Verification of real-time IGS products and their influence on Precise Point Positioning

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Presentation plan

1. Introduction
   - RTIGS project
   - Motivation
   - Methodology
2. RTIGS current status
   - Accuracy
   - Latency
   - Quality degradation over time
3. Short-time predictions
   - Prediction of orbit corrections
   - Prediction of clock corrections
4. Conclusions

RTIGS project

Target combination product performances are:

- Satellite Clock Accuracy: **0.3 ns**
- Station Clock Accuracy: **0.3 ns**
- Orbit Accuracy: At the level of the **IGS Ultra** predictions (**5cm**)
- Latency (when available in RT): **10 s**

Update interval in stream:

- orbit corrections: **60s**
- clock corrections: **5s**
- code biases: **5s**

Beginner difficulties

1. Lack of documentation on how to apply corrections:
   - high standardization (Ntrip, RTCM),
   - few papers and presentations about RTIGS (with bugs).

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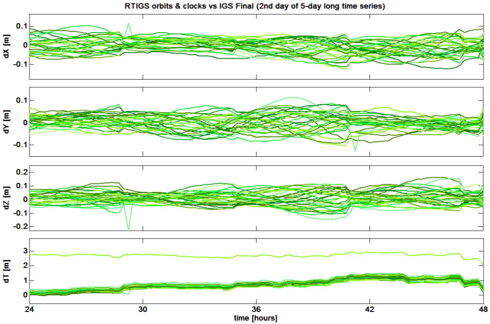
2. Poor quality verification (until recently):
   - only target accuracy provided,
   - PPP monitor scenarios,
   - AC combination results (Number, RMS and sigma).

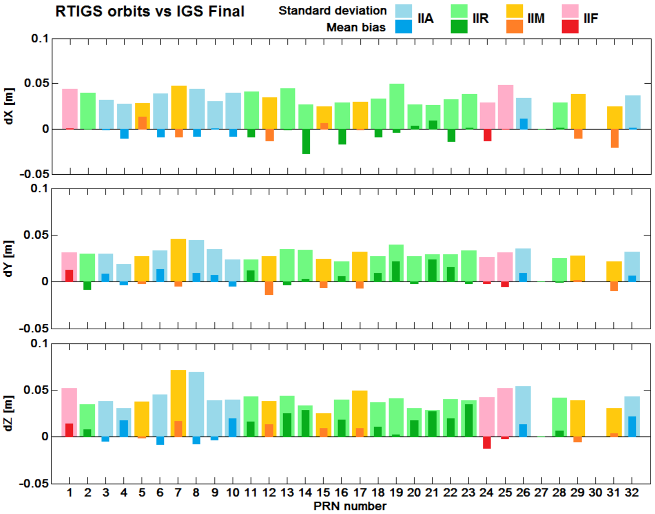
RTIGS project verification methodology (1)

1. Record navigation data and time-series of real-time correction (5 days)
2. Apply clock and orbit corrections, recalculate APC to CoM
3. Compare results with IGS Final orbits/clocks



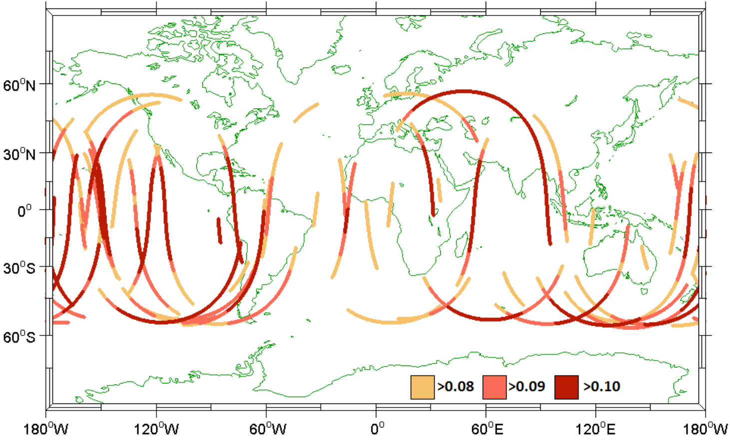
4. Compute statistics for residuals for each satellite
5. Analyze outliers

RTIGS orbit quality (1)



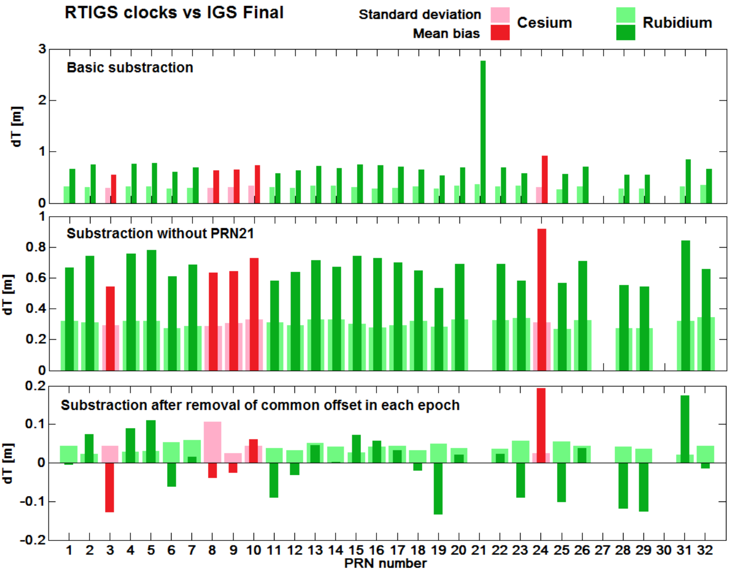
Average STD < 0.050 m, avarage bias $\pm$ 0.025 m

RTIGS orbit quality (2)

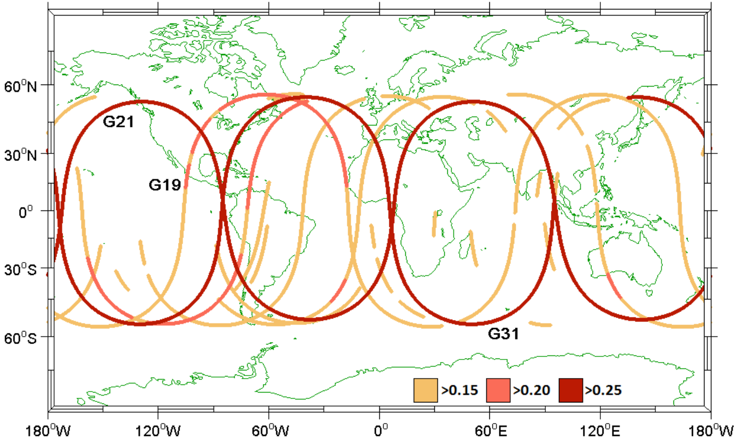


Poor quality over Pacific Ocean and Southern Ocean

RTIGS clocks quality (1)

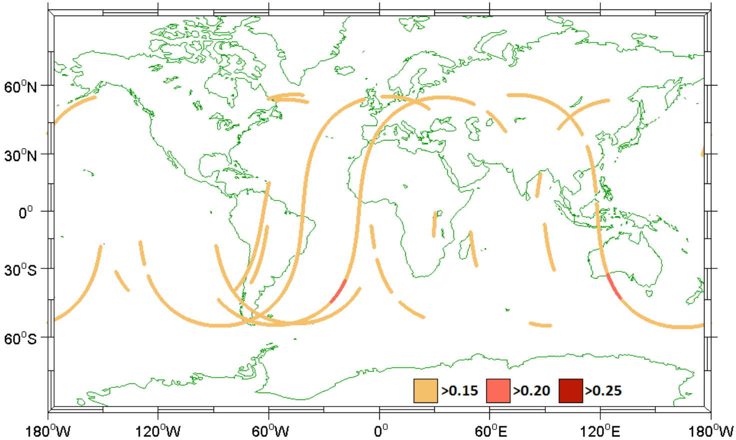


RTIGS Rubidium clocks quality (1)



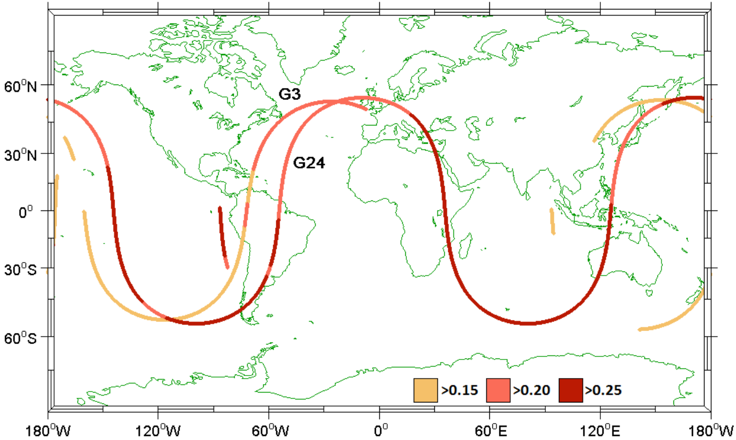
Repeatable outliers for PRN: 19 (IIR), 21 (IIR), 31(IIM)

RTIGS Rubidium clocks quality (2)



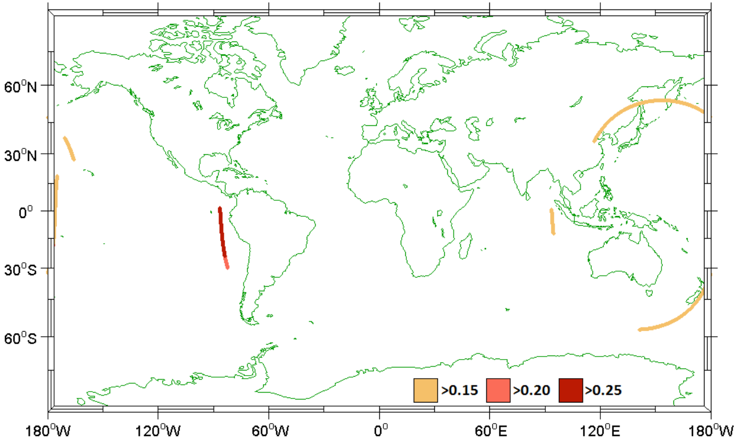
Random nature of outliers for the remaining 4 satellites

RTIGS Cesium clocks quality (1)



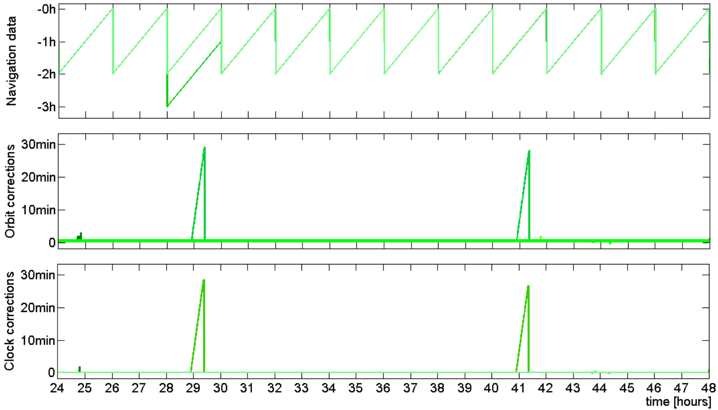
Repeatable outliers for PRN: 3 (IIA) and 24 (IIF)

RTIGS Cesium clocks quality (2)



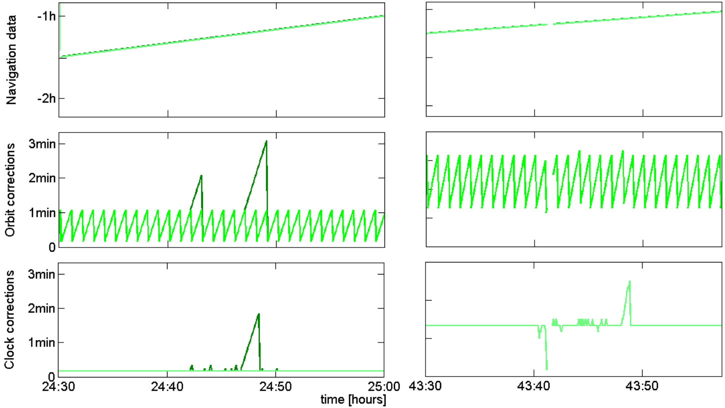
Single cases of outlying long-arcs for remaining satellites

Latency - overview



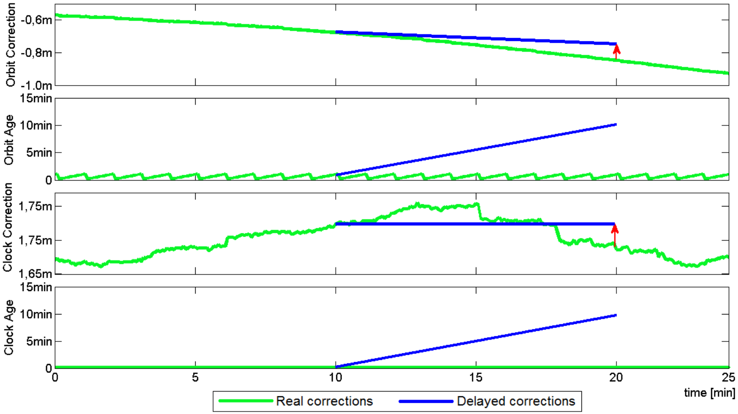
Isolated cases of missing data for 30min, more few-minutes gaps

Latency - uncommon cases



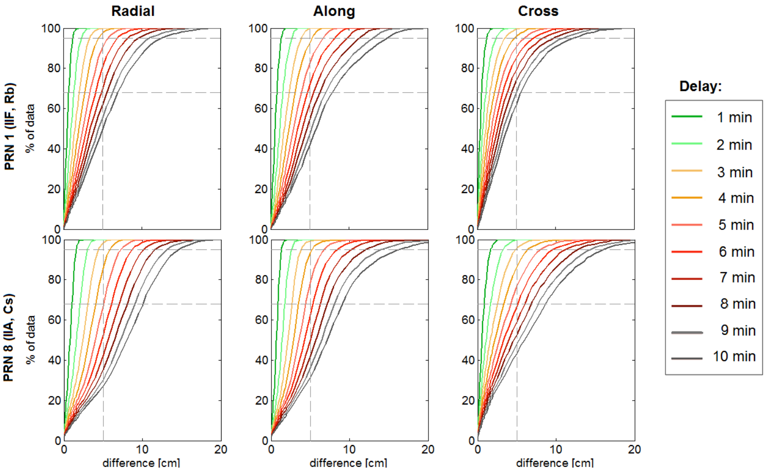
1) Two close in time cases of data gap (2 & 3 messages) for individual satelllite.
2) Few minutes of repeatable uncommon clock correction latency + data gaps.

Metodology



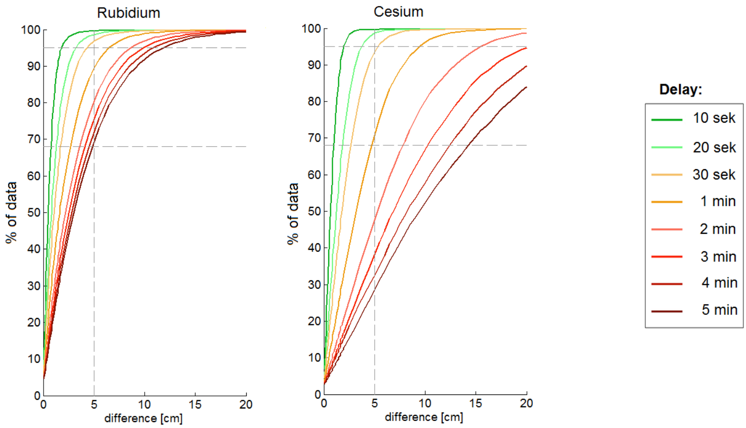
- Simulated data transfer interruptions for various time-periods
- Difference between real-time corrections and delayed data as a measure of quality degradation over time

Delayed orbit corrections



After 1 min. 95% of corrections degrades $<$ 2 cm; 4min. $<$ 5cm
Correction for satellites with Cesium clocks degrades slightly faster.

Delayed clock corrections



After 10 sec. 95% of corrections degrades < 2 cm, 30 sec. < 5cm
Correction for satellites with Cesium clocks degrades significantly faster.

In field measurements

Real-time in-field kinematic PPP:

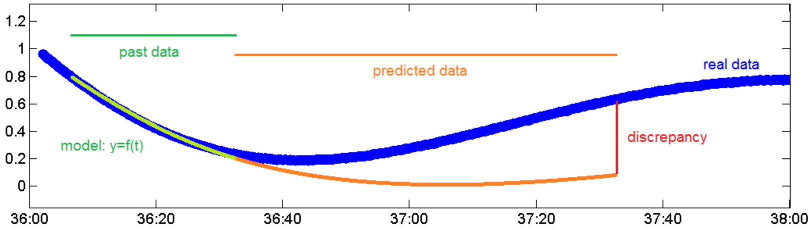
- continous positioning in changing conditions:
  - environmental (troposphere, ionosphere),
  - spatial (terrain, horizon obstracles);
- rely on availiable orbits and clocks;
- require constant Ntrip connection.

In case of interruption in Internet connection (eg. outside the GSM range) -
- is it possible to continue measurements?

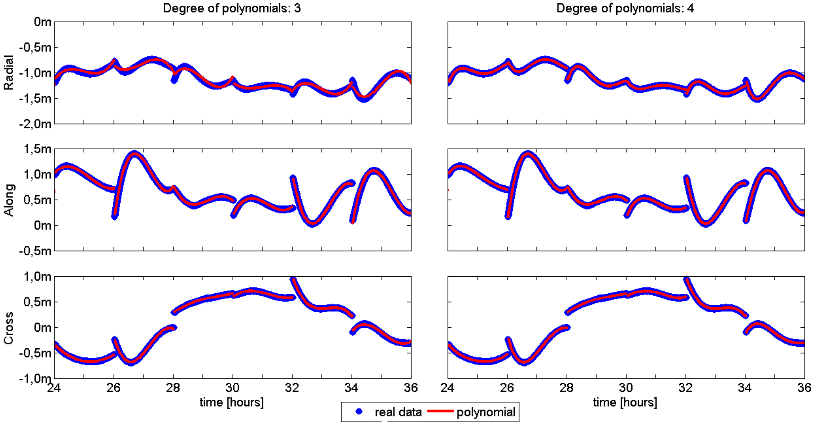
Methodology

By using the data from the past - predict the corrections:

- how to fit the model?
- what accuracy is required?
- how much past data is needed?
- how far one can predict?

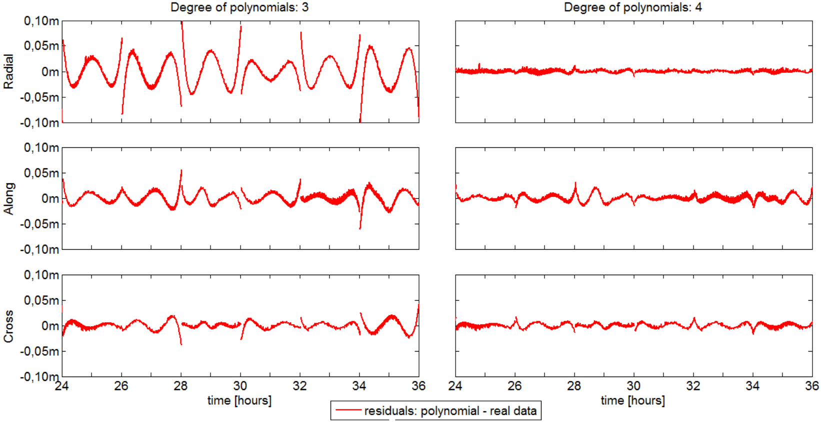


Polynomial fit



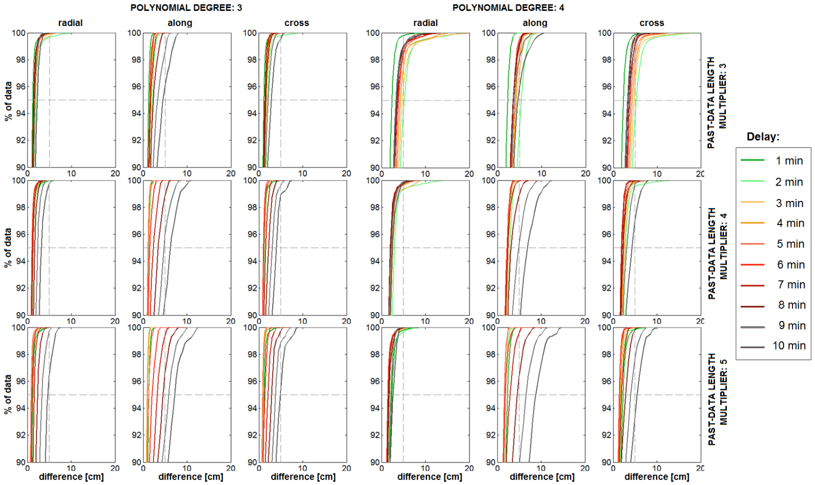
Polynomials of degree 3 and 4 fited into 2-hour time series of orbit correction data (PRN 1: IIF,Rb)

Polynomial fit



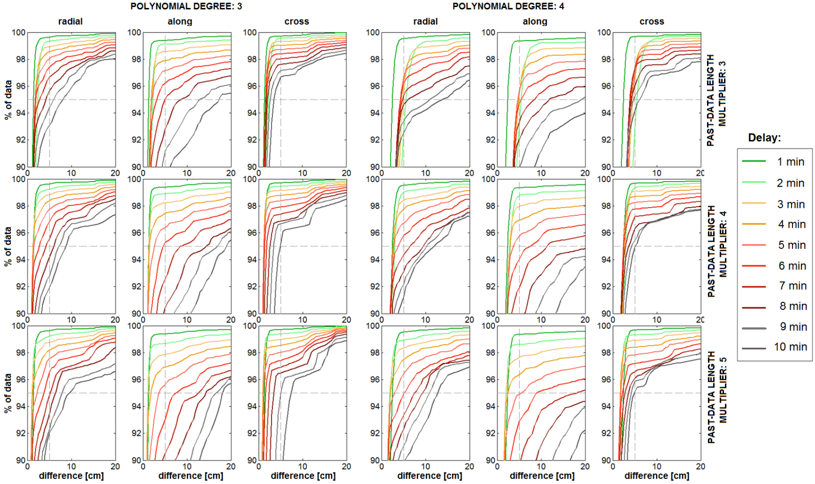
3-deg polynomials: mean=0.000m, StdDev=0.030m, range=(-0.119 : +0.108)
4-deg polynomials: mean=0.000m, StdDev=0.007m, range=(-0.035 : +0.031)

Results of polynomial orbit predictions (PRN1: IIF, Rb)



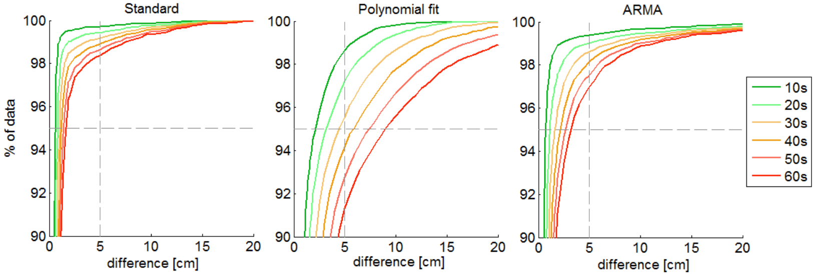
Slower degradation: 2cm after 5min.; 5cm after 10min., (for: deg=3, multi=3)
(instead of: 2cm after 1min.; 5cm after 4min.)

Results of polynomial orbit predictions (PRN8: IIA, Cs)



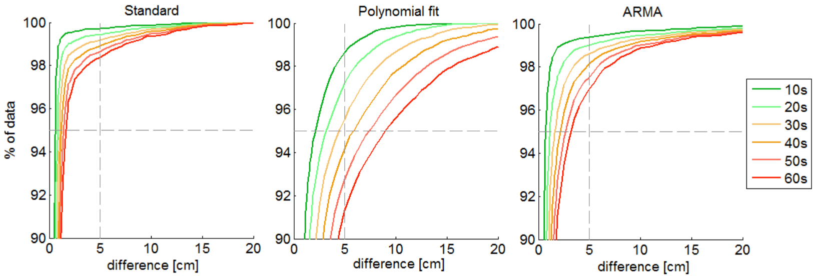
Slower degradation: 2cm after 4min.; 5cm after 7min., (for: deg=3, multi=3)
(instead of: 2cm after 1min.; 5cm after 4min.)

Clock corrections



None of the prediction method improved the results for clocks.

Clock corrections



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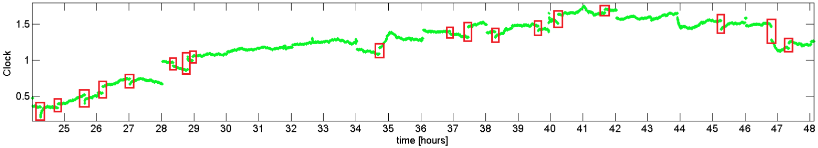

Conclusions

1. IGS provides real-time corrections for broadcast orbits and clocks;
2. In general, RTIGS products meet the target accuracy:
   - RMS=5cm for each orbit component, RMS=9cm for clocks,
   - there are interruptions in data transmission as well as outliers,
   - the correction (especially for clocks) degrades very fast,
   - users should be careful and aware of imperfections;
3. In case of interruptions in data transmission:
   - it is possible to extend the lifetime of orbit corrections by 3-deg. polynomial prediction,
   - clock prediction methods gives worse results;
4. "Guide to use RTIGS products" wolud be helpful:
   - may encourage the scientific community to take advantage of them.