Updating the CODE ultra-rapid procedure

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Introduction

The International GNSS Service (IGS) issues four sets of so-called ultra-rapid products per day, including satellite orbits and Earth Rotation Parameters (ERPs). Each of them covers 48 hours: The first half is based on observational data up to t_{last} = 6, 12, 18, or 24 UTC of the current day for the corresponding set. The second half is a prediction for real-time applications.

The IGS ultra-rapid product combines the contributions from individual IGS Analysis Centers. Last year, the submissions from the Center for Orbit Determination in Europe (CODE) were revised and updated. This poster highlights the transition from the old to the new CODE ultra-rapid product and the associated improvement in reliability and performance.

The old CODE ultra-rapid procedure

Until summer 2013, the CODE ultra-rapid product was based on the output of the last two CODE «rapid» analyses and a 3-day solution, in which the last day contained 6, 12, 18, or 24 hours of observations. The ERPs were modeled as piece-wise linear over one calendar day, for the predicted part they were derived from IERS Bulletin-A. The daily orbit positions emerging from the three solutions were fed into a parameter estimation program of the Bernese GNSS Software package (Dach et al. 2007) using an orbit parameterization especially designed for prediction.

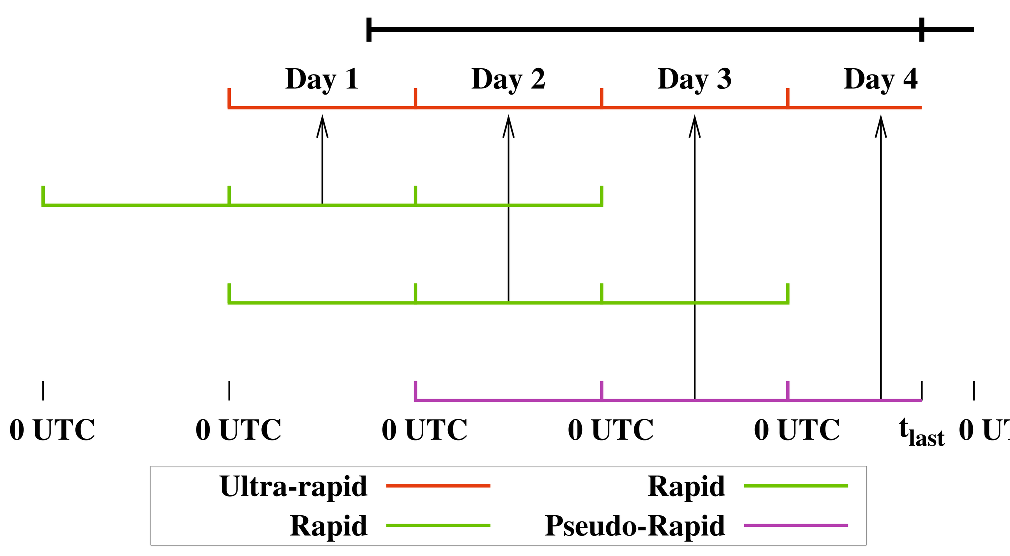

Fig. 1: Origin of orbit positions in the old CODE ultra-rapid product (here a solution for t_{last}=18 UTC).
Green: orbital positions originating from the most recent two complete CODE rapid 3-day solutions; Magenta: most recent long-arc orbit solution based on the two most recent daily rapid normal equationn files (NEQs) and the NEQ from the (un-)complete current day; Red: composed orbit arcs from parameter estimation processes (green and magenta) used as the basis to fit the long arc; Black: 72h orbit arc fitted to the orbit positions from the most recent rapid and ultra-rapid solutions (red); start of predicted part is shown, as well.

The use of the estimated ERPs referring to the previous day for the following 24 hours may lead to unrealistic results for prediction. Therefore, the a priori ERPs from the most recent Bulletin-A were used in the old CODE ultra-rapid for ERP prediction after some point in time.

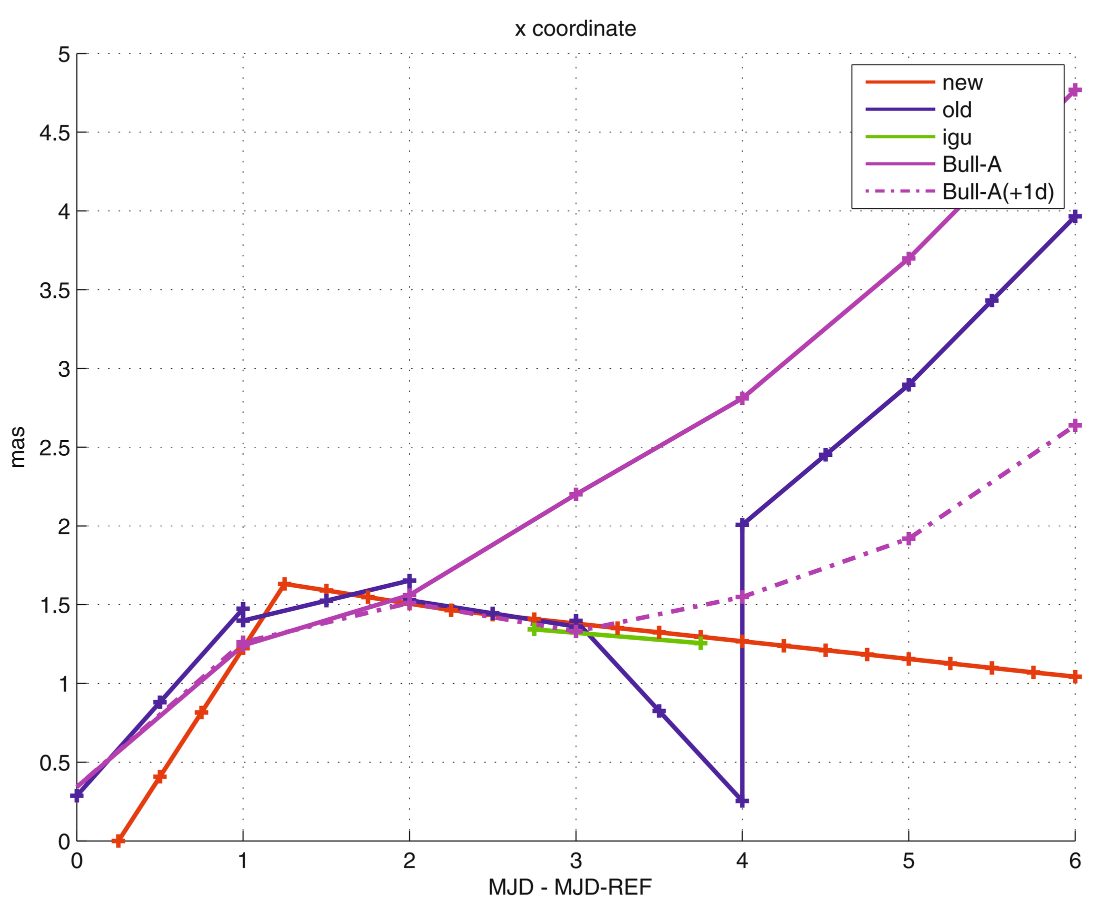

Fig. 2: Estimated and a priori x-coordinate of the pole (de-trended) for a 6 UTC ultra-rapid solution.
Blue: old CODE ultra-rapid; Magenta solid: Bulletin-A available at the time of generating the ultra-rapid; Magenta dash-dot: Bulletin-A available one day after generating the ultra-rapid; Green + signs: IGS ultra-rapid (igu) pole positions (estimated and predicted); Red: new CODE ultra-rapid for comparison (description in the middle section).
Note that the ERPs of the old CODE ultra-rapid product are continuous at the boundary of days 3 and 4, because the corresponding ERP values stem from the same 3-day solution (magenta line in Fig. 1). They are not continuous at the other two internal day boundaries by construction though.

Eventually, after 10-Jul-2013, the estimated and shifted a priori ERPs of the old procedure were made to coincide at the beginning of the last day, but the shifted a priori ERPs were used only after the end of the last day. This measure slightly improved the CODE ultra-rapid orbit predictions. The impact of the change is barely visible in the x- and y-rotations of the CODE orbit estimates w.r.t. the IGS ultra-rapid product, whereas a clear improvement is visible in the rotations about the z axis (see Fig. 6).

The new CODE ultra-rapid procedure

The current CODE ultra-rapid product was developed in 2013 and has been submitted to the IGS since November 2013. Other than the old procedure, the new CODE ultra-rapid solution is based on the output of exactly one 3-day analysis, containing between 54 and 72 hours of observations. The parameterization of the ERPs was modified to avoid estimates relying only on short data spans. A priori ERP information for the prediction is no longer required.

- The observed part of the new ultra-rapid product does not refer to three different 3-day solutions, but to exactly one, where three NEQs of three consecutive days (two complete and the current one) are used.
- Weakly determined orbit and ERP parameters referring to the last 24 hours of the observed part of the ultra-rapid products are avoided.
- The ERPs in the predicted part of the ultra-rapid product are defined by the two ERP parameters referring to the last 24 hours coverd by observations.

The CODE orbit model allows estimating the following parameters for each orbital arc:

- Set of six osculating orbital elements
- At maximum nine empirical orbit parameters (three constant accelerations in three orthogonal directions, three once-per-rev. accelerations in the same directions) of the Empirical CODE Orbit Model (ECOM, Beutler et al. 1994)
- Pseudo-stochastic pulses in radial direction R, in along-track direction S, and in out-of-plane direction W at 12 hours intervals (noon and midnight of each calendar day)

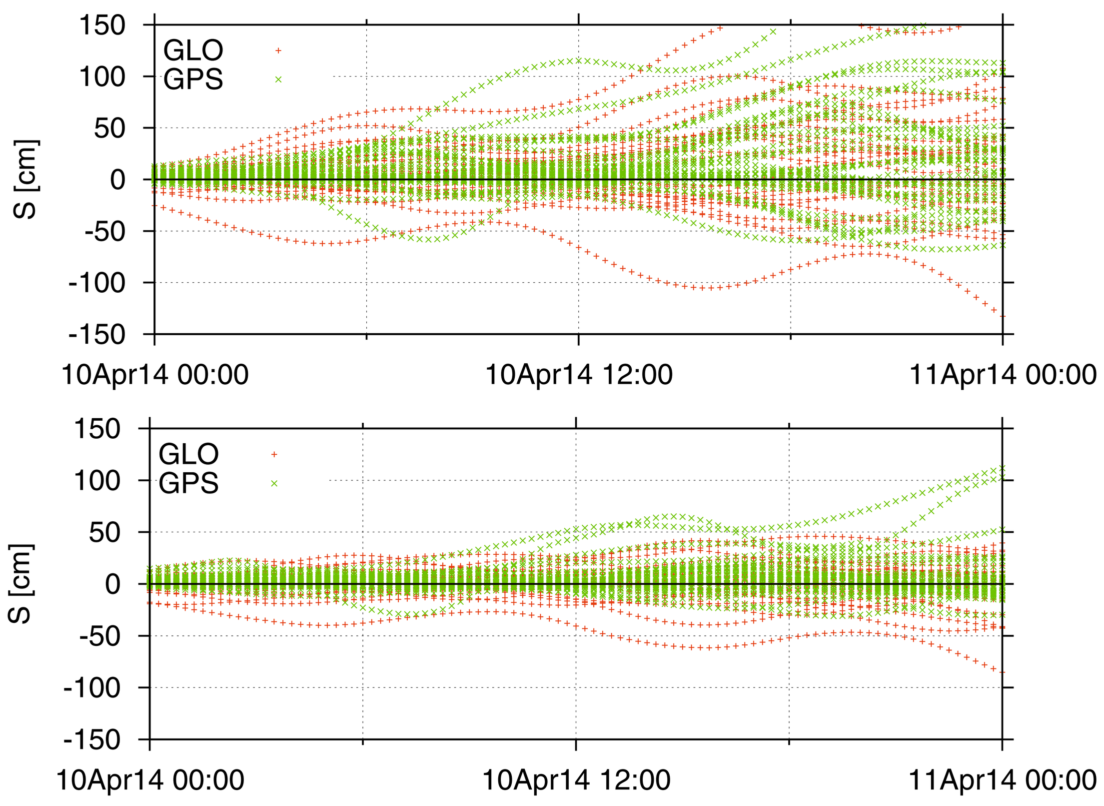

Fig. 3: Differences of the 24 hours of predicted GLONASS and GPS orbits from a 24 UTC ultra-rapid solution w.r.t. the corresponding CODE rapid orbits in along-track S-direction using the standard CODE orbit model with pulses (top) and the full ECOM without pulses (bottom). Whereas there are no substantial differences for the R and W components (not shown here), the prediction in S based on the ECOM is clearly superior to the standard CODE model based on the reduced ECOM parameterization including the pulses at a 12 hours spacing as it was obtained from the parameter estimation step.

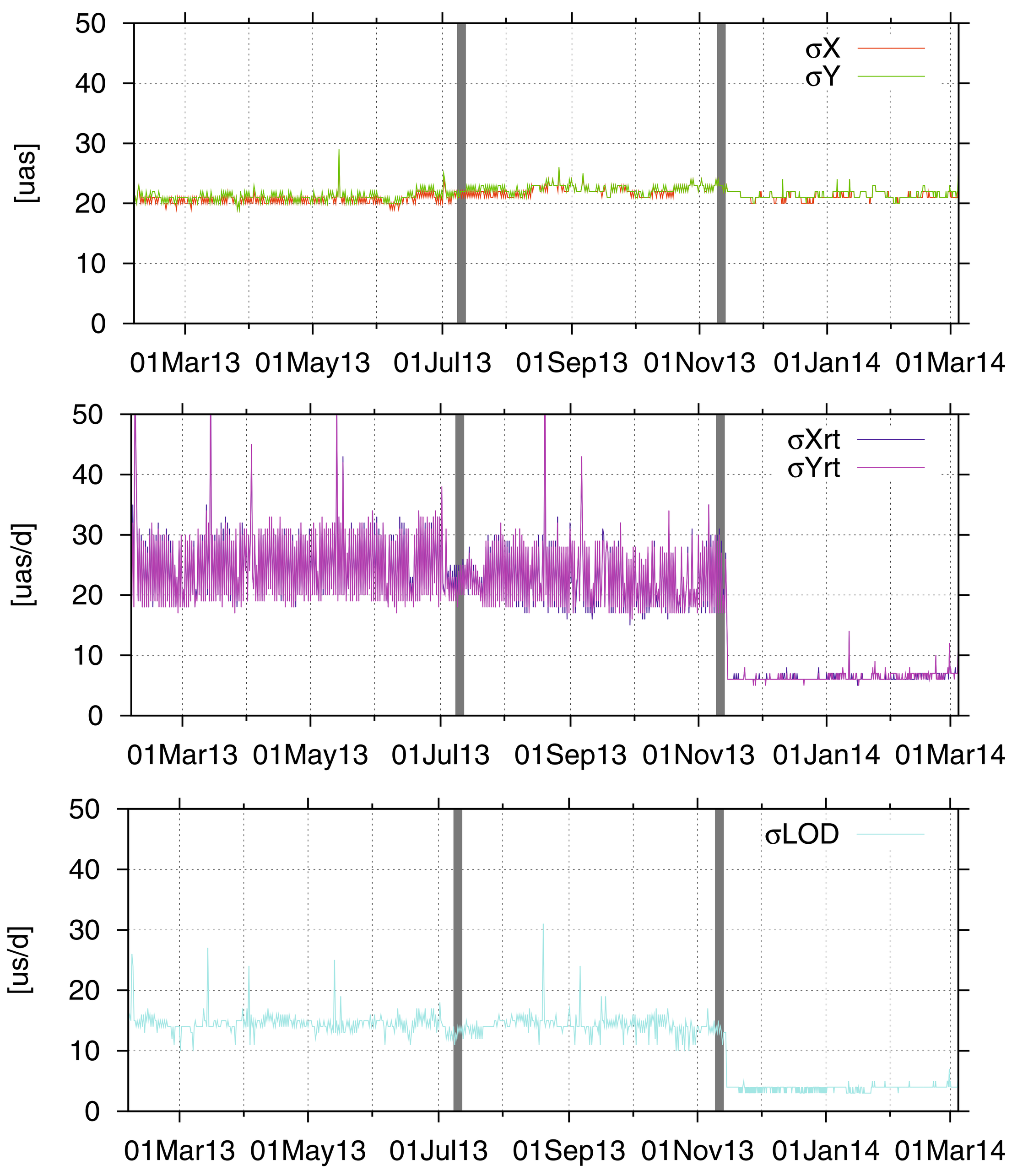

Fig. 4: Formal a posteriori errors of the polar motion in the x- and y-coordinates, their rates, and LOD of the submitted CODE ultra-rapid ERP product.

The formal errors of the x- and y-components of polar motion did not change as a consequence of the two parts of the redesign in 2013. The formal errors of the polar motion rates in x and y and LOD did, however, significantly decrease after the implementation of the complete new CODE ultra-rapid procedure. This improvement is due to the consistency of the ERPs, which now all stem from exactly one 3-day analysis.

Comparison with the IGS product

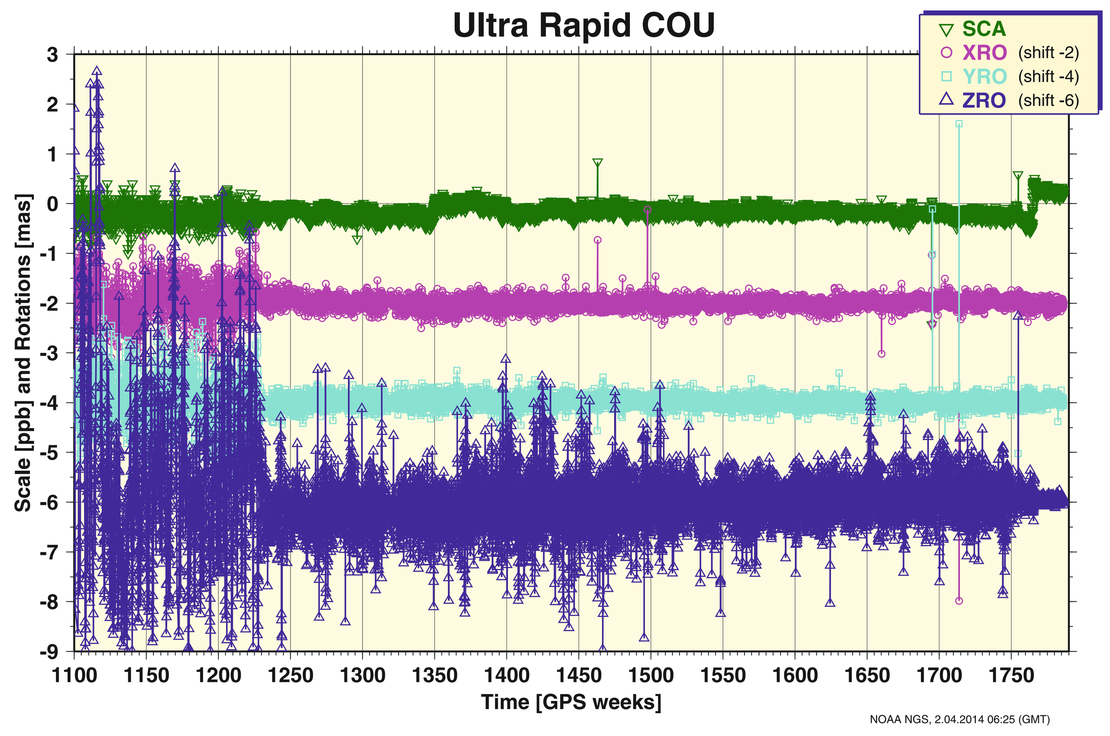

Fig. 5: Evolution of scale and rotations of the submitted CODE ultra-rapid orbits w.r.t. the combined IGS ultra-rapid product (GPS-only) since 2001; Source: http://acc.igs.org

- The CODE contributions prior to GPS week 1229 were pure predictions based on the three most recent complete CODE rapid products.
- After GPS week 1229, the observations available up to 6, 12, 18, and 24 UTC of the current day were included for generating the corresponding CODE ultra-rapid orbits.
- A profound review of the CODE ultra-rapid procedure took place in 2013 and led to the remarkable improvement of the z-rotation after GPS week 1764.

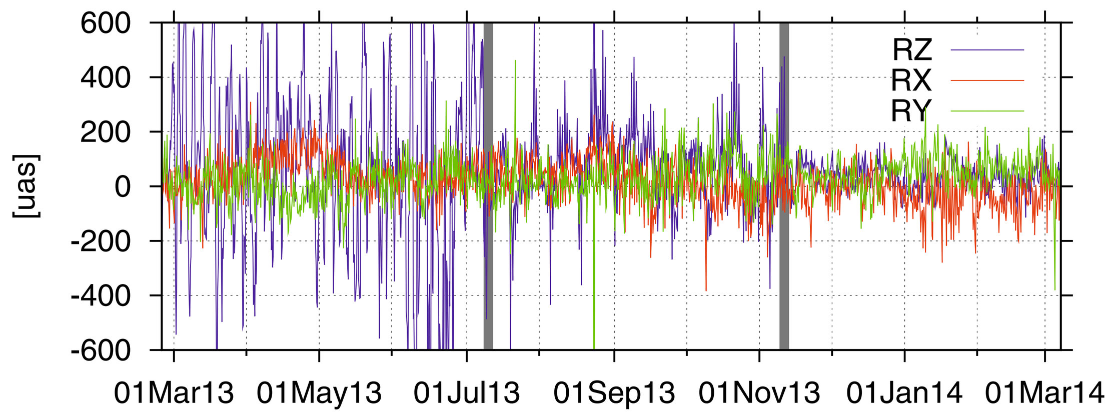

Fig. 6: Rotation parameters for the z-, x- and y-rotations of the Helmert transformation between CODE's submitted ultra-rapid orbits and the combined IGS product (GPS-only).

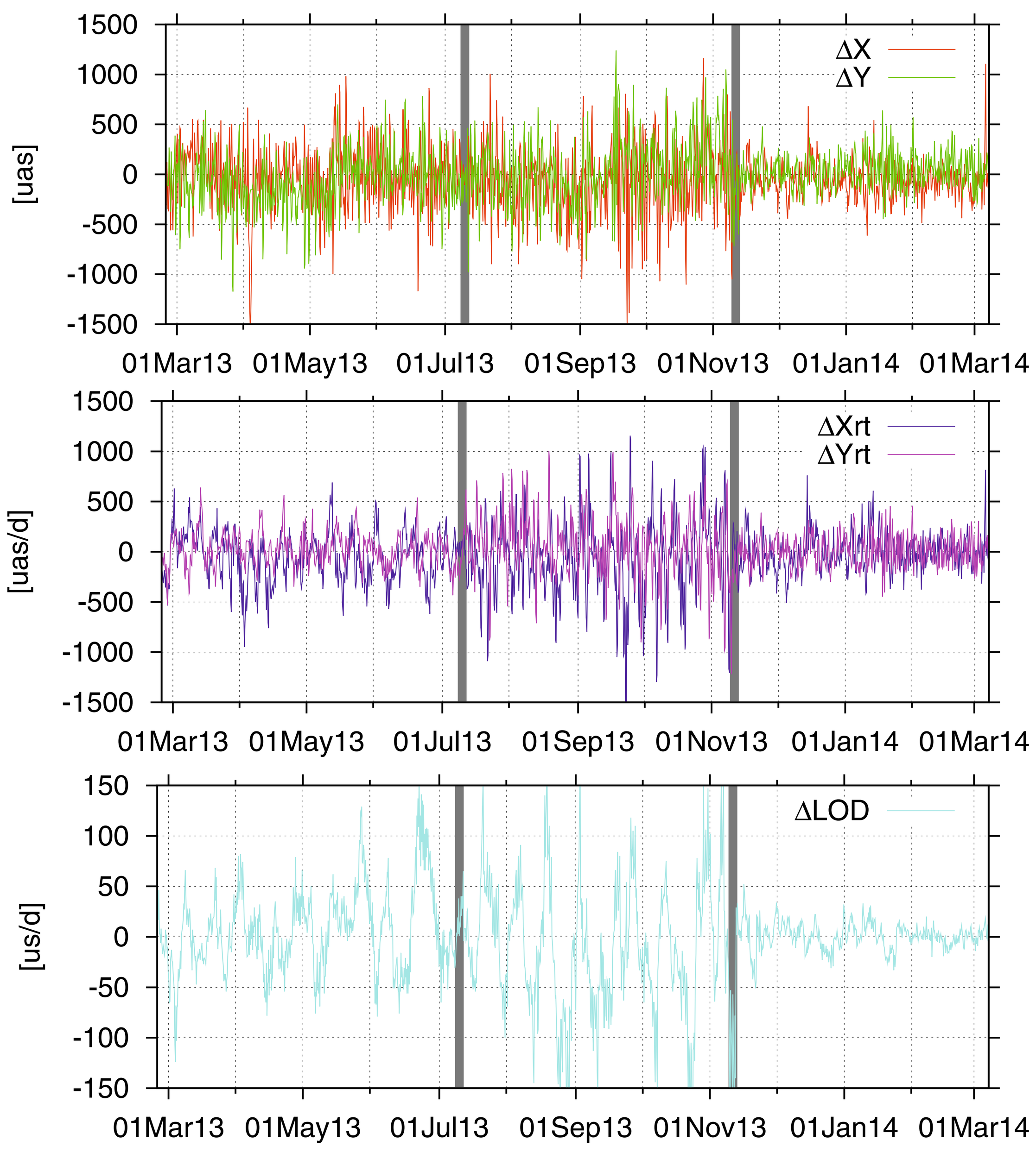

Fig. 7: Predicted part of the polar motion components in x and y, their rates, and LOD of the submitted CODE ERPs w.r.t. the combined IGS product.

Conclusions

- A fully consistent multi-day solution for orbits and ERPs is the basis for a successful orbit prediction over a period of 24 or more hours, e.g., for SLR predictions.
- The orbit parameterization is different for parameter estimation and orbit prediction. Stochastic pulses (introduced to absorb potential deficiencies of the dynamic orbit model) should be avoided for orbit prediction.
- As the deadlines of the IGS ultra-rapid products are not synchronized with the update schedule of Bulletin-A, a simple linear extrapolation of the ERPs is more appropriate for a one to few days prediction. For longer intervals, the sophisticated background models of Bulletin-A may be preferable for ERP prediction.

References

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