Real Time Monitoring of IGS Products within the RTIGS Network

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Introduction

„RTR- Control"

Test Results

Conclusion and Outlook

Content

Recommendation of the last IGS- Workshop

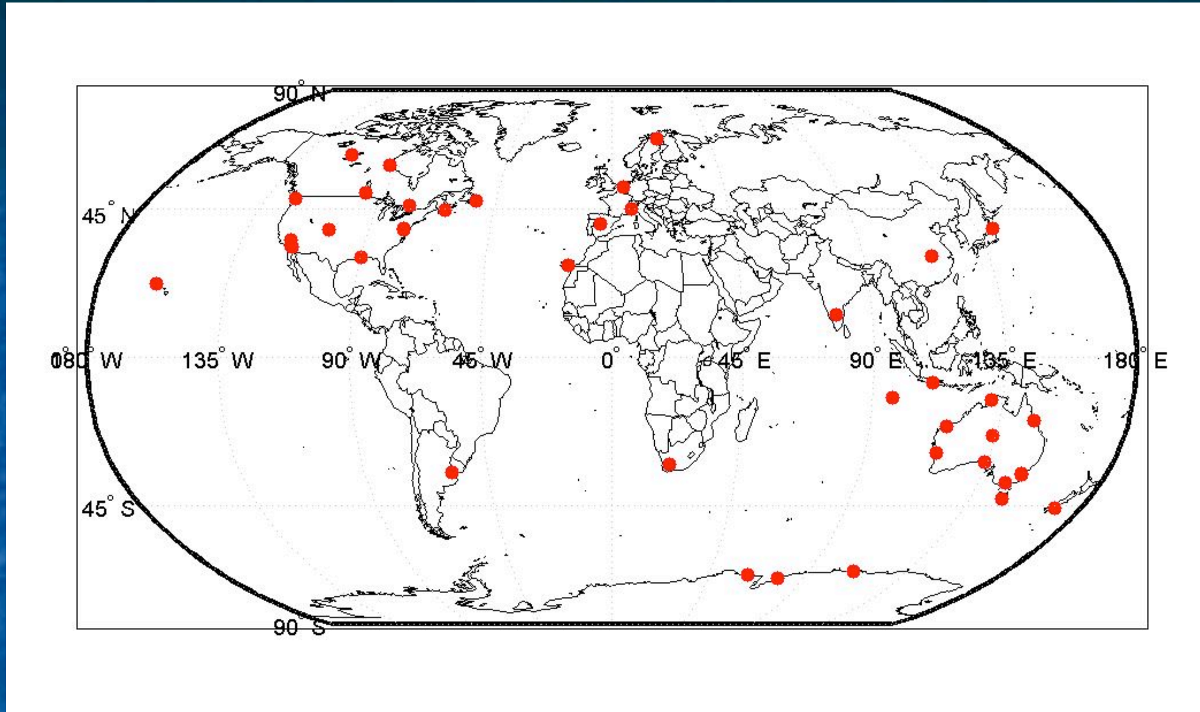
(Bern, 2004)

„IGS should set up an integrity monitoring of IGS Real Time (IGU) Products"

This work should be interpreted as a first prototype under development.

Introduction

RTIGS- Network



Used for:

real time integrity monitoring
of Ultra Rapid Orbits

Development of „RTR- Control"

Introduction

How it Works - 1

Input Data

- Code Pseudoranges (Received via RTIGS- datastream)
- IGU- Orbits

Calculations

- Comparison of calculated ranges with corrected Pseudoranges

Results

- diagnose of incorrectly predicted satellite- orbits and clocks
- detection of multi-path distorted pseudoranges

How it Works - 2

1. Download of most recent IGU- Orbits
2. Permanent reception of raw observation data
3. 15 sec interval - calculation of PR- differences
4. Least Squares Adjustment
5. Output and archiving of results

15 sec interval - calculation of PRd and Least Squares Adjustment

- Calculation of the Receiver- Satellite Range

- Correction of the measured code Pseudoranges

- Estimation of the approximate receiver- and satellite clock correction

- Least Squares Adjustment (PRd, Clock Corrections)

Step 1: Calculation of the Receiver- Satellite Range

$$CR_k^j = \sqrt{\left(Xe_k - Xs^j\right)^2 + \left(Ye_k - Ys^j\right)^2 \left(Ze_k - Zs^j\right)^2}$$

CR_k^j = calculated range from receiver k to satellite j

Xe_k, Xe_k, Xe_k = known coordinates of receiver k

Xs_j, Xs_j, Xs_j = coordinates of satellite j (IGU - Orbits)

Step 2: Correction of the measured code Pseudoranges

$$PRc_k^j = PR\_L3_k^j - dtrop_k^j + drel_k^j * c$$

PRc_k^j = corrected pseudorange from receiver k to satellite j

$PR\_L3_k^j$ = L3 linear combined code pseudorange from receiver k to satellite j

$dtrop_k^j$ = tropospheric correction of $PR\_L3_k^j$ estimated with the Saastamoinen model

$drel_k^j$ = calculated relativistic correction of $PR\_L3_k^j$

c = speed of light

Step 3: Estimation of the approximate receiver- and satellite clock correction

Step 3a:

$$PRda_k^j = PRc_k^j + SCCa^j * c - CR_k^j$$

$PRda_k^j$ = auxiliary pseudorange - difference from receiver k to satellite j

$SCCa^j$ = approximate value of the clock correction for satellite j from IGU - Orbits

Step 3b:

$$RCCa_k = \frac{\sum_{i=1}^{n} \frac{PRda_k^n}{c}}{n}$$

$RCCa_k$ = approximate clock correction for receiver k

n = number of visible satellites

Step 4: Least Squares Adjustment

Observation Equations

$$PRd_k^j = PRc_k^j - CR_k^j - l_0$$

$$PRd_k^j = \text{pseudorange - difference from receiver } k \text{ to satellite } j$$

Approximate Values

$$l_0 = \left(RCC_k - SCC^j\right) * c$$

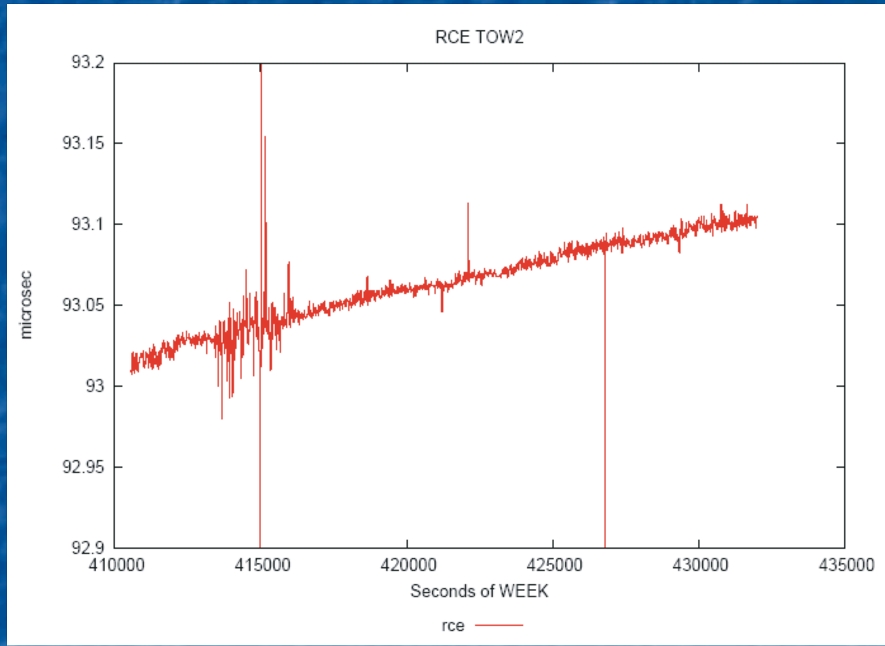
$$RCC_k = \text{clock correction for satellite } k$$

$$SCC^j = \text{clock correction for satellite } j$$

Parameters: Clock Correction Improvements

Results of the Adjustment

- Corrected Receiver Clocks
- Corrected Satellite Clocks
  - ➢ Clock prediction model errors



- Pseudorange Residuals
  - ➢ Multipath effects, orbit errors and noise

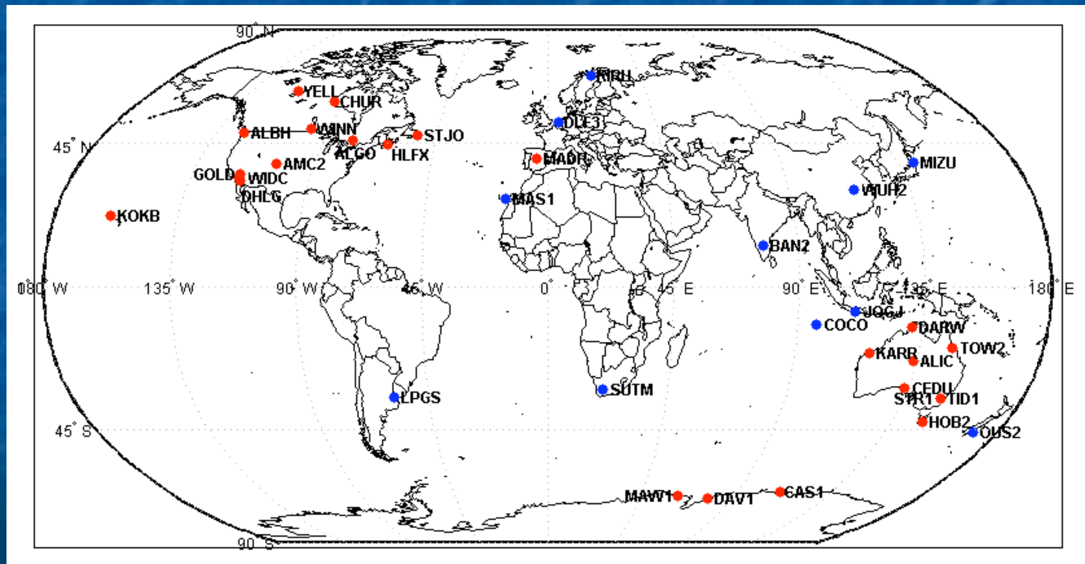
Test Results

Date: Thursday, 16th of March, 2006

Orbits: IGU13674_12.sp3 and IGU13674_18.sp3

Change to more recent ephemeris: 425173s (=22:06 UTC)

Real Time Data: 24 stations (marked red)

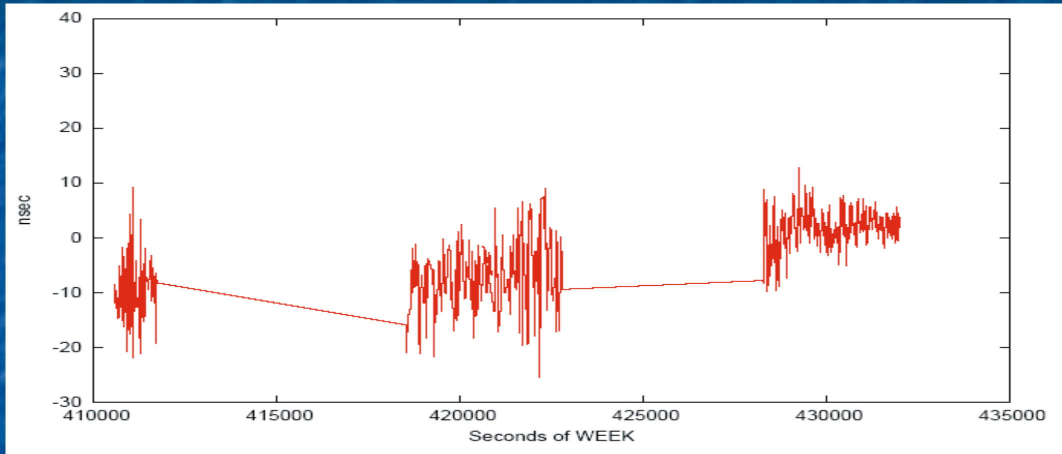


General Results – Network Distribution!

Differences to

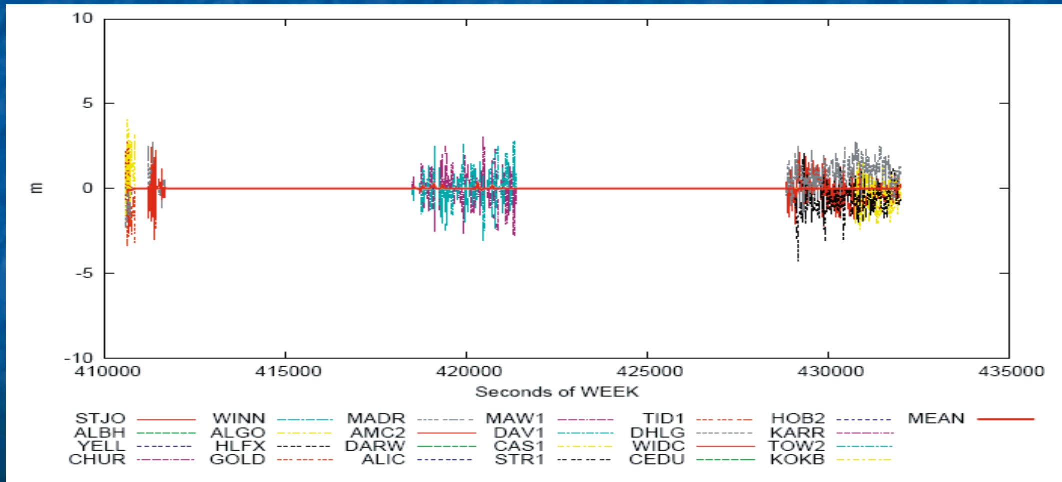
Predicted IGU- Clock

(PRN 5)



Pseudorange Residuals

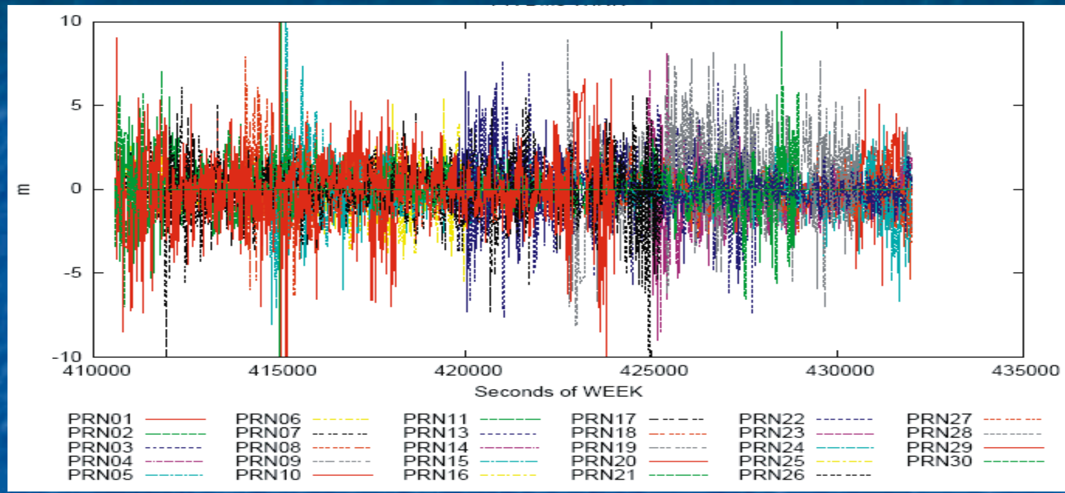
(PRN 5)



General Results – Receiver Dependency!

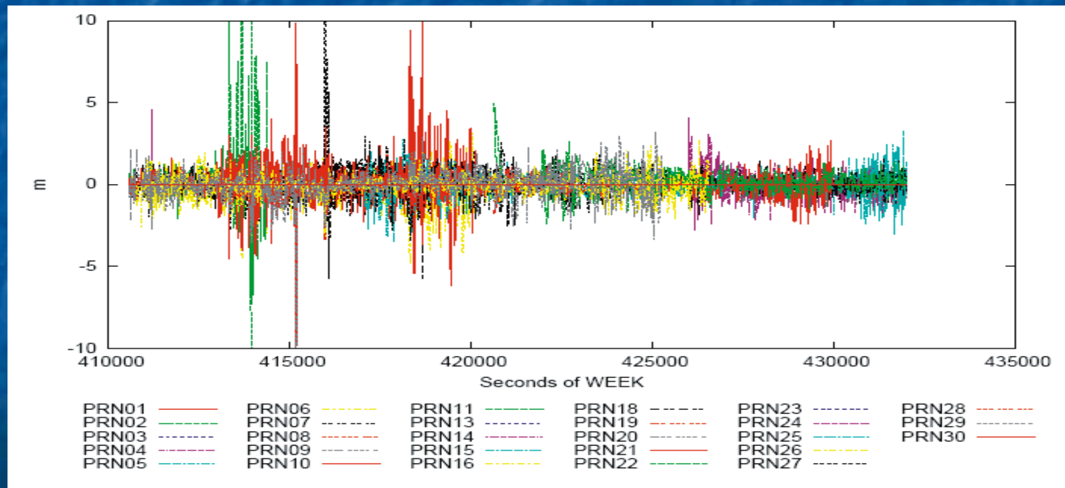
Pseudorange Residuals

(Station WINN)



Pseudorange Residuals

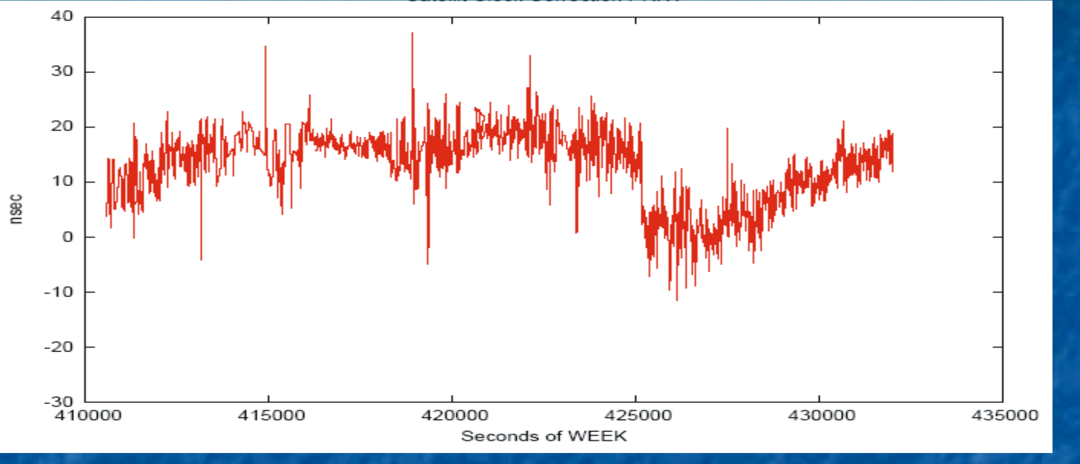
(Station ALGO)



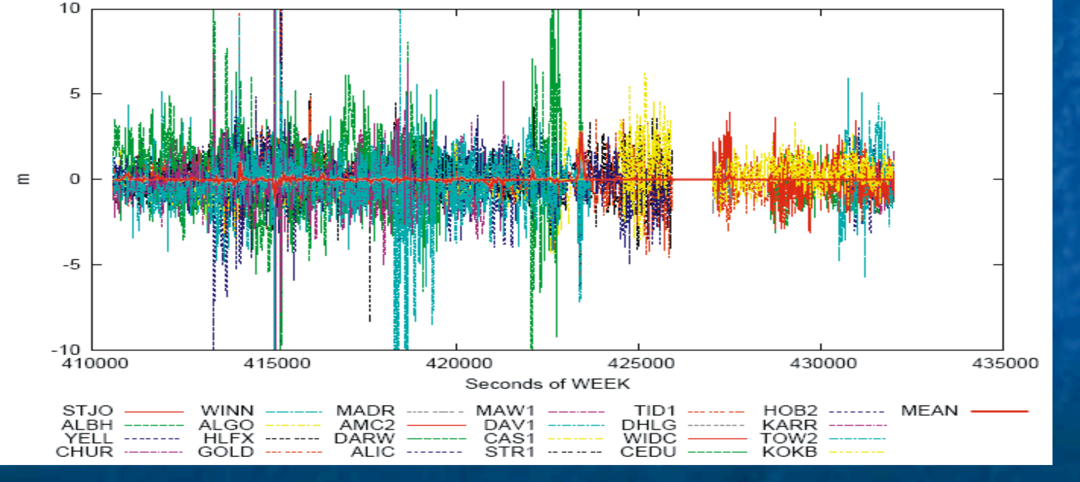
Particular Results – PRN1

Differences to

Predicted IGU- Clock



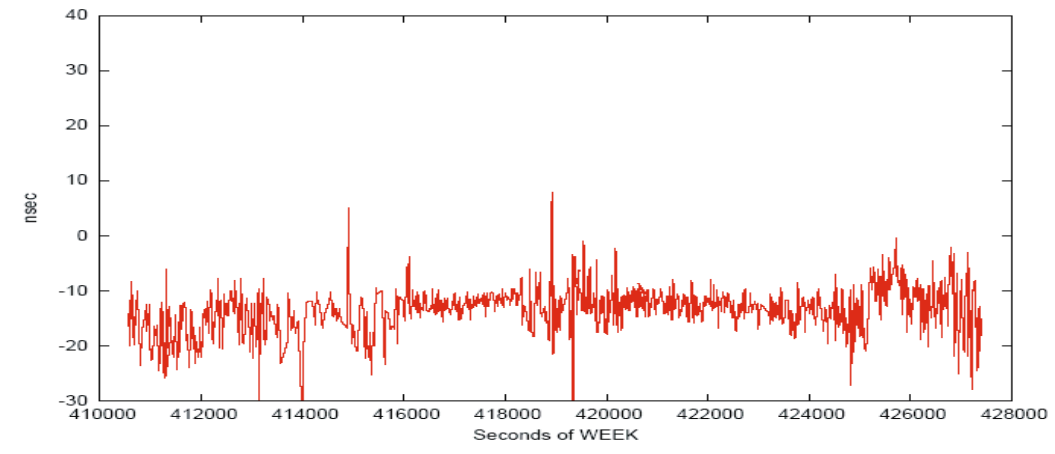
Pseudorange Residuals



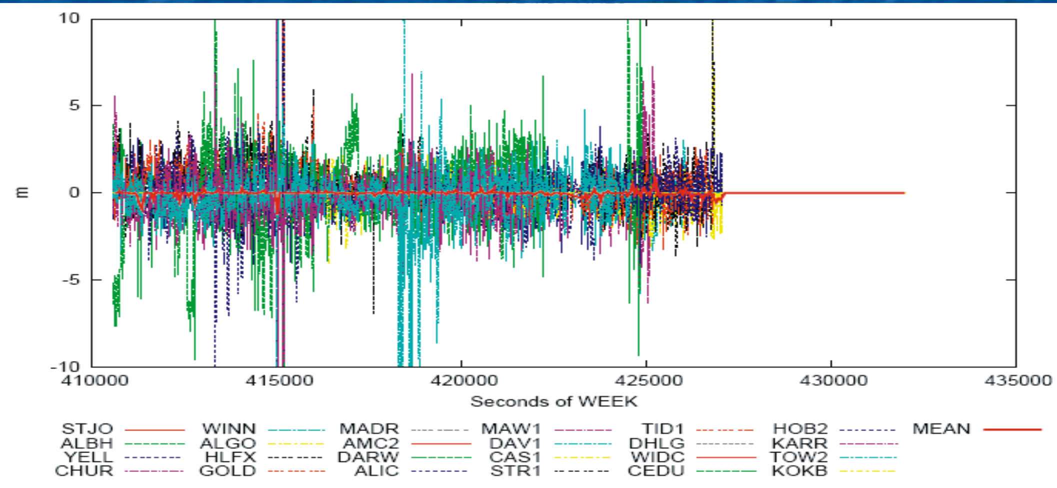
Particular Results – PRN 25

Differences to

Predicted IGU- Clock



Pseudorange Residuals

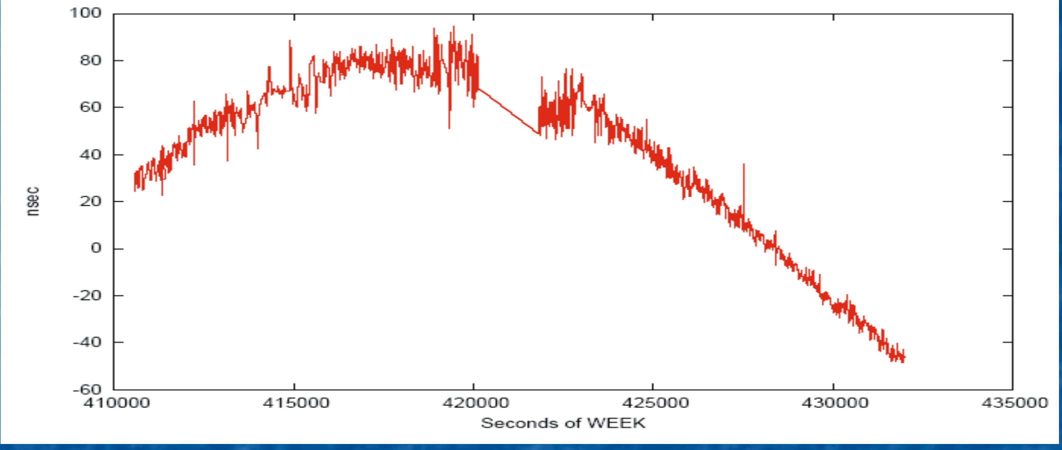


Particular Results – PRN19

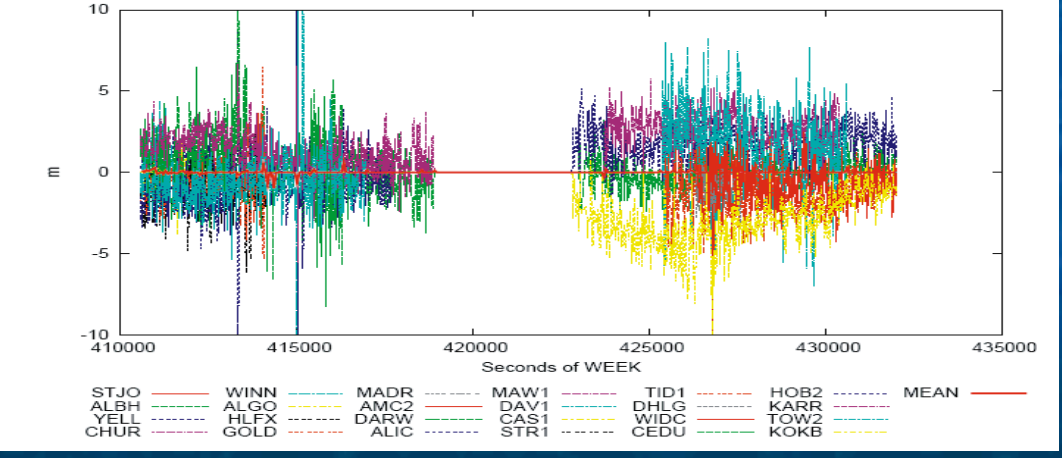
(Artificial Orbit Error!!! – 20m in X, Y, Z)

Differences to

Predicted IGU- Clock



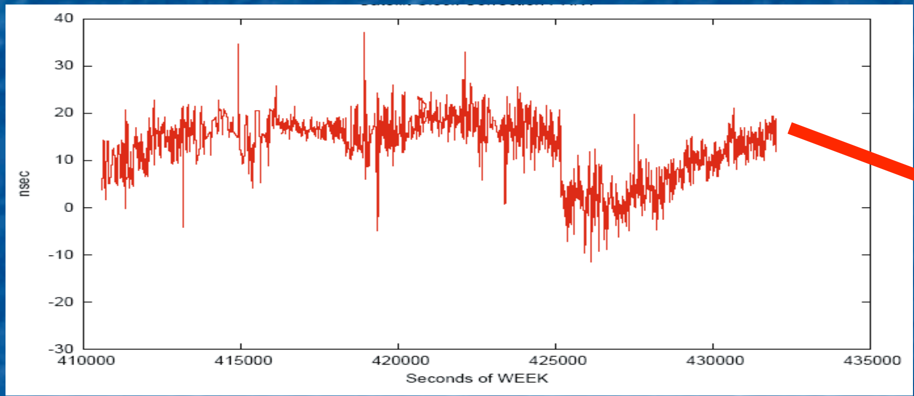
Pseudorange Residuals

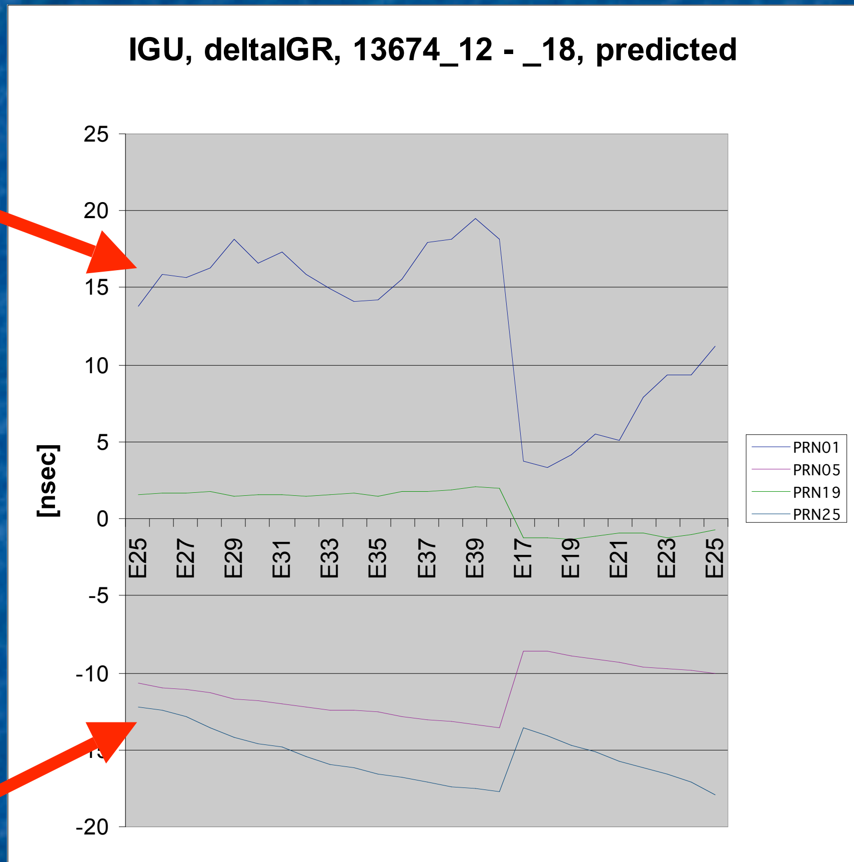


Test Results

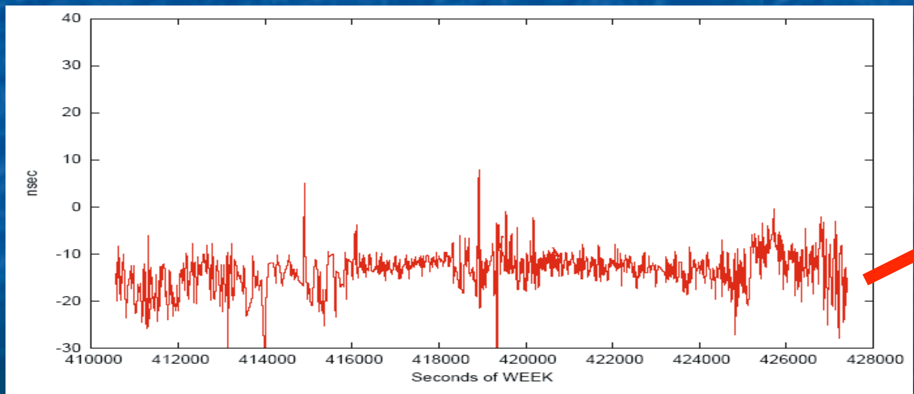
Analysis 1: Comparison Corrections - delta IGU-IGR

Clock Corrections – PRN 1





Clock Corrections – PRN 25

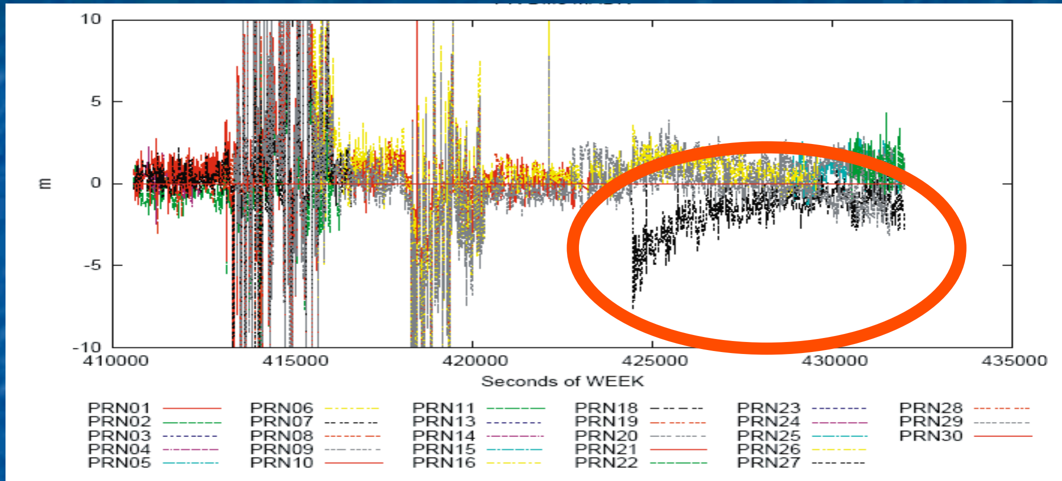


Test Results

Analysis 2: Single multipath- distorted Pseudorange

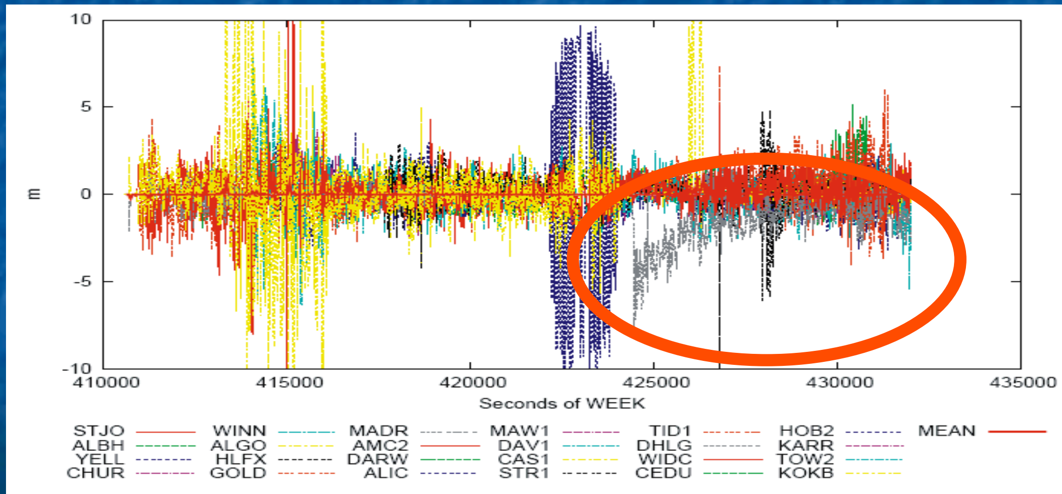
Pseudorange Residuals

Station MADR



Pseudorange Residuals

Satellite PRN 18



• “RTR- Control” can detect mismodeled satellite clocks predictions

• The time series of the clock differences IGU – IGR and the differences computed by the program show the same trend and absolute values.

• Orbit errors mainly propagate into the satellite clock corrections but can also be seen in the pseudorange residuals.

• Multipath distorted pseudoranges are detected in the pseudorange residuals and do not effect the receiver- or satellite clock estimation.

Conclusion

Program Development

- improvement of modeling of pseudorange correction
- better separation of satellite orbit-, satellite clock- and ranging errors
- future use of phase ranges
- ongoing tests – more observations to one satellite – better and more reliable results

RTIGS- Network

- distribution of the stations has to be improved

User groups interested

- IGS itself
    - ➢ for qualifying issued orbits

- Authorities and Companies operating Real Time GNSS station networks
    - ➢ for preventing the usage of mismodelled satellites in range error correction

THANK YOU