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Federal Office of Topography swisstopo

wissen wohin
savoir où
sapere dove
knowing where

swisstopo

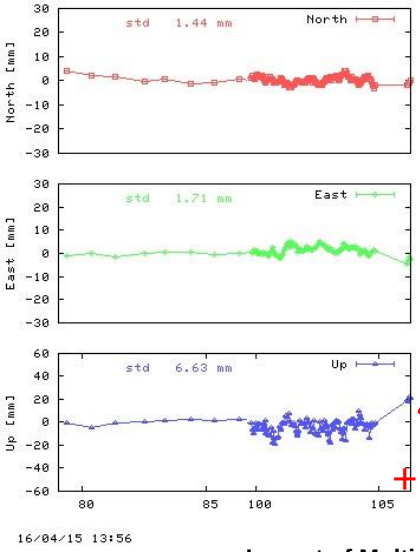
Impact of Multi-GNSS analysis on precise geodetic applications

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

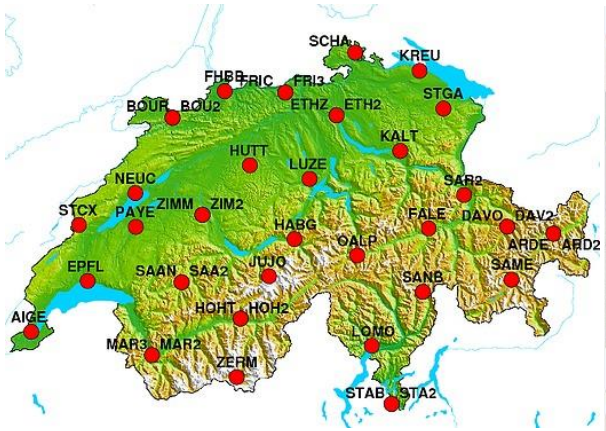
Multi-GNSS at Swiss permanent stations

- Feb-May 2015: **all 41 Swiss stations are enhanced from GPS/GLO receivers to Multi-GNSS** (+ 15 chokering antennas: causing jumps of ~ 2 cm despite individual antenna PCVs)
- June 19, 2015: **AGNES data flow in RINEX3**

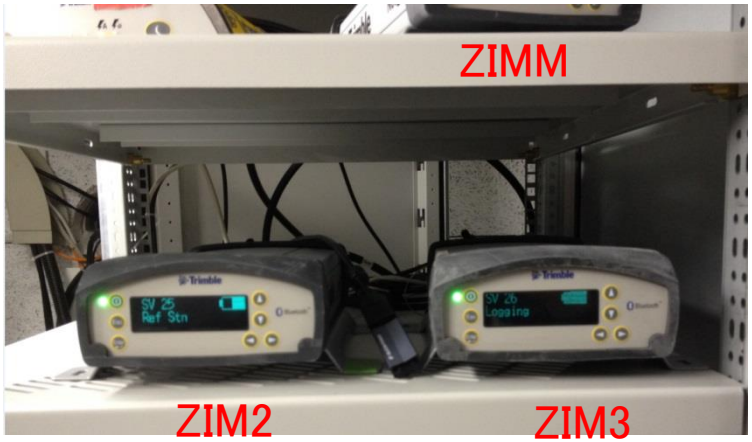
PAYE



+ ~2 cm



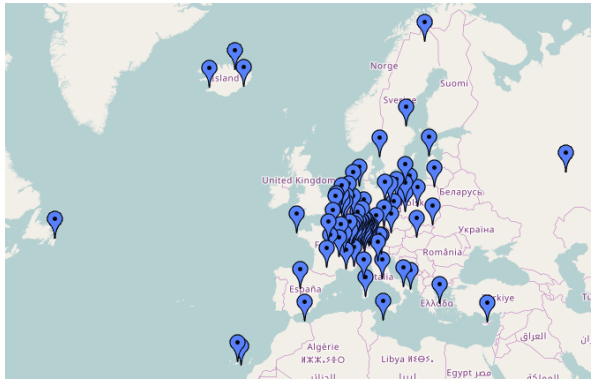
ZIMJ
(Javad)

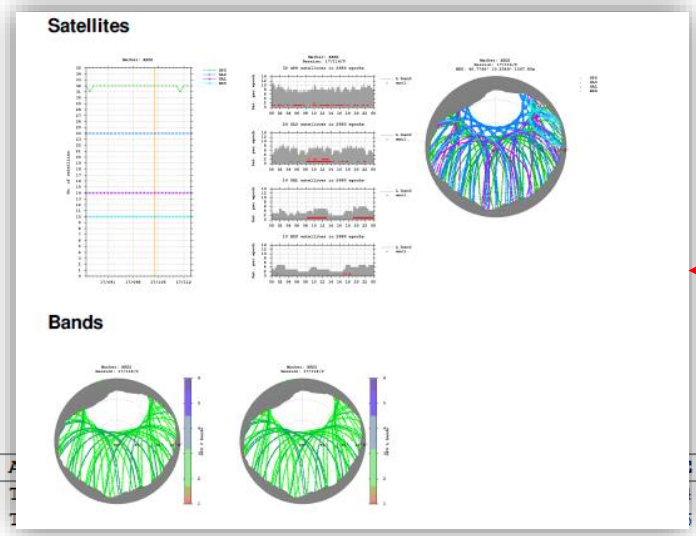


Monitoring RINEX3 Tools

EUREF Multi-GNSS WG

- Monitoring using Anubis and BNC
  http://pnac.swisstopo.admin.ch/pages/en/anubis_monitor_r3.html
  - 130 stations with RINEX3 (long and short names)
  - BNC for editing an merging RINEX3





> 50 (R2) – 110 (R3) plots/site/day

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

Field Equipment swisstopo

- Old GPS-only receivers end-of life reached
- Evaluation campaign in Thun (December 2015)
- All manufacturers fulfilled technical specifications
- Purchase of 8 Multi-GNSS receivers and antennas end of 2015: Trimble NetR9 in Feb. 2016; RINEX3 data flow in place

Zug GNSS Test campaign

ZUG16
ZUG16_
ZUG16_1470136995
ZUG16_1470139447
ZUG16_1470807254
ZUG16_1470809910
ZUG16_1470815109
ZUG16_1A_
ZUG16_1AI
ZUG16_2A_
ZUG16_42_
ZUG16_4A_
ZUG16B
ZUG16B0_
ZUG16B4_
ZUG16B43T
ZUG16_BCK
ZUG16_CMP
ZUG16F
ZUG16F11N
ZUG16F13T
ZUG16F21N
ZUG16F23T
ZUG16GR1
ZUG16L
ZUG16L0_
ZUG16L4_
ZUG16L4_2
ZUG16L42I
ZUG16L4_.bck
ZUG16L4_.bck2
ZUG16L4_I
ZUG16L5_
ZUG16M
ZUG16M11N
ZUG16M11N_I
ZUG16M13T
ZUG16M13T_I
ZUG16M21N
ZUG16M21N_5
ZUG16M23T
ZUG16M23T_5
ZUG16M41N
ZUG16M41N_5
ZUG16M41N_B
ZUG16M41N.bck
ZUG16M41N_I
ZUG16M41N_N
ZUG16M43T
ZUG16M43T_5
ZUG16M43T_B
ZUG16M43T.bck
ZUG16M43T.bck2
ZUG16M43T_I
ZUG16M43T_N
ZUG16O
ZUG16O41N
ZUG16O43T
ZUG16P
ZUG16P41N
ZUG16P43T
ZUG16_T
ZUG16_TEST

- April 5-6, 2016
  - 1 session old equipment
  - 1 session new equipment

- Data flow validation (repair formats; missing APROX POSITION in RINEX3)
- BSW53 Tests
  - MGEX orbits CODE
  - 60 BSW53 BPE alternatives analysed

Influence: GPS -> Multi-GNSS

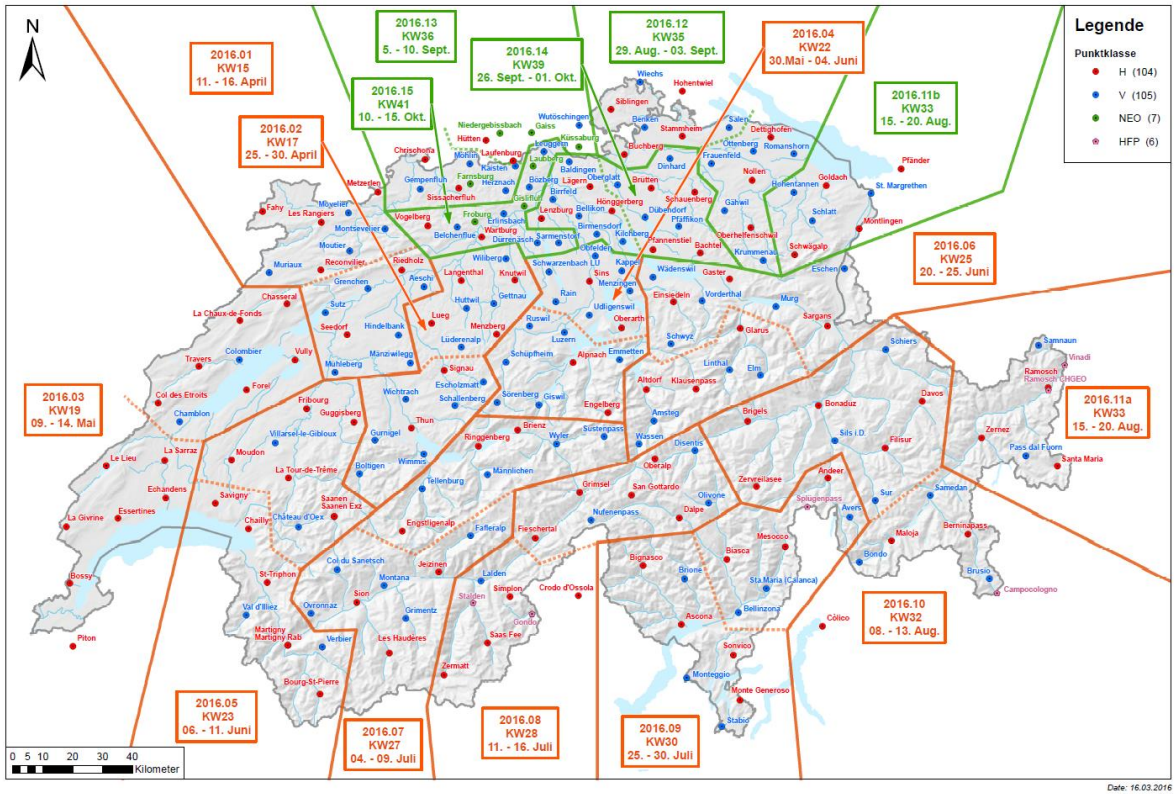
```
Session 1 versus Session 2
-------------------------------------------------------------------------
FILE 1: F1_160970.CRD: AUTOCAMP_160970: Final session coordinate results
FILE 2: F1_160980.CRD: AUTOCAMP_160980: Final session coordinate results
LOCAL GEODETIC DATUM: IGb08
RESIDUALS IN LOCAL SYSTEM (NORTH, EAST, UP)
-------------------------------------------------------------------------
| NUM |      NAME         | FLG |     RESIDUALS IN MILLIMETERS    |   |
-------------------------------------------------------------------------
|     |                   |     |                                 |   |
|   1 | 1100              | A A |      -0.08      0.01      0.58 |   |
|   2 | 1131.652          | A A |      -0.37      1.79     13.27 | V |
|   3 | 1200              | A A |      -0.95      0.67      0.20 |   |
|   4 | 1300              | A A |       0.22     -0.50     -1.24 |   |
|   5 | 300               | A A |       0.45     -0.28     -0.60 |   |
|   6 | 800               | A A |       0.36      0.09      1.06 |   |
|     |                   |     |                                 |   |
-------------------------------------------------------------------------
|     | RMS / COMPONENT   |     |       0.57      0.44      0.92 |   |
|     | MEAN              |     |       0.00      0.00      0.00 |   |
|     | MIN               |     |      -0.95     -0.50     -1.24 |   |
|     | MAX               |     |       0.45      0.67      1.06 |   |
-------------------------------------------------------------------------
```

Comparison: Old (GPS) – New (Multi-GNSS)

Steel mast vs. Tripod
→ Tripod for CHTRF

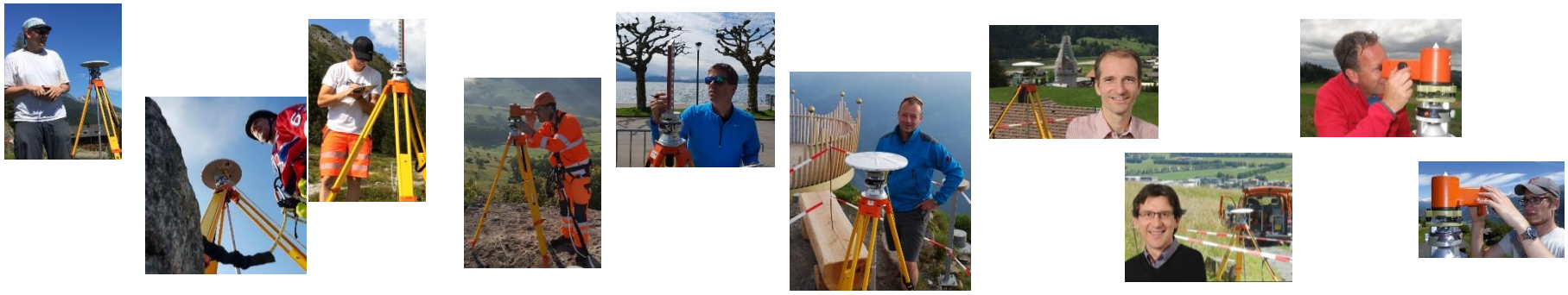
CHTRF2016 Multi-GNSS campaign

- All ~200 reference points to be measured
- Multi-GNSS experiences gained on this campaign (permanent analysis second step; less time critical)



CHTRF2016 Multi-GNSS campaign

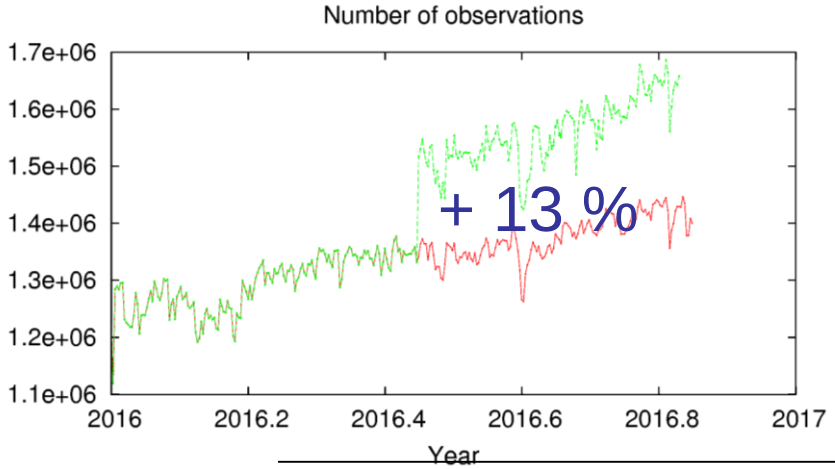
- 10 operators
- 15 weeks (Mo – Sa)
- April 11 – October 14, 2016
- ~ 44 hours of measurements per point
- All data analysed already: Multi-GNSS; BSW53
  - Horizontal position ~ 1 cm with official coordinates
  - Vertical position: to be validated (switch from relative to absolute antenna PCVs)



Switch to Multi-GNSS for EUREF

- E-Mail announcement on 29-Jul-2016 (EUREF Mail 8644)
- RINEX-3 observation data (if available), otherwise RINEX-2
- CODE MGEX products available in time! Thanks to AIUB/CODE
- Troposphere modelling changed from GMF to VMF
- ~ 13% more double-difference observations w.r.t. GPS+GLO (additional constellations not yet complete)
- Impact on coordinates is small: std N/E/Up: 0.3/ 0.3/0.7 mm

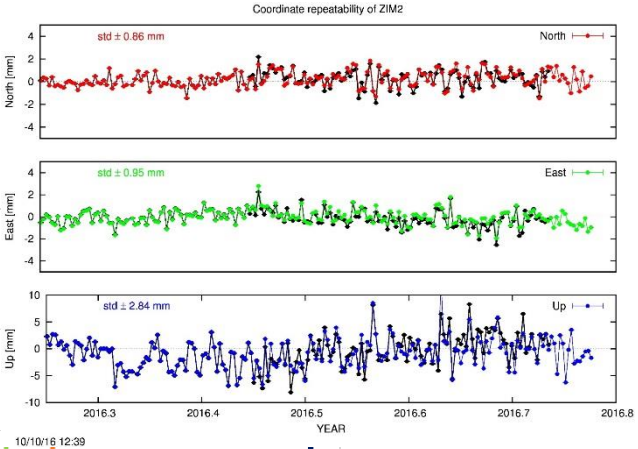
week 1905

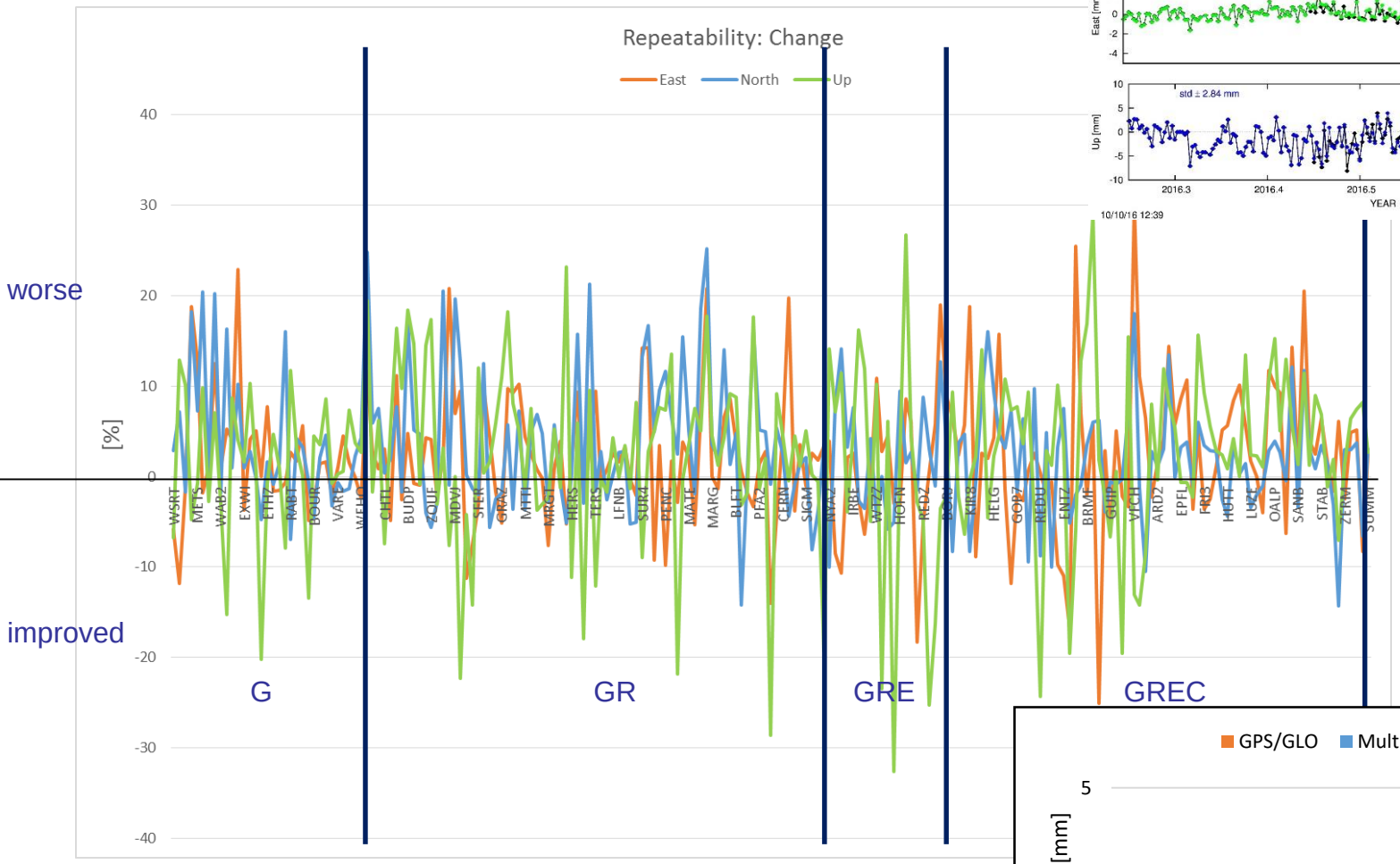


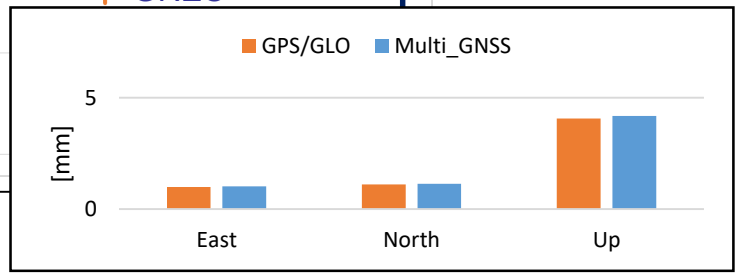

```
LIST OF OUTLIER STATIONS
------------------------
STATION                          RESIDUALS (MILLIMETERS)
                                   N      E      U
EGLT 10032M001                  -0.91  -0.01 -0.87  Egletons, FR  (GREC)
GUIP 10004M501                  -0.37  -0.87  0.94  Guipavas, FR  (GREC)
OBE4 14208M007                   1.14   0.87  0.14  Oberpfaffenhofen, DE (GRE)
```

AGNES Multi-GNSS: Repeatabilities

- 206 stations, 15 parallel proc. weeks new vs old processing scheme







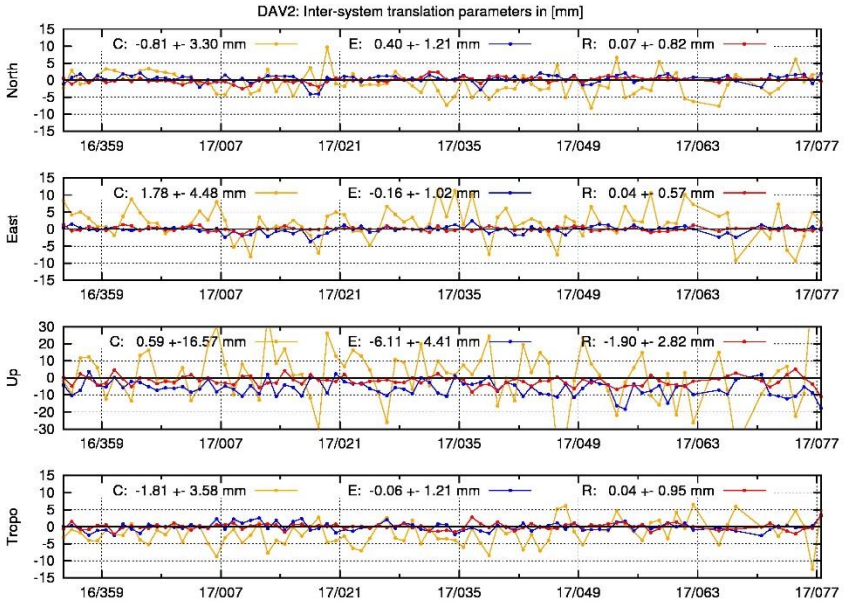
Inter-System parameter

- AGNES processing using Multi-GNSS
- Since Nov. 2016 on pnac web

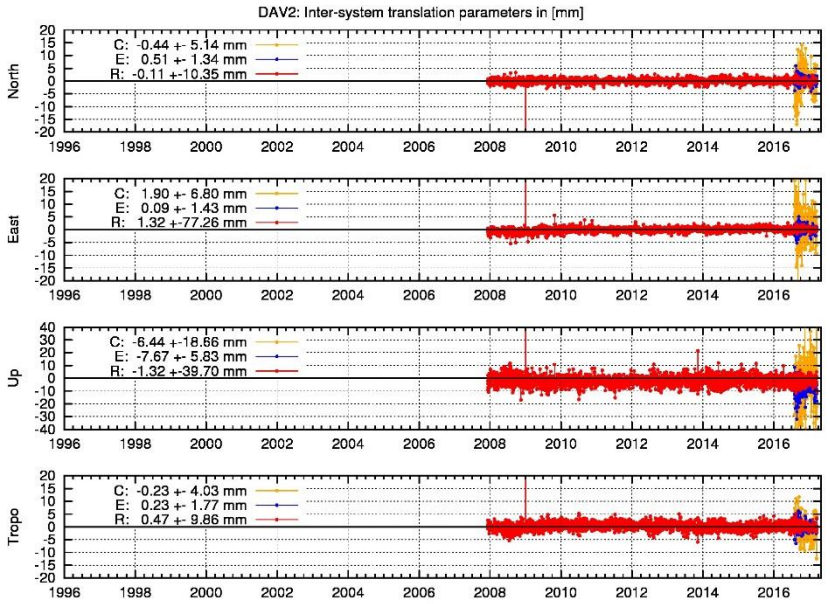
GPS (Ref)
GLO
GAL
BDS

DAV2

Daily: last month



Daily: Long-term



GPS/GLO
from repro2

Multi-GNSS
BSW53

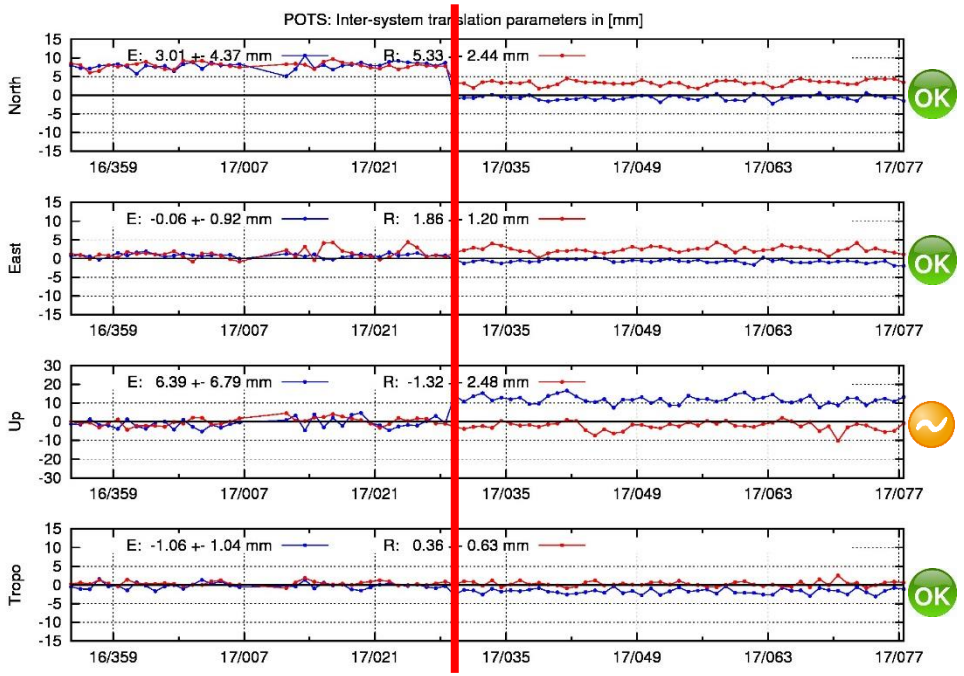
IGS14 antenna PCV change

http://pnac.swisstopo.admin.ch/pages/en/qsumpots.html#TRA_MONTH

- POTS (JAV_RINGANT_G3T NONE 316)
  case EPN: ind. PCVs from Robot incl. GAL

IGS08 group

E14 robot calibration

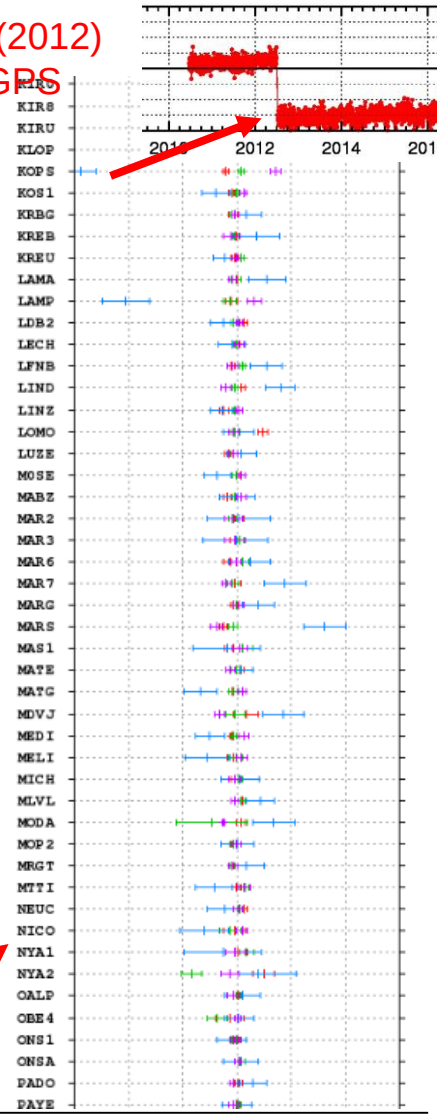


GLO

GAL

GAL satellite PCVs from GPS/GLO

KOPS antenna change (2012)
APOS – dh 3 cm GLO-GPS



IGS14 rec. antenna model change (Feb 2017)

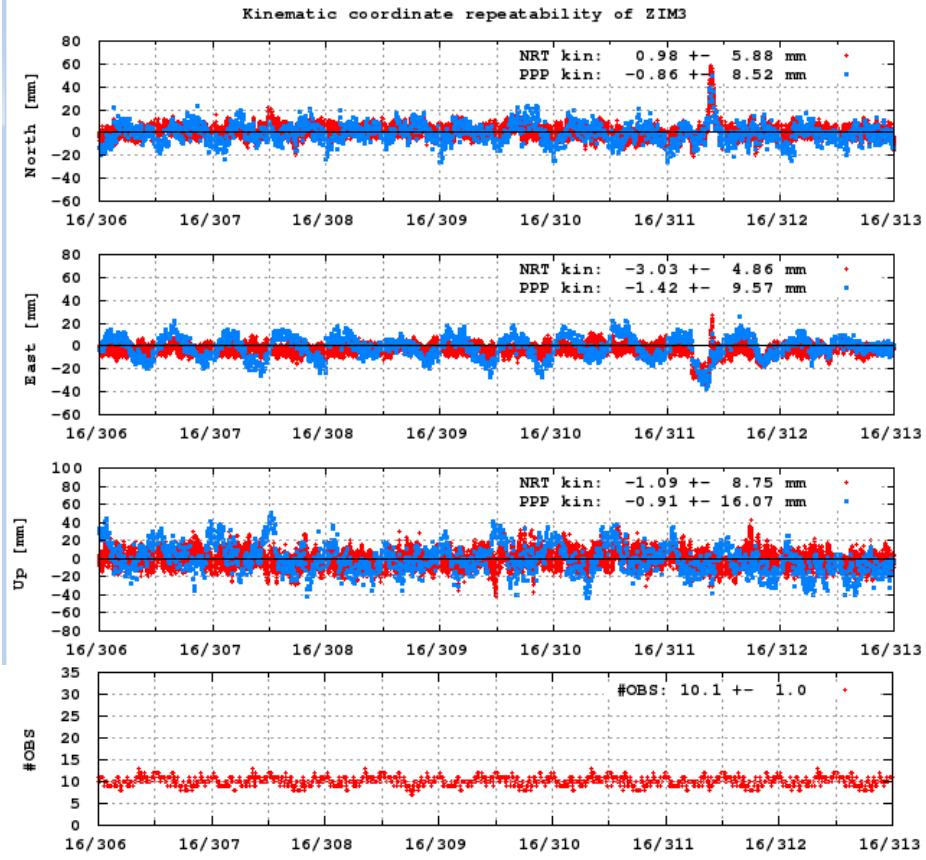
Mean estimates for all stations: R :4P - 2P

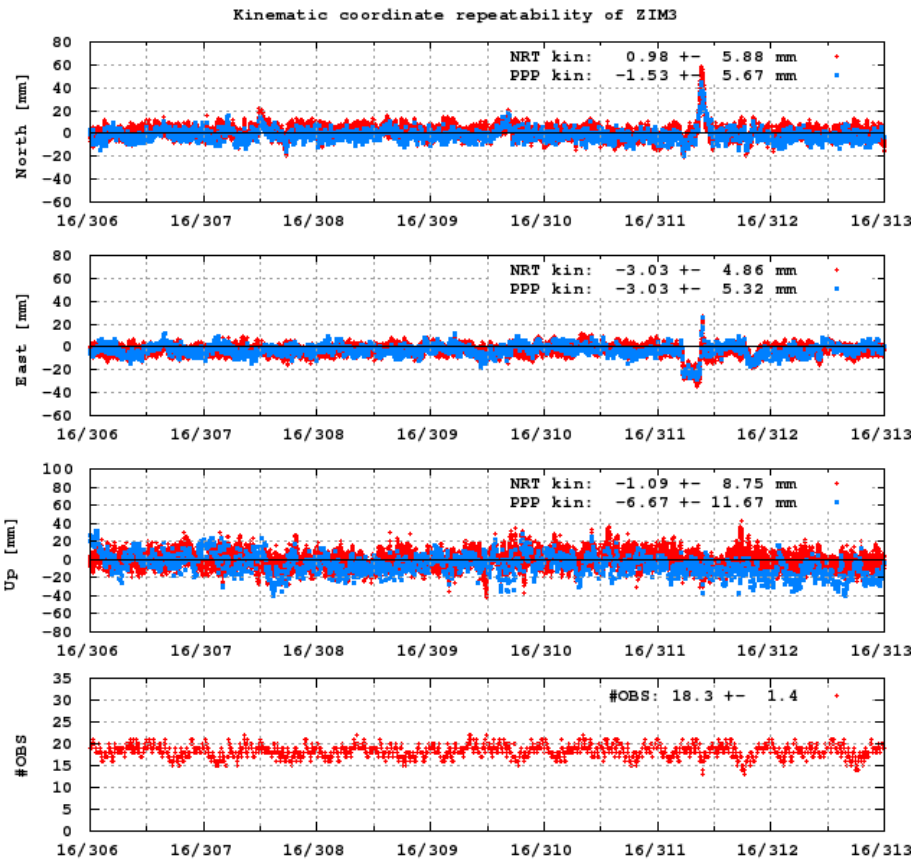
Mean estimates for all stations: E :4P - 2P

Mean estimates for all stations: C :4P - 2P

PPP for product/strategy evaluation

- CODE final rapid product
- Left: GPS only (V_USE=G), right: GPS+GLO (V_USE=GR)





- PPP and Network-Mode: very comparable kin. repeatability

PPP for product/strategy evaluation

- Kin. coordinate repeatabilities over one week for ZIM3

V_B	V_USE	North [mm]	East [mm]	Up [mm]	#OBS/Epo
COD	G	8.52	9.57	16.07	10.1
COD	GR	5.67 (-33%)	5.32 (-44%)	11.67 (-27%)	18.3 (+81%)
COM*	G	11.23	11.42	21.79	9.9
COM	GR	6.86 (-39%)	7.03 (-38%)	14.56 (-33%)	17.7 (+79%)
COM	GRE	6.54 (-42%)	6.50 (-43%)	13.29 (-39%)	21.4 (+116%)
COM	GREC	6.27 (-44%)	6.21 (-46%)	13.22 (-39%)	24.2 (+144%)
GBM	G	9.06	9.78	17.46	10.1
GBM	GR	5.82 (-36%)	5.50 (-44%)	12.46 (-29%)	18.2 (+80%)
GBM	GRE	5.65 (-38%)	5.00 (-49%)	11.87 (-32%)	22.0 (+118%)
GBM	GREC*	5.78 (-36%)	10.24 (+5%)	13.49 (-23%)	25.4 (+151%)

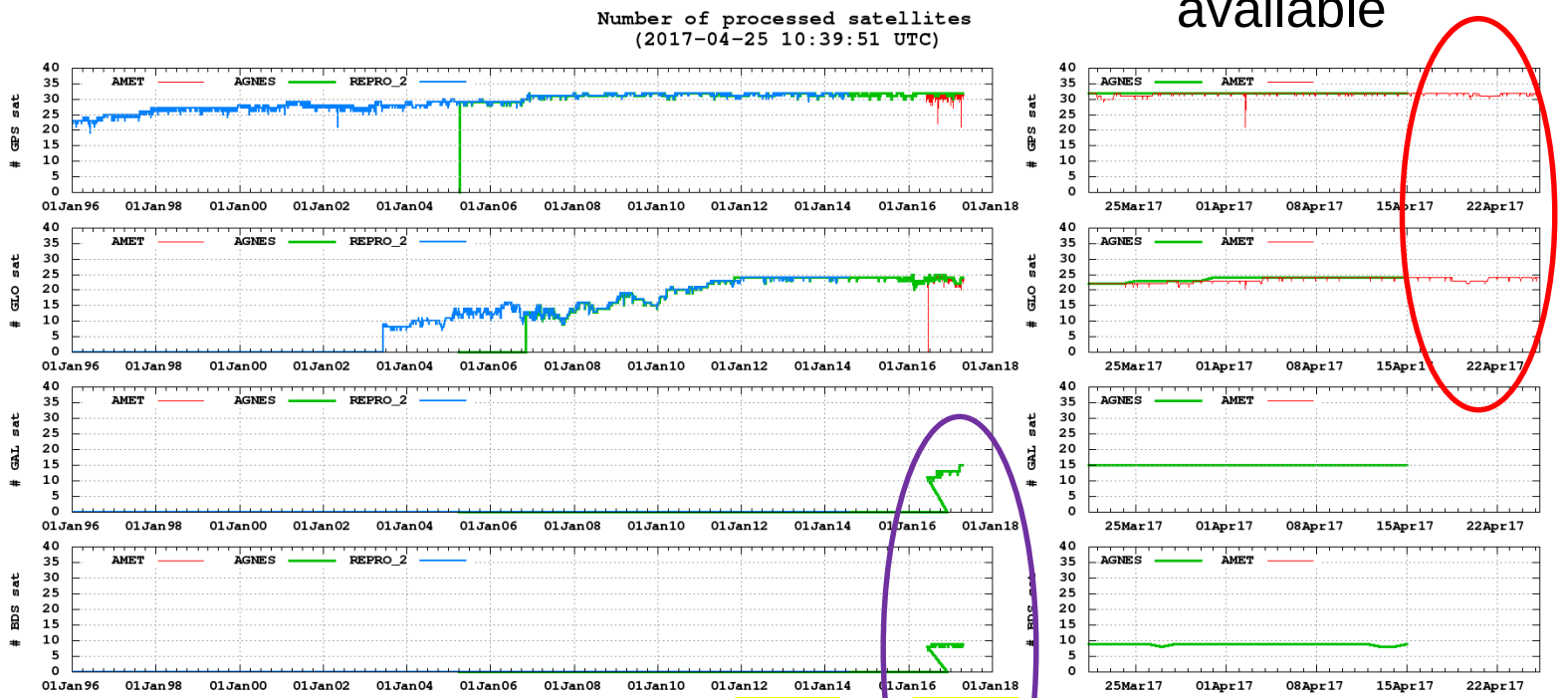
*COM: Satellite clocks have 300 s sampling, all others 30 s

*GBM: Issue with C05 (GEO), which is not included in COM

- General benefit adding more GNSS

Summary (view on # satellites)

- Reprocessing 2(BSW52): GPS+GLO - next planned in 2-3 yrs 55
- Campaigns (BSW53): GPS+GLO+GAL+BDS
- EUREF / AGNES (BSW53): GPS+GLO+GAL+BDS 80
- AMET (hourly) (BSW53): GPS+GLO – Multi-GNSS if EPN hourly available



31 GPS

24 GLO

15 GAL

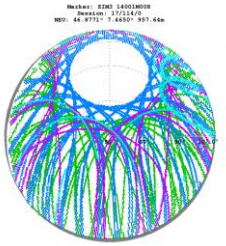
10 BDS

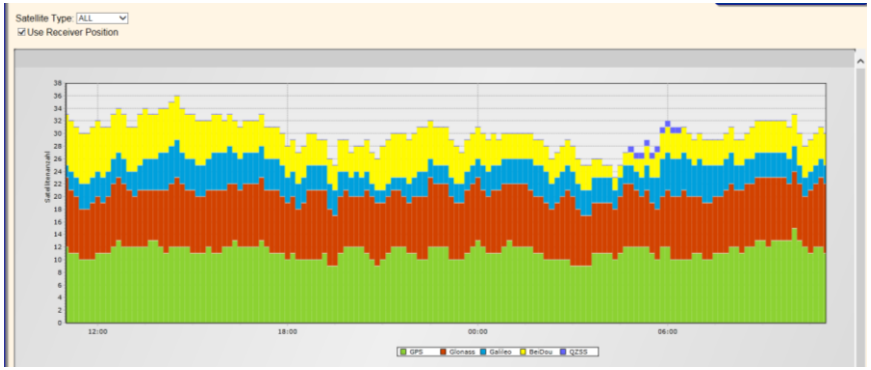
80 Total

23 → 38 → 55 → 80

GAL+BDS

Thanks for your attention





GNSS view from Zimmerwald