Orbit and ERP modeling issues of a multi-GNSS analysis

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Introduction

Since GPS week 1706 (16-Sep-2012), the Center for Orbit Determination in Europe (CODE), analysis center of the International GNSS Service (IGS), is generating two sets of combined GPS/GLONASS solutions for the IGS final product series: The clear-cut 1-day solution "COF" and the solution "COD", based on overlapping 3-day orbital arcs and on a continuous, 24-h piece-wise linear Earth rotation parameter (ERP) representation within the 1- and 3-day arcs. Both solution series contain all active GPS and GLONASS satellites. The 3-day solutions are directly derived from the normal equations of the 1-day solutions, ensuring the best possible consistency of the two series.

The differences between the 1-day and the 3-day solutions contain the following peculiarities:

- Triple use of the data of a particular day in three subsequent 3-day solutions
- Handling of the station coordinates (treated as constant over 1 and 3 days, respectively)
- Continuity of ERPs at the boundaries of the middle day
- Continuity of the orbits at the boundaries of the middle day

The impact of these differences on orbit and ERP products are investigated.

Orbit misclosures

The misclosure of an orbit at the day boundary is an indicator for the quality of the solution. Orbit misclosures from a multi-GNSS analysis in the terrestrial coordinate system (Fig. 1, top) have clear signals in the 1-day solution but not in the 3-day solution. In the inertial coordinate system (Fig. 1, bottom), the signals of the 1-day solution are much smaller but still visible. The results from the 3-day solution are in general very consistent over time and on a high level of accuracy.

Analysis of the ERP series

The comparison of the pole rates from the IGS, ESA and COF solutions with the rates of CODE's 3-day solution (COD, Fig. 2) reveals:

- The COD solution is close to the IGS solution
- The ESA and COF solutions have similar excursions especially in Y-rate
- Small traces of spurious signals (e.g., in February 2013) remain in the IGS solution (in the difference IGS minus COD)

Time series of more than four years were compared with IERS 08 C04 (Fig. 3 and 4). The differences of the ESA, COF and (to a lesser extent) the IGS solutions contain signals in the Y-rate with periods related to the GLONASS constellation. The time series of COD and C04 are most consistent.

Single- versus multi-GNSS solutions

From Meindl (2011) and Meindl et al. (2013) a four year data set of a combined GPS/GLONASS (CMB) and consistent single-system solutions (GPS, GLO) based on the observations from a global network of 92 GPS/GLONASS receivers is available. The COF (1D) and COD (3D) processing schemes were applied for comparison purposes.

The rates of polar motion at noon of a particular day may be calculated by fitting the polar motion components of consecutive days centered around the particular day by polynomials. The comparison with the estimated rates shows that 1-day GLONASS ERP series (Fig. 5, top) are very much disturbed. The 3-day GLONASS solutions are, however, only about a factor 2 to 3 weaker than the corresponding GPS solutions. The combined solutions (Fig. 5, bottom) are roughly of the same quality as the GPS-only solutions (Tab. 1).

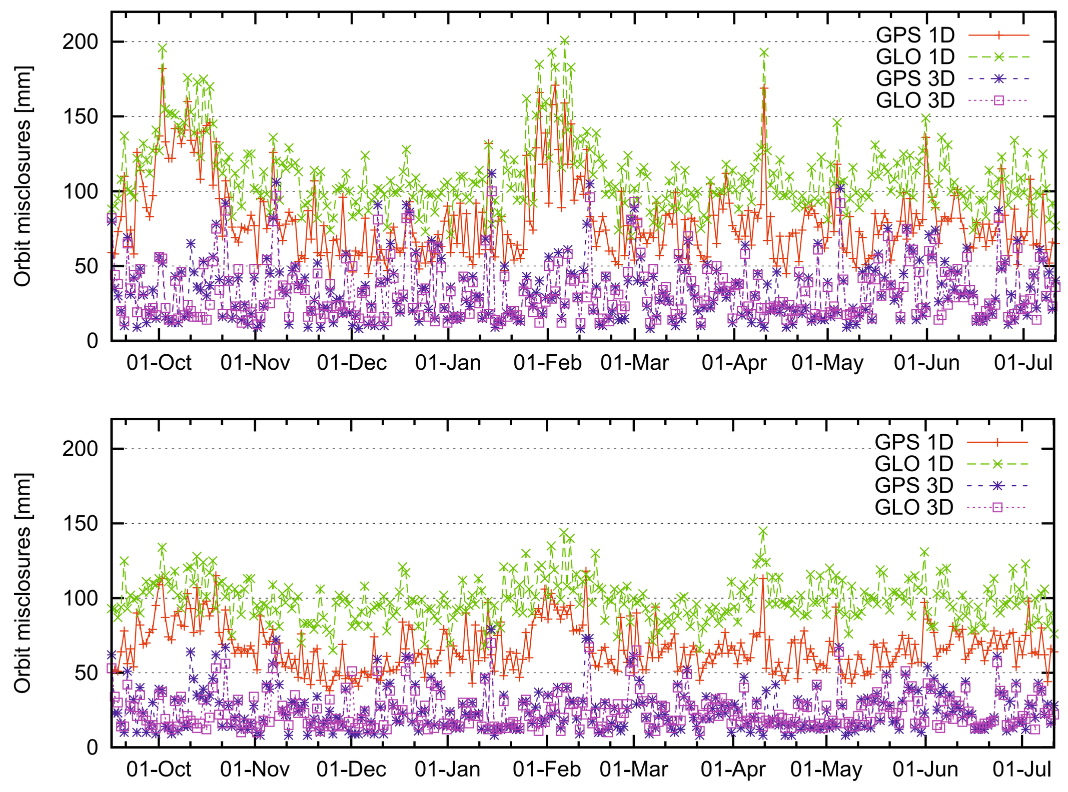

Fig. 1: 3-dimensional orbit misclosures of the non-eclipsing GPS and GLONASS satellites at the boundaries of subsequent days from the 1-day and 3-day solutions of CODE since GPS week 1706. Top: terrestrial coordinate system; bottom: inertial coordinate system. There are clear signals in the 1-day solution in October 2012 and February 2013 for GLONASS *and* GPS. The misclosures from the 3-day solution are small for both systems.

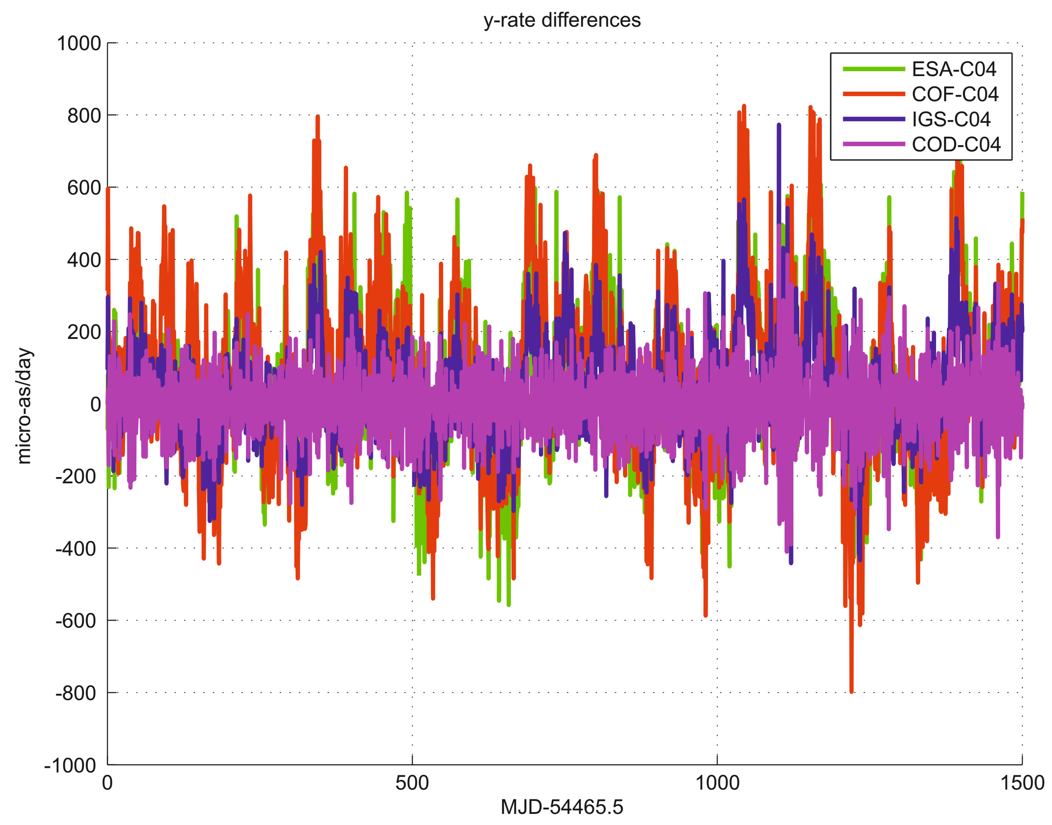

Fig. 3: Differences of the polar motion rate in Y from the ESA, COF, IGS and COD solutions w.r.t. IERS 08 C04 over more than four years starting in 2008. COF and ESA on the one hand, COD and IGS on the other hand are on the same quality level. COD agrees best with the rates derived from C04.

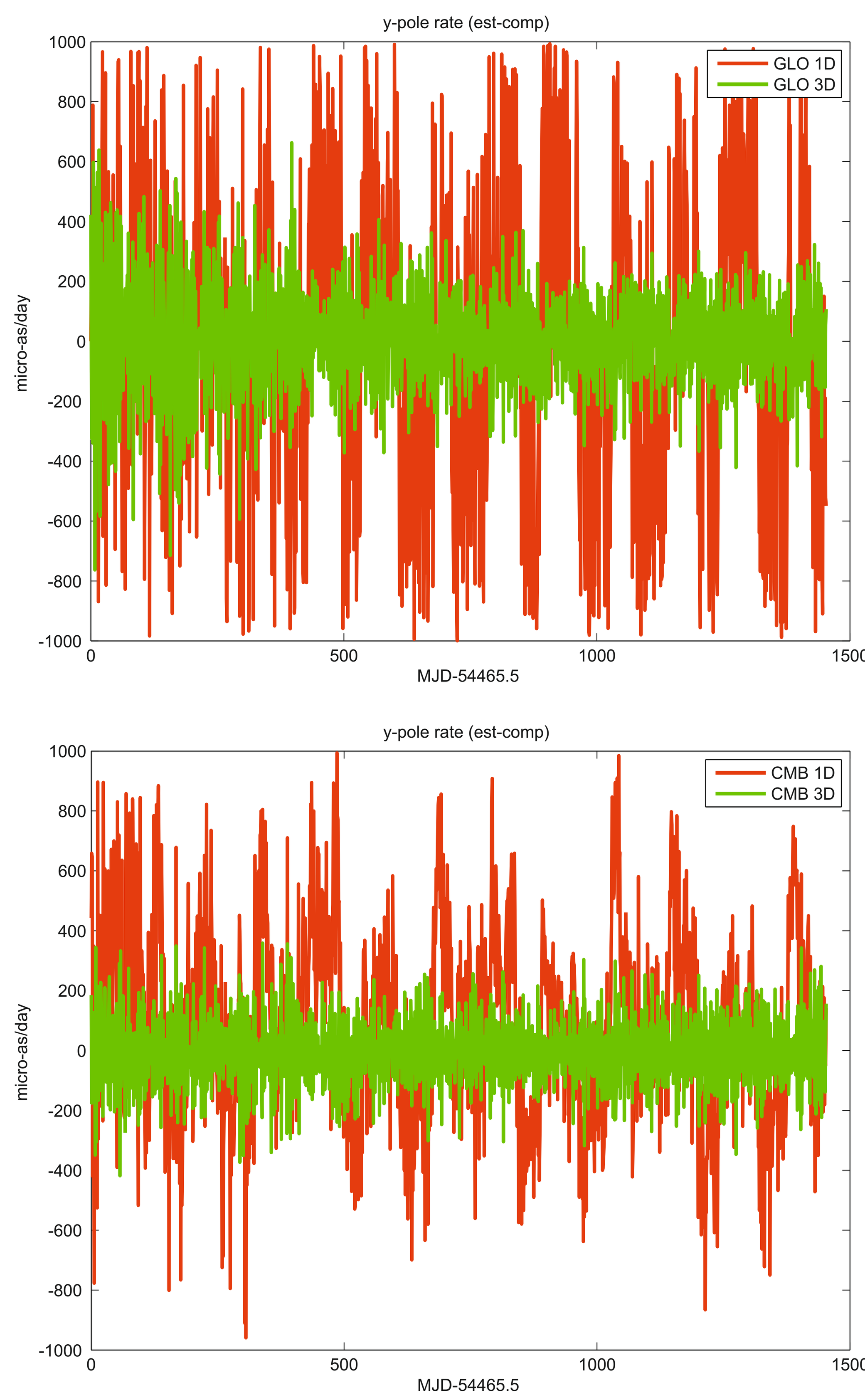

Fig. 5: Estimated minus computed polar motion rate in Y at noon based on fitting polynomials for the GLONASS-only (top) and GPS/GLONASS combined (bottom) solutions over four years starting in 2008.

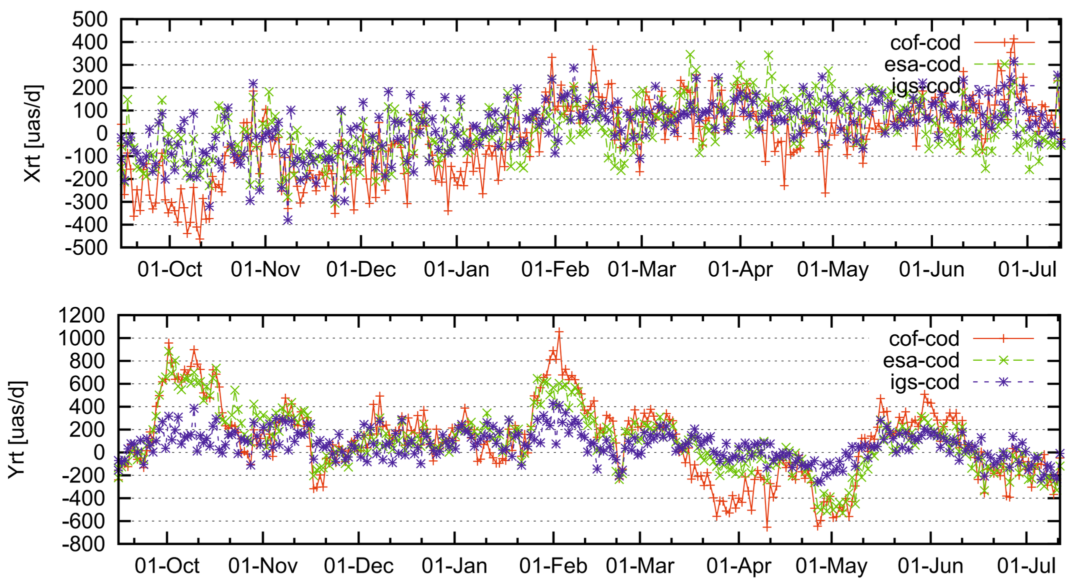

Fig. 2: Differences of the polar motion rates in X and Y from the COF, ESA and IGS solutions w.r.t. the COD solution since GPS week 1706. The local maxima in Y-rate of COF and ESA correspond to the "excursions" in the 1-day orbit misclosures in Fig. 1.

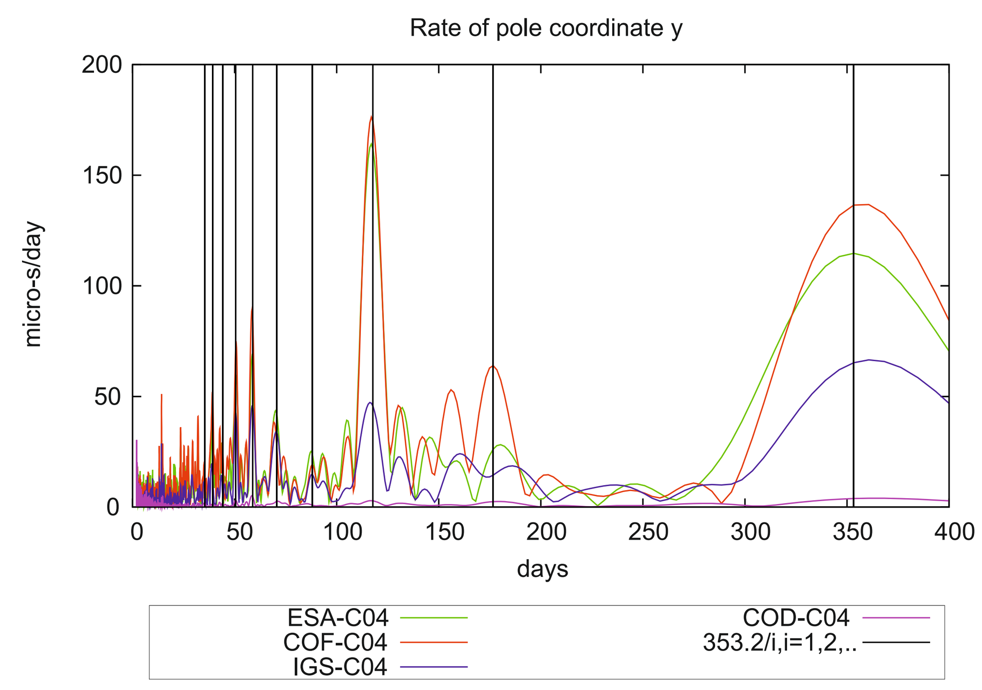

Fig. 4: Spectra of the differences of polar motion rates in Y based on more than four years of data. The vertical lines indicate the harmonics of the draconitic year of the GLONASS constellation.

Misclosures of ERPs at day boundaries

GNSS	Sol	Coord	Offset µas	RMS µas
GLO	1D	x	-56	722
GLO	3D	x	-6	104
GLO	1D	y	32	1072
GLO	3D	y	7	98
GPS	1D	x	37	215
GPS	3D	x	3	37
GPS	1D	y	110	273
GPS	3D	y	-4	40
CMB	1D	x	11	202
CMB	3D	x	3	40
CMB	1D	y	81	317
CMB	3D	y	-3	39

Tab. 1: Statistical properties of the ERP misclosures at day boundaries calculated using the estimated pole coordiantes and rates from two adjacent days. There are major improvements from the 1-day to the 3-day solutions.

Conclusions

- Orbit misclosures from the 3-day solutions do not contain signals related to the satellite constellations. The excursions due to GLONASS also affect the GPS misclosures in the 1-day solutions.
- Orbits in the terrestrial system contain ERP inconsistencies between subsequent days.
- Spurious signals reside in the ERP series of all 1-day solutions, in particular in the ERP rates. Such signals are only marginally present in the 3-day solutions.
- ERP misclosures at day boundaries are much smaller for 3-day solutions than for 1-day solutions.
- *3-day solutions are statistically questionable (triple use of data), but they substantially mitigate or even remove spurious signals in GLONASS and GPS or combined GPS/GLONASS analysis thanks to the much better separation of orbit and ERP parameters.*

References

Meindl, M. (2011) Combined Analysis of Observations from Different Global Navigation Satellite Systems. Geod.-geophys. Arbeiten in der Schweiz, Vol. 83, ETH Zürich, Switzerland

Meindl, M., G. Beutler, D. Thaller, A. Jäggi, R. Dach (2013) Geocenter coordinates estimated from GNSS data as viewed by perturbation theory. Adv. Space Res., Vo. 51(7), pp. 1047–1064