CODE High-rate GPS Satellite Clock Corrections

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Introduction

CODE started to regularly generate 30-seconds phase consistent high-rate satellite clock corrections. The product will soon be submitted to the IGS for the rapid and the final solution. The procedure used to generate the high-rate clock corrections based on the previously computed 5-minute clock corrections is described. Results from kinematic precise point positioning experiments used to validate the product are presented.

Clock Estimation Procedure at CODE

1. Screening on RINEX level (RAPID and FINAL)

- Preprocessing of each RINEX file, dual frequency code and phase.
- Screening of Melbourne-Wuebbena linear combination for outliers and cycle slips.
- For cycle slips: use geometry-free linear combination to determine their size. Repair of cycle slips in code observations, new ambiguity in phase observations.
- Screening of difference between the ionosphere-free linear combinations of code and phase measurements for outliers.
- Smoothing of code observations using carrier phase measurements (Springer, 2000).

2. Screening of Post-fit Residuals

2.1 RAPID - Screening in Regional Clusters

- Screening in two iterations with stations grouped into 12 regional clusters.
- Independent clock estimation for each cluster.
- Orbits, ERPs, station coordinates, and troposphere parameters from CODE rapid three-days double-difference solution. Estimation of parameters for station not contributing to double-difference solution.
- In second iteration a station may appear in more than one cluster to guarantee a minimum redundancy for each observation to detect all outliers.

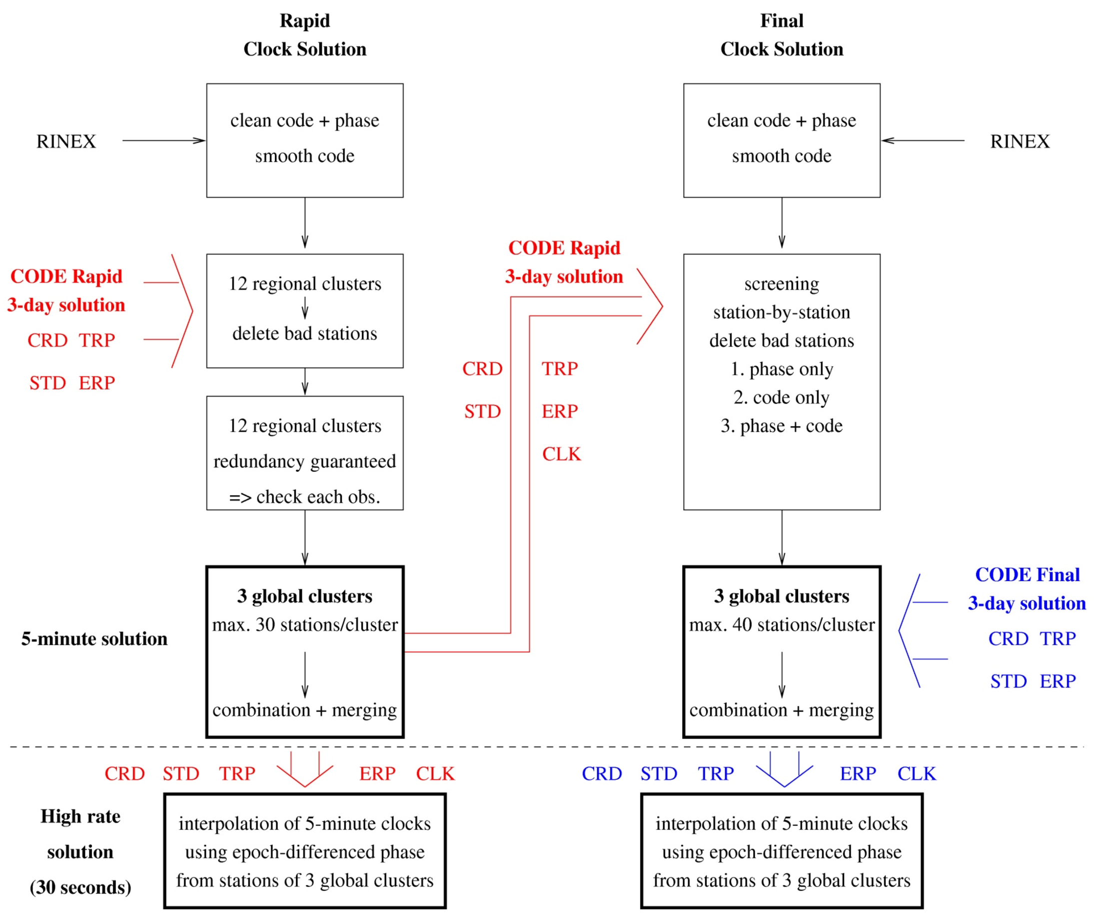

Figure 1: Flow diagram of rapid resp. final clock estimation procedure at CODE, steps 1 to 4.

2.2 FINAL - Screening Station by Station

- Screening station by station.
- Introduction of orbits, satellite clocks, ERPs, station coordinates, and troposphere parameters from CODE rapid solution. Estimation of station parameters if not available.
- Processing for code and phase in separate analysis. Then consistency check using both measurement types in common analysis.

3. Clock Solution (RAPID and FINAL)

3.1 Cluster-wise Clock Estimation

- Three global clusters with max. 30 station for rapid and 40 stations for final clock solution.
- Introduction of orbits, ERPs, station coordinates, and troposphere parameters from rapid resp. final three-days double-difference solution.
- Epoch-wise preelimination of huge number of clock parameters, and recovery of clocks in back-substitution step.

3.2 Combination of Cluster Solutions

- Epoch-wise estimation of clock offsets between individual cluster solutions to transform all clocks to the same reference.

3.3 Selection of Reference Clock

- Alignment of the combined clock solution to each reference clock candidate and computation of mean RMS for all clocks assuming a linear clock model.
- Selection of reference based on largest number of epochs with clocks and lowest mean RMS of linear fit for all clocks.

4. High-rate Clocks (RAPID and FINAL)

4.1 The Generation of High-rate Clocks

- Orbits, ERPs, station coordinates, and troposphere parameters fixed to CODE rapid resp. final three-day double-difference solution.
- Estimation of clock epoch-differences based on epoch-differenced phase observations for the same stations used for the 5-minute clock solution.
- Constraining of the clock corrections to the 5-minute CODE rapid resp. final clock corrections (Steps 1 - 3).
- The result is an interpolation of the precise 5-minute clock corrections based on the phase observations.
- Very efficient method.

4.2 The High-rate Clock Product

- Distribution in Clock RINEX format.
- The high-rate clocks contain
  - Satellite clock corrections at 30-second sampling.
  - Station clock corrections at 5-minute sampling.
  - Clock corrections at 5-minute intervals are copied from CODE rapid resp. final clock solution.
  - Same reference as for CODE rapid resp. final clock solution.

Validation of High-rate Clocks

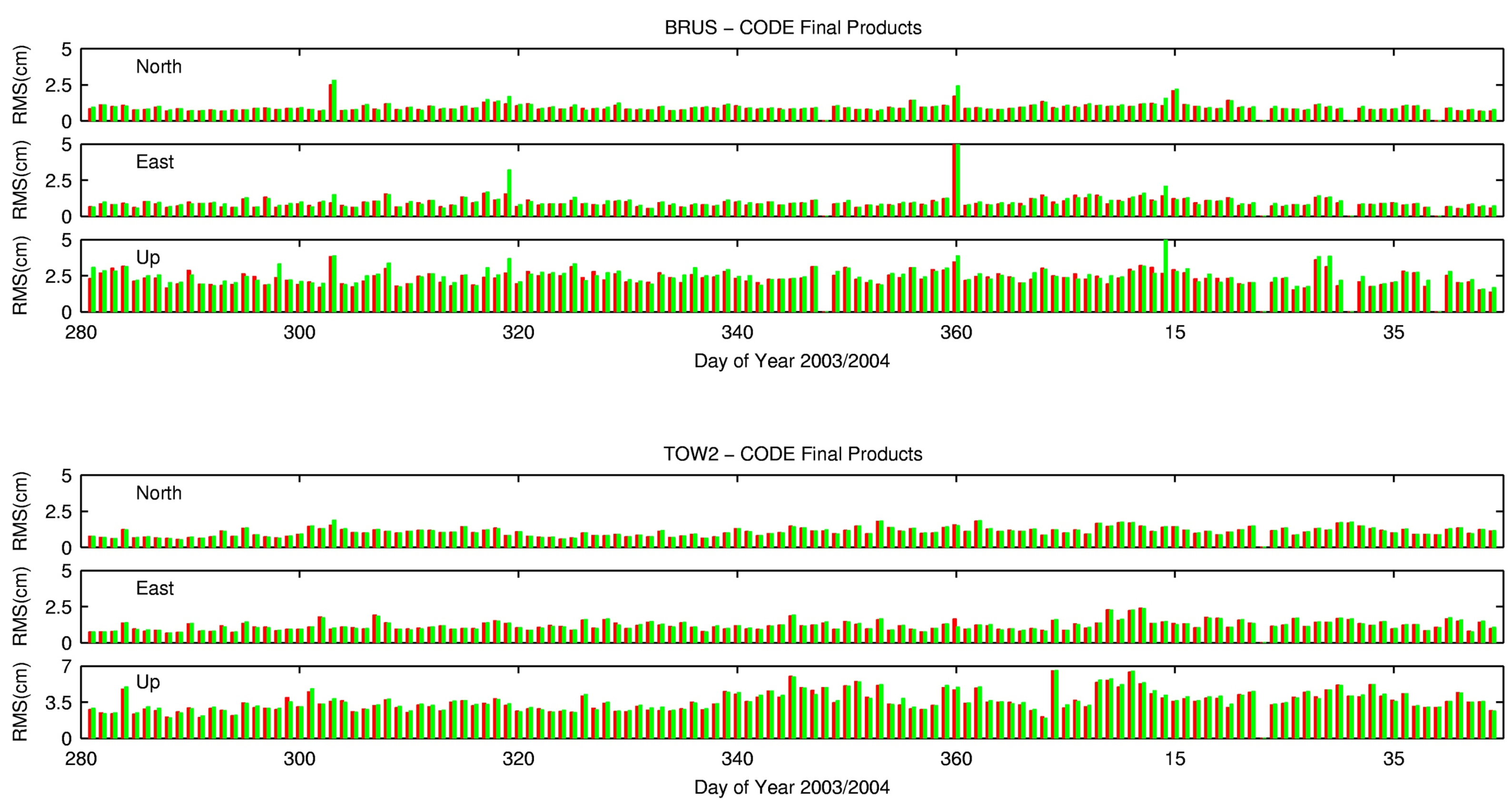

Figure 2: RMS errors (cm) per component of kinematic point positioning of BRUS and TOW2 using CODE final products, left bar: 30-second sampling (solution 1), right bar:official 5-minute sampling (solution 2).

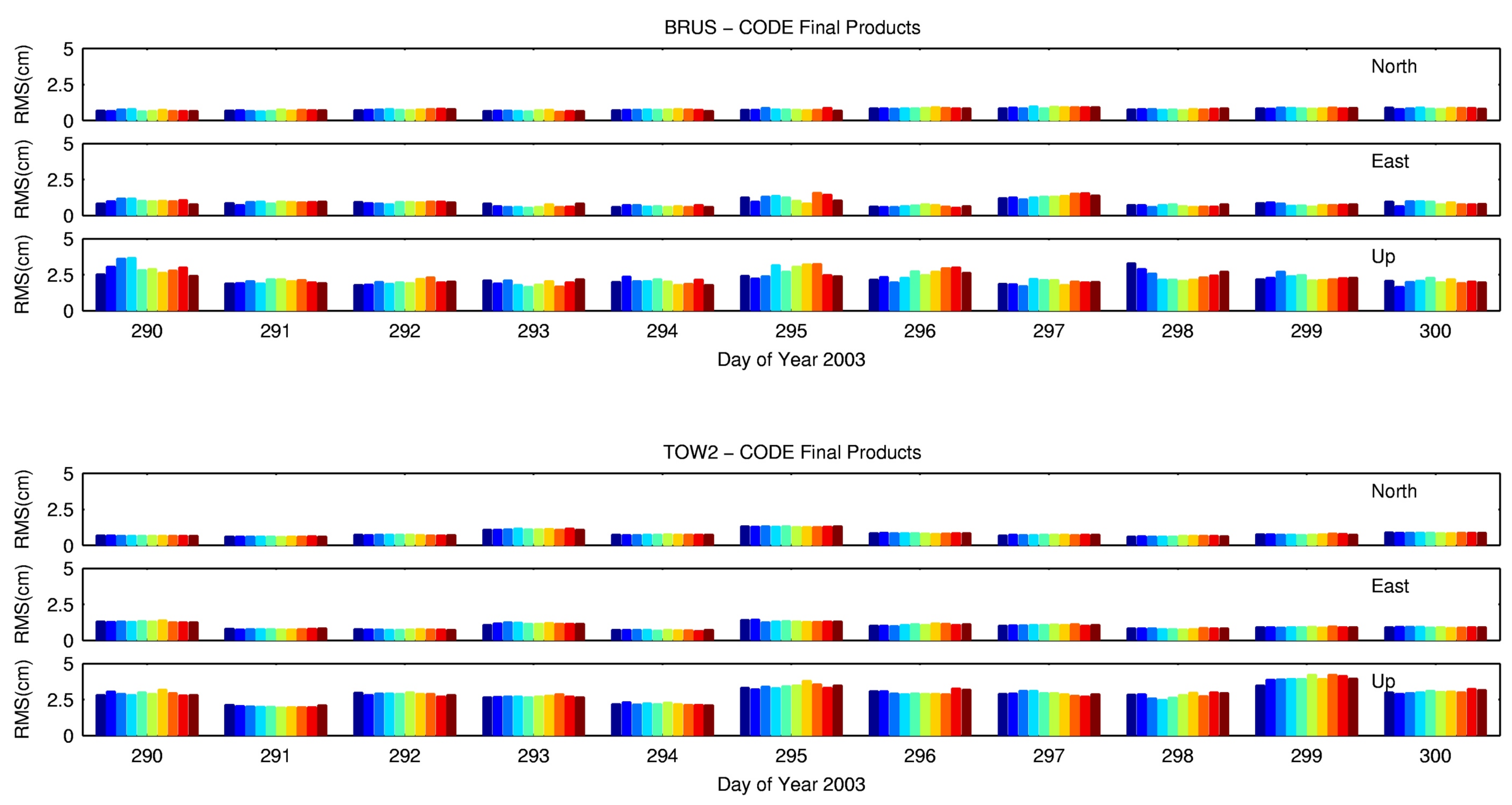

Figure 3: RMS errors (cm) per component of kinematic point positioning of BRUS and TOW2 using CODE final products (day 290-300, 2003), 30-second clock corrections, ten different solutions (2-11) with 5-minute sampling according to Figure 4.

The high-rate satellite clock corrections (30-second sampling) are validated by a kinematic point positioning of two stations (BRUS, TOW2). Eleven solutions with different sampling intervals are computed using the new 30-second CODE final satellite clock corrections.

- **Solution 1:** 30-second sampling.
- **Solutions 2-11:** 5-minute sampling, each solution is shifted 30 seconds w.r.t. the previous one (Figure 4).

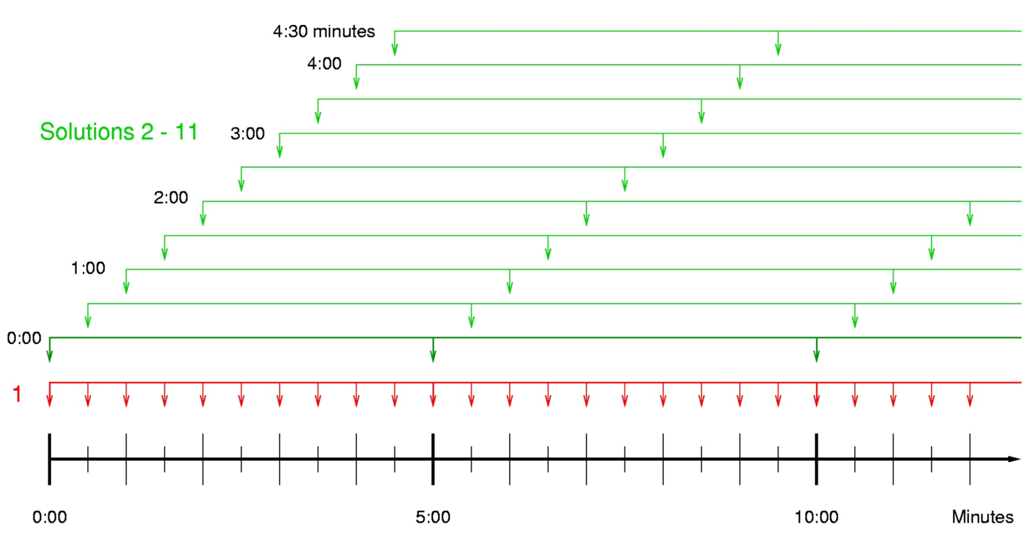

Figure 4: Different sampling rates and start epochs used for the kinematic point positioning.

- Figure 2 indicates that both satellite clock correction sets (5-minute and 30-second) show the same quality for a kinematic point positioning of a terrestrial station.
- The 10 solutions which are shifted 30 seconds w.r.t. each other (Figure 3) show no systematic effects in the RMS errors.
- The different kinematic point positioning solutions are very homogeneous which is an indicator for the good quality of the 30-second clock corrections.

=> The high-rate clock corrections have the same quality as the original 5-minute clock corrections and the interpolation using the phase observations causes no degradation of accuracy.

Availability and Completeness

- Usually the high-rate clock corrections are available shortly after the (rapid or final) 5-minute solution for the whole GPS constellation for the whole day (2880 epochs).
- Exceptions are only
  - satellite transmission gaps or
  - missing epochs in the 5-minute clock corrections (Step 1 to 3) due to data problems.

Summary

- The clock estimation at CODE is an elaborate procedure containing several data screening steps.
- The procedures are slightly different for rapid and final analysis.
- The generation of high-rate satellite clock corrections is a very efficient and simple procedure (interpolation of the 5-minute clock corrections using the phase observations of a global station network).
- Validation of the high-rate clock corrections shows a homogeneous quality for the whole interpolation interval of 5 minutes.
- The high-rate clock corrections are usually available for the whole GPS constellation for all 2880 epochs.

References

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