wissen wohin
savoir où
sapere dove
knowing where

swisstopo

Multi-GNSS activities at swisstopo

E. Brockmann, D. Ineichen, S. Lutz

Analyses using Bernese GNSS Software at swisstopo

swisstopo EUREF products (LPT)

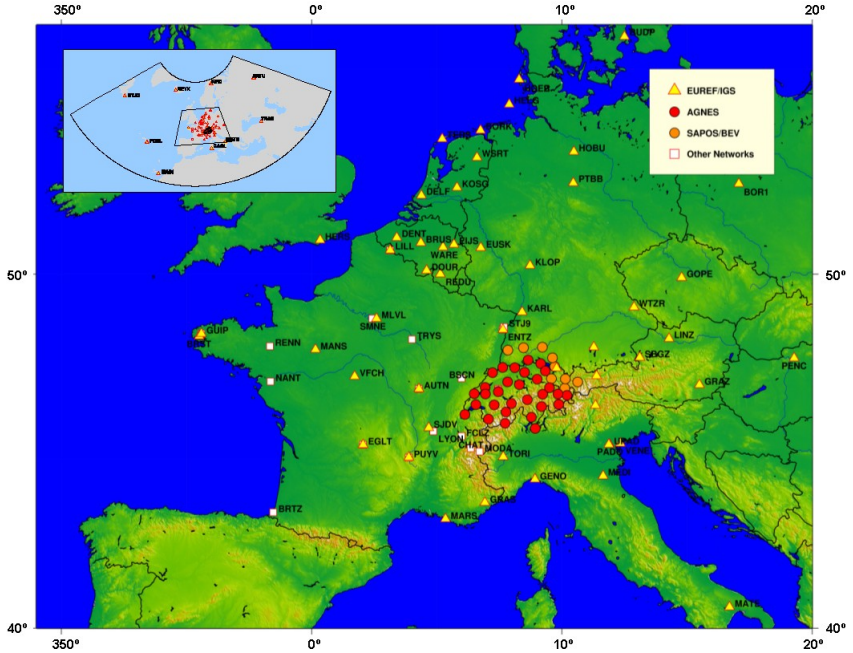
Final SNX+TRO (daily LPT)

Rapid SNX (daily LPR)
Ultra SNX (hourly LPT)

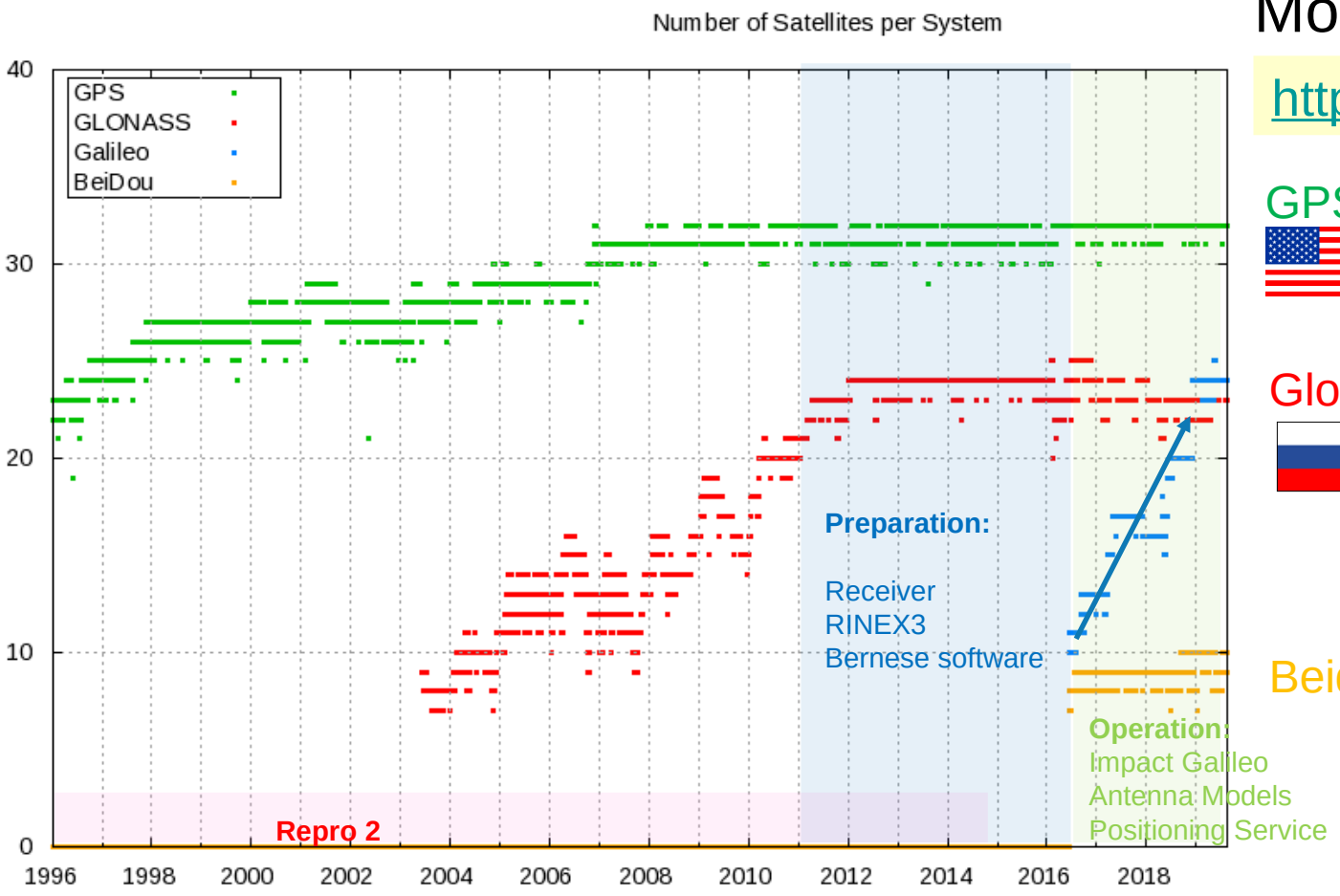
network (#stations)	availability	comments
EUREF sub-network (>60)	100 % daily	reference frame Europe
AGNES + sub-network EUREF (>200)	100 % daily	reference frame Switzerland
AGNES + sub-network EUREF (>200)	98 % hourly	monitoring + numerical weather prediction

BSW53
July 2016
GREC
MGEX FINAL

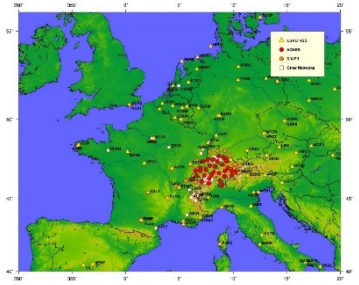
BSW53
GR July 2016
GRE Sep 2019
ULTRA



Evolution Multi-GNSS at swisstopo Permanent Analysis Center (PNAC)



Monitoring System:



http://pnac.swisstopo.admin.ch

GPS: 32

Glonass: 24

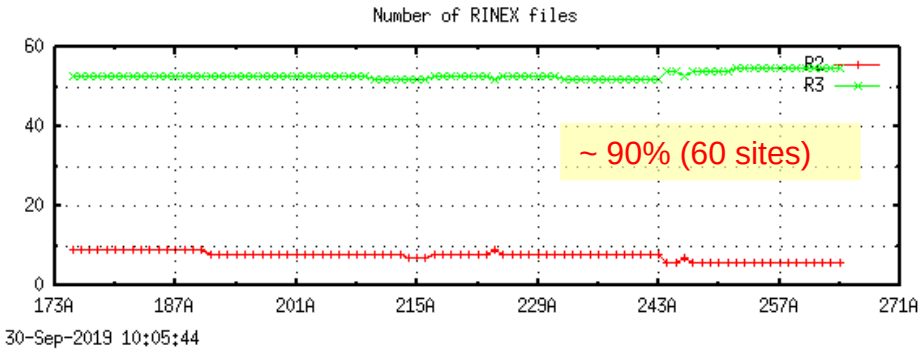
Galileo: 24

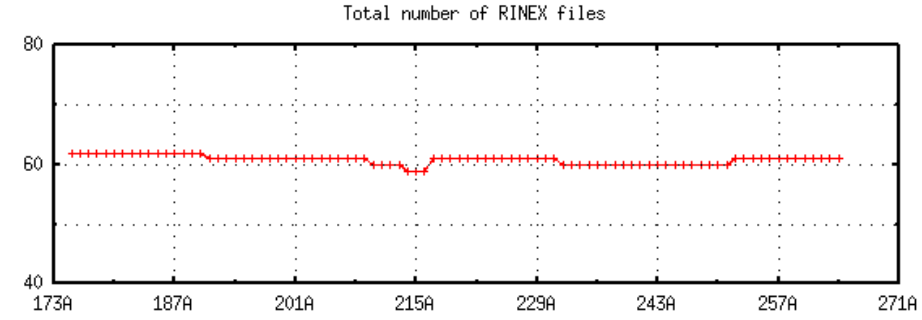
Beidou (BDS3 not yet): 10

http://pnac.swisstopo.admin.ch/pages/en/agnes_statistics.html#NUM_SAT_SYS

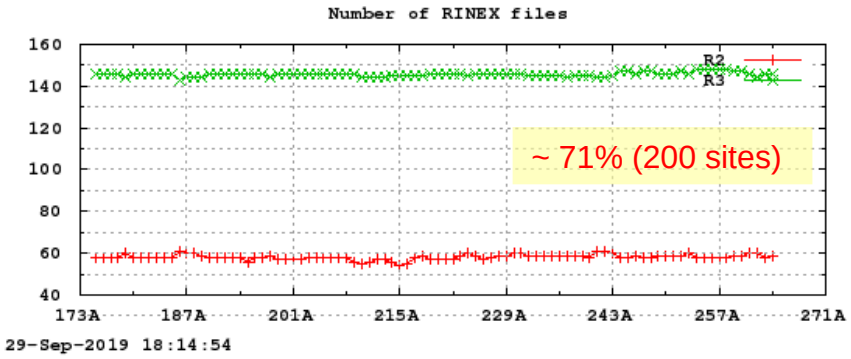
Number of RINEX-2 / RINEX-2 Files (2019 Jun-Sep)

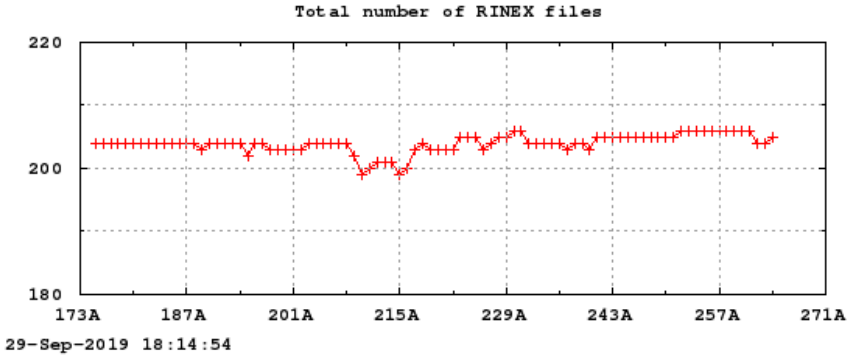
Daily (EUREF)





Daily (AGNES)





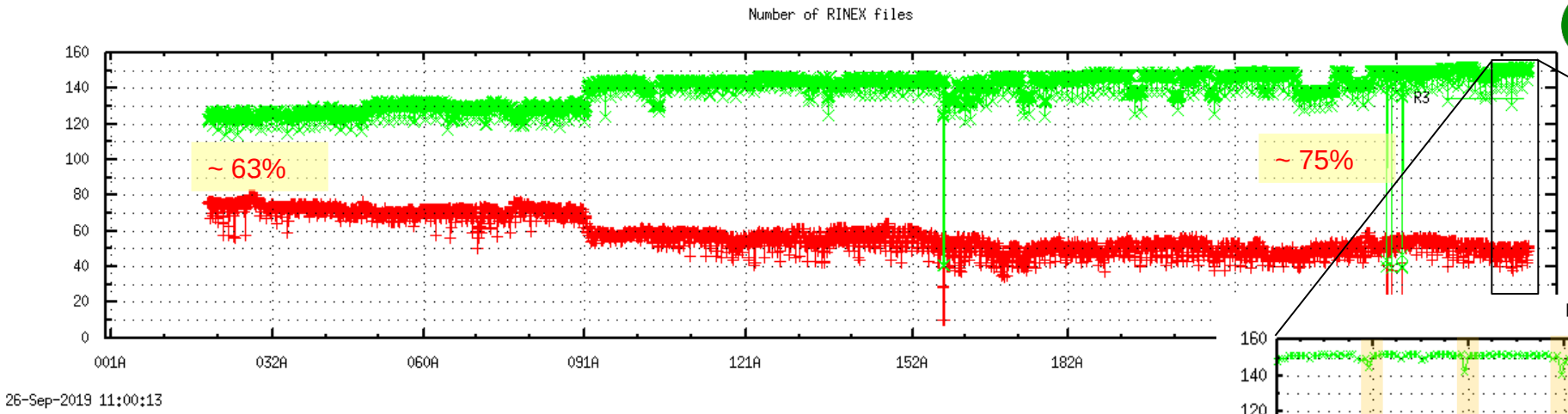
~ 70 - 90% of the EUREF stations (100% AGNES since Jul 2015) submit RINEX-3 files (daily),

Streamed data D-A-I still RINEX-2

Sep. 2019

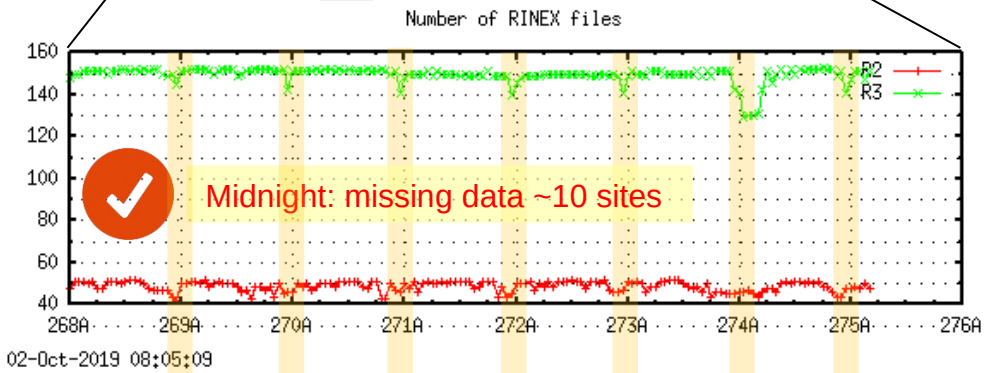
Number of RINEX-2 / RINEX-2 Files (2019 Jan-Sep)

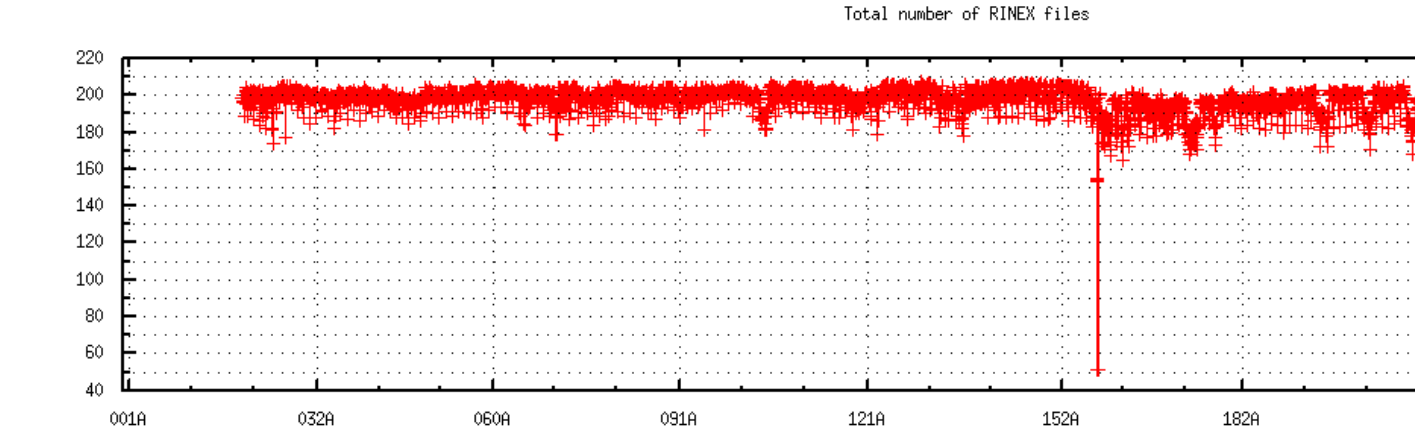
Hourly statistics (~200 sites)

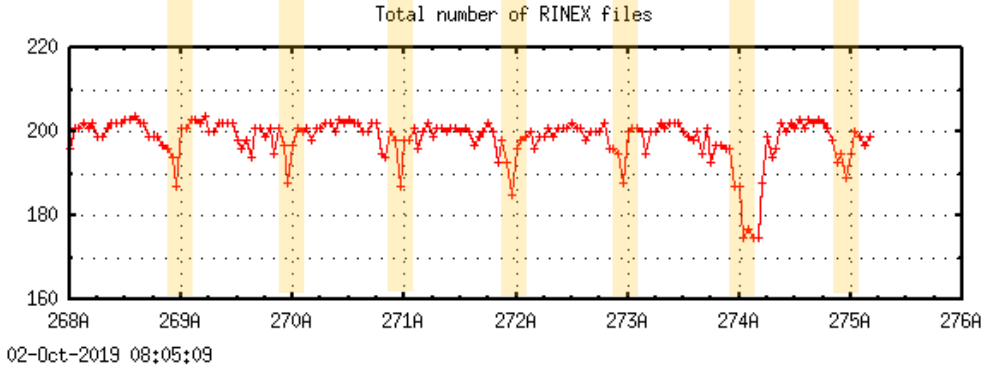


~ 75% of the EUREF stations (100% AGNES since Jul 2015) submit RINEX-3 files (hourly),

Streamed data D-A-I still RINEX-2 Sep. 2019



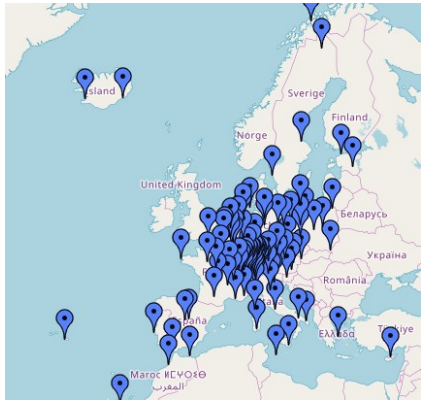




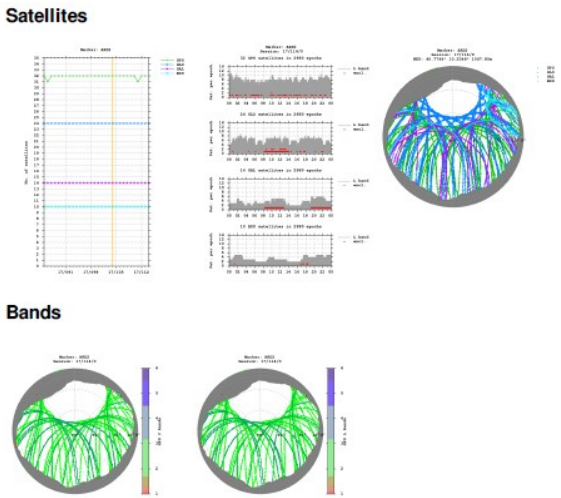
Monitoring RINEX-3 Tools

EUREF
Multi-GNSS
WG

- Monitoring using Anubis (->GOPE), BNC (->BKG)
  http://pnac.swisstopo.admin.ch/pages/en/anubis_monitor_r3.html
  - 160 stations with RINEX3
  - BNC, gfzrnx, CCRINEX (devel) for editing an merging RINEX2/3



2015



Helpfull to find bugs in firmware !

> 50 (R2) – 110 (R3) plots/site/day

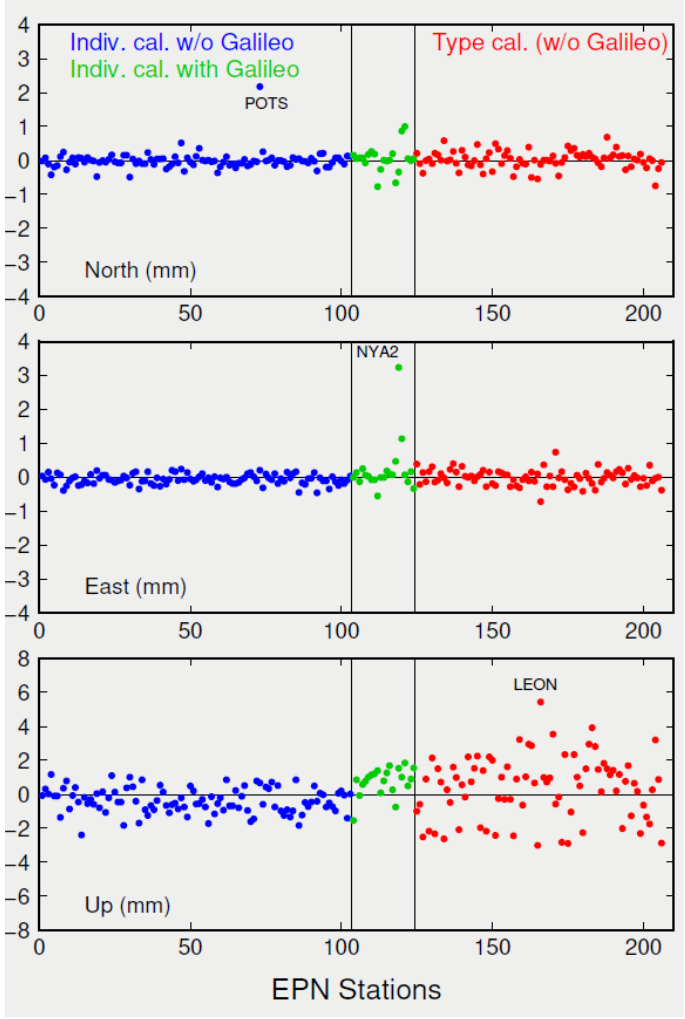
Sortable table

NAME		RECEIVER												nC	nJ	nS	PDF
AIGE		TRIMBLE NETR9	5.22	T										10	0	0	aige r3.pdf
AJAC	10077M005	LEICA GR25	4.02	T										10	0	2	ajac r3.pdf
ARD2		TRIMBLE NETR9	5.22	TRM59800.00	NONE	3.02	30	2880	1.03	88.48	32	24	14	10	0	0	ard2 r3.pdf
ARDE		TRIMBLE NETR9	5.22	TRM33429.20+GP	NONE	3.02	30	2880	1.24	88.82	31	0	0	0	0	0	arde r3.pdf
AUTN	10080M001	LEICA GR25	4.02	TRM57971.00	NONE	3.02	30	2880	0.03	97.42	31	24	15	10	0	2	autn r3.pdf
AXPV	10057M001	TRIMBLE NETR9	4.85	TRM57971.00	NONE	3.02	30	2880	0.01	99.24	31	24	17	10	0	5	axpv r3.pdf
BADH	14288M001	LEICA GR25	4.10/6.523	LEIAR10	NONE	3.03	30	2880	0.04	98.60	31	24	10	0	0	4	badh r3.pdf
BCKL	BCKL	LEICA GRX1200+GNSS	9.20/6.405	LEIAR25.R4	NONE	3.02	30	2880	0.00	99.63	31	24	0	0	0	0	bckl r3.pdf

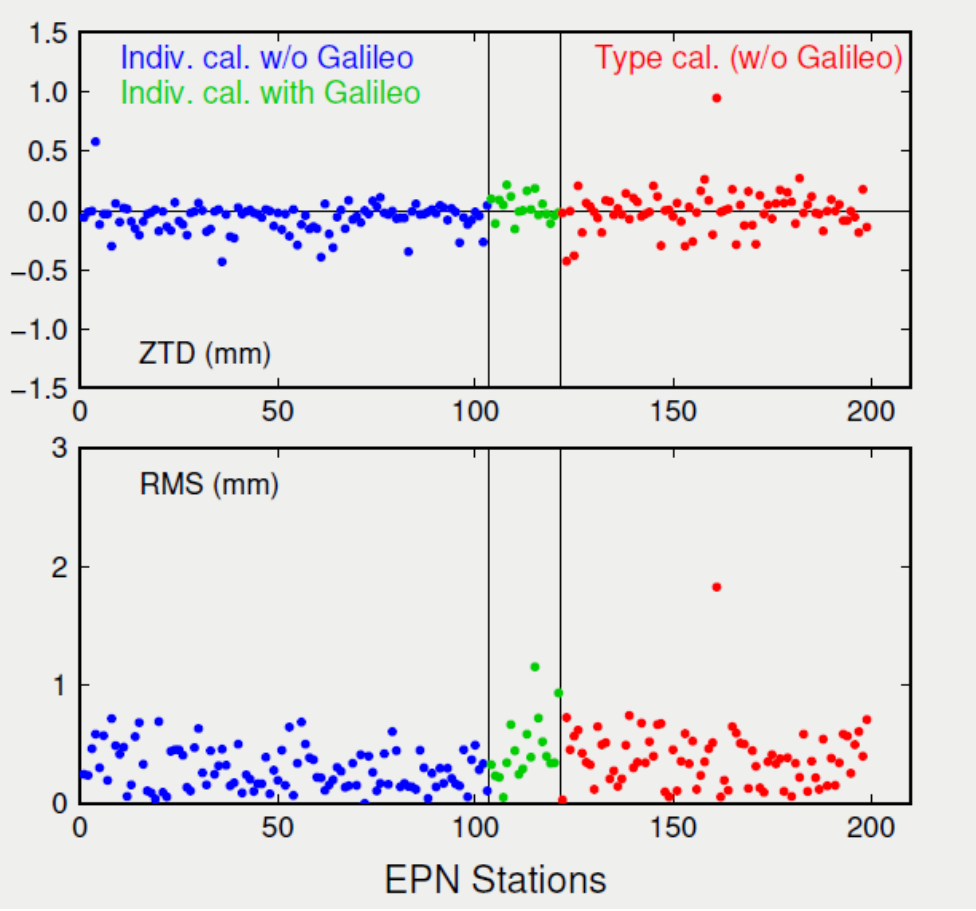
EUREF: Galileo Processing

9 ACs, 44 weeks (2000 – 2043),
parallel processing,
Mean Difference: GR - GRE

Impact coordinates



Impact troposphere



~ 11 from 16 Analysis Center process Galileo since May 2019

-> see T. Liwosz, R. Pacione, E. Brockmann :
„Usage of Galileo in EUREF Permanent Network Data and Products"
Galileo Sympsium, Zurich, 2019

Reference for Multi-GNSS observations

- one MIX coordinate (+TRP): N,E,U,T

4

or

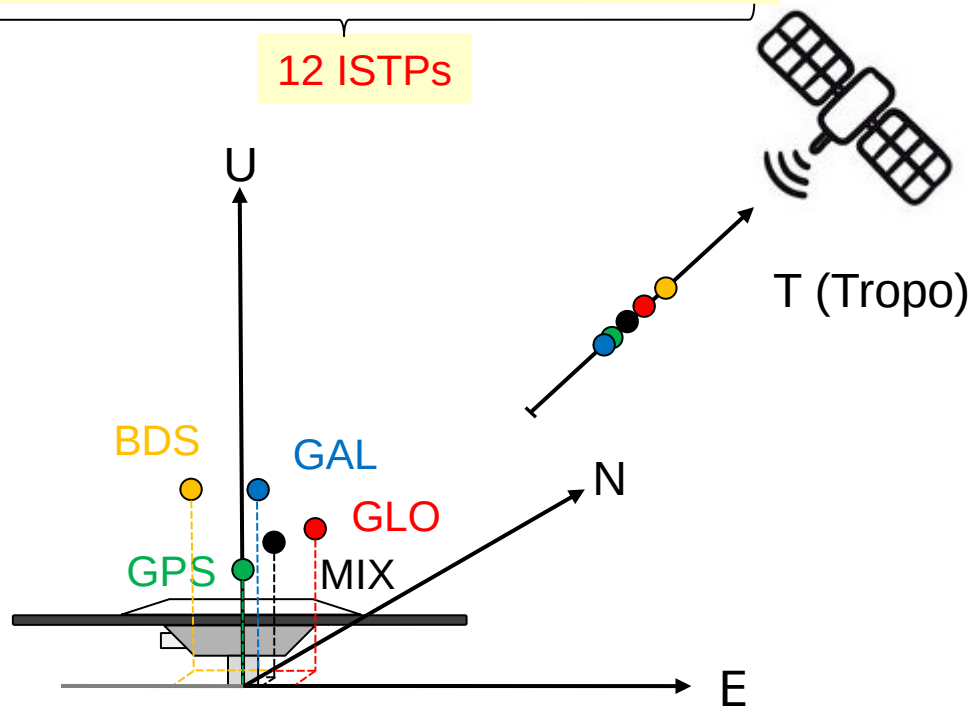
- per satellite system one coordinate (+TRP):
  N,E,U,T | N,E,U,T | N,E,U,T | N,E,U,T

4x4

Reference | dN,dE,dU,dT | dN,dE,dU,dT | dN,dE,dU,dT

12 ISTPs

ISTPs:
„**I**nter **S**ystem
Translation **P**arameter“

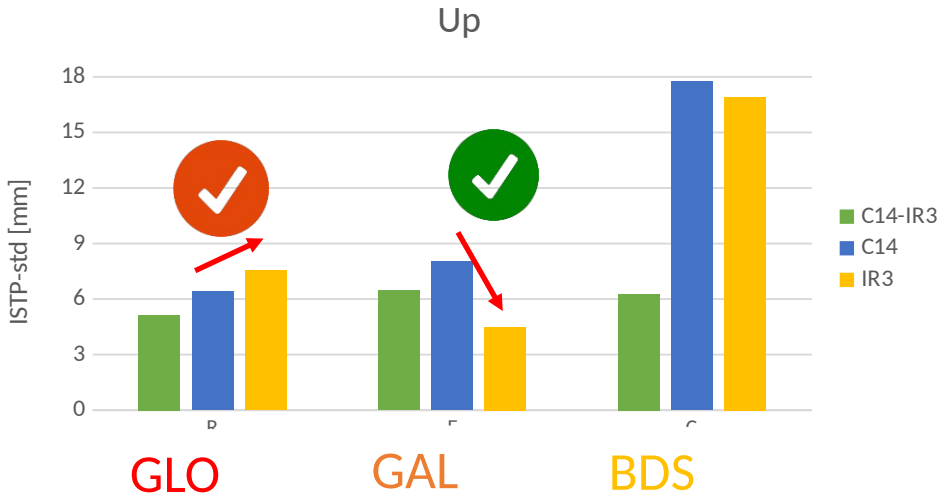


No antenna calibrations available for GAL, BDS

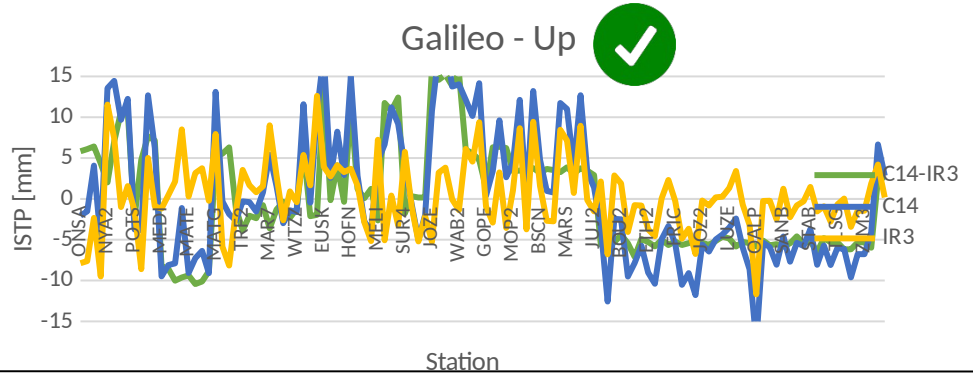
Galileo robot calibrations from Geo++

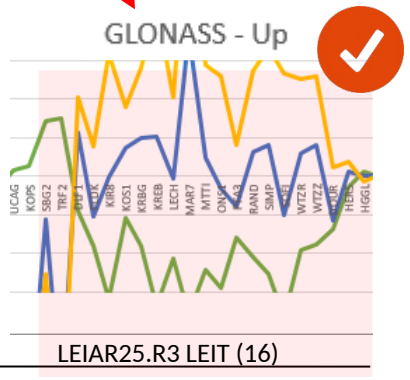
EUREF
Multi-GNSS
WG chair

- New Galileo+BeiDou antenna calibration values of Geo++ for IGS repro3 (IR3, June 2019)
- Impact study using 1 day of data (200 stations in Europe)
  - Difference GPS-Galileo smaller with IR3 compared to C14 (I14)
  - BeiDou values better than chamber values (vertically)
  - LEIAR25.R3 LEIT – GLONASS values worse (IR3 10-15 mm, C14 not significant)



Not a GLO problem, but GPS+GAL

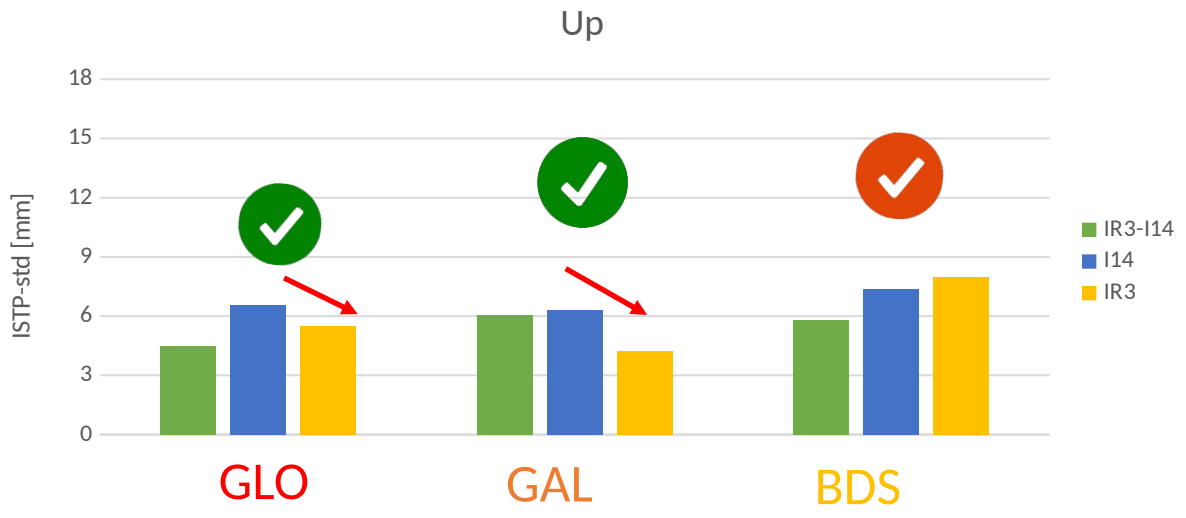




Galileo robot calibrations from Geo++ - Updated LEIAR25.R3 LEIT (13.9.2019)

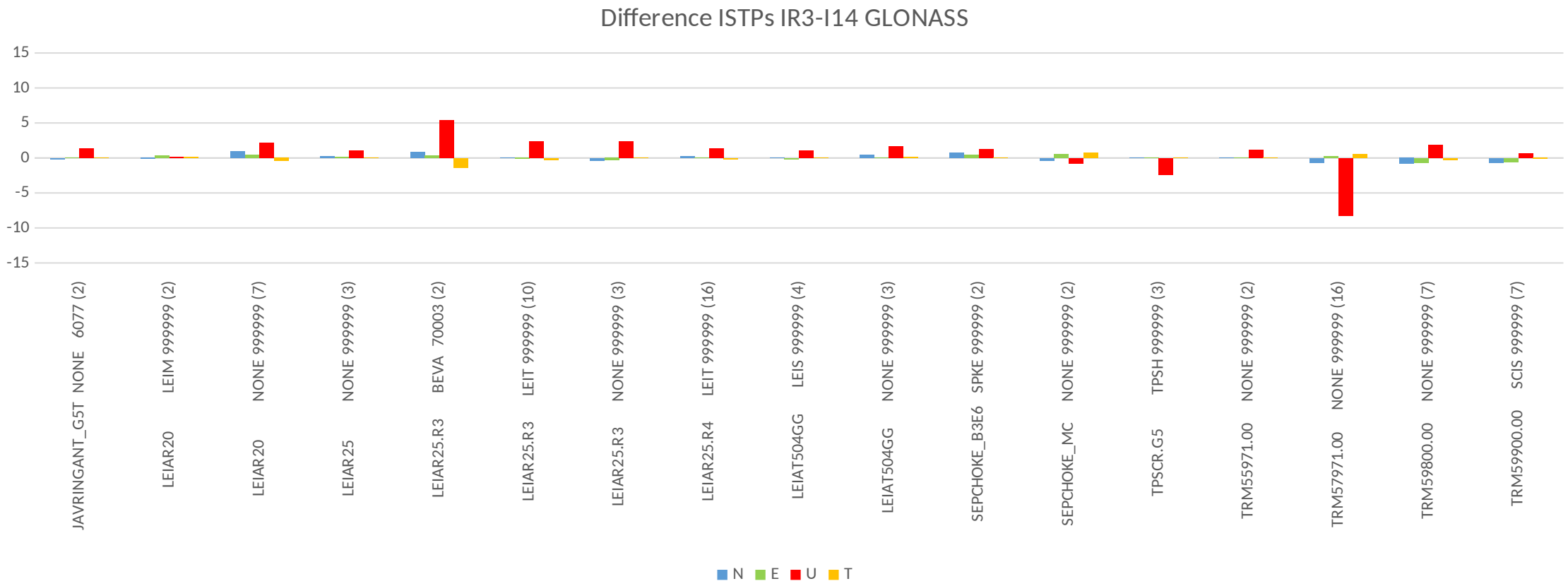
EUREF
Multi-GNSS
WG chair

- Check based on a EU data set (no Swiss stations)
- E14 instead C14 PCV
- better agreement between GPS to GAL and to GLO
- BSD slightly worse; adopted values from GPS seem to work also



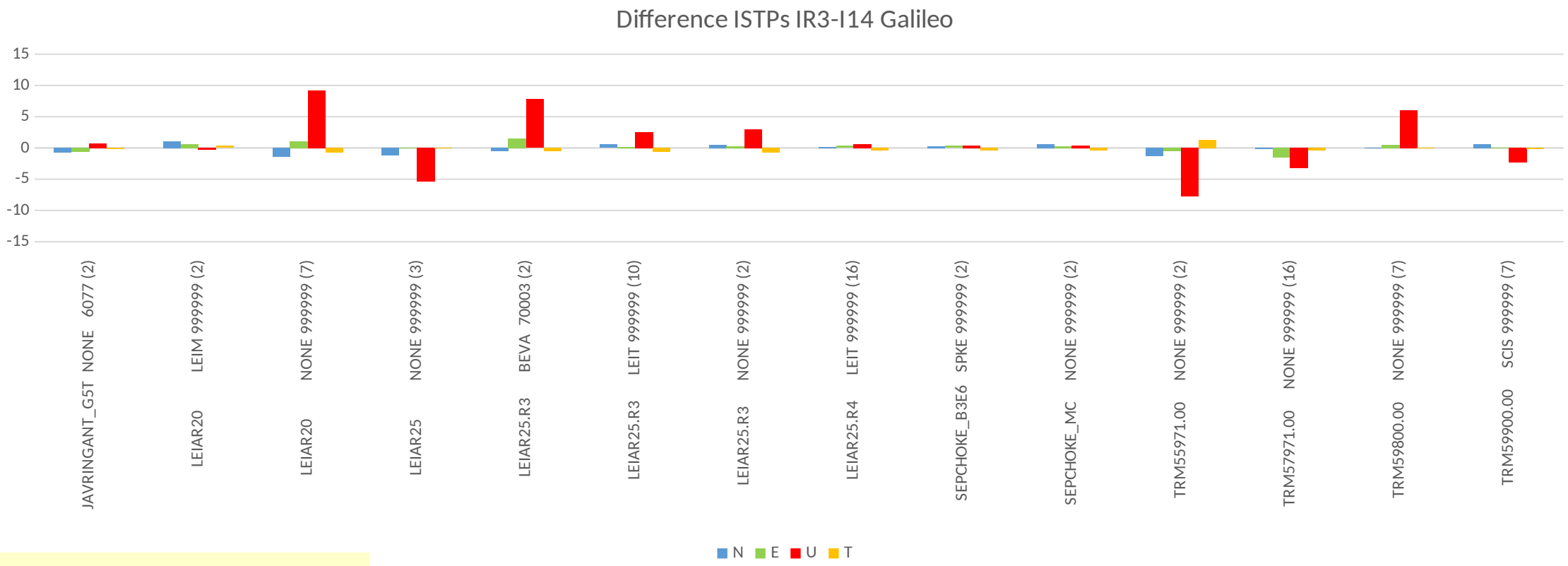
Impact GLONASS by antenna type

EUREF
Multi-GNSS
WG chair



Impact Galileo by antenna type

EUREF
Multi-GNSS
WG chair



Individual Galileo PCVs not yet available from Geo++

Overall impact GREC / Antenna model

EUREF
Multi-GNSS
WG chair

121 sites 1 week

	Helmert	rms [mm]
Impact GPS - GREC	hor	ver
IR3_Update	0.458	1.479
I14	0.532	1.994
E14	0.506	1.855

Up: IR3 GREC best agreement to GPS

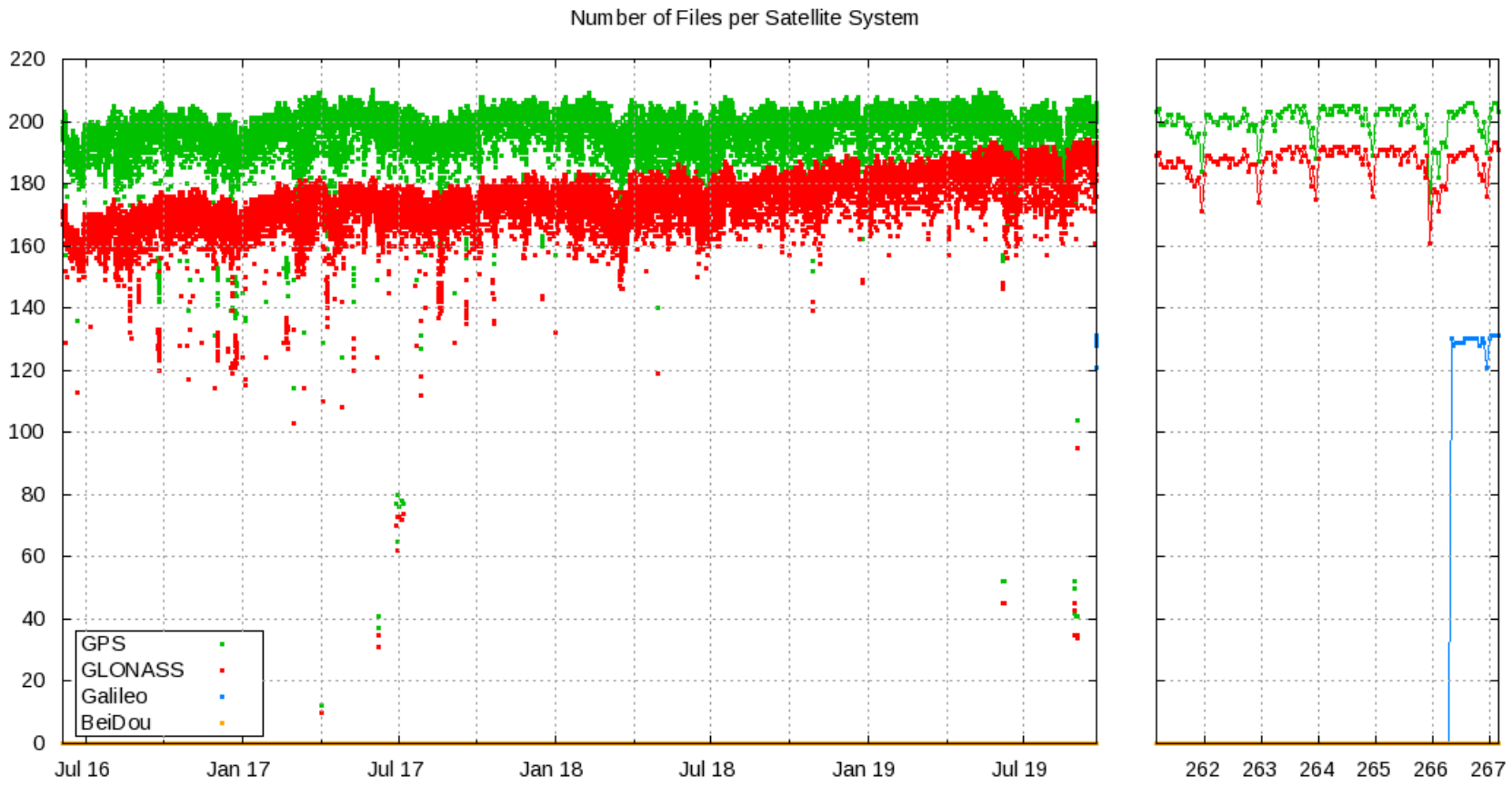
Impact of GREC about same oder of magnitude as impact of PCV change

	Helmert	rms [mm]
Impact antennamodel GREC	**hor**	**ver**
IR3_Update-I14	0.584	1.028
E14-I14	1.112	2.826

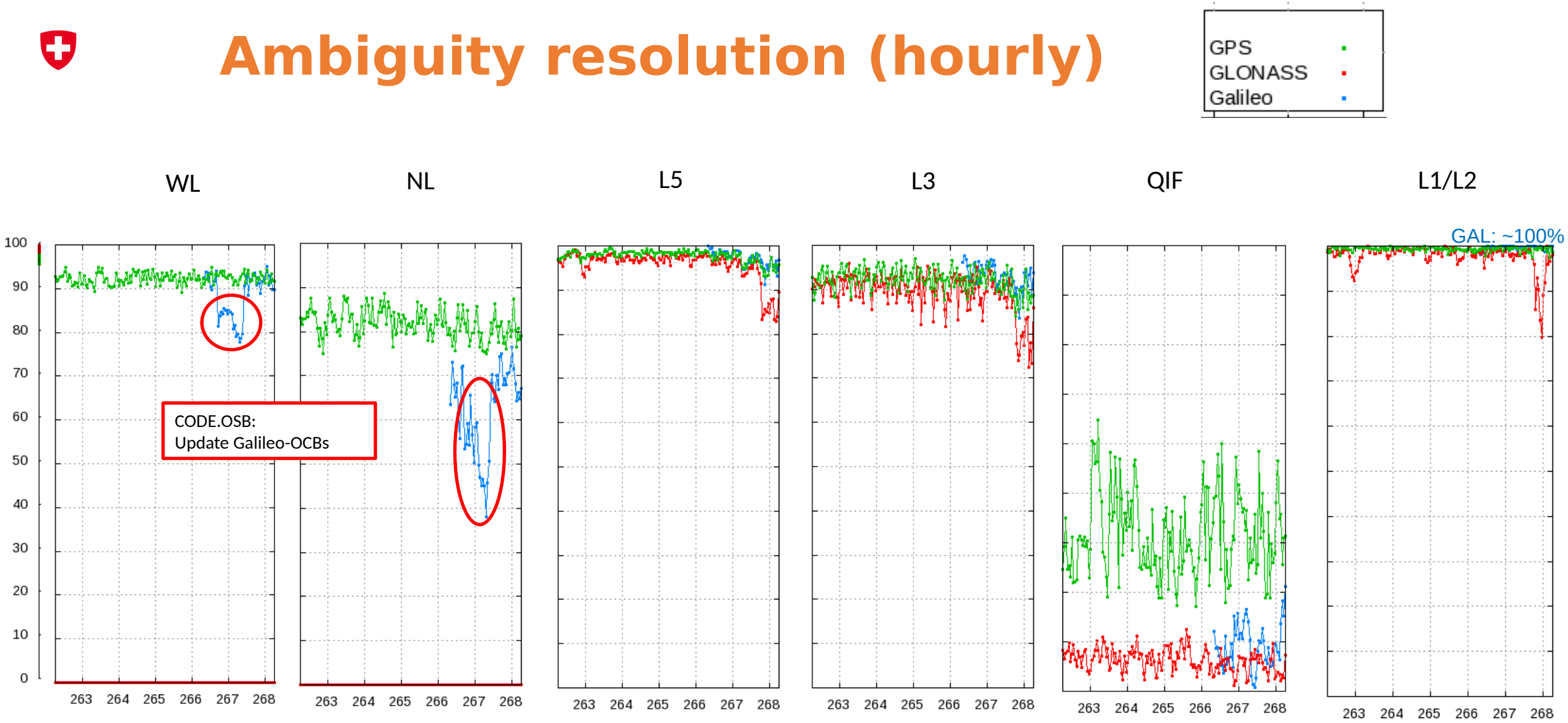
IGS antenna models I14/IR3 closer than EUREF antenna models

Galileo in Rapid and Ultra-Rapid products

CODE products inclusing Galileo since 23.9.2019 (TCODE)

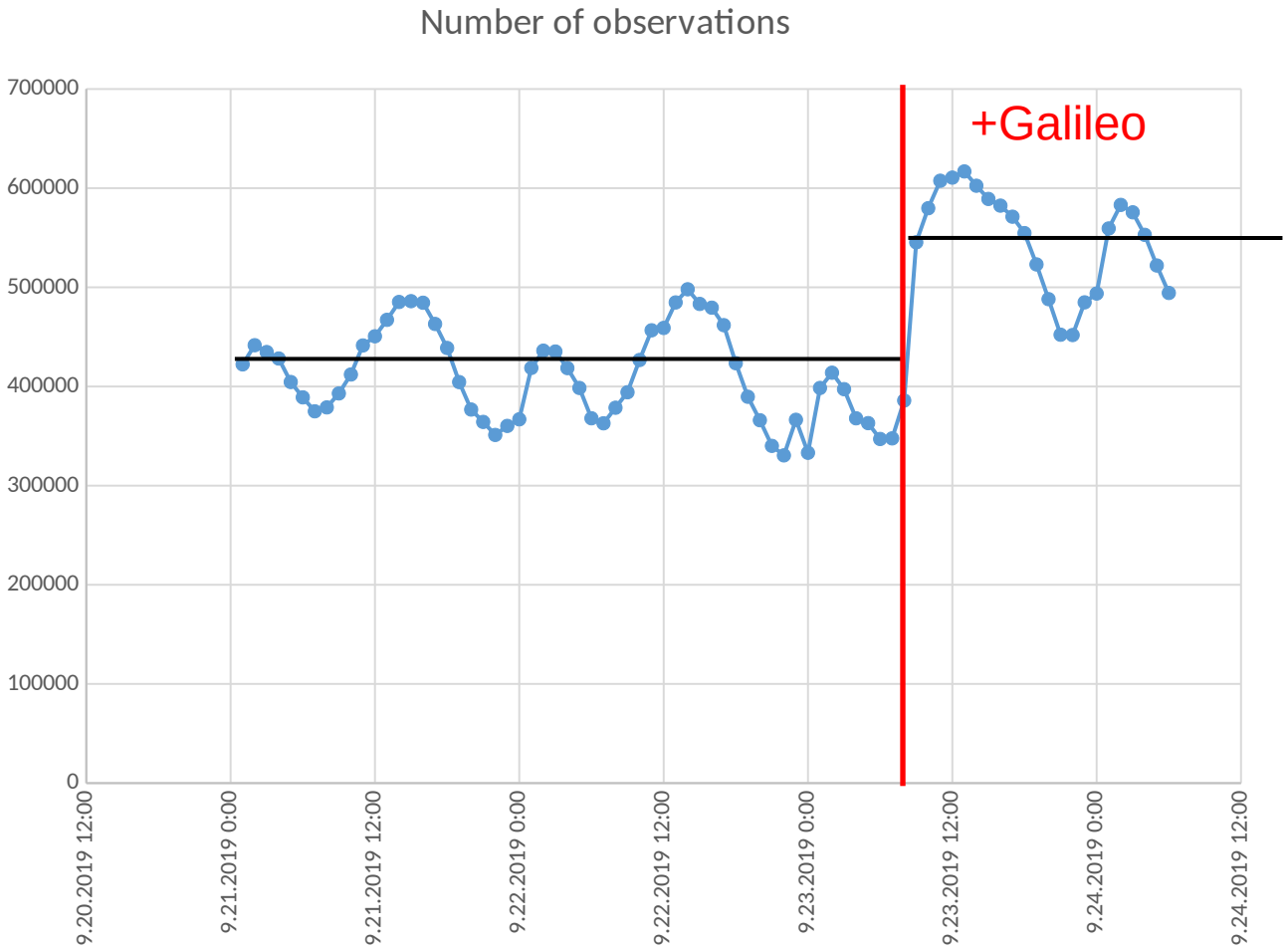


Ambiguity resolution (hourly)

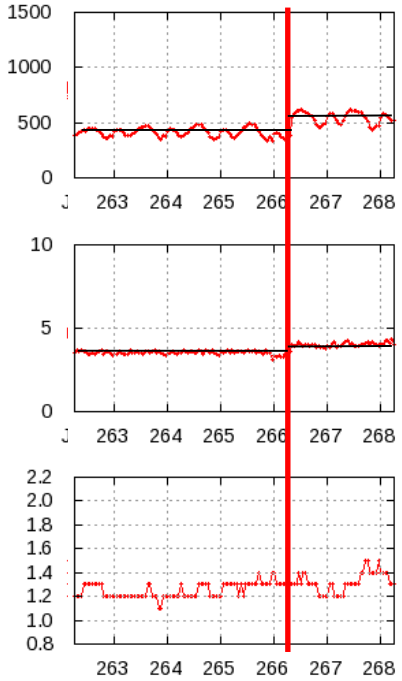


http://pnac.swisstopo.admin.ch/pages/en/amet_statistics.html#AMB_XY

Impact: # of observations



~ 25-33 % more observations in adjustment (4 hour data)



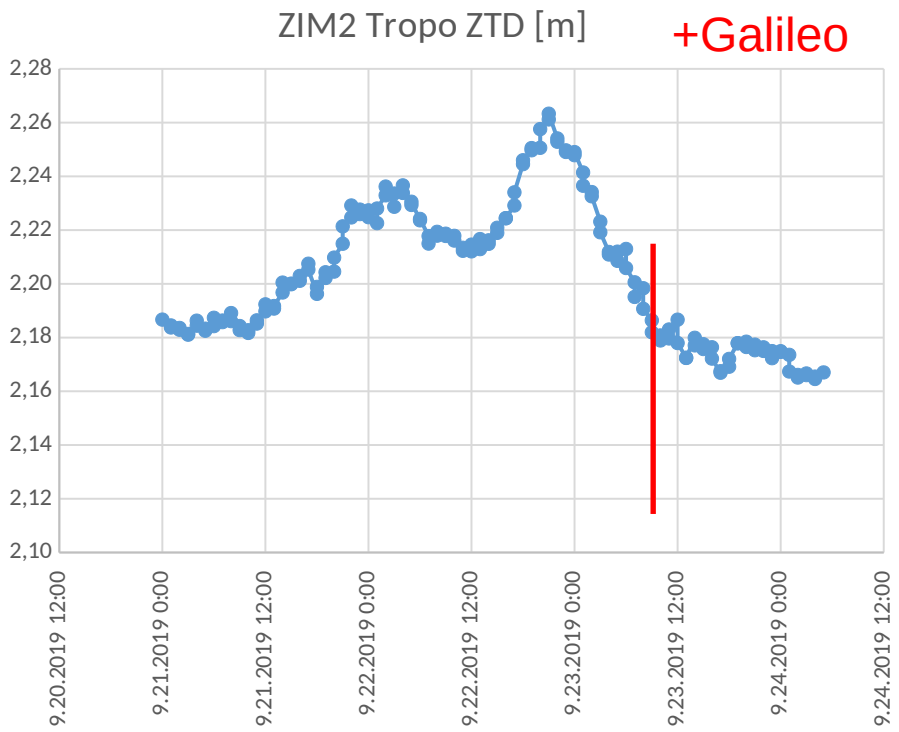
#OBS/1e3

#PAR/1e3

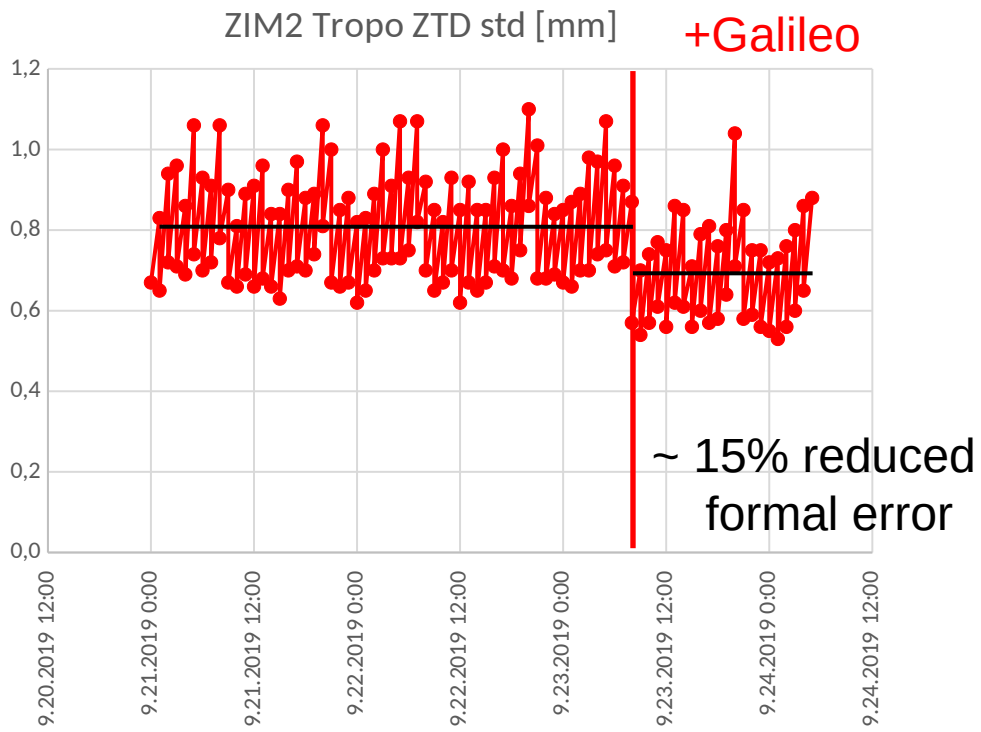
RMS [mm]

Troposphereparameter: ZIM2

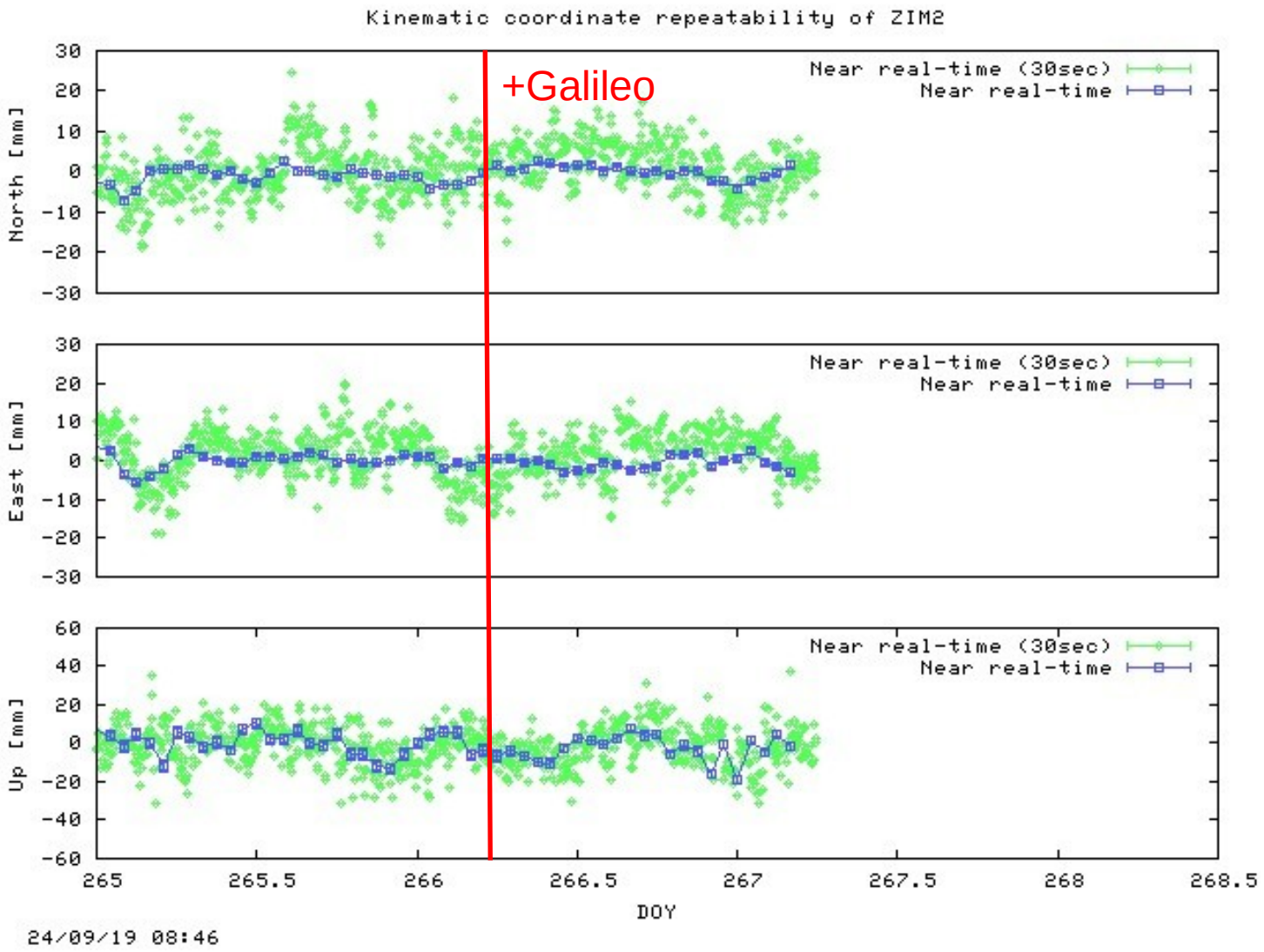
Impact ZTD (+ std as error bar)



Impact standard deviation (formal error)



Impact coordinates



No «jumps» visible
(Galileo PCVs from GPS)

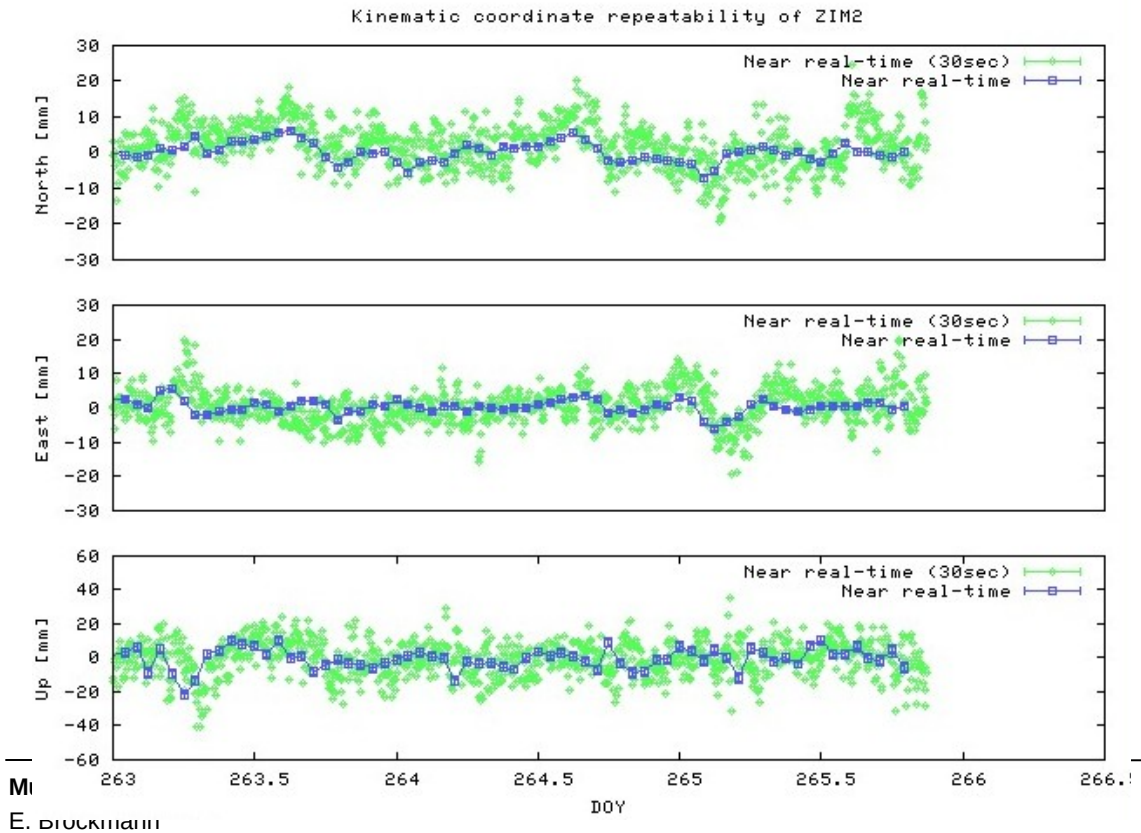
Comparison before/after (statistics): ZIM2

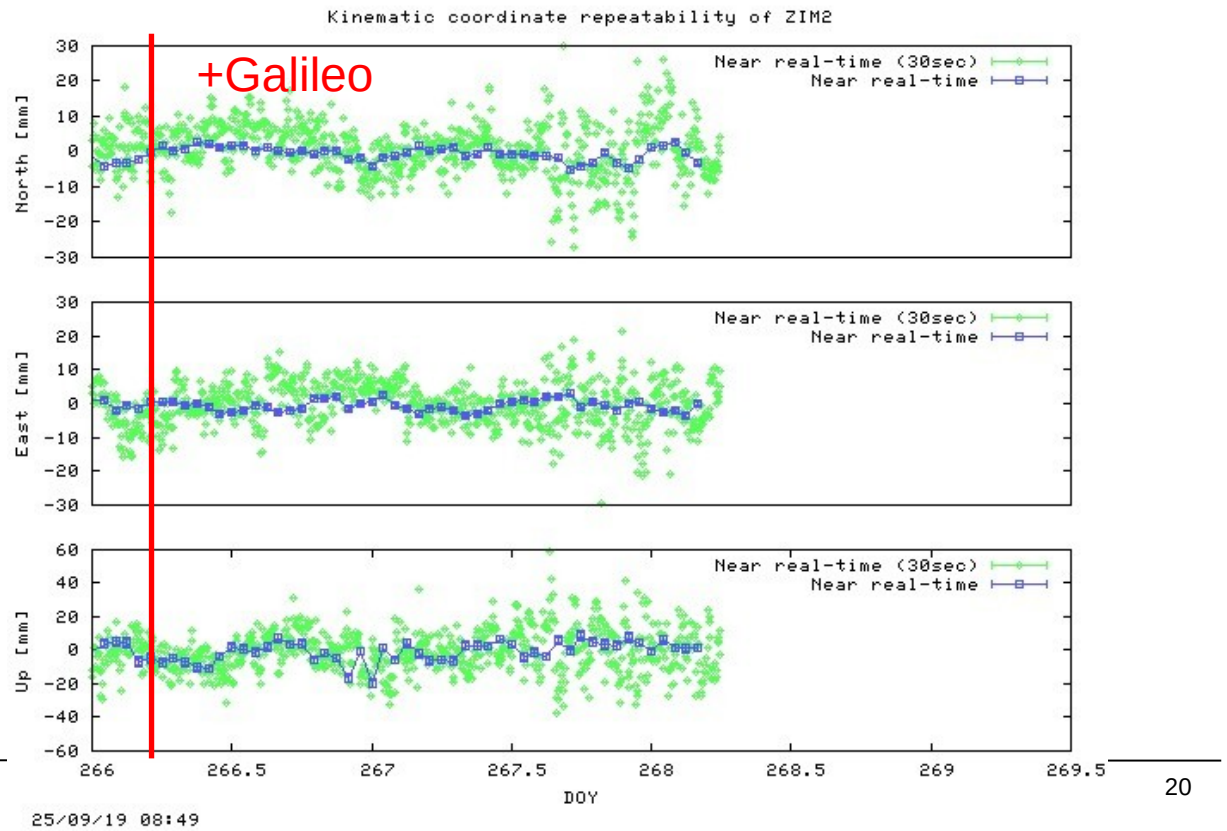
stations with «worse» satellite visibility may profit more

Repeatability: (data span different…)

- Daily coordinates: no significant impact
- Hourly coordinates: hor: ~ 15% vertical: ~ 5% (improvement)
- Kinematic: hor.+vert: ~ -15% (degration)

~ 15% reduced formal error



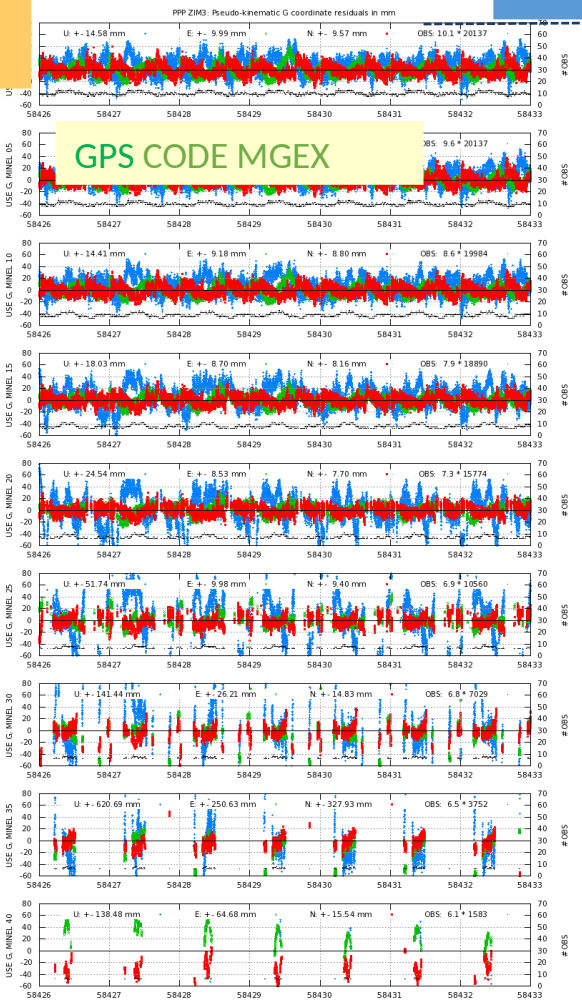


kPPP (kinematic Precise Point Positio

Nov. 2018

BSW53:
ZIM3
1 week
PPP-kinematic

0-40 Elev.



0 Elev.

5 Elev.

10 Elev.

15 Elev

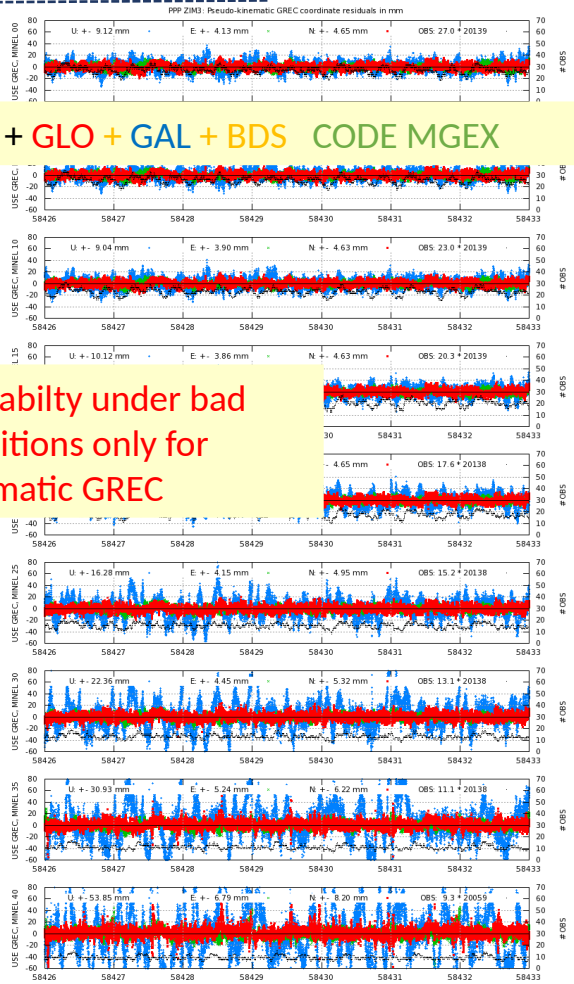
20 Elev

25 Elev.

30 Elev.

35 Elev.

40 Elev.

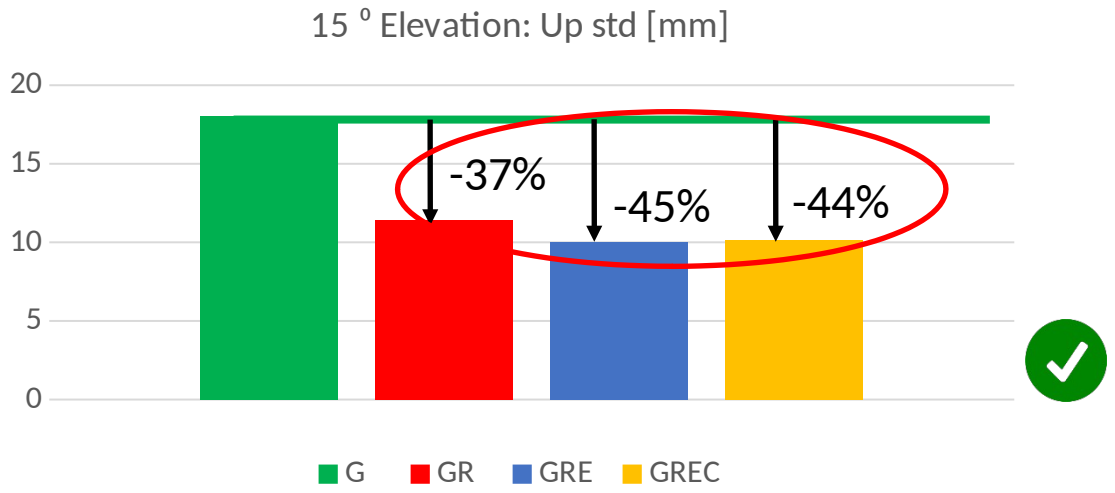


GPS + GLO + GAL + BDS CODE MGEX

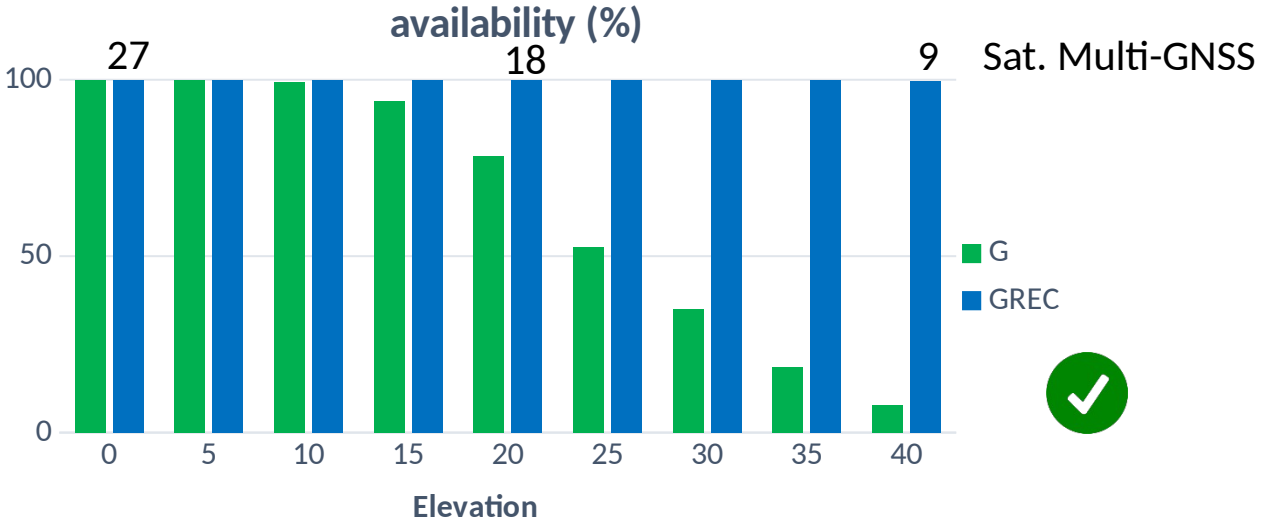
Availabilty under bad conditions only for kinematic GREC

kPPP: Improvement with Multi-GNSS

- Precision (0-15°) / repeatab. improvement w.r.t GPS
  - ~35 % with GLO or GAL
  - ~45 % with GLO + GAL
  - No further improvement with BDS



- Availability (20-40°) w.r.t. GPS
  - Multi-GNSS allows coordinate results even under very bad conditions



Conclusion

- Multi-GNSS is operational
  - RINEX-3 data format in place (but in parallel to still maintained RINEX-2): ~75% hourly and daily availability
  - CODE Multi-GNSS (final) orbits in-time available since Mid 2016 (MGEX, GREC), Ultra + Rapid (GRE) products since Sep. 23, 2019
  - EPN LACS: 11/16 using Galileo
  - Galileo: Reference frame impact (long-term + daily + hourly) small. Mainly availability improvement of kinematic results under difficult conditions.
- Galileo calibrations introduced for IGS repro3 will further improve agreement between GNSS systems; EPN PCV handling to be evaluated.