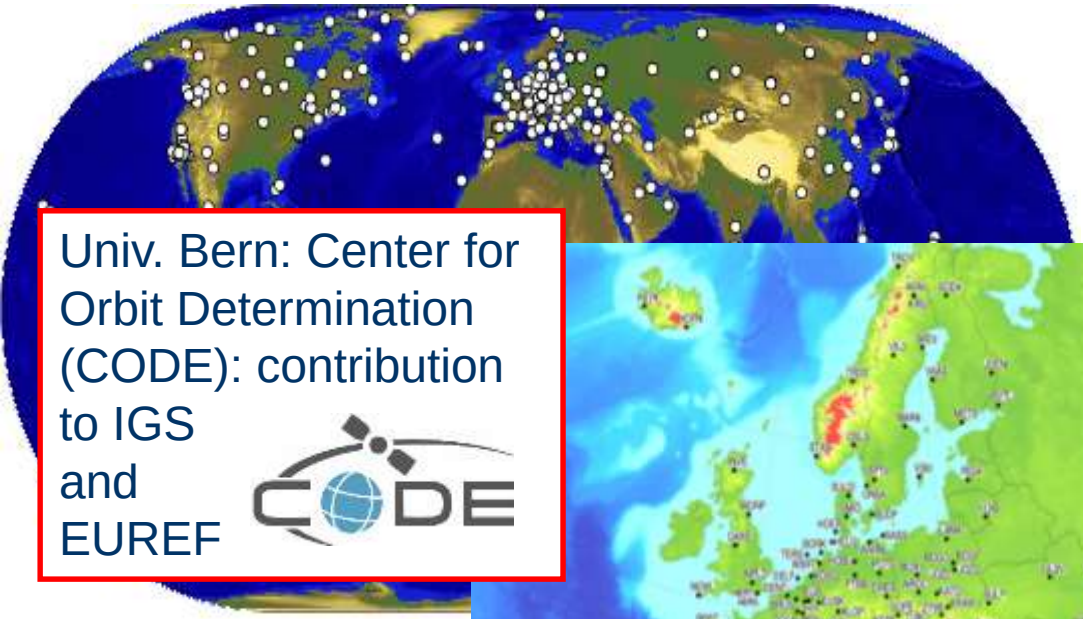
wissen wohin
savoir où
sapere dove
knowing where

swisstopo

Advantages and challenges of Multi-GNSS for precise geodetic applications

E. Brockmann, S. Lutz, D. Ineichen, S. Schaer

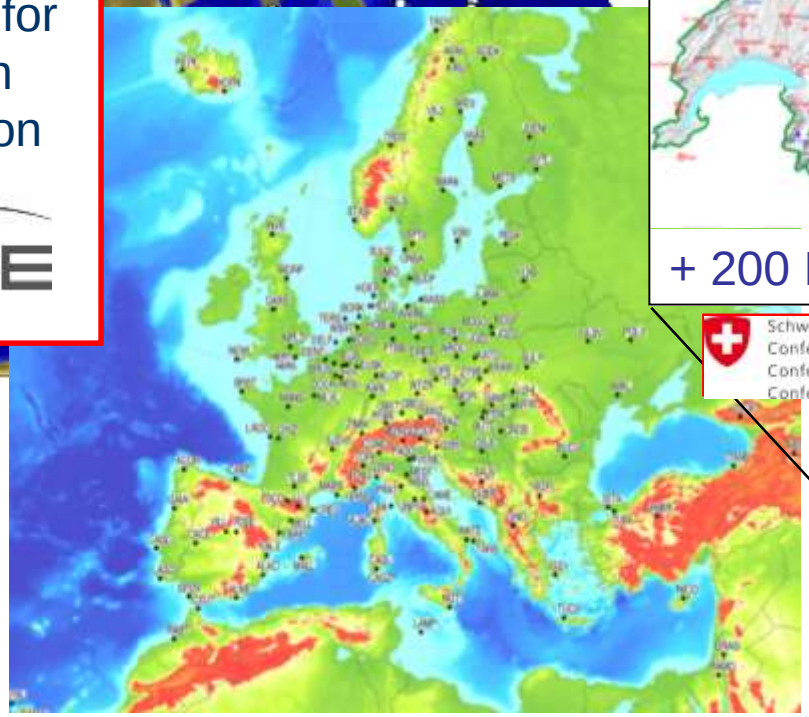
Hierarchical Permanent Networks

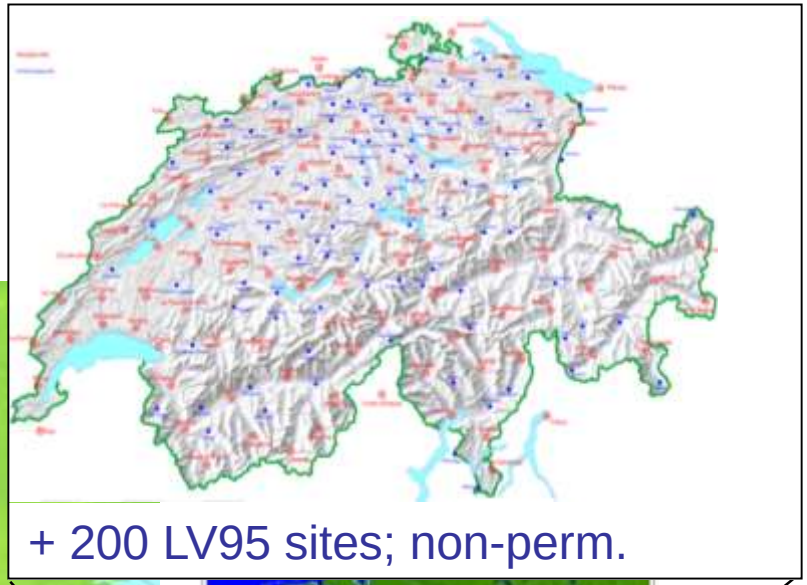


Univ. Bern: Center for Orbit Determination (CODE): contribution to IGS and EUREF

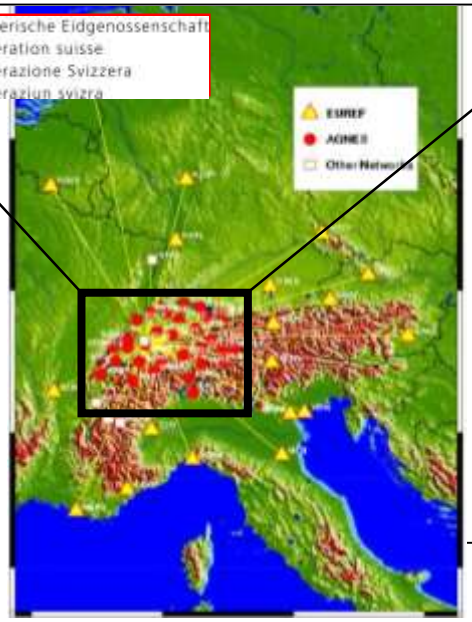
Global: IGS
Int. GNSS Service
(500 stations)

Europe: EUREF
(300 stations)





+ 200 LV95 sites; non-perm.



National: AGNES
(30 stations)

Multi-GNSS working fields

AGNES Network
CHTRF 2016

infrastructure (stations)

Standards
Q-Monitoring

RINEX 3.03

data flow

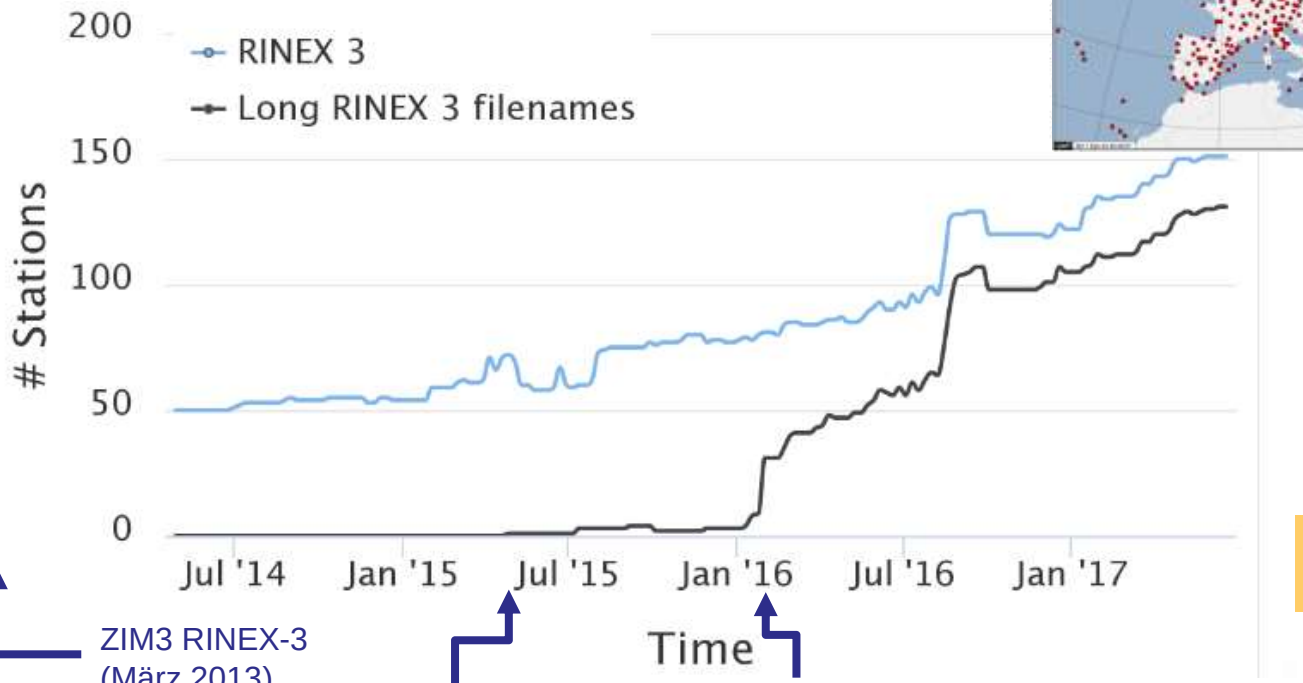
Bernese Software:
Analysis AGNES,
CHTRF 2016
campaign (operational)

analysis

Multi-GNSS in Europe (EUREF)

EUREF Multi-GNSS WG

- EUREF – chair of Multi-GNSS working group



totally, 320 stations

ca. 50% of the EUREF-stations deliver RINEX-3

No GAL + BDS antenna calibrations

ZIM2 RINEX-3 (Aug. 2011)

ZIM3 RINEX-3 (März 2013)

41 AGNES RINEX-3

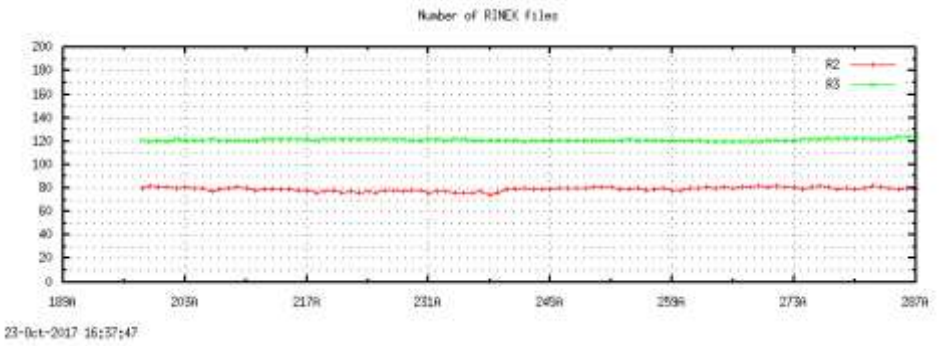
9 field receivers RINEX3

EPNCB, Nov. 2017

RINEX-3 in operational analysis

- AGNES (daily):
  210 stations

  57% RINEX-3
  43% RINEX-2

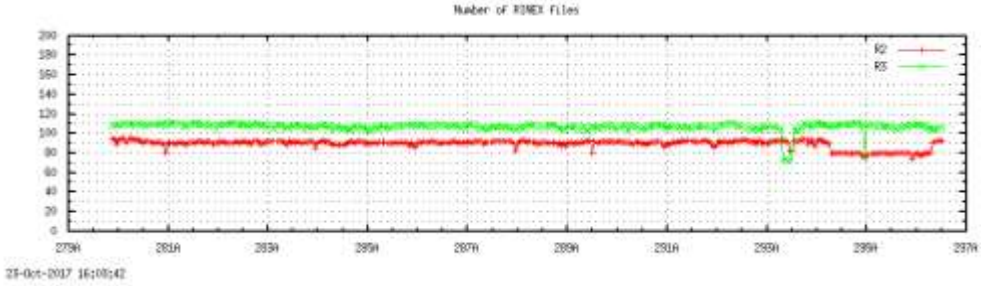


RINEX-3 priority since Juli 2016

- AMET (hourly):
  208 stations

  53% RINEX-3
  47% RINEX-2

RINEX-3 priority since Sep. 2017

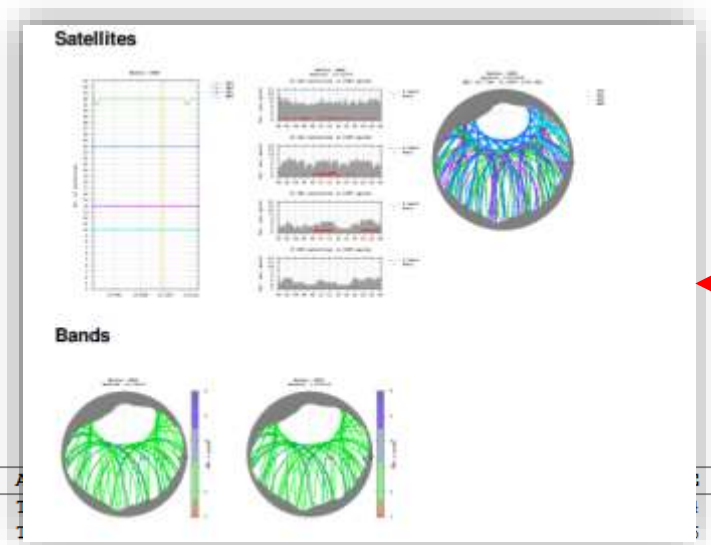


RINEX-3 also for
GPS/GLO stations

Monitoring RINEX-3 Tools

EUREF Multi-GNSS WG

- Monitoring with “Anubis” (GOPE) and “BNC” (BKG)
  http://pnac.swisstopo.admin.ch/pages/en/anubis_monitor_r3.html
  - 130 stations with RINEX-3 (long and short names)
  - BNC+gfzrnx (GFZ) for editing, concatenation



> 50 (R2) – 110 (R3) plots/station/dag

Sortable table

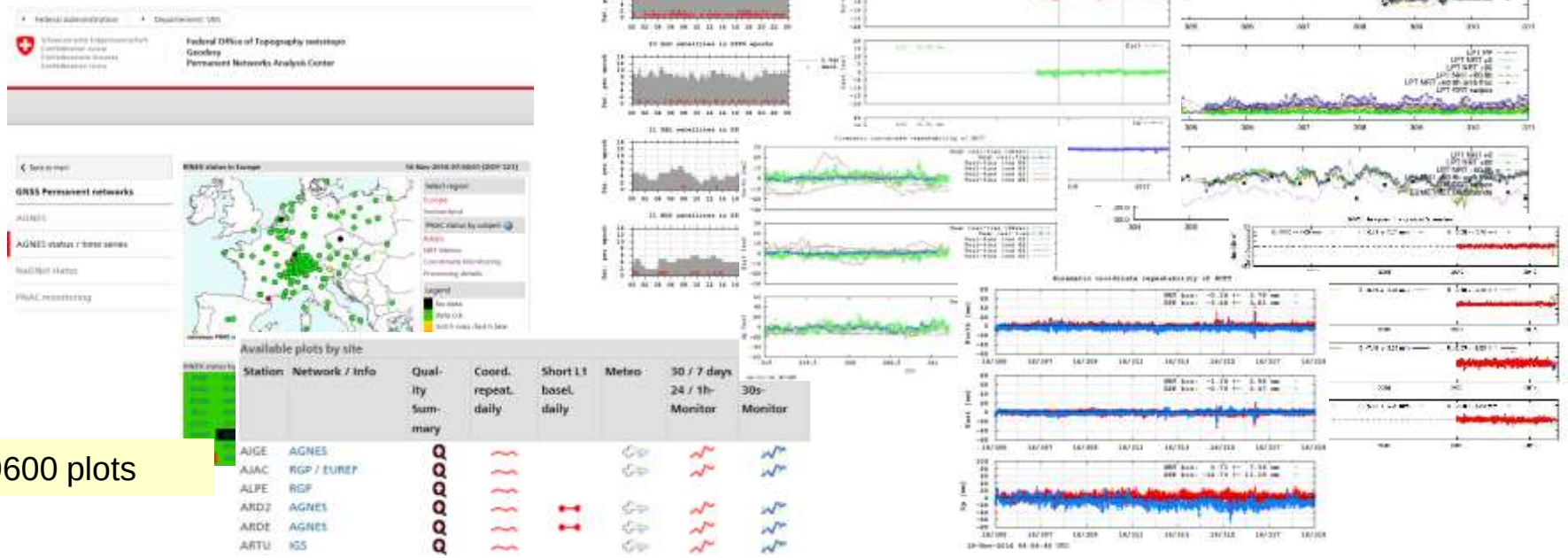
NAME	RECEIVER											nC	nJ	nS	PDF
AIGE	TRIMBLE NETR9	5.22										10	0	0	aige r3.pdf
AJAC 10077M005	LEICA GR25	4.02										10	0	2	ajac r3.pdf
ARD2	TRIMBLE NETR9	5.22	TRM59800.00	NONE	3.02	30	2880	1.03	88.48	32	24	14	10	0	0	ard2 r3.pdf
ARDE	TRIMBLE NETR9	5.22	TRM33429.20+GP	NONE	3.02	30	2880	1.24	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

web PNAC monitoring

To be mentioned ! (1)

- Web-based monitoring system (30 min updates; on Amazon web cloud since mid 2016)
- All important processing info available – alert via SMS/e-mail in case of troubles

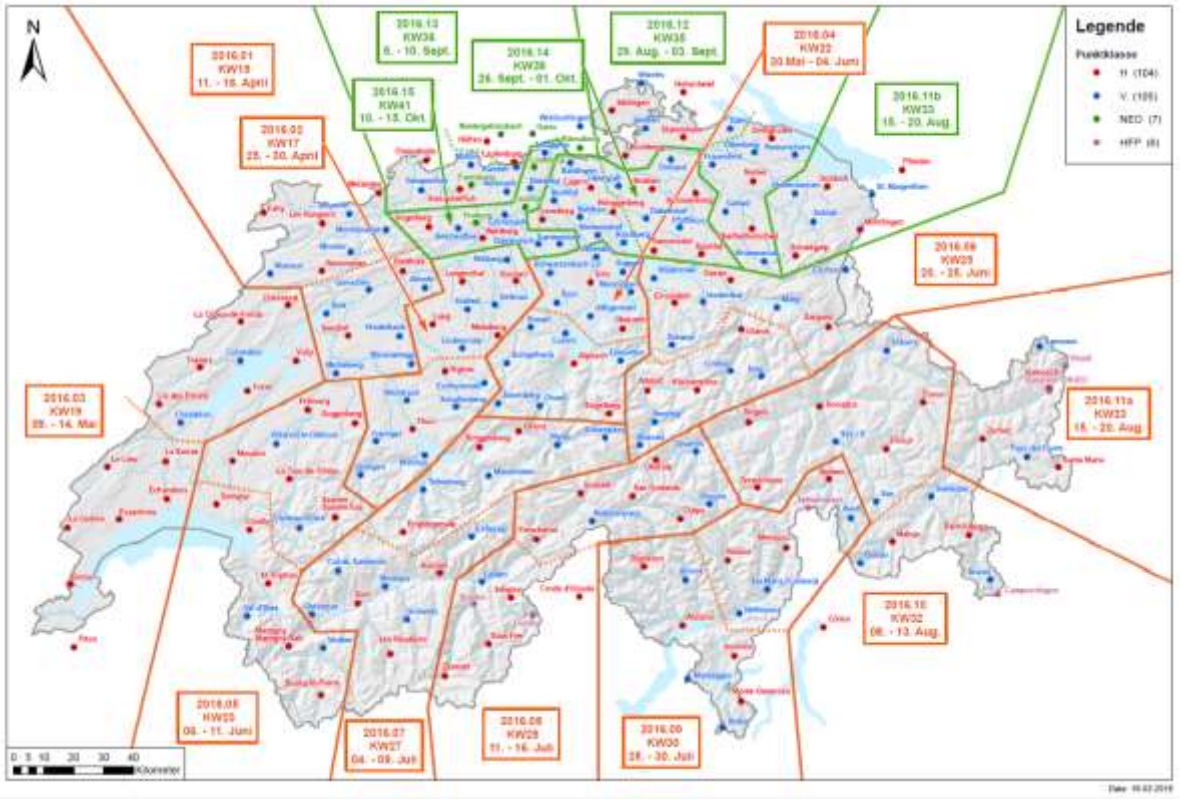
http://pnac.swisstopo.admin.ch/



~9600 plots

CHTRF2016: Multi-GNSS field campaign

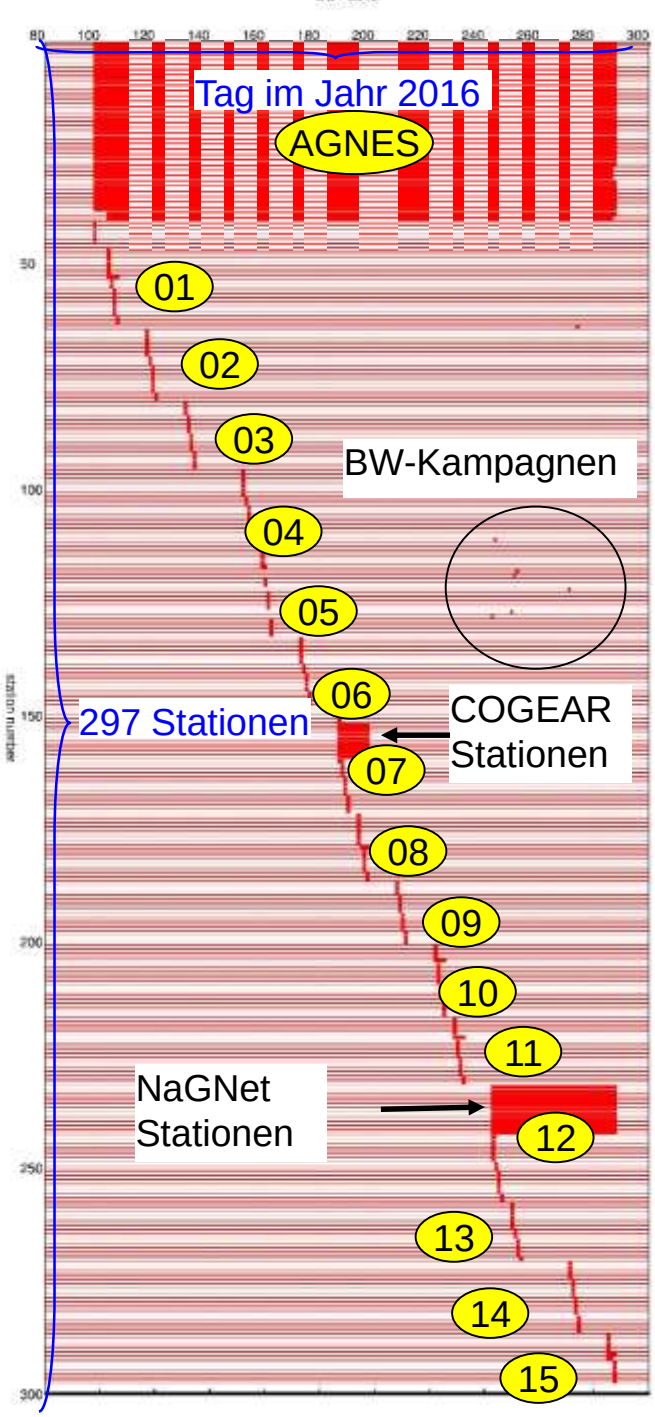
- all ~200 reference points measured in summer 2016
- Multi-GNSS knowledge extension (permanent analysis later because campaigns are less time-critical)



Campaign 2016

- 10 observer
- 15 weeks (Mo – Sa)
- 297 points (incl. AGNES)
- ~ 44.6 h observations / point
- 5 campaigns from Baden-Württemberg integrated (6 h measurements, separated in time)

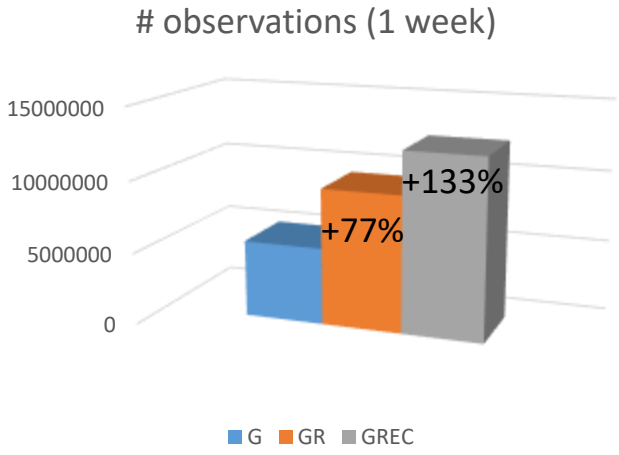
- Analysis using BSW5.3 (development version)
- Analysis delay 1-2 months – CODE Multi-GNSS orbits not operational, yet

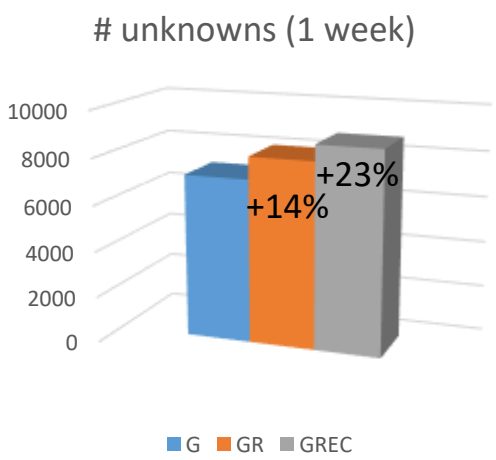


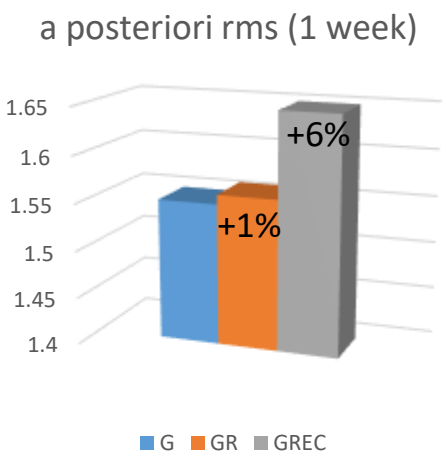
Statistics 7 days

GPS GREC: GPS GLO GAL BDS

Campaign CH16_11 (1 week)	G	GR	GREC	G->GR [%]	G->GREC [%]
Total number of authentic observations	5352366	9499869	12481201	77	133
Total number of adjusted parameters	7119	8086	8778	14	23
A posteriori RMS of unit weight [mm]	1.55	1.56	1.65	1	6
Total number of observation files	228	228	228		
Total number of stations	55	55	55		
Total number of satellites / day	30	55	74	83	147







30 55 74
satellites per day

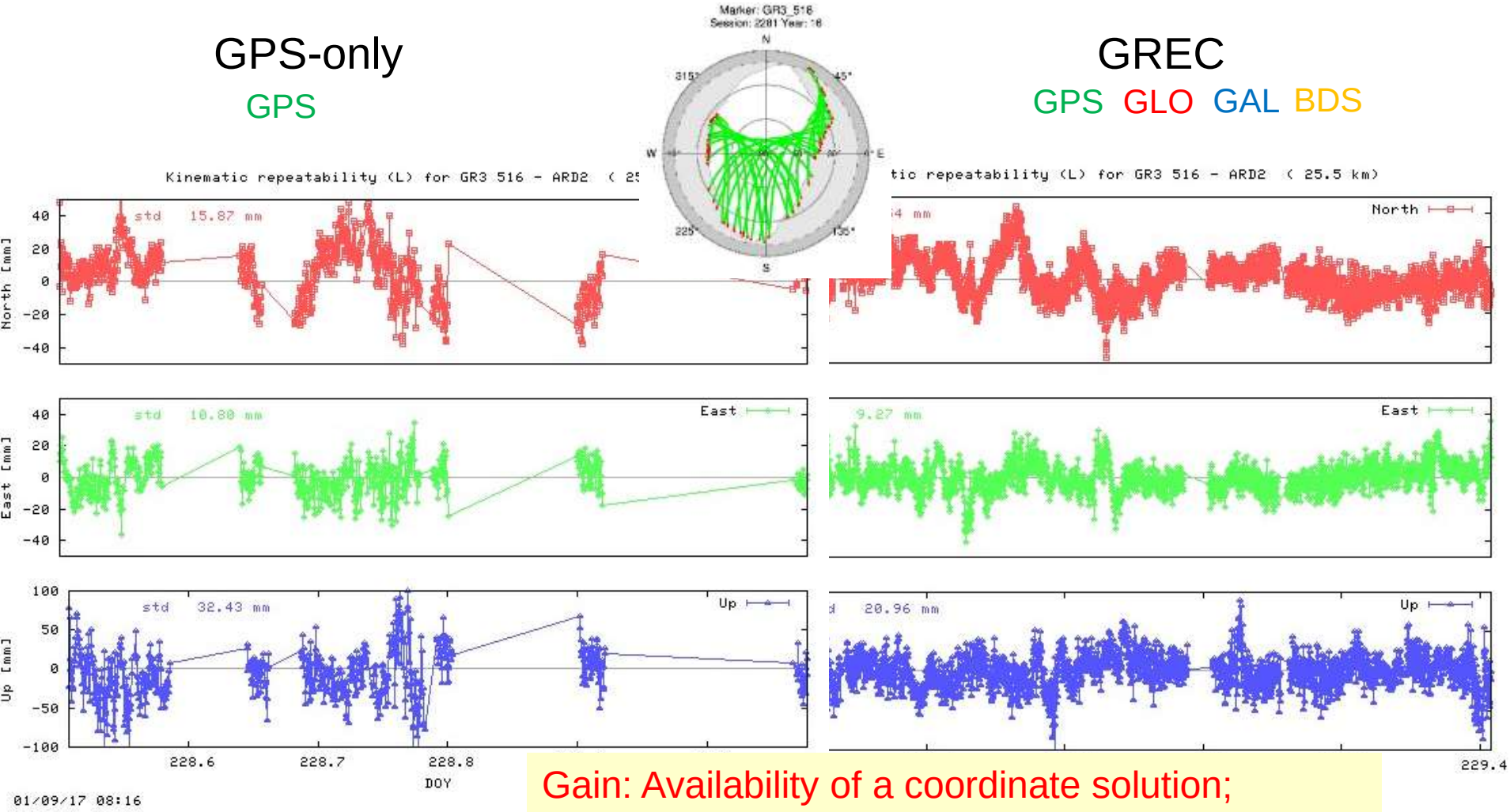
Gain Multi-GNSS: kinematic coordinates

GPS-only

GPS

GREC

GPS GLO GAL BDS



Gain: Availability of a coordinate solution;
only secondary a slightly higher accuracy

ISTPs: „Inter system translation parameter“

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

4

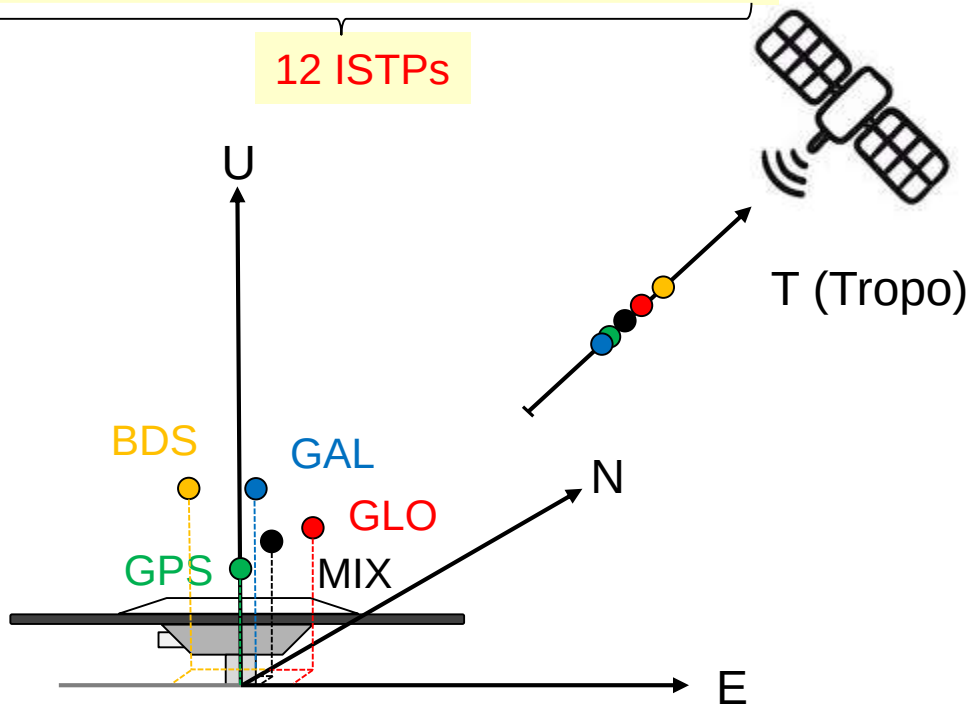
or

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

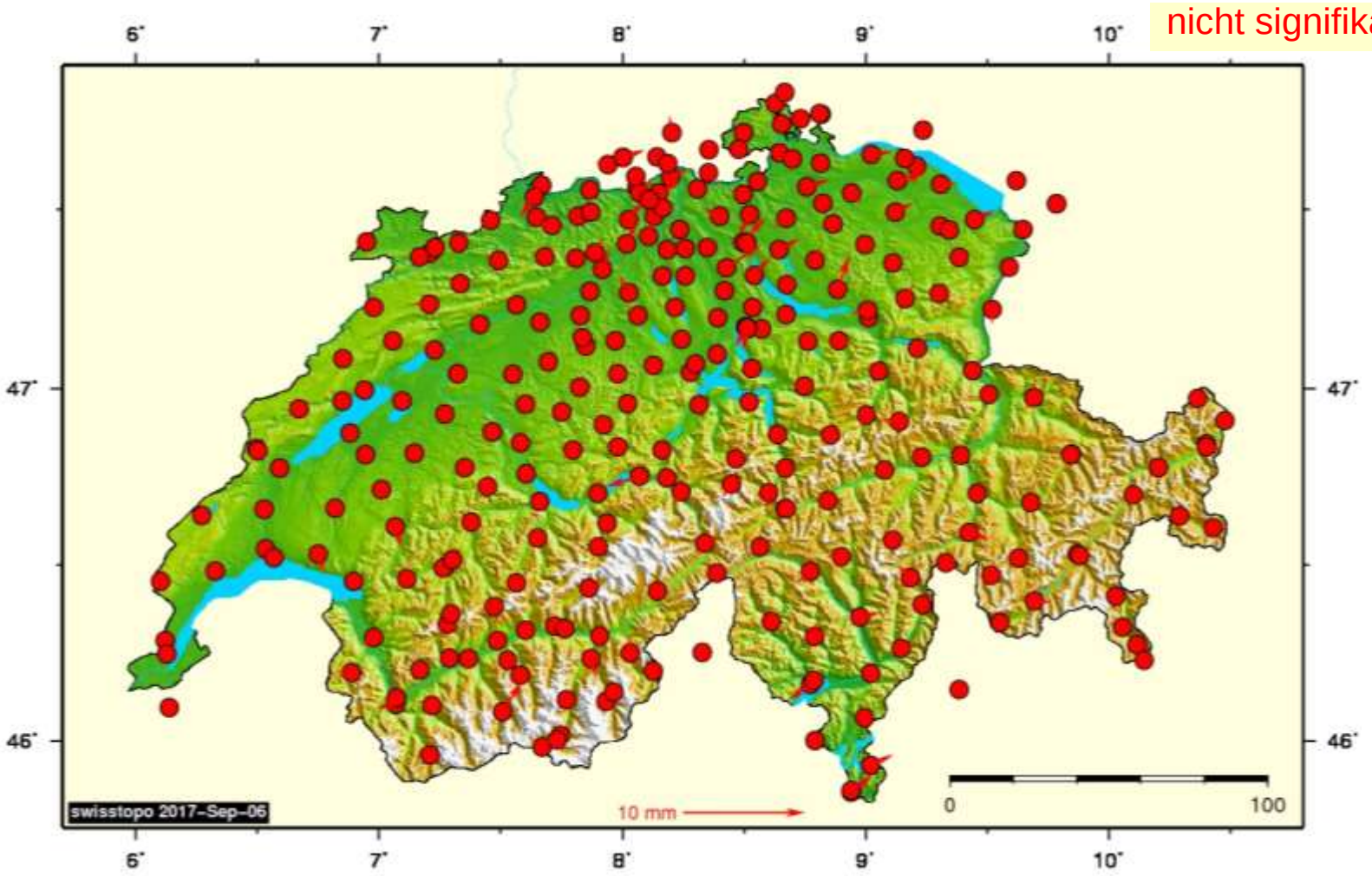
4x4

Referenz dN,dE,dU,dT | dN,dE,dU,dT | dN,dE,dU,dT

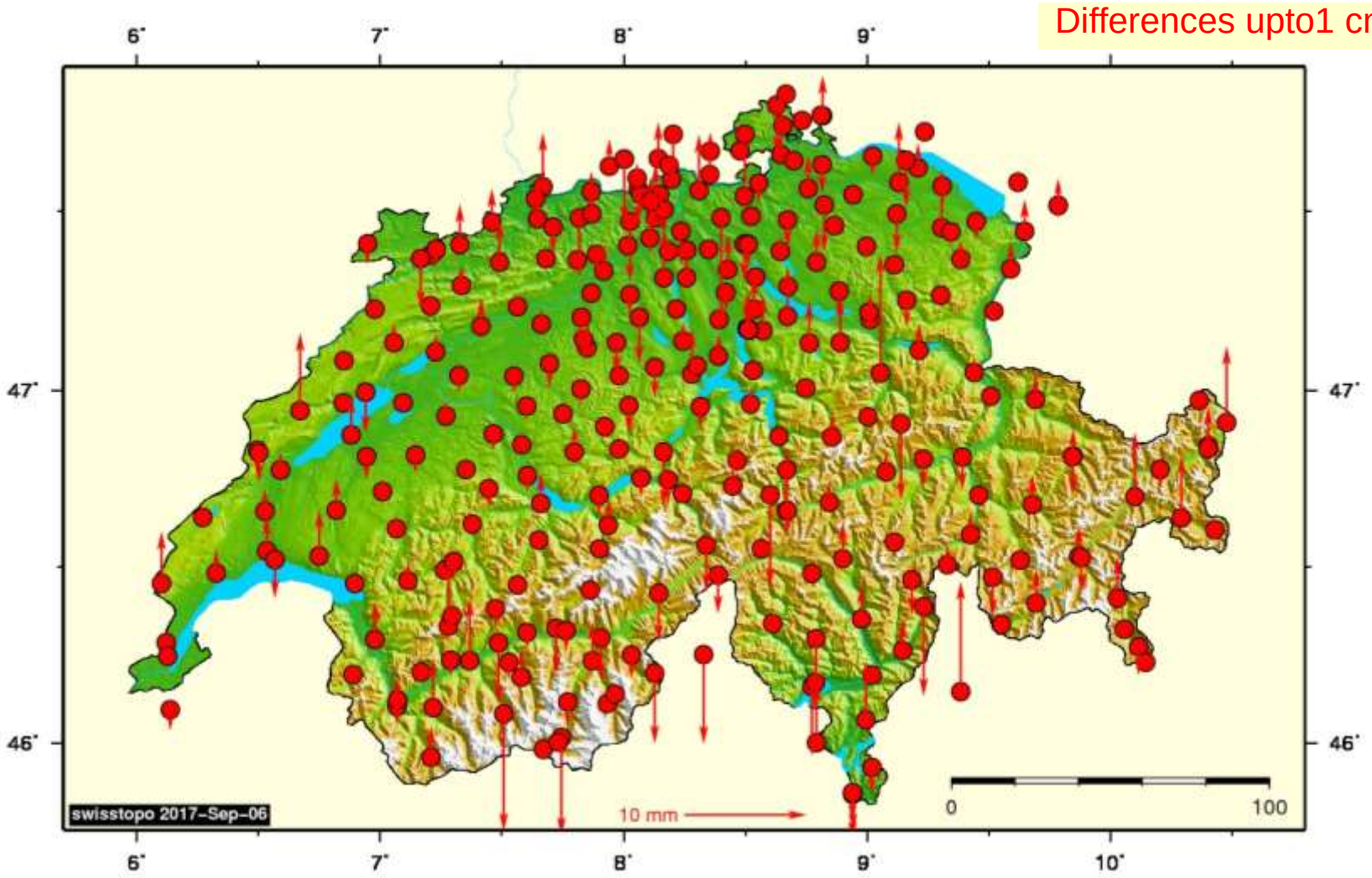
12 ISTPs



CHTRF16 hor. difference: MIX-GPS



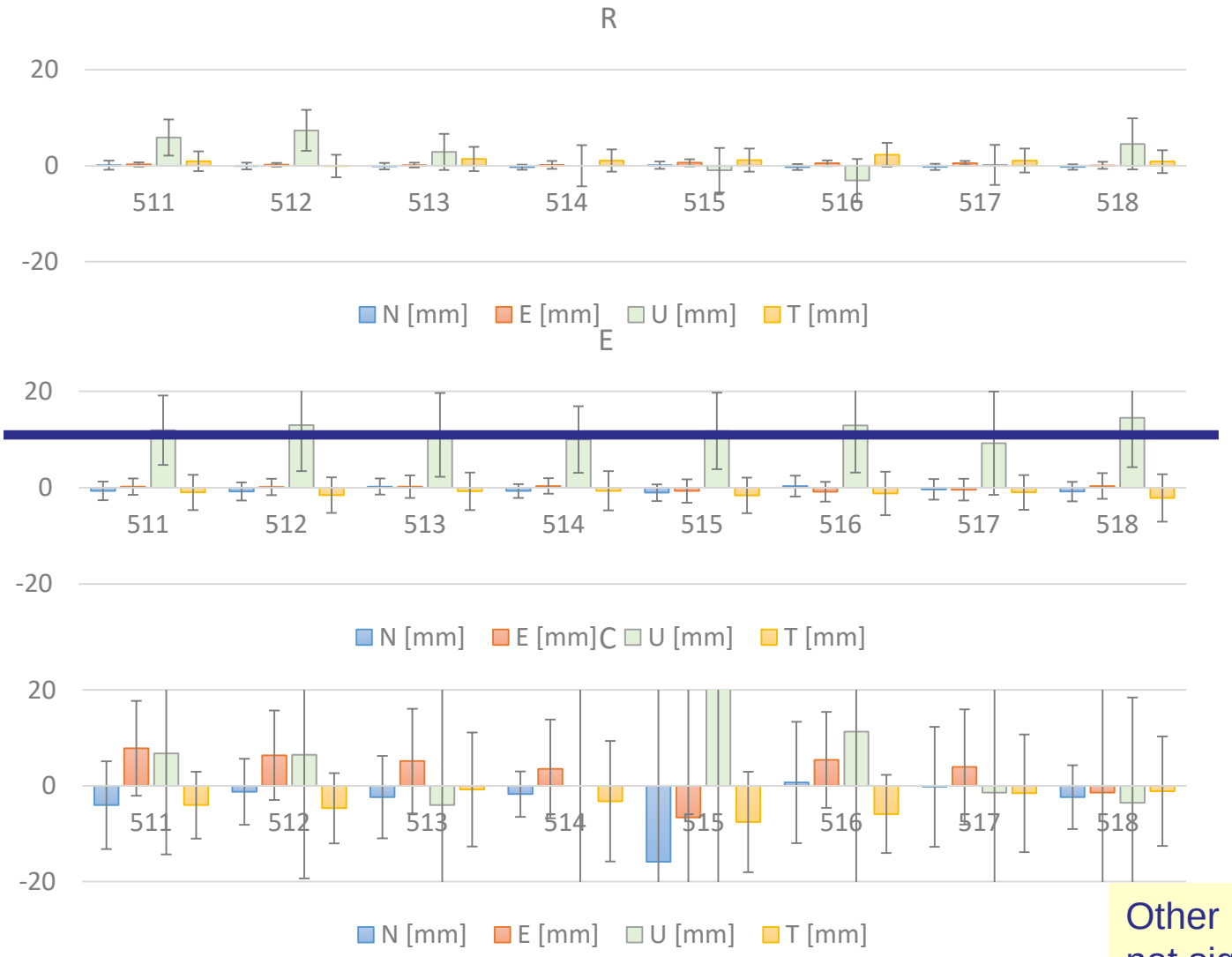
CHTRF16 vertical difference: MIX-GPS



ca. 30 observations / antenna

ISTPs filed equipment

GPS (Ref)



GLO

GAL

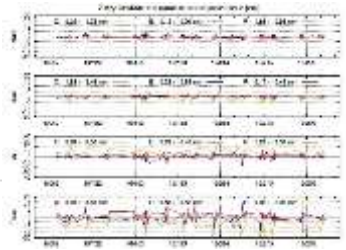
BDS

Up GAL:
12 ± 2 mm
significant

Other ISTPs
not significant

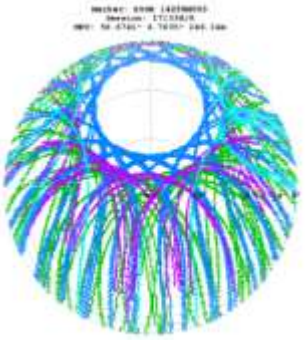
ca. 90 observations / antenna

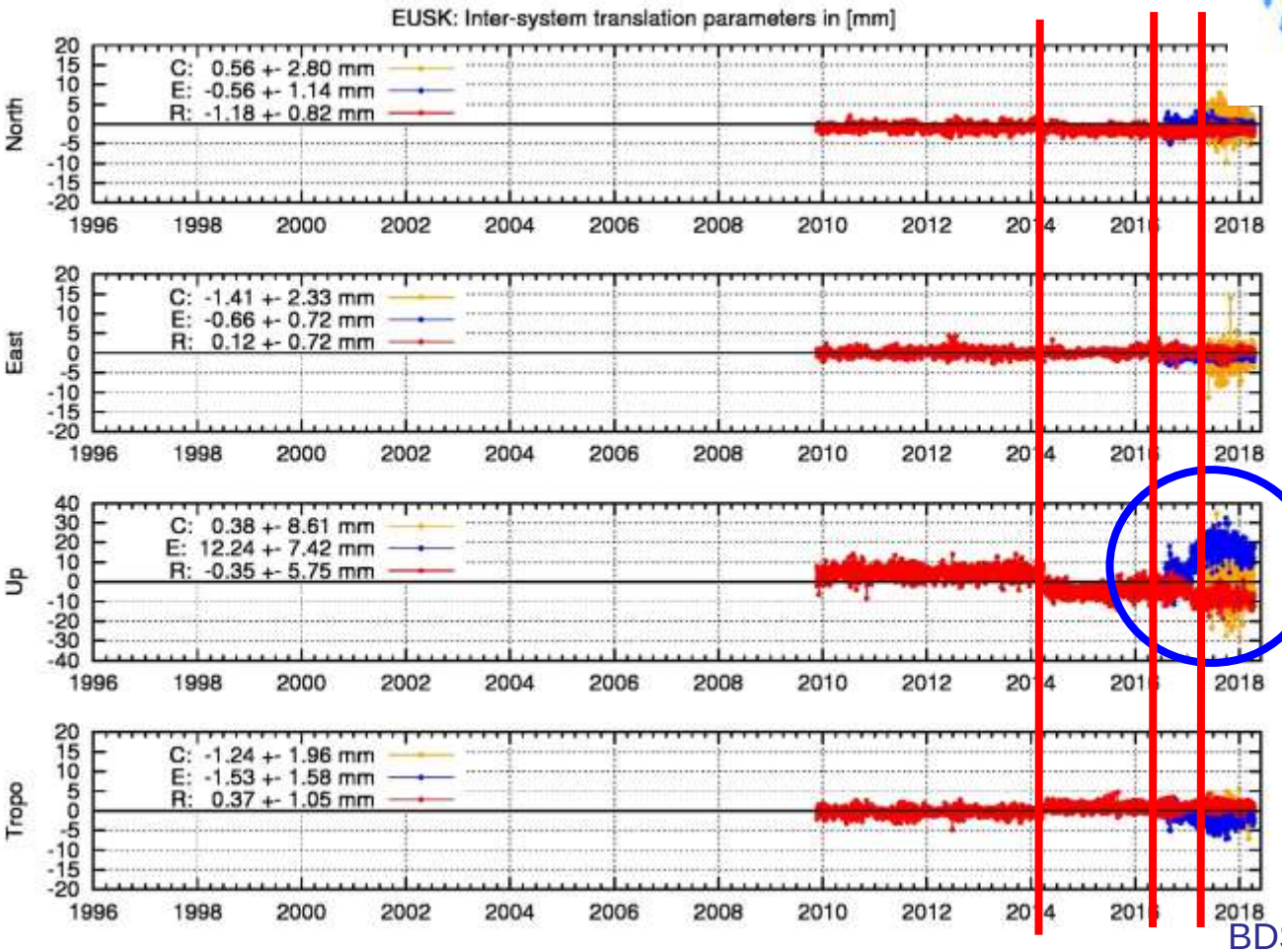
AGNES-CHTRF16 ISTPs



- No significant ISTPs
- Datum definition of ISTPs necessary

ISTPs: EUSK site (Germany)





GPS (Ref)

GLO

GAL

BDS

GPS-GAL Up ?

BDS+GAL Tracking

GAL Tracking

Antenna change

EUREF

- Reference frame Europe (ca. 300 stations)
- 16 Analysis centres (daily + weekly analysis)
  Multi-GNSS provided by swisstopo since 29-Jul-2016

Netz (320 Stationen) LPT-Sub-Netz: 60 Stationen

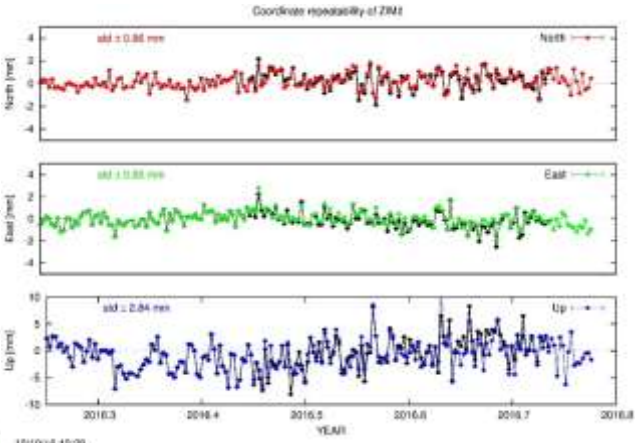
Auswerteparameter

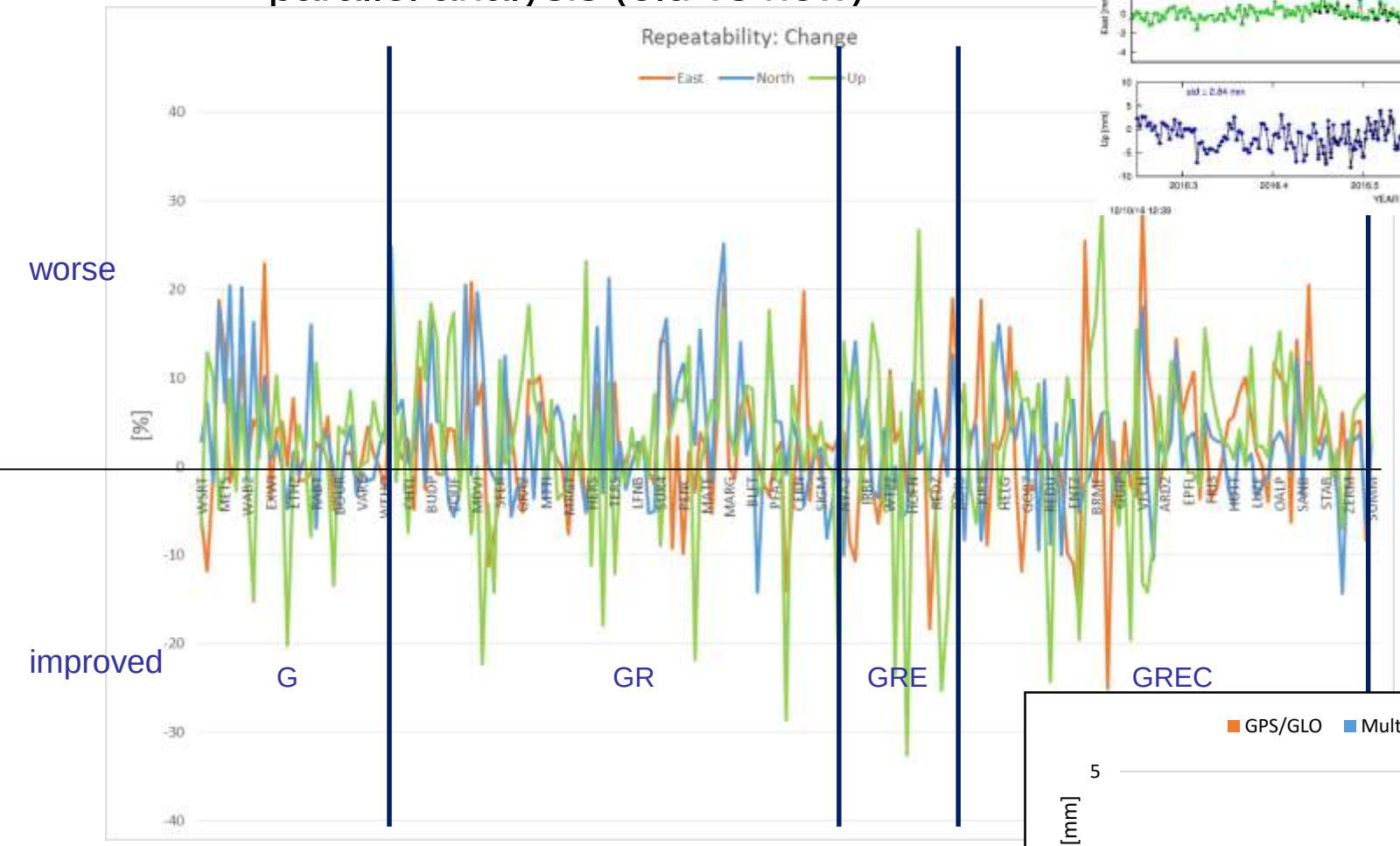
LPT = L+T = swisstopo

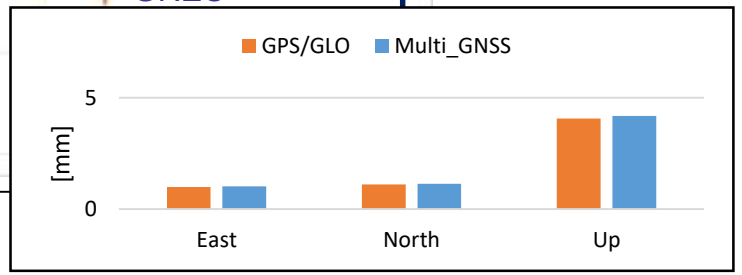
AC	Mapping function	Gradients	cut-off	GNSS System	
ASI	VMF1	yes	3	GPS	GIPSY
BEK	WET_GMF	yes	3	GPS+GLONASS	Berner Software
BKG	WET_GMF	yes	3	GPS+GLONASS	
COE	WET_VMF	yes	3	GPS+GLONASS	
IGE	WET_GMF	no	3	GPS+GLONASS	
IGN	WET_GMF	yes	3	GPS+GLONASS	
LPT	WET_VMF	yes	3	GPS+GLONASS+GALILEO+ BeiDou	
MUT	WET_GMF	yes	3	GPS+GLONASS	
NKG	WET_GMF	yes	3	GPS+GLONASS	
OLG	WET_VMF	yes	3	GPS+GLONASS	
RGA	WET_VMF	yes	3	GPS+GLONASS	
ROB	WET_GMF	yes	3	GPS+GLONASS	
SGO	WET_VMF	yes	3	GPS+GLONASS	
SUT	WET_VMF	no	3	GPS+GLONASS	
UPA	WET_GMF	yes	3	GPS+GLONASS	
WUT	WET_VMF	yes	3	GPS+GLONASS	

AGNES Multi-GNSS: repeatabilities

- 206 stations, 15 weeks parallel analysis (old vs new)







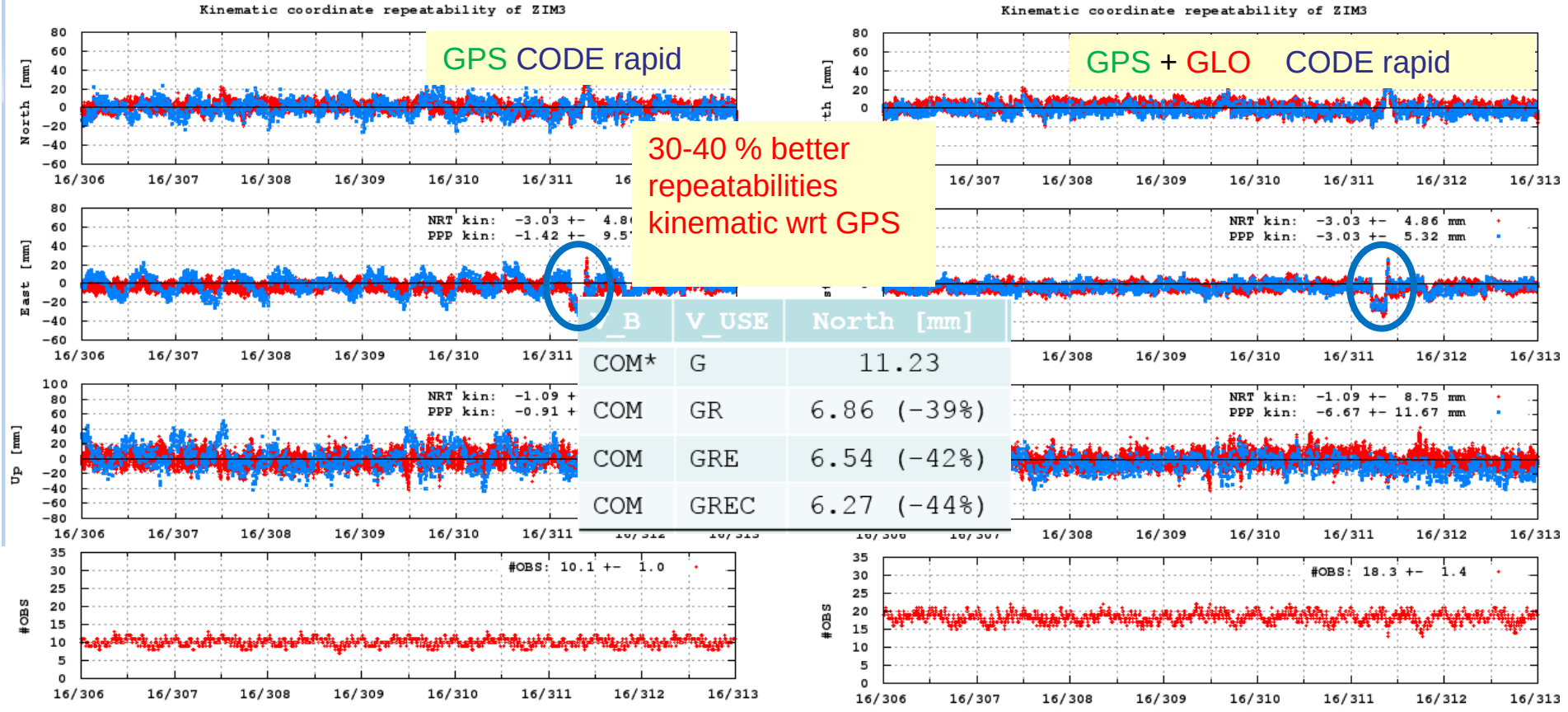
PPP as Alternative

Orbits+ clocks

To be mentioned ! (2)

ZIM3
1 week
PPP-kinematic

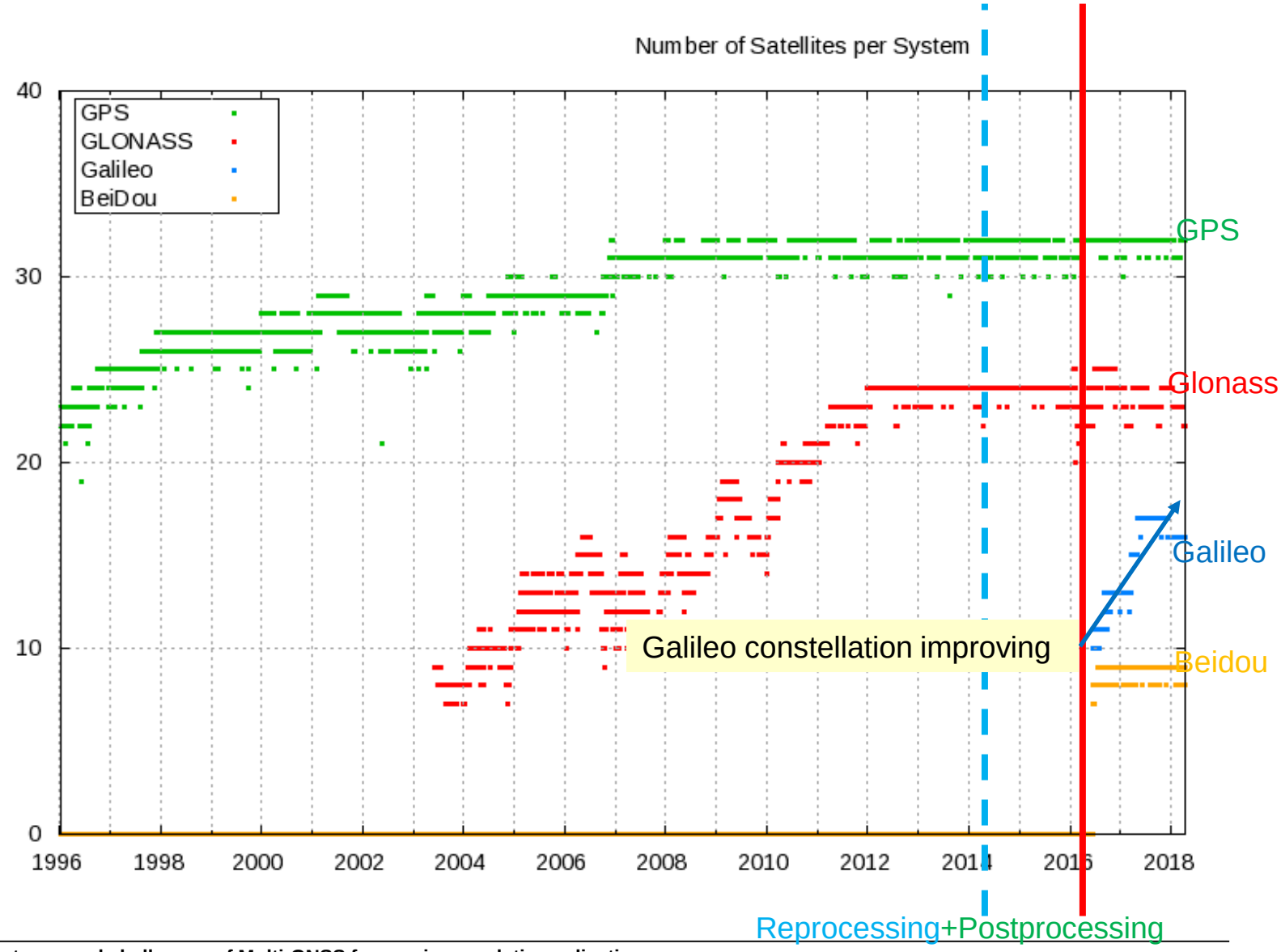
- PPP: no reference station! Product evaluation possible !
- Short computation time (and linear with # of stations)
  PPP and Network-mode: very comparable results



30-40 % better repeatabilities kinematic wrt GPS

V_B	V_USE	North [mm]
COM*	G	11.23
COM	GR	6.86 (-39%)
COM	GRE	6.54 (-42%)
COM	GREC	6.27 (-44%)

Multi-GNSS: systems analysed



Summary

- Multi-GNSS operational in precise applications with ~80 sat.
  - AGNES permanent stations and field equipment
  - Data flow RINEX-3 established
  - Analysis Multi-GNSS (GAL+BDS) using BSW53;
    
    MGEX products operational
  - EUREF activities follow closely
- Gain for observation times > 1 day negligible; for observations < 1 hour / real-time better availability (slightly better accuracy)
- RTXNet (Trimble, Multi-GNSS in real-time) available in CH – 15% of the users work with RTCM 3.2 MSM-mountpoints
- Reference frame control is more complex (coordinates per satellite system; missing GAL+BDS antenna calibrations)