Positioning by multiGNSS: the user point of view based on processing of real data

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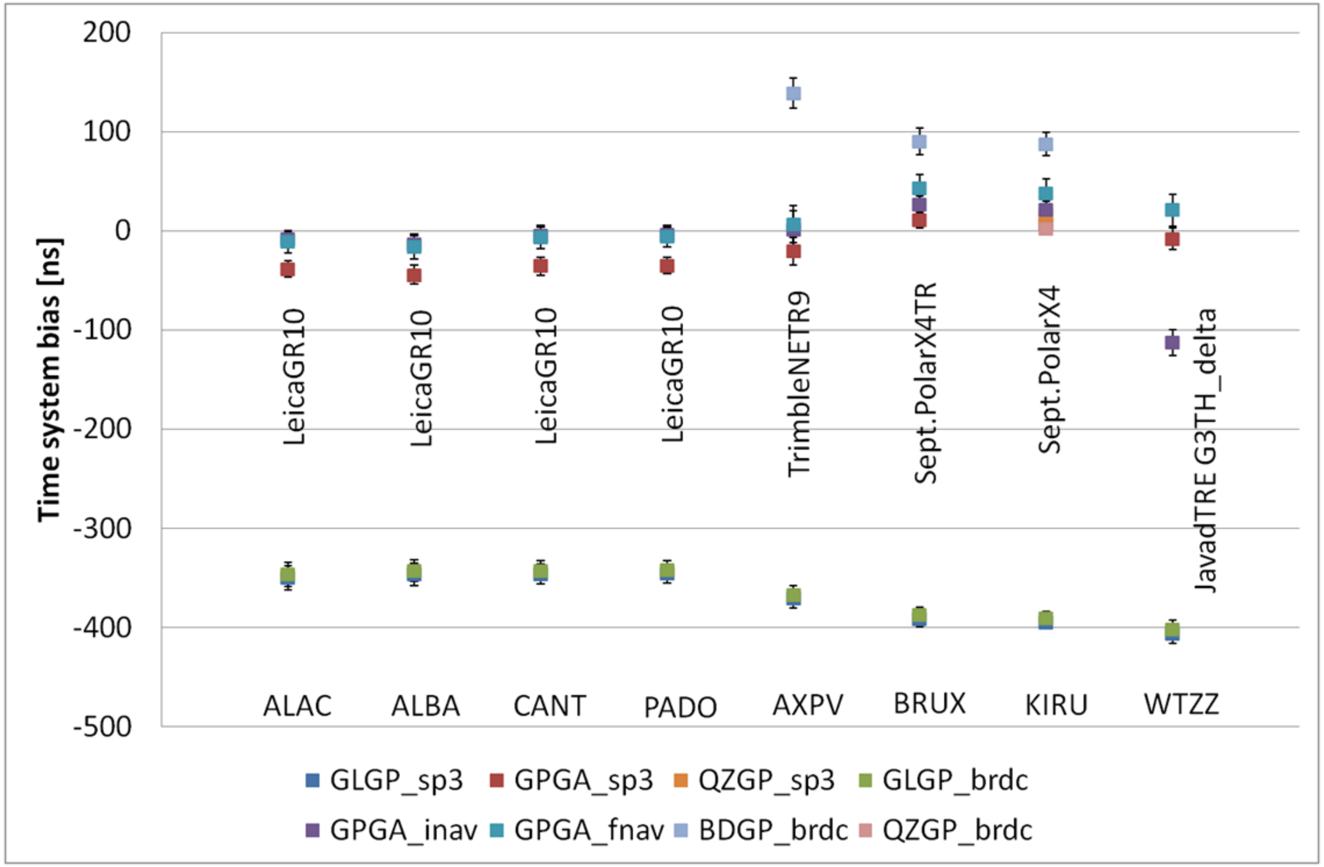
- Use RINEX 3.02 data from severeal types of multiGNSS receivers within the MGEX Project of IGS, for European stations
- Systematic monitoring of Coordinates, TZD, Time Offsets
- Offset of time scales of Glonass Galileo Beidou QZSS are monitored, as well as receiver dependent biases → maintain web page
- Possibility of broadcast to user the GNSS-to-GPS TimeOffset, TZD, receiver dpendent bias

Time system biases and receiver dependent biases in 2013 data

- Glonass to GPS Time Offset
- Galileo to GPS Time Offset (I/nav, F/nav)
- Beidou to GPS Time Offset
- QZSS to GPS Time Offset
- All have been monitored for different receiver types and using broadcast and SP3 orbits



Dalla Torre and Caporali, GPS Solutions 2014 (DOI 10.1007/s10291-014-0388-2)

The data validity status bit has the values shown in Table 75:

Data Validity Status	Definition
0	Navigation data valid (tbc)
1	Working without guarantee

Table 75. Data validity Status Bit Values

The signal status bits have the values shown in Table 78.

Signal Health Status	Definition (tbc)
0	Signal OK
1	Signal out of service
2	Signal will be out of service
3	Signal Component currently in Test

Table 78. Signal Health Status Bit Values (definitions are tbc)

Message Type	5.Record 2. Word	Bits set	6.Record 2.Word	Bits set
I/NAV (E5b-E1)	513	9,0	E5b 390 (HS=3) 384 (HS=0)	6,7,8
F/NAV (E5a-E1)	258	8,1	E5a 48	3,4,5

Since 2013-12-03 the 6.record 2.word is set to zero

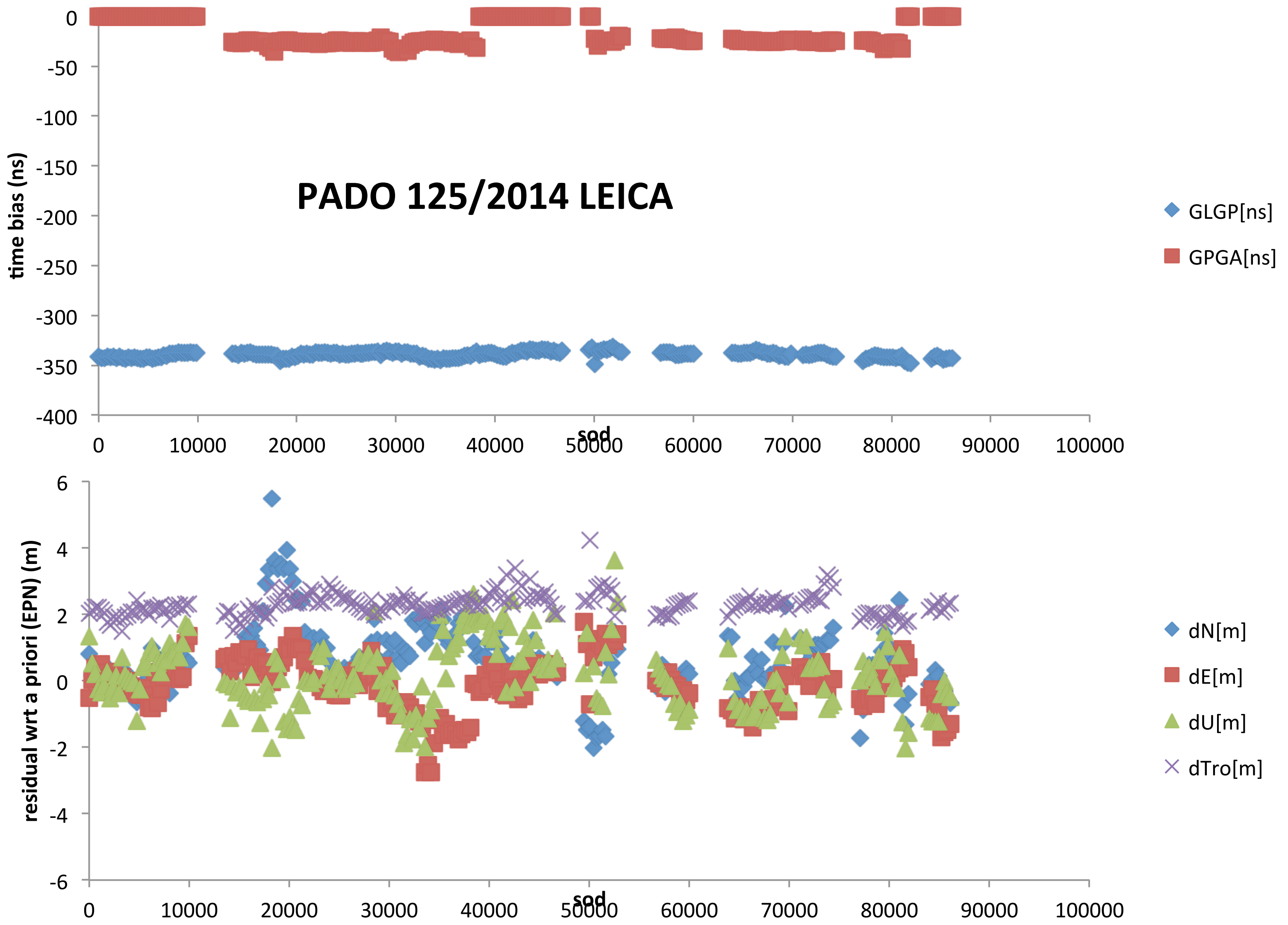
T ORBIT - 5	- IDOT (radians/sec) - Data sources (FLOAT --> INTEGER) Bit 0 set: I/NAV E1-B Bit 1 set: F/NAV E5a-I Bit 2 set: I/NAV E5b-I Bits 0-2 : non-exclusive Bit 3 reserved for Galileo internal use Bit 4 reserved for Galileo internal use Bit 8 set: af0-af2, Toc, SISA are for E5a,E1 Bit 9 set: af0-af2, Toc, SISA are for E5b,E1 - GAL Week # (to go with Toe) - spare	4X,4D19.12 ****)
BROADCAST ORBIT - 6	- SISA Signal in space accuracy (meters) Undefined/unknown: -1.0 - SV health (FLOAT converted to INTEGER) Bit 0: E1B DVS Bits 1-2: E1B HS	4X,4D19.12 *****)

RINEX 3.02.IGS.RTCM.doc 2013-04-03

TABLE A8
GNSS NAVIGATION MESSAGE FILE - GALILEO DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
	Bit 3: E5a DVS Bits 4-5: E5a HS Bit 6: E5b DVS Bits 7-8: E5b HS - BGD E5a/E1 (seconds) - BGD E5b/E1 (seconds)	

GPS+Glonass+Galileo positioning is done daily at IGS/EPN/MGEX site PADO:
-GLGP and GPGA time offset estimated (top plot)
-Time series of coordinates relative to nominal ETRF2000 values, and TZD (bottom plot)



Systematic monitoring of multiGNSS European sites

- Web page: map of multiGNSS permanent sites in Europe, with different receiver types; updated weekly
- For each site, link to downladable plots and data sheets (.csv) with the following information
  - Time offset to GPS
  - Coordinate residuals from multiGNSS processing
  - Post Fit residuals, with different symbols for different GNSS's
  - TZD estimates
- Software: own Matlab development

MultiGNSS european network.

Select a site clicking on the relative marker.

Legenda = Javad Leica Septentrio Trimble

Daily estimates of clock offsets and drift relative to GPS. View file

About this Web Page

Background

To investigate the interoperability of the various GNSS constellations we compute epochwise the positions of European permanent GNSS receivers by analyzing data simultaneously from different GNSS constellations.

Method

Use RINEX 3.02 data freely available within the MGEX data base. Process pseudoranges in ionofree combination, and broadcast ephemeris. Use as apriori coordinates official ITRF2008/IGb08 values.

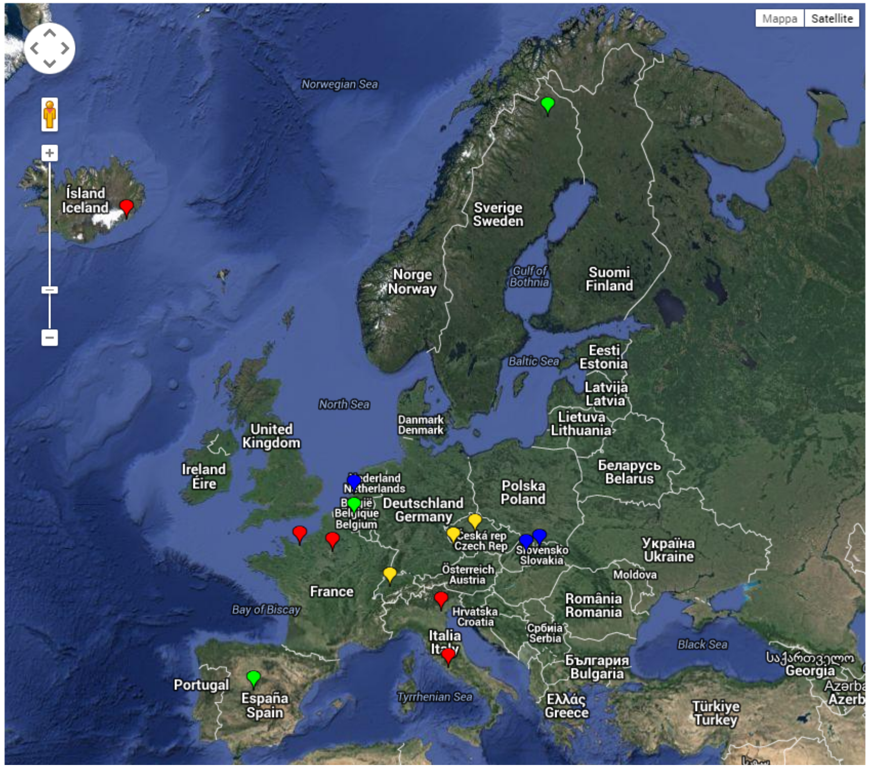
Solve for 3 coordinates, 1 clock offset for each GNSS constellation, 1 Tropospheric Zenith Delay (ZTD) at each computation epoch.

The computation is made daily for a sample of European GNSS sites, and different receiver types. This Web site is updated on a weekly basis, beginning Jan.1, 2014.

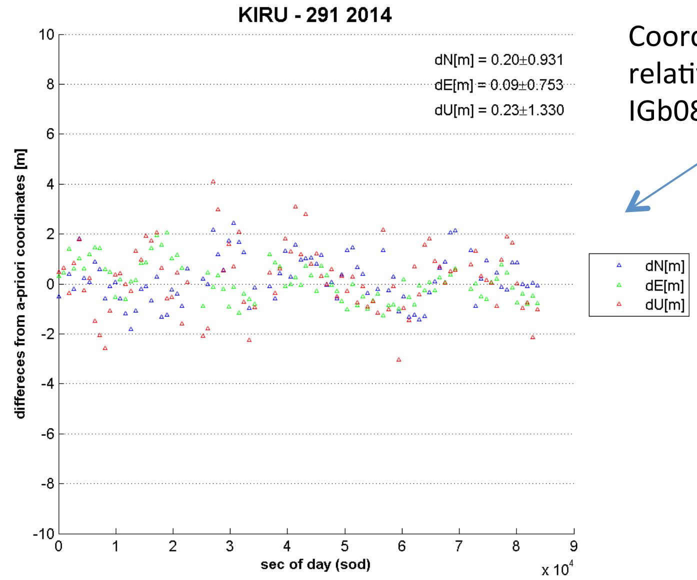
Goal

Our goal is to provide data, in tabular and plot format (**see Keyword File Type**), enabling one to assess (**see Keyword Parameter**):

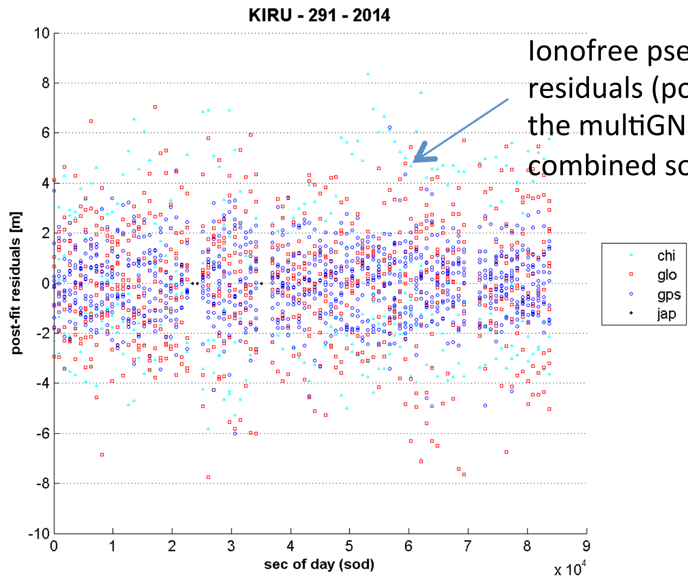
-Parameter = Position: epochwise departures in North East Up from a priori position



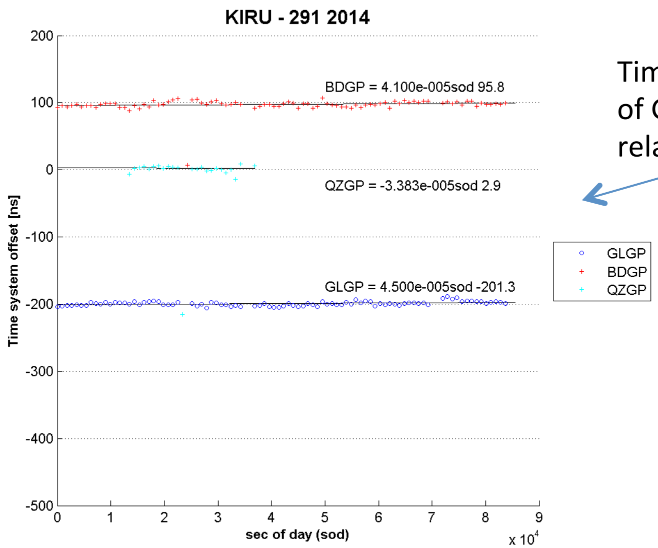
Example: KIRU for October 18, 2014



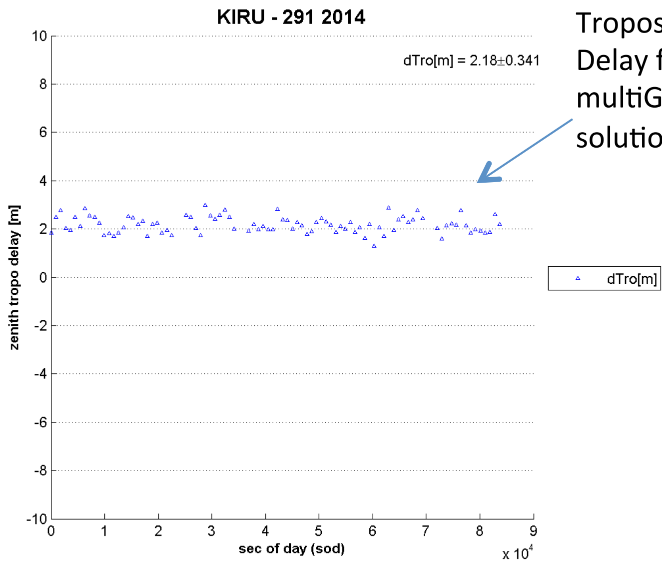
Coordinate residuals relative to official IGb08 values



Ionofree pseudorange residuals (post fit) of the multiGNSS combined solution



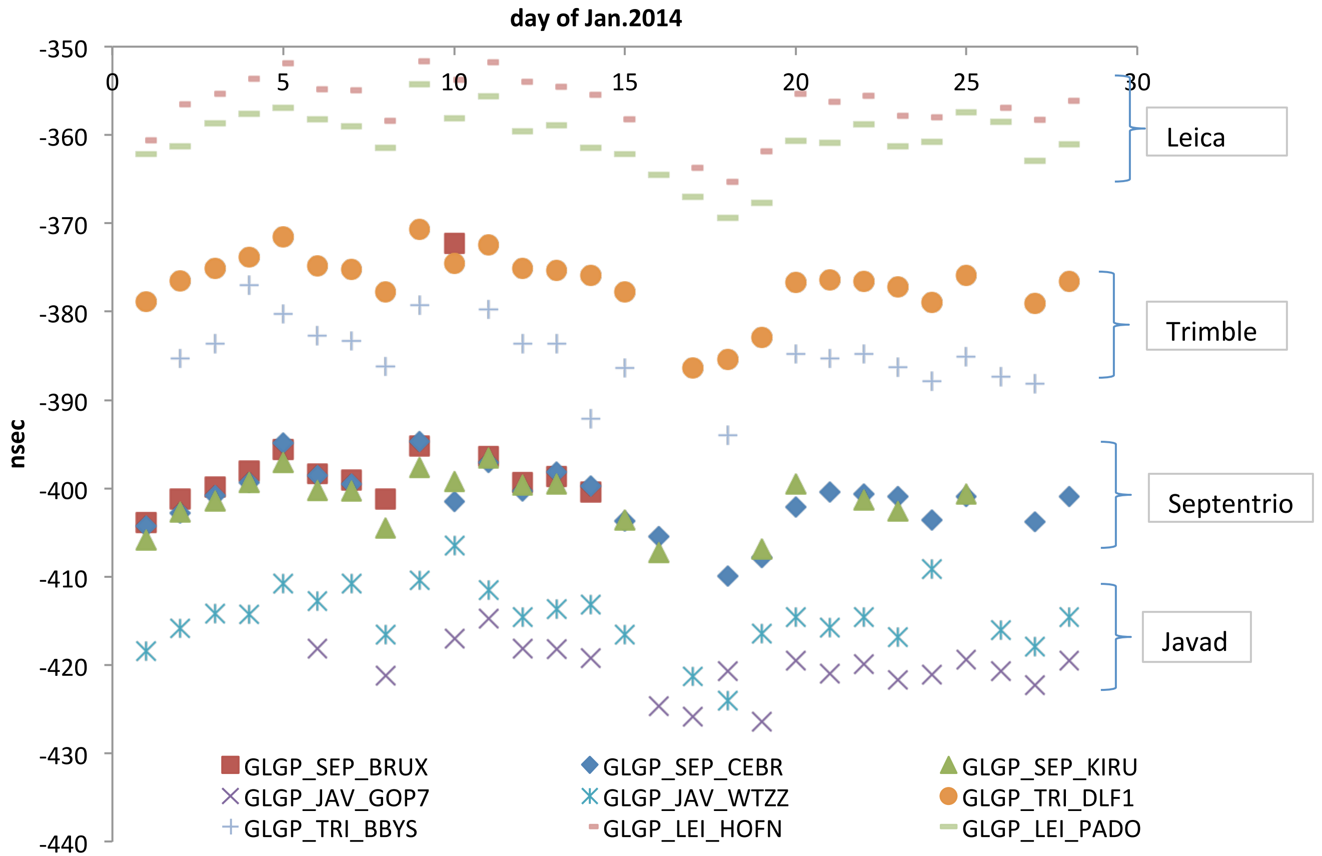
Time offset and drift of GNSS time scale relative to GPS



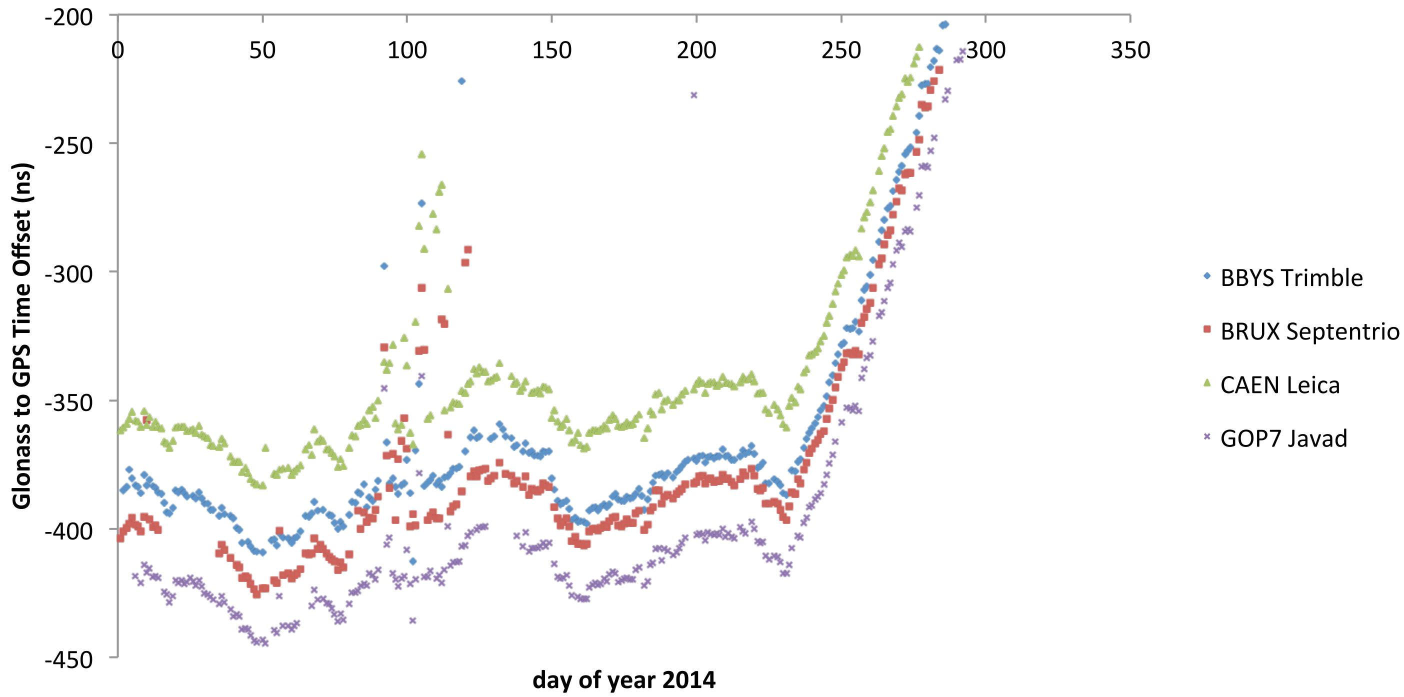
Tropospheric Zenith Delay from the multiGNSS combined solution

Glonass to GPS Time Offset: varies from day to day, depends on receiver type

(error bars not shown; differences within each receiver group are negligible
DCB's for satellites and MGEX stations and not applied: their size is <15-20 ns max)

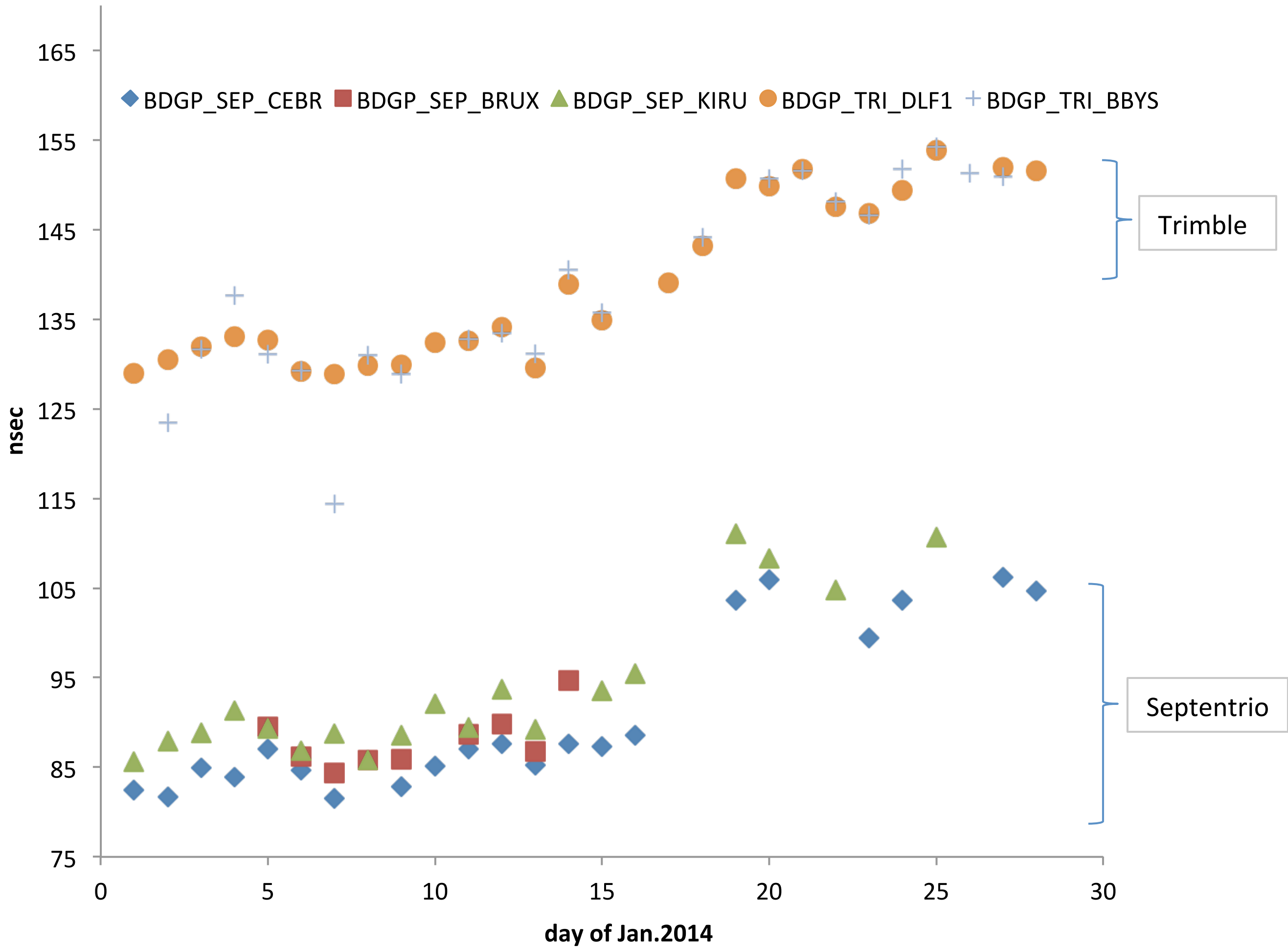


Glonass clock steering

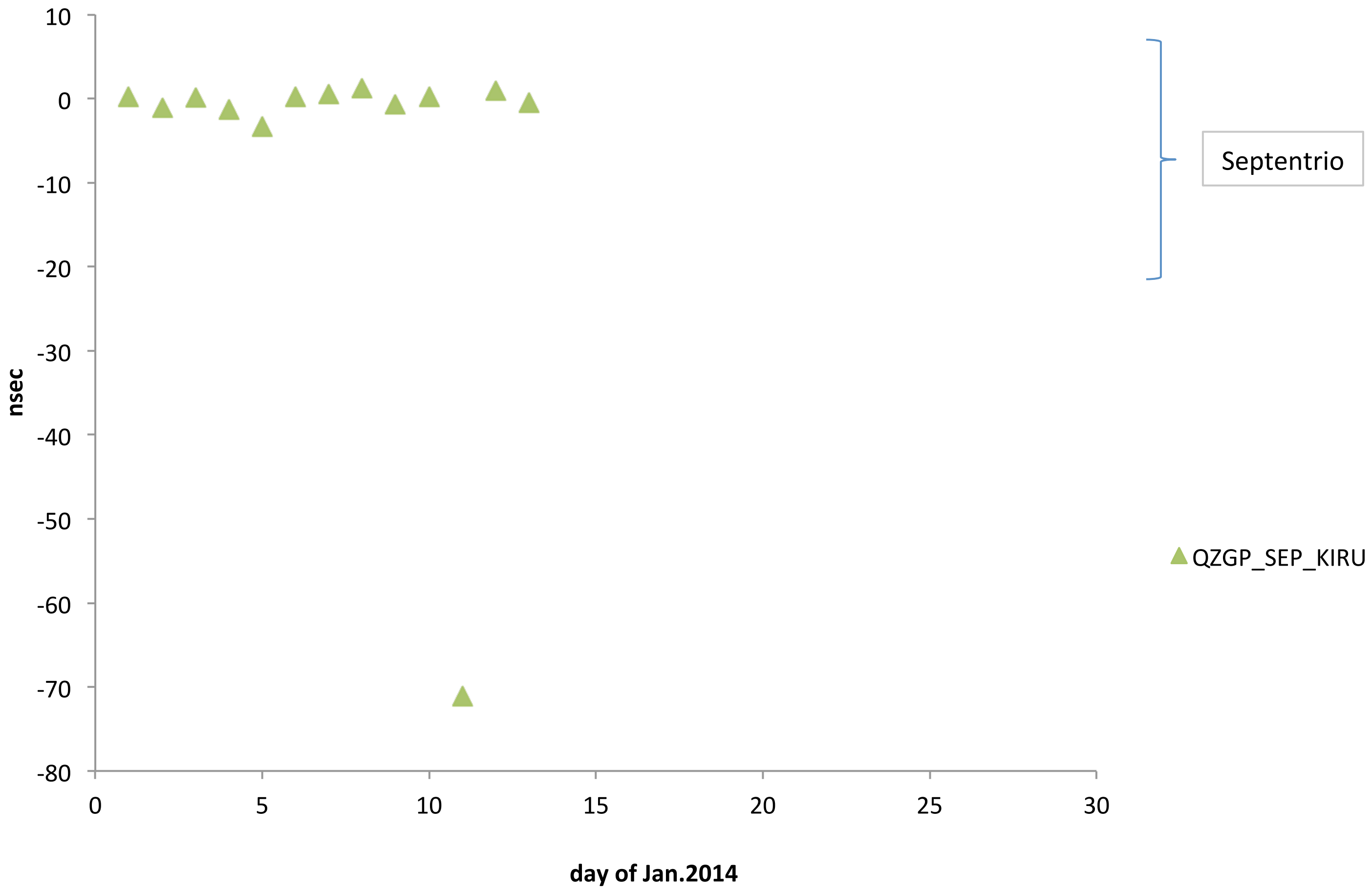


Starting August 19, 2014 (doy 231) the Glonass time offset relative to GPS is being reduced progressively

BeiDou to GPS Time Offset: systematic drift, depends on receiver type

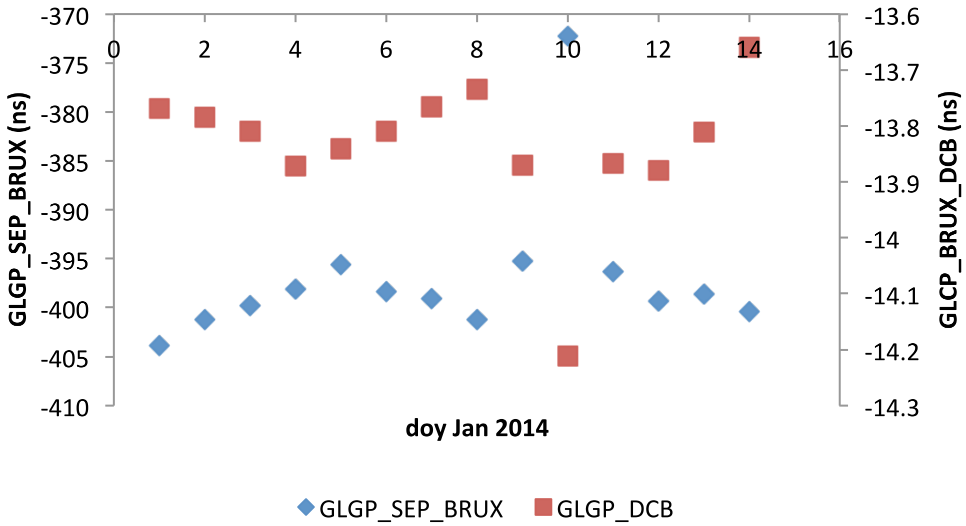


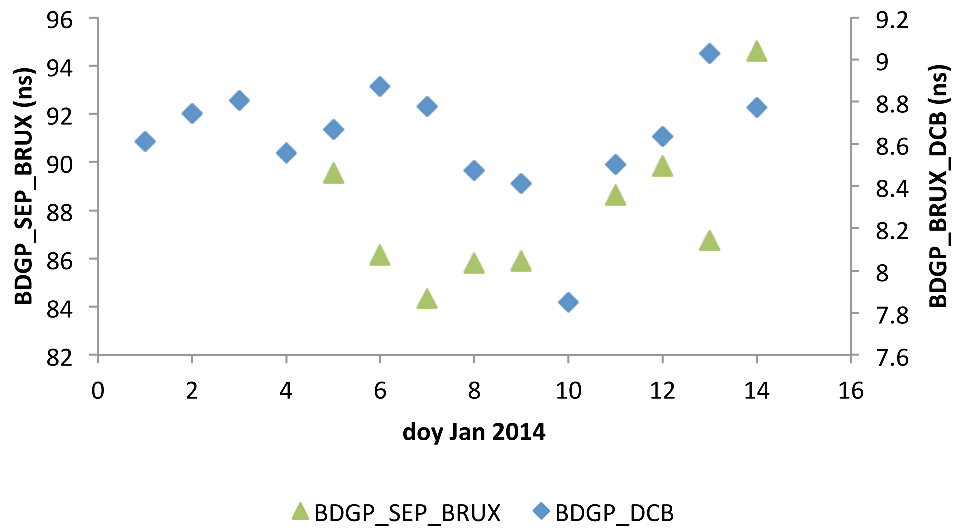
QZSS to GPS Time Offset: close to zero, only KIRU data



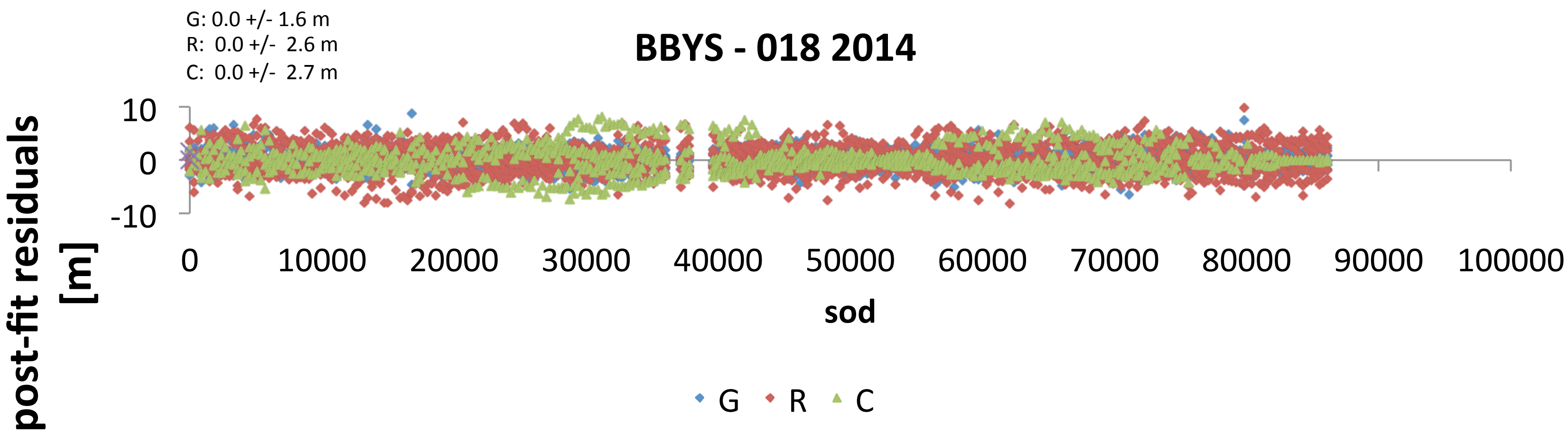
Understanding the new DCB Sinex from IGS

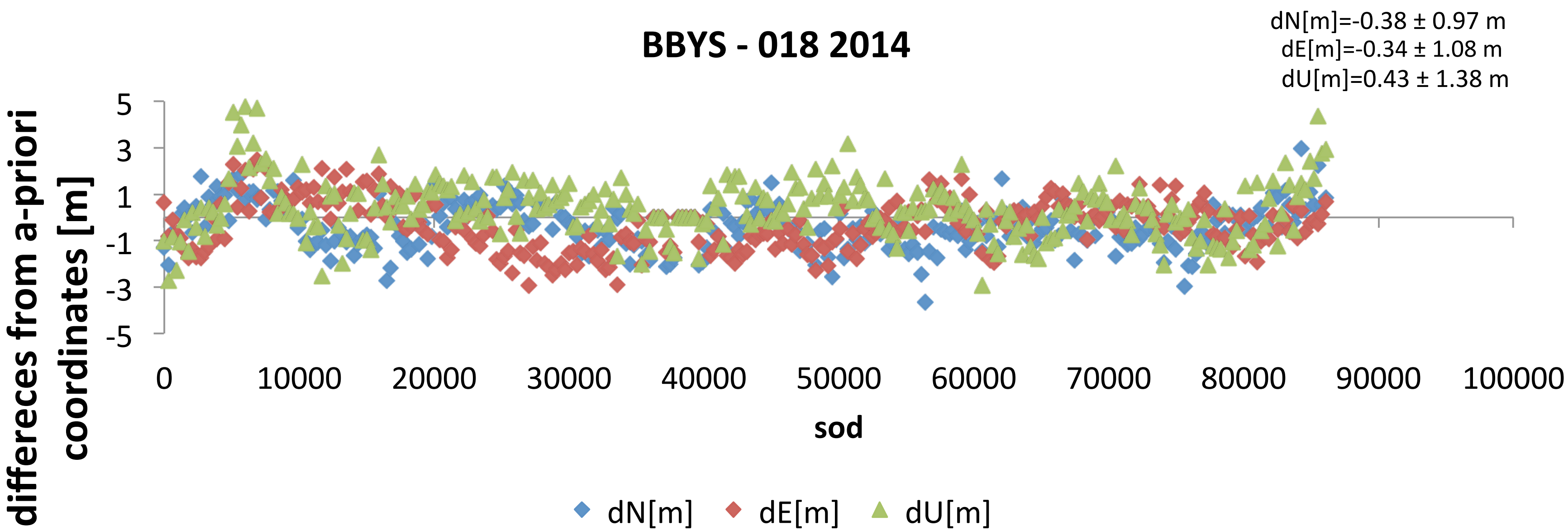
* - Multi-GNSS differential code biases (DCBs) in this product have been derived from observations of the IGS MGEX network. Details of the DCB estimation process are described in Montenbruck O., Hauschild A., Steigenberger P., "Differential Code Bias Estimation using Multi-GNSS Observations and Global Ionosphere Maps"; ION International Technical Meeting, 26-28 Jan. 2014, San Diego (2014).
* - A zero-mean constellation condition is applied to separate satellite and receiver biases on a daily basis.
* - Standard deviations reflect the uncertainty of individual satellite and station biases adjusted from the observed set of satellite +station biases.
* - This product may contain redundant, but potentially conflicting, bias information (e.g. GPS C1C-C1W and C1W-C2W along with C1C-C2W). Since individual biases are based on different sets of monitoring stations, consistency of these biases cannot be ensured, i.e. DCB(C1C-C2W) will typcially differ from the sum of DCB(C1C-C1W)+DCB(C1W-C2W). Where available, direct use of a DCB for a given signal pair is expected to better represent GNSS pseudorange observations than chaining of multiple DCBs.



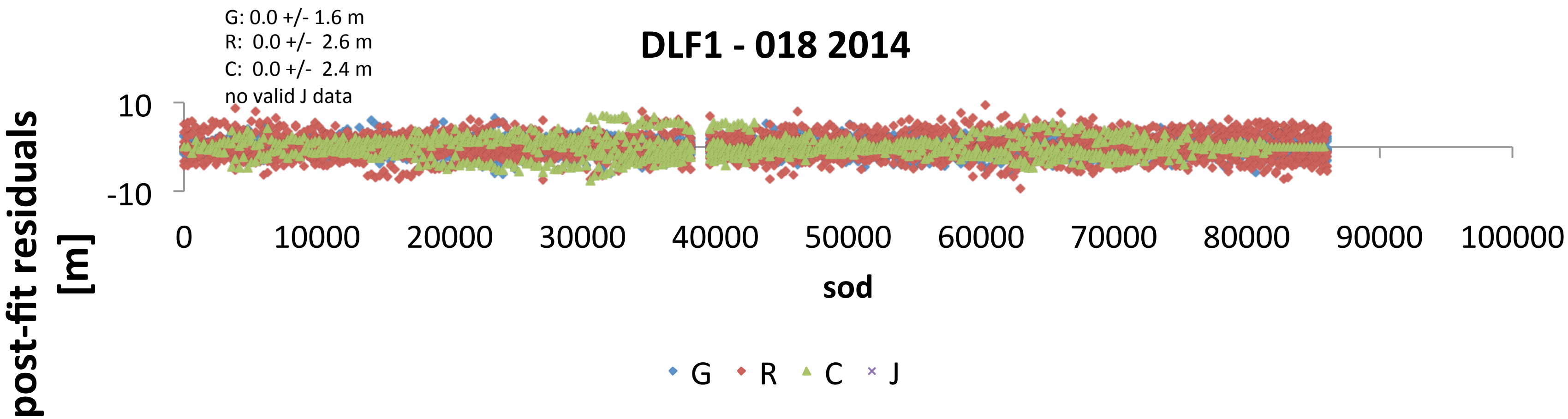


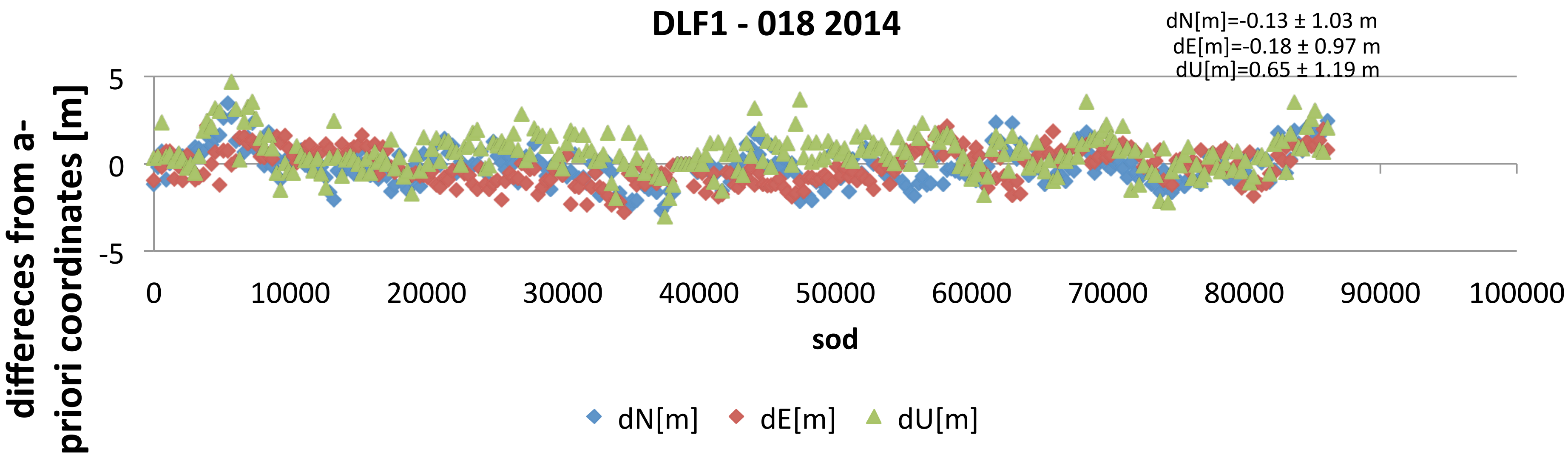
Postfit and time series of coordinates Trimble (1/2)



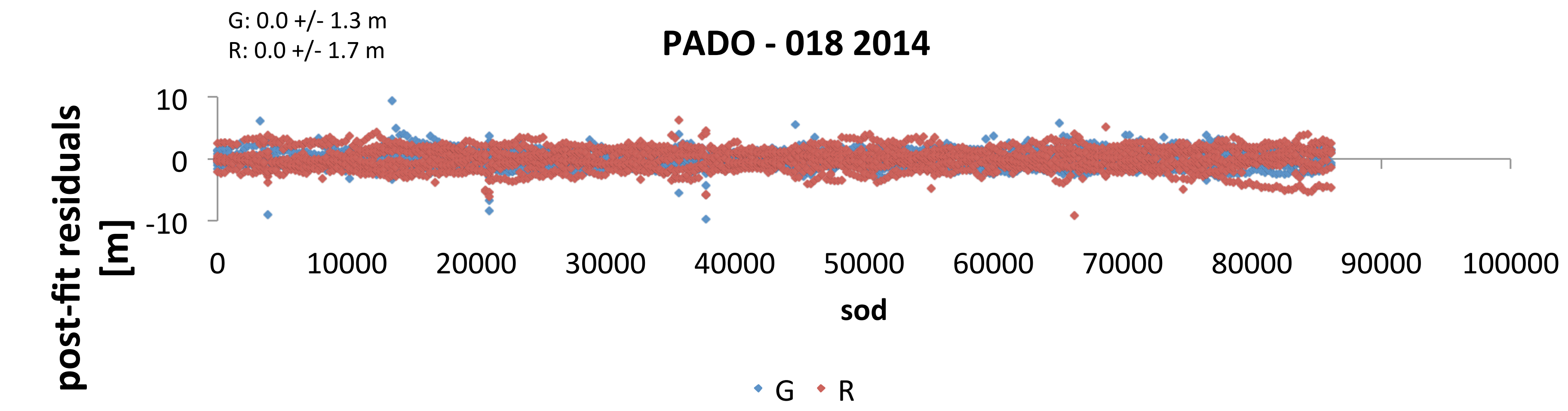


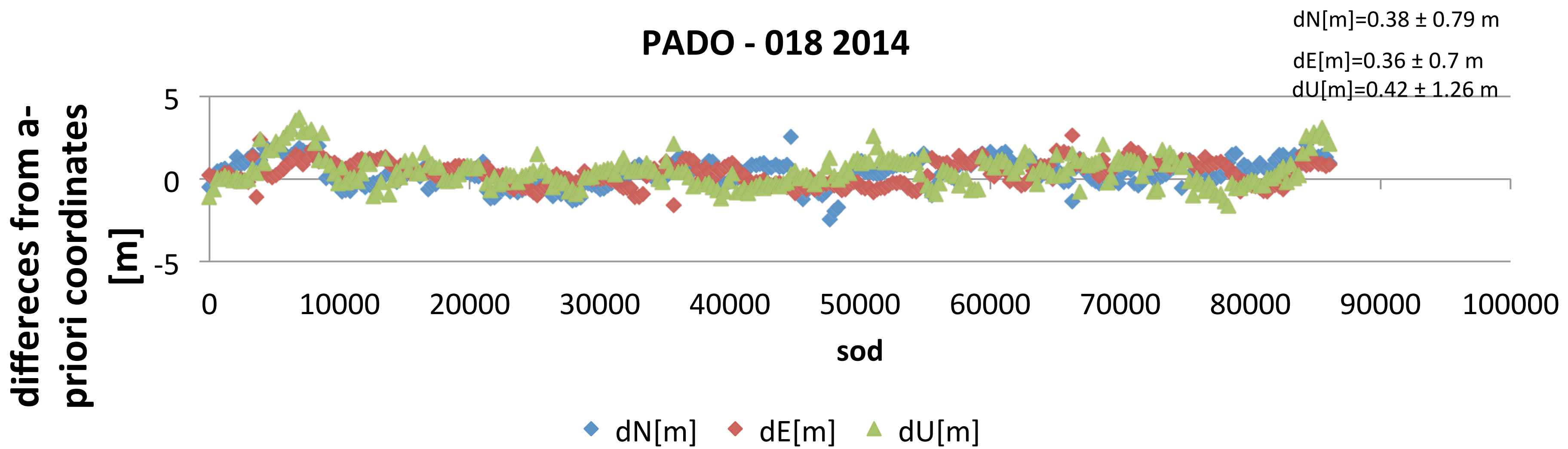
Postfit and time series of coordinates Trimble (2/2)



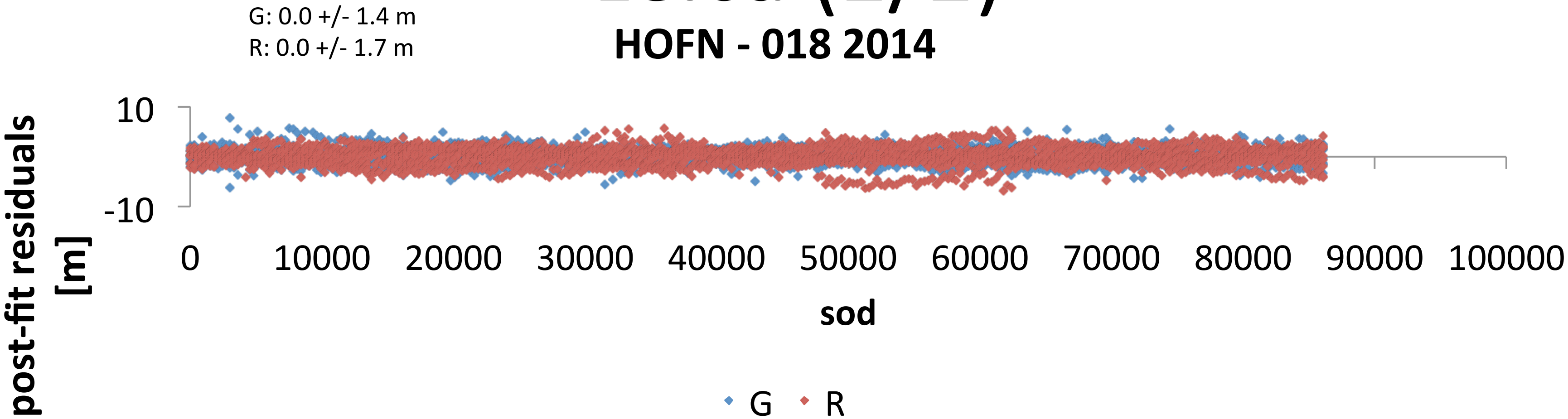


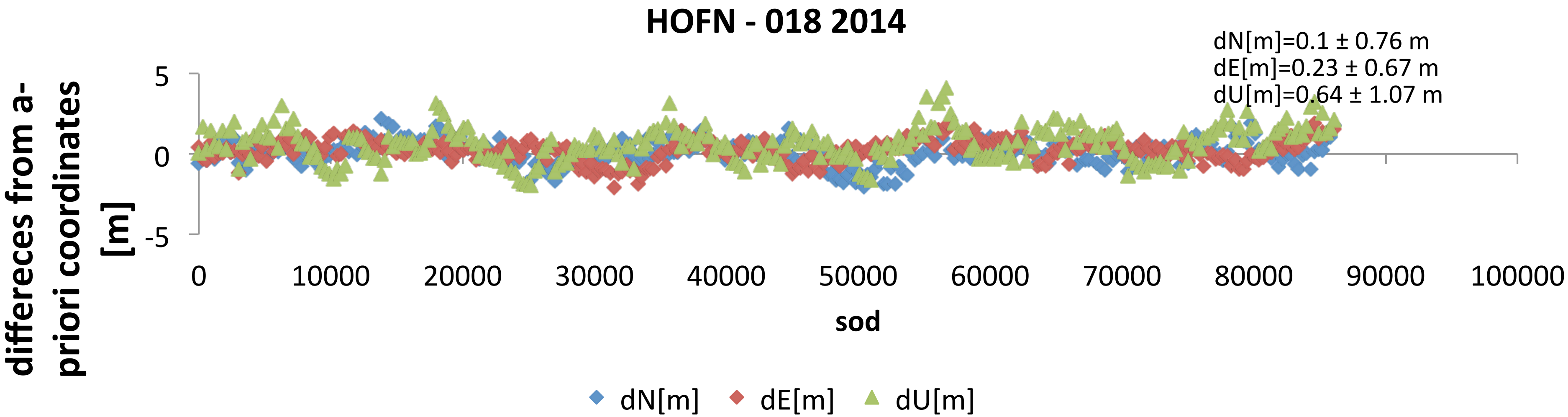
Postfit and time series of coordinates Leica (1/2)



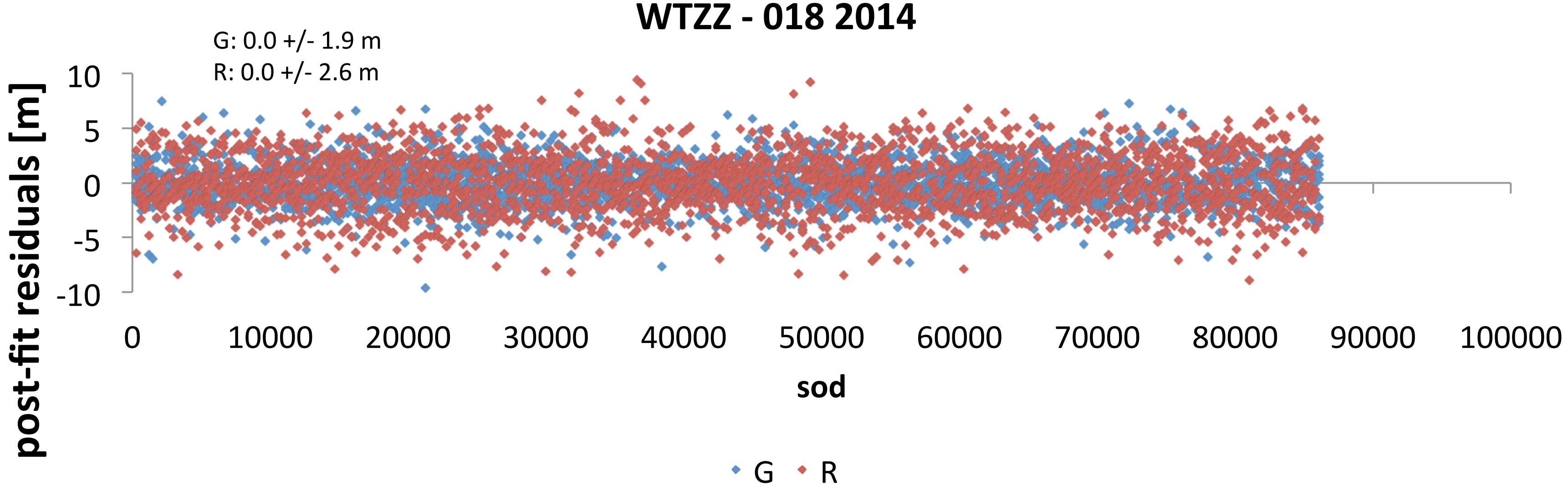


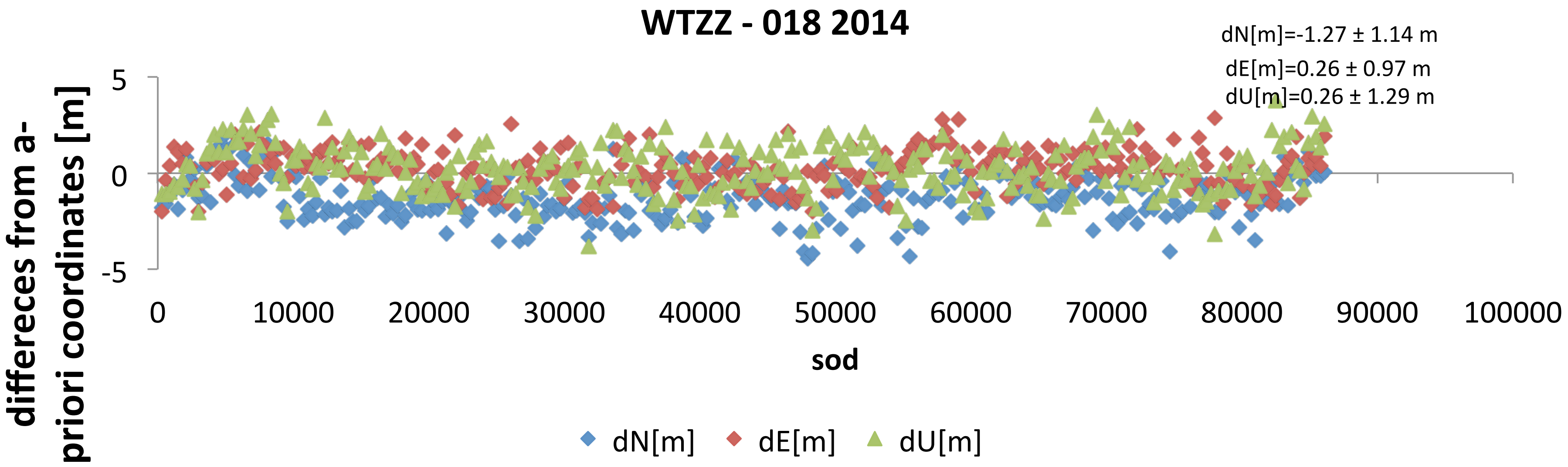
Postfit and time series of coordinates Leica (2/2)



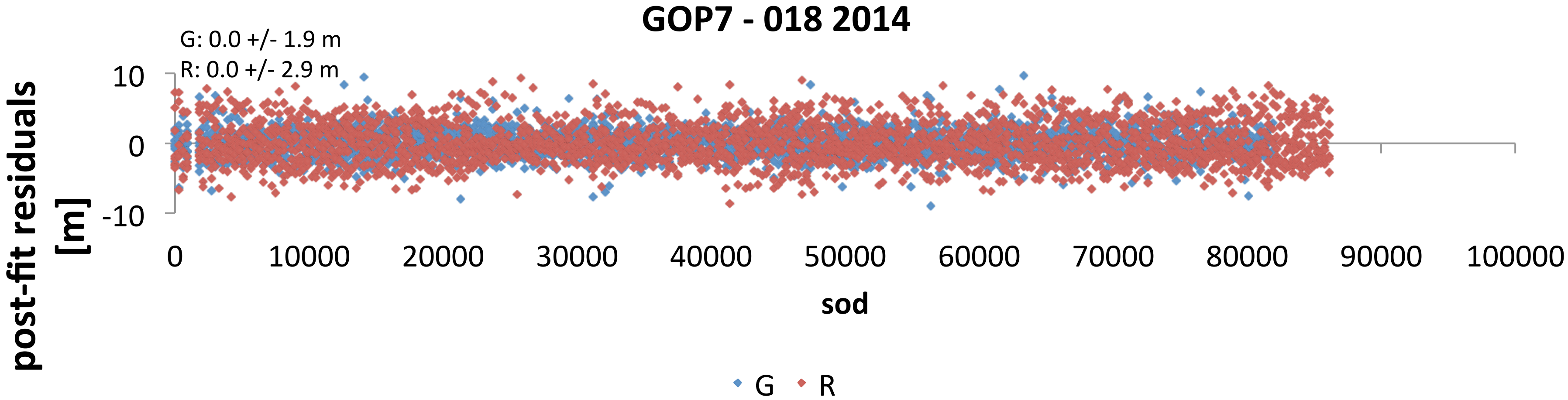


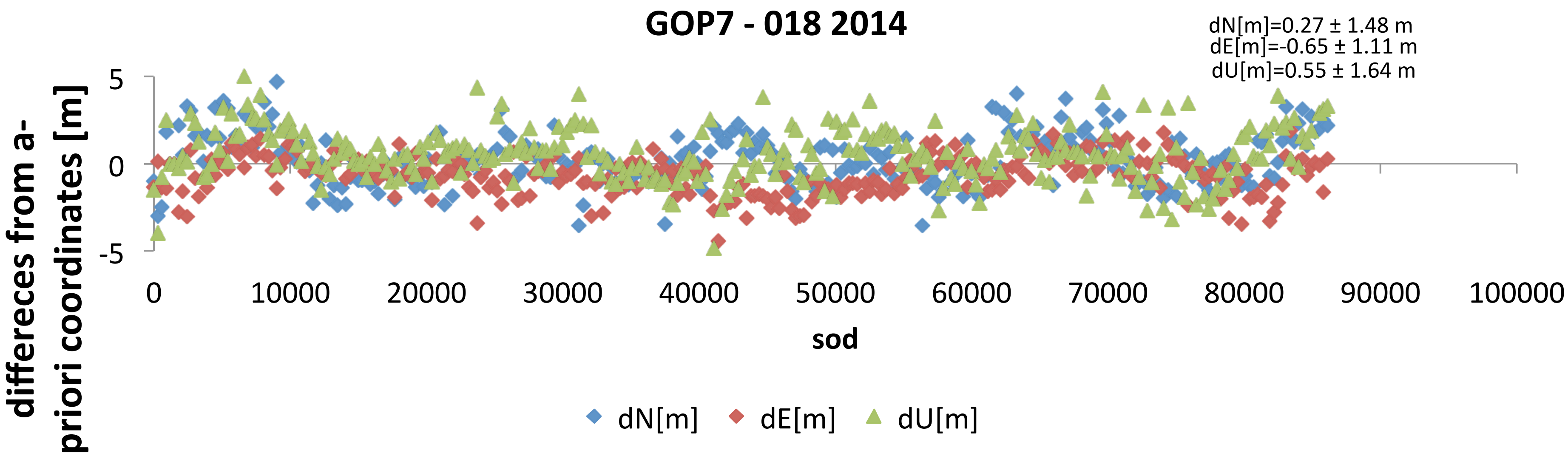
Postfit and time series of coordinates Javad (1/2)



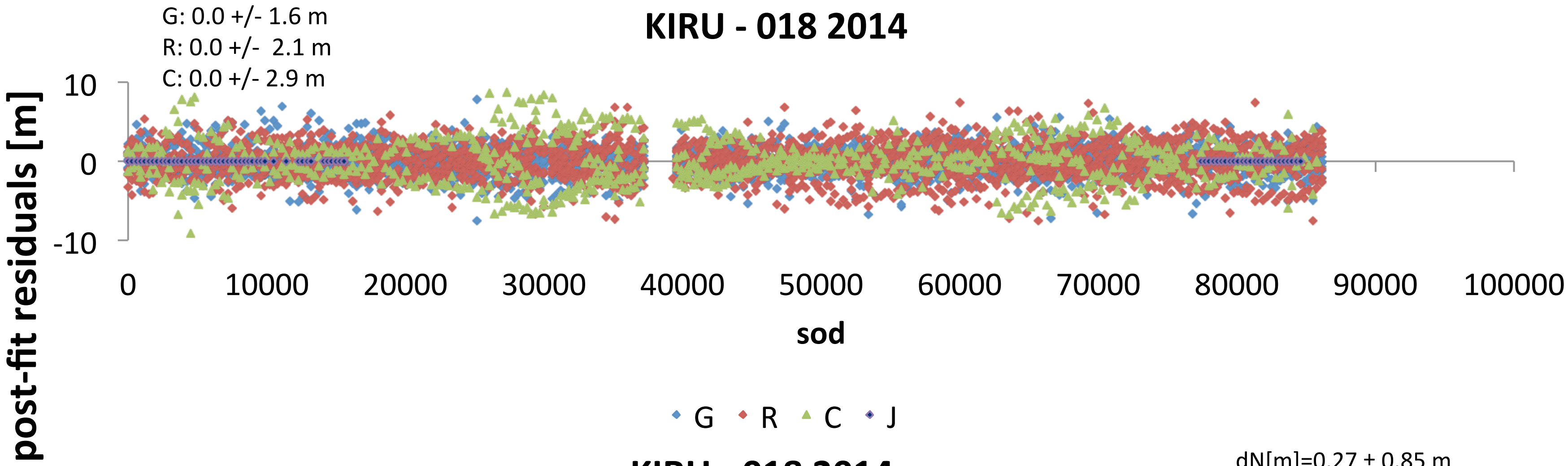


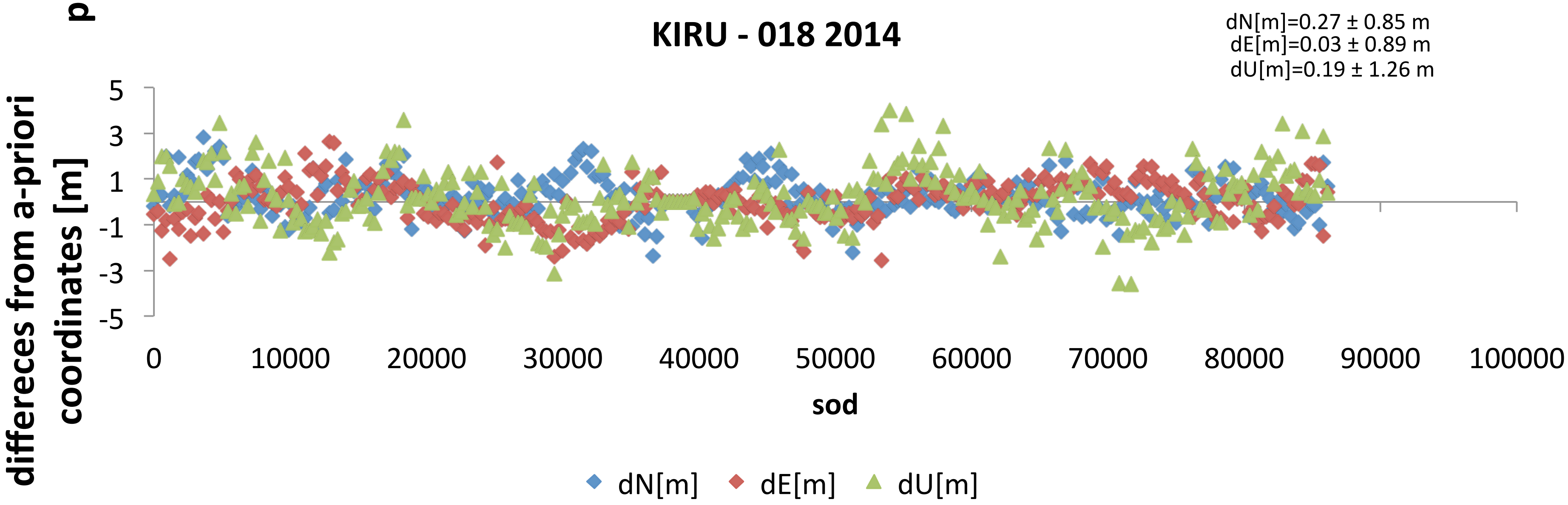
Postfit and time series of coordinates Javad (2/2)



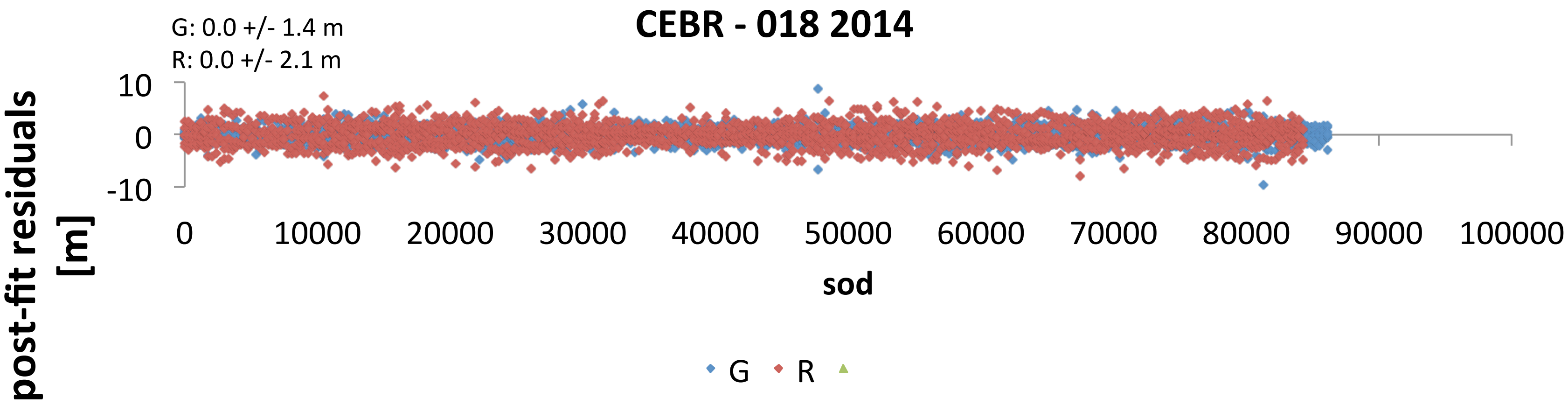


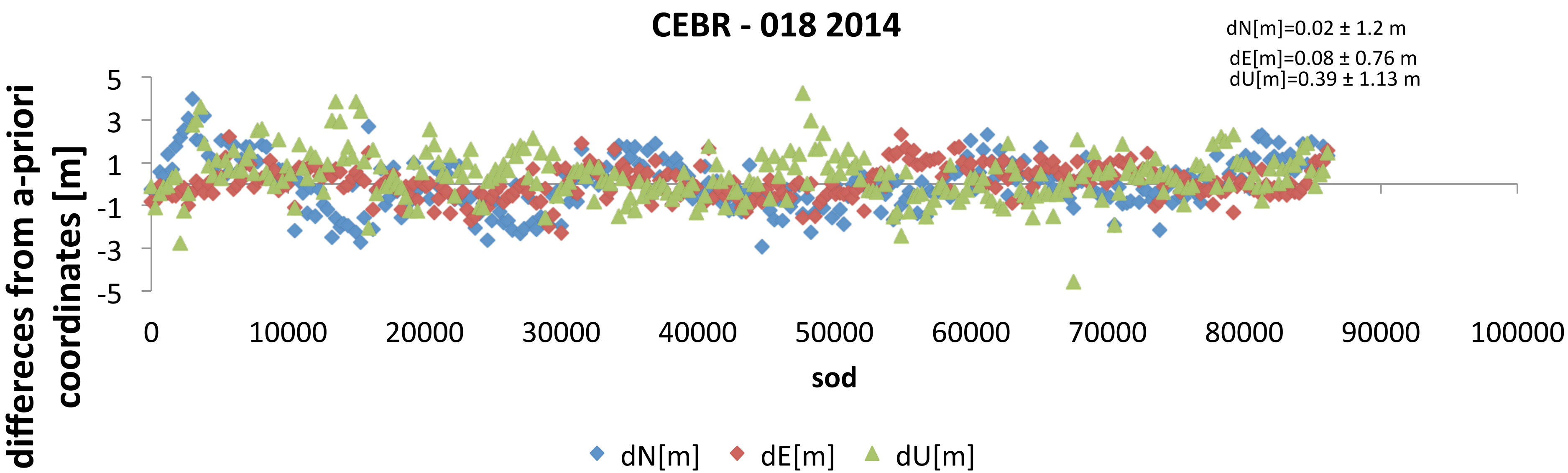
Postfit and time series of coordinates Septentrio (1/2)



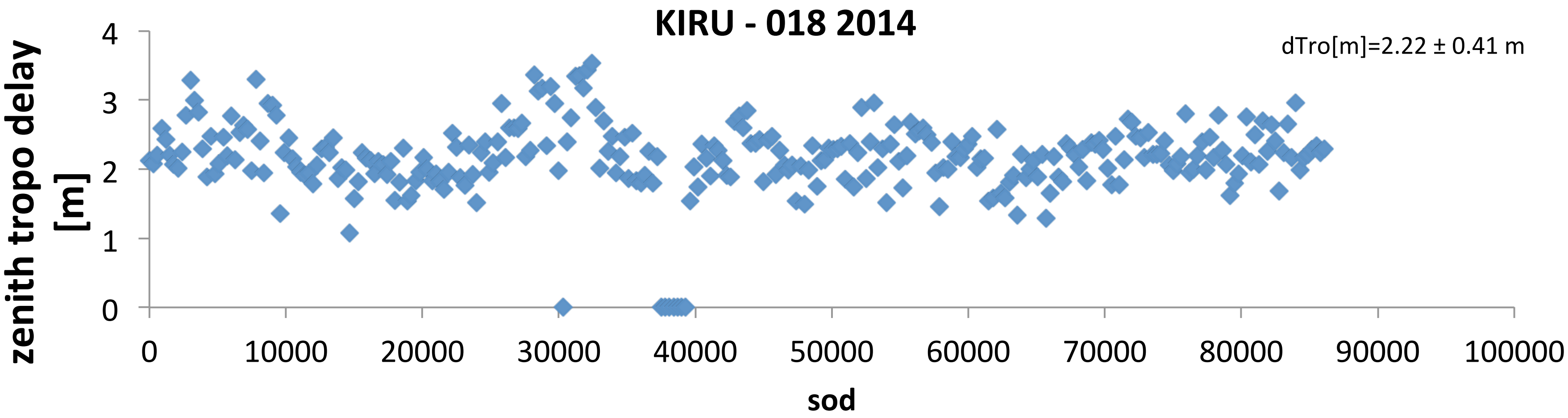


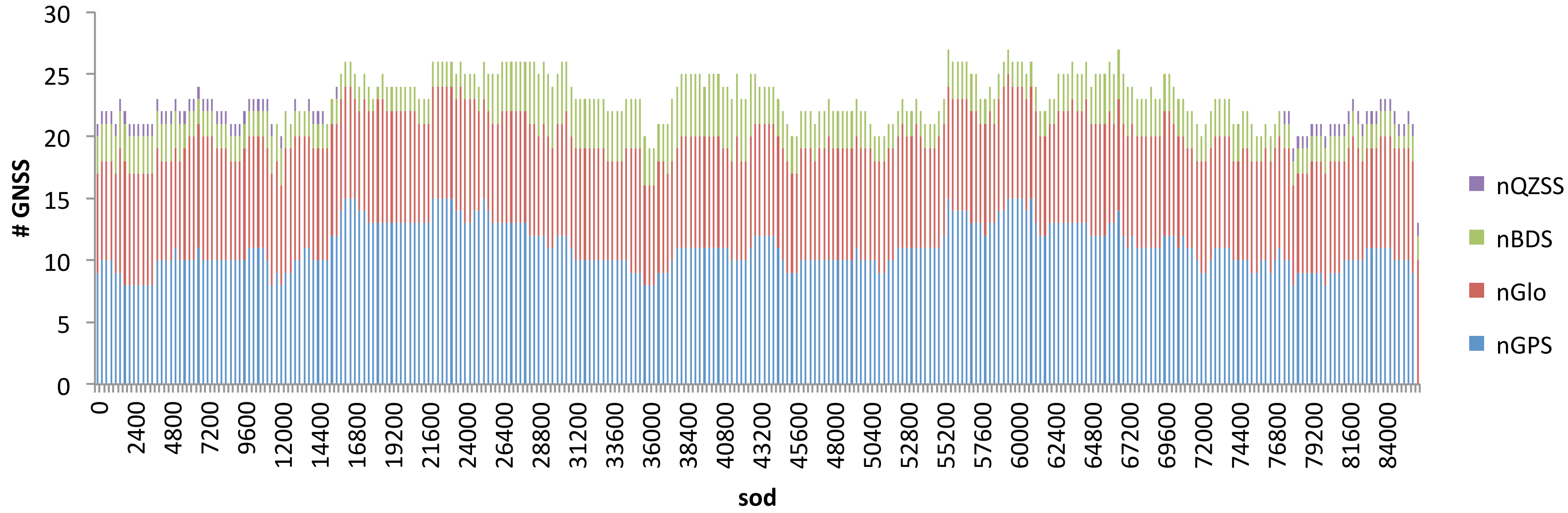
Postfit and time series of coordinates Septentrio (2/2)





TZD estimated epochwise from pseudoranges to multiple GNSS





Conclusions

- Interoperability of GNSS is demonstrated, **<u>but</u>** has an obstacle in:
  - Time Scales of GNSS are offset relative to GPS; offset may not be time independent
  - Offset depends on the receiver type
  - For Galileo we have data in 2014 with invalid HS and DVS, but maybe the data are acceptable anyway; GGTO is made more complicated by the presence of F/NAV and I/NAV clock models, and irregular upload of the message (especially F/NAV)
- Disadvantage for user: needs to solve for separate satellite time offsets (one for each GNSS) → add more unknowns to the nav solution
- Possible user support from Permanent GNSS sites:
  - Monitor Time Offset for several GNSS sites and receivers
  - TZD epochwise with <0.5 m rms
  - Broadcast calibration data using EGNOS messages, or RTCM over Ntrip?
- Benefit for the user receiving these additional data: estimate 3 coords and one time offset = 4 unknowns → much more robust fix