GPS Clock Correction Estimation for Near Real-time Orbit Determination Applications

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Motivation and Background

A study has been performed by AIUB and DLR to assess the achievable orbit accuracy for Low Earth Orbiting (LEO) satellites using different types of near real-time (NRT) GPS orbit and clock products. A realistic NRT orbit determination (OD) scenario has been assumed with the requirements of 10 cm radial orbit accuracy and of 3 hours latency for the orbit product (after the first observation of an orbital arc; 100 min for data collection and downlink, 20 min for science data processing => 60 min for OD). Batches of 3 hours are processed with an overlap of 80 minutes w.r.t. the previous batch using data from the GRACE B satellite for a 3-days period from 7-9 October, 2006.

Three sources for GPS orbits and satellite clock corrections are discussed:

=> IGUp: publicly available IGS ultra-rapid product, predicted part (IGS = International GNSS Service)

=> RT: commercial JPL RTG products (RTG = Real-Time Generated)

=> IGUp+c: generated NRT clock corrections on top of IGS ultra-rapid predicted orbits

Concept for Determination of NRT GPS Clocks

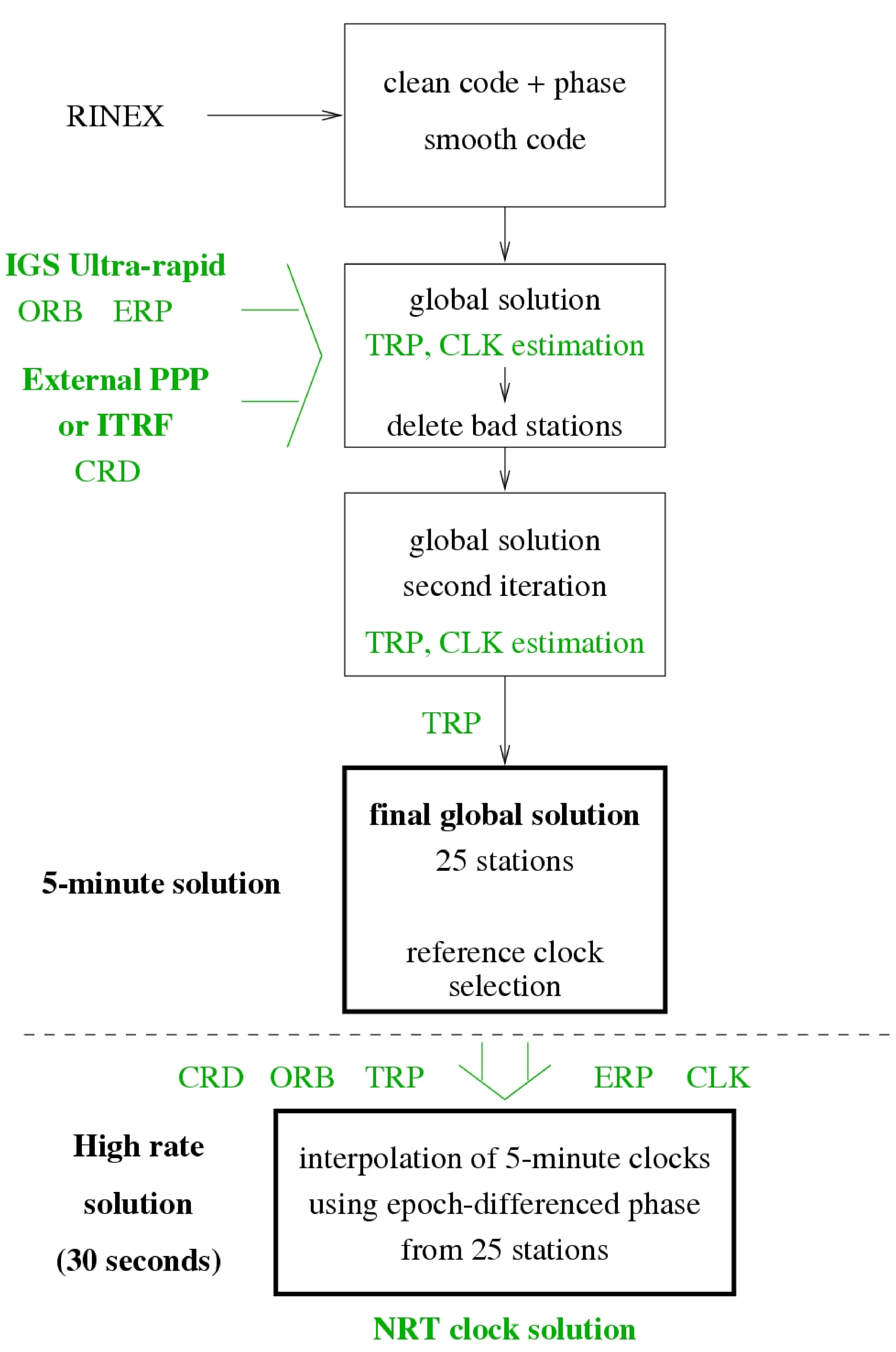

Figure 1: Flow diagram for the NRT GPS clock solution (IGUp+c).

The processing scheme in Figure 1 is derived from the GPS clock correction estimation procedures [Bock et al., 2004] at the CODE (Center for Orbit Determination in Europe) analysis center of the IGS [Hugentobler et al., 2007]. The processing is done with the Bernese GPS Software [Dach et al., 2007].

Downloading the data from a real-time data stream was not a scope of the study. The data from the IGS high-rate network are downloaded from the databases in batches of 15 minutes and resampled to 30 seconds. Globally distributed 25 stations are selected to guarantee overall coverage and also redundancy for the clock estimation.

Latency of the data files is a critical issue for this NRT application (see Figure 2).

Data Availability

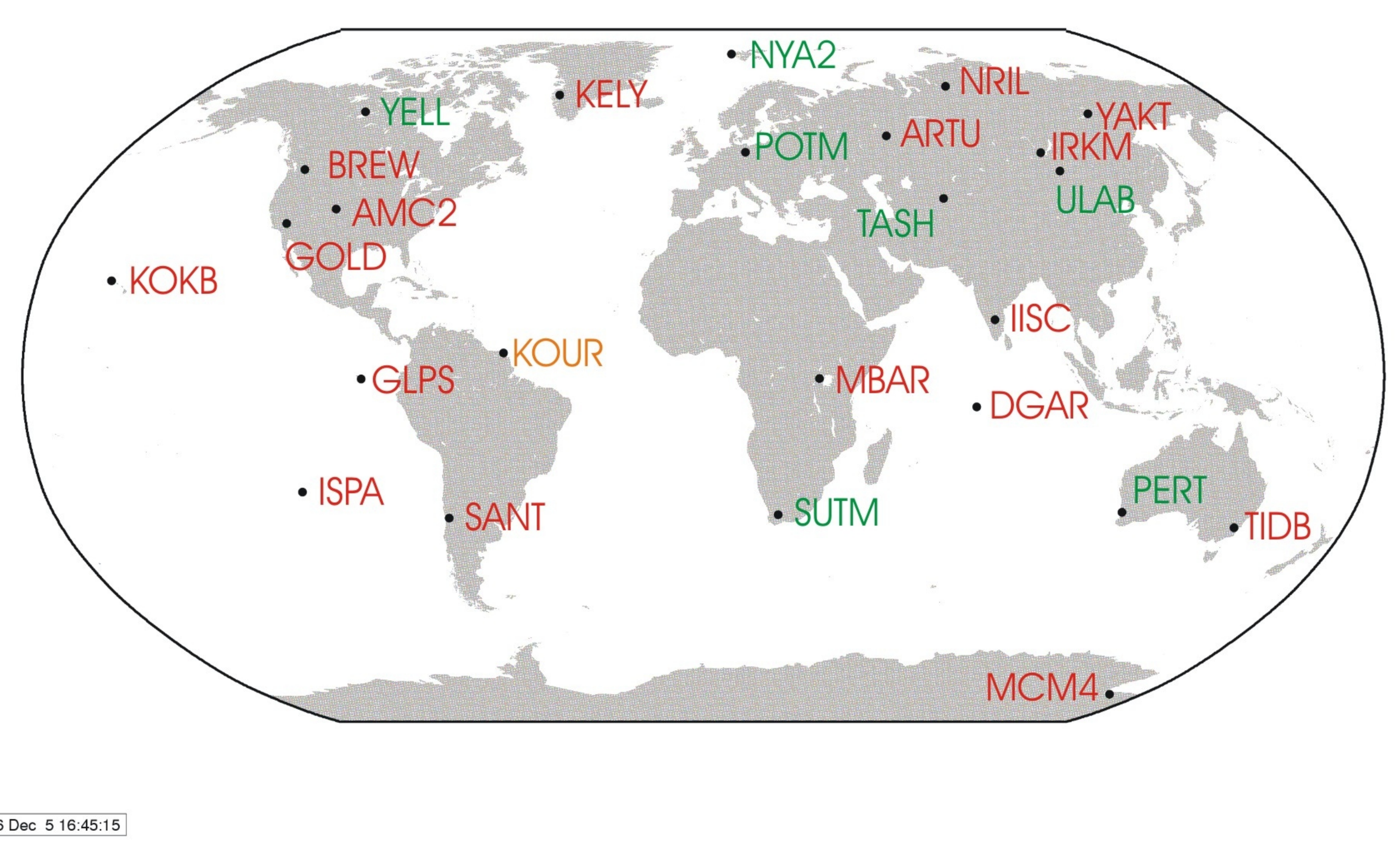

Figure 2: 25 selected IGS high-rate stations used for the NRT clock solutions (October 7-9, 2006); green: median latency after the end of the 15-min data batch < 6 min, orange: up to 60 min, red: up to 66 minutes.

It is obvious that it is not possible to set up a NRT application when the latency of the data is as shown in Figure 2. The performance has to be improved or the real-time data has to be used instead.

The NRT clock generation for this study is performed in a post-processing mode, therefore all station data was assumed to be available in time.

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Processing Details

Solution	Date	start time	end time	IGS Ultra Orbits
01	7 Oct. 2006	00:20:00	03:20:00	igu13956_00.sp3
02		02:00:00	05:00:00	igu13956_00.sp3
03		03:40:00	06:40:00	igu13956_00.sp3
04		05:20:00	08:20:00	igu13956_00.sp3
05		07:00:00	10:00:00	igu13956_06.sp3
06		08:40:00	11:40:00	igu13956_06.sp3
07		10:20:00	13:20:00	igu13956_06.sp3
08		12:00:00	15:00:00	igu13956_12.sp3
09		13:40:00	16:40:00	igu13956_12.sp3
...		...	...	...

Table 1: Solution list used for the NRT GPS clock generation (IGUp+c). 3-hours data batches are processed with the IGS ultra-rapid orbits available at that time. In total 43 solutions (7-9 Oct, 2006) are generated.

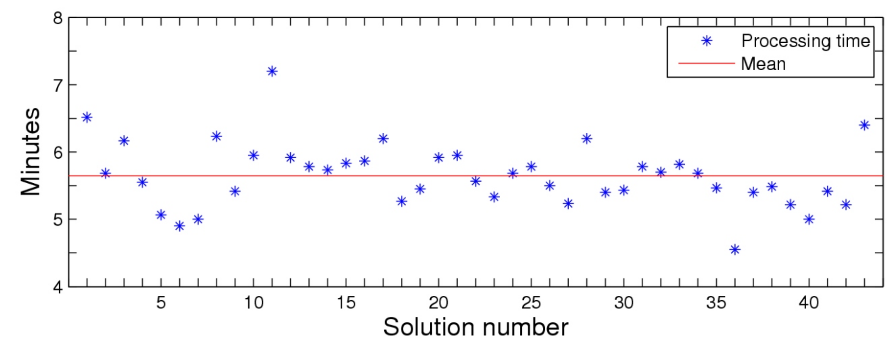

Figure 3: Processing time for the different NRT GPS clock solutions (Linux Cluster, parallel runs on several nodes (2.4 GHz CPU), if possible). Mean processing time of less than 6 minutes is low enough to be useful for NRT applications.

Validation of NRT GPS Clocks

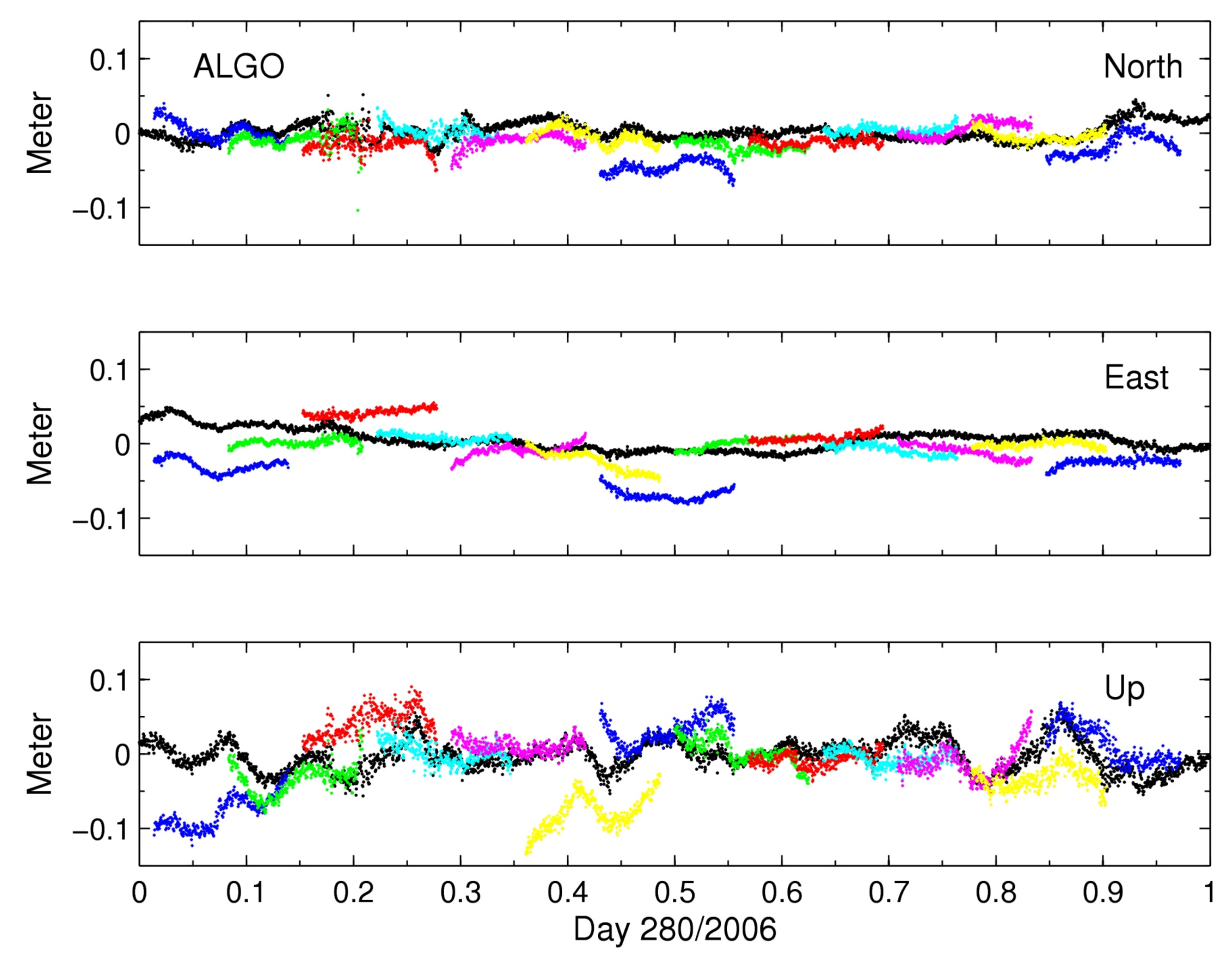

Figure 4: Kinematic precise point positioning (PPP) solutions w.r.t. static PPP using CODE final GPS orbits and 30-seconds clock corrections (station ALGOnquin, Canada); black: CODE final orbits and clocks, other colors: 3-hours batches using IGUp+c.

Agreement between reference and IGUp+c solutions is below 10 cm, even for the Up component (corr. to radial component of a LEO orbit).

NRT Orbit Determination

The three available NRT GPS products (IGUp, RT, and IGUp+c) are used for a NRT reduced-dynamic orbit determination for the GRACE B satellite for October 7-9, 2006 using DLR's GHOST software [Montenbruck et al., 2005]. The 43 3-hours data intervals are processed and the last 100 minutes of the orbital arcs are compared (Figure 5) with an independent reference solution (JPL's Level 1B orbit solution).

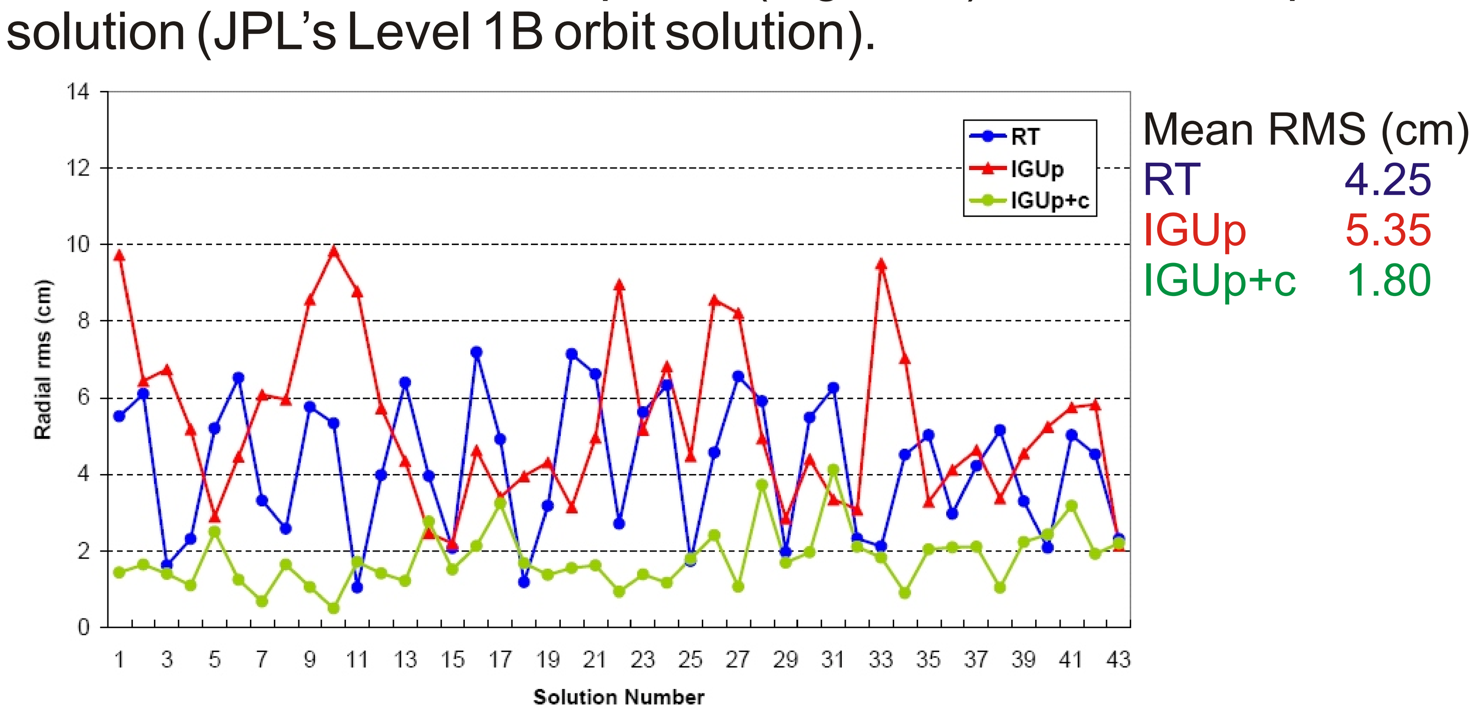

Figure 5: Radial orbit errors of NRT GRACE B data processing using different types of NRT GPS orbit and clock information. For all three NRT GPS products the radial orbit error (rms) is less than 6 cm.

The IGUp+c solution is even compatible with "post-processing" orbit solutions using CODE final GPS orbits and clocks (mean radial rms over three days w.r.t. JPL reference solution: 1.44 cm).

Summary and Conclusions

An approach for NRT GPS clock generation based on freely available GPS data and products is outlined. The quality of these clocks is confirmed in a LEO NRT orbit determination scenario where the stringent radial orbit error of 10 cm can easily be met.

Acknowledgements

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References

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