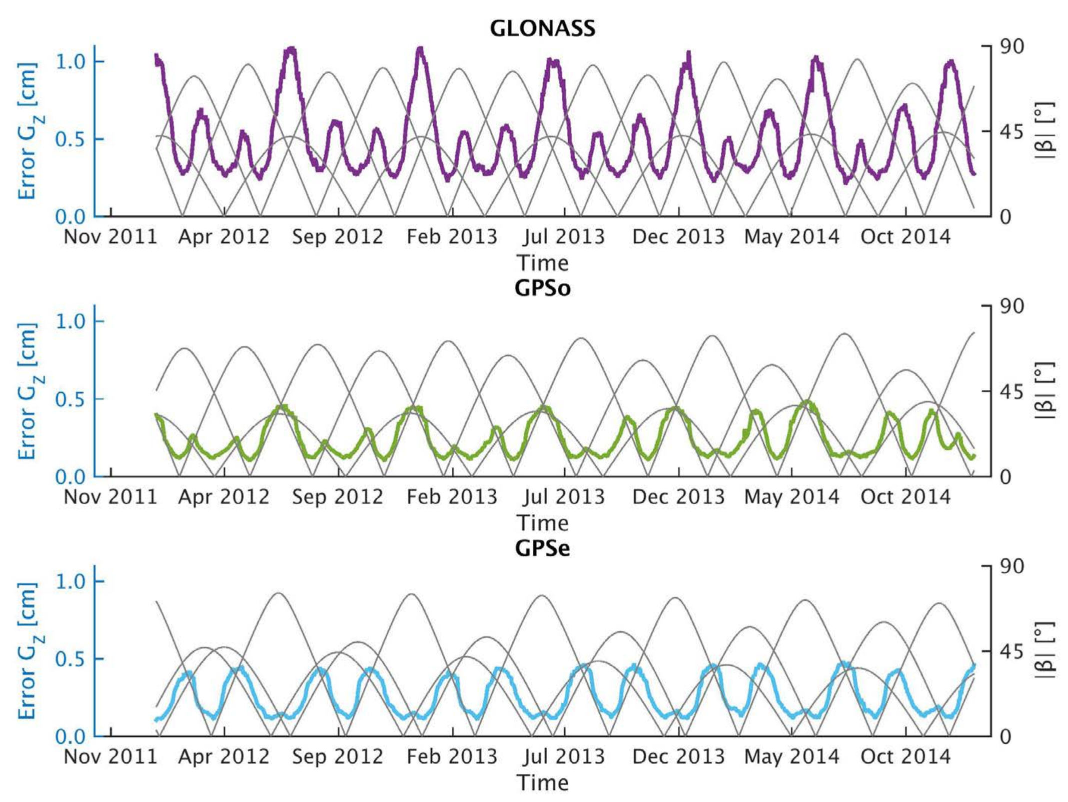

Figure 5: Time series of the formal error of the estimated geocenter Z coordinate and the absolute value of the elevation β of the Sun above the orbital planes of GLONASS, GPSo and GPSe.

Pole Coordinates

The spectra of the differences between the time series of the calculated pole coordinates and the corresponding IERS 08 C04 series are shown in Fig. 6-7. For both pole coordinates (X and Y) only the constellations with 3 orbital planes show a prominent peak at the period of 1/3 year. This spectral line at 1/3 year is therefore most likely caused by the number of orbital planes in the constellation.

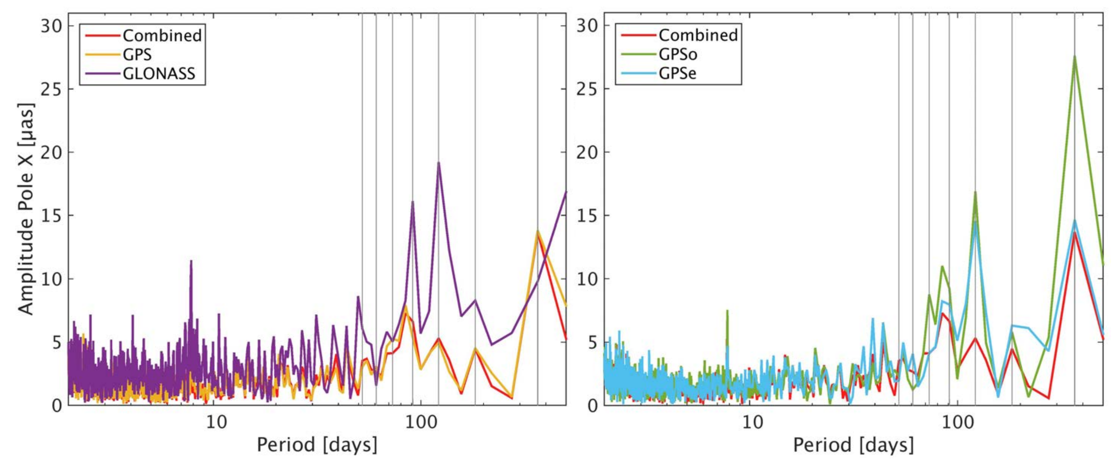

Figure 6: Amplitude spectra of the differences between the computed X pole time series and the IERS 08 C04 X pole series.

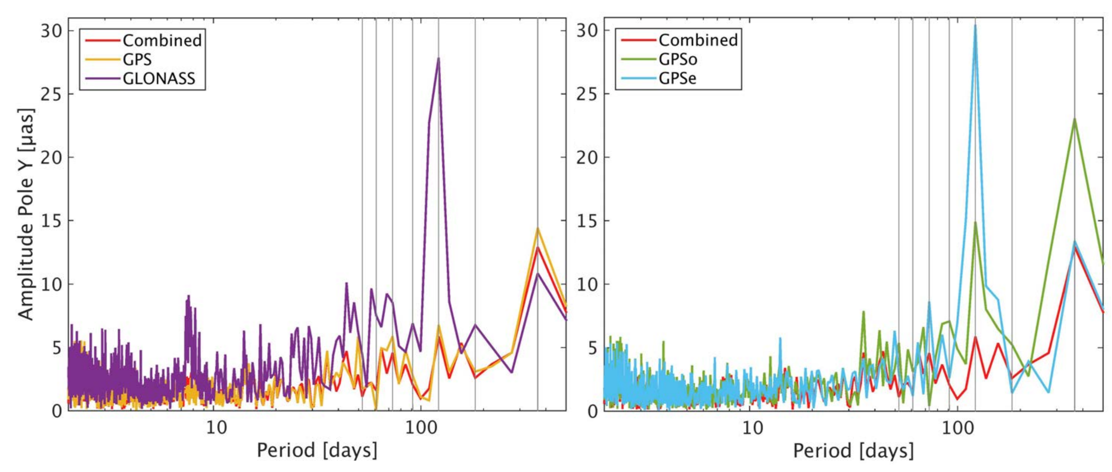

Figure 7: Amplitude spectra of the differences between the computed Y pole time series and the IERS 08 C04 Y pole series.

The polar motion rates and the length of day (LOD) are not discussed because Lutz et al. (2015) discovered big uncertainties for orbital arcs of one day length.

Conclusions

- The number of orbital planes in a GNSS constellation does not seem to influence the geocenter coordinates. A high formal error for GLONASS suggests that the inclination of the planes plays a more important role.

- 3 instead of 6 orbital planes in a GNSS constellation may cause systematic differences in the pole coordinates. It is expected that the combination of different GNSS may compensate for this deficit.

References

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