Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office of Topography swisstopo

wissen wohin
savoir où
sapere dove
knowing where

swisstopo

Activities Permanent Networks and Reference Frames in Switzerland and Europe

E. Brockmann, D. Ineichen, S. Lutz

Programm

«Herbstanlass 2019»

23.10.2019 I 12 – 18

Geostation Zimmerwald [web I loc]

11.30 – 12.45	**Mittagessen** (fakultativ) im Restaurant National Bern [web I loc]
13.30	**Treffpunkt** in Zimmerwald
13.45 – 14.45	**Vorträge** und Einblicke in die Forschungsgebiete • **Geodäsie in der Schweiz** • **AGNES** • **Zukünftiges dynamisches CH-Referenzsystem** • **Swisstopo & Virtual Reality (VR)** • **Innovationsthemen swisstopo**
14.45 – 15.30	**Kaffeepause**, Austausch und Networking
15.30 – 17.00	**Geführter Rundgang** in der Forschungsstation Zimmerwald • **CH-geodätischer Fundamentalpunkt** • **Raumschrottbeobachtung** • **Satellite Ranging Teleskop**
17.00 – 17.30	Ende der Veranstaltung

Breaking ground in winter 1955, middle: Prof. Dr. Max Schürer

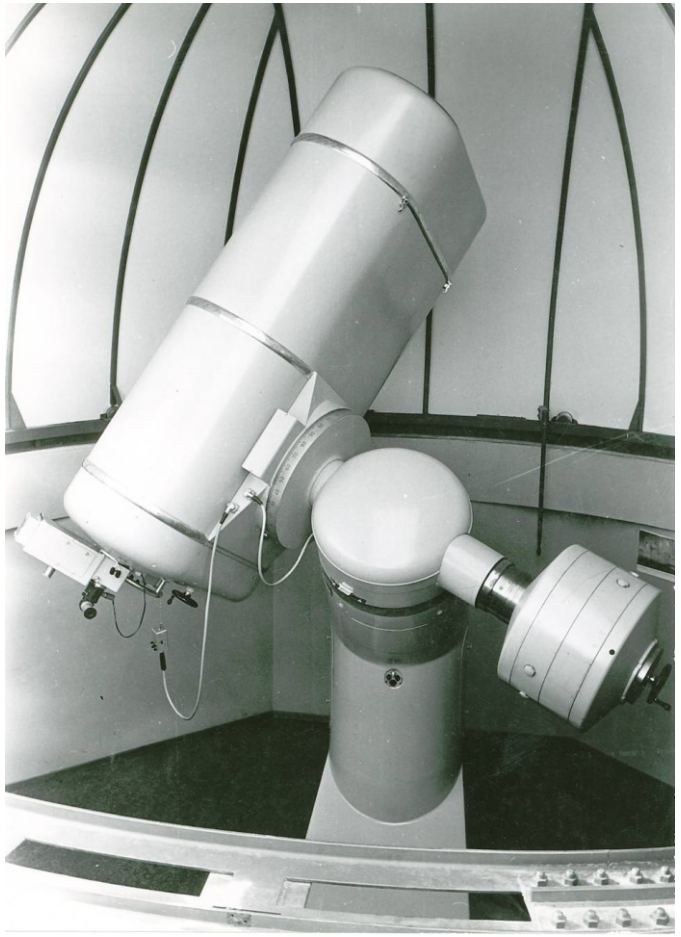

Observatory with scaffolding, Spring 1956 - pure Astronomy («Sternwarte»)

Statistics

Number of pictures collected in Zimmerwald with the Schmidt camera: **10 376**

Number of newly-discovered objects:

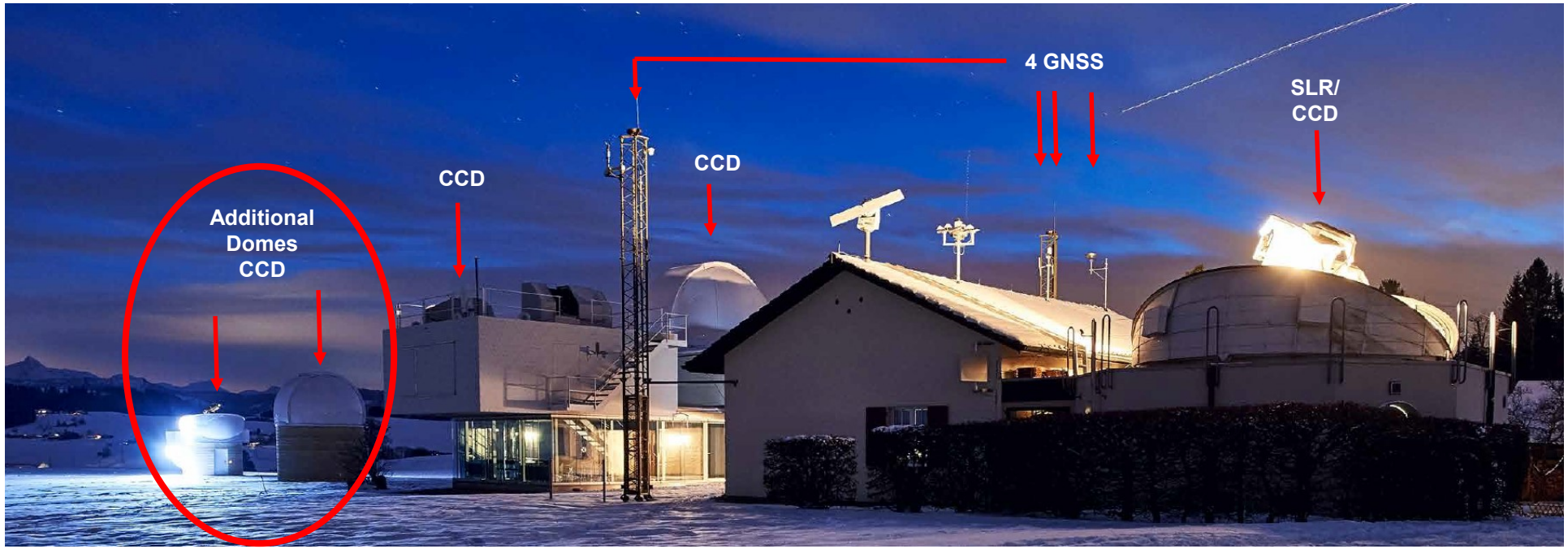
ca. 50 supernovae und novae (exploding stars)
ca. 100 minor planets (asteroids, planetoids)
7 comets



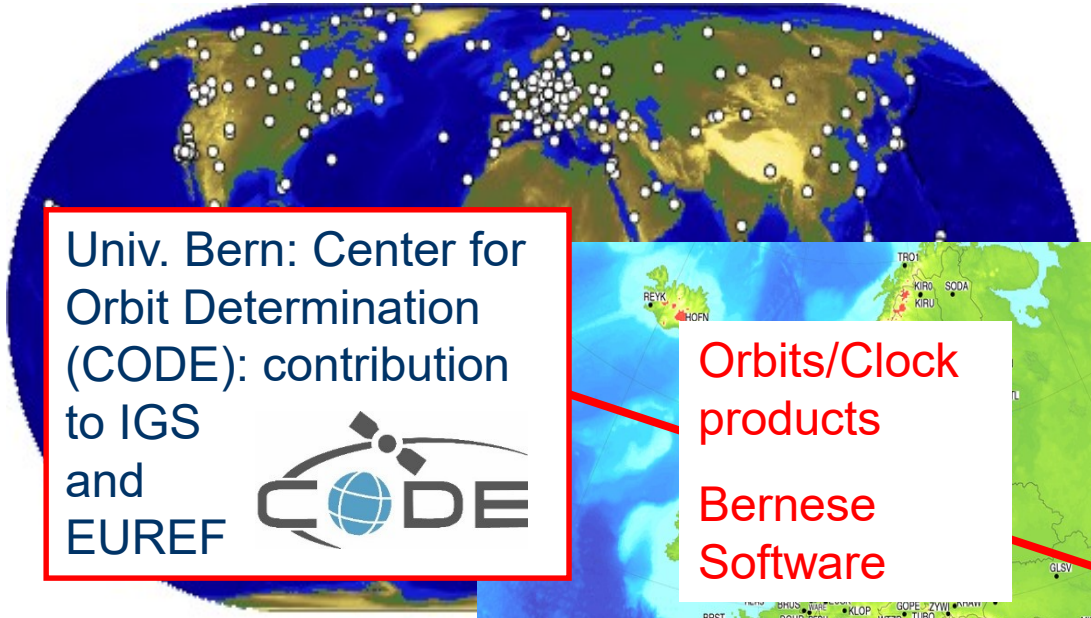
The comet „Wild/2“, discovered from Prof. Dr. Paul Wild was „visited“ in NASAs successfull Stardust-Mission (January 2, 2004 in 240 km distance)

Geostation Zimmerwald

- 4 GNSS stations (ZIMM, ZIM2, ZIM3, ~~ZIMJ~~) actively delivering data to IGS/EPN
- SLR: Satellite Laser Ranging
- 2 additional CCD telecopes for space debris (since 2018)
- **Reference for all geodata in Switzerland and linking station to international networks**



Hierarchical Permanent Networks



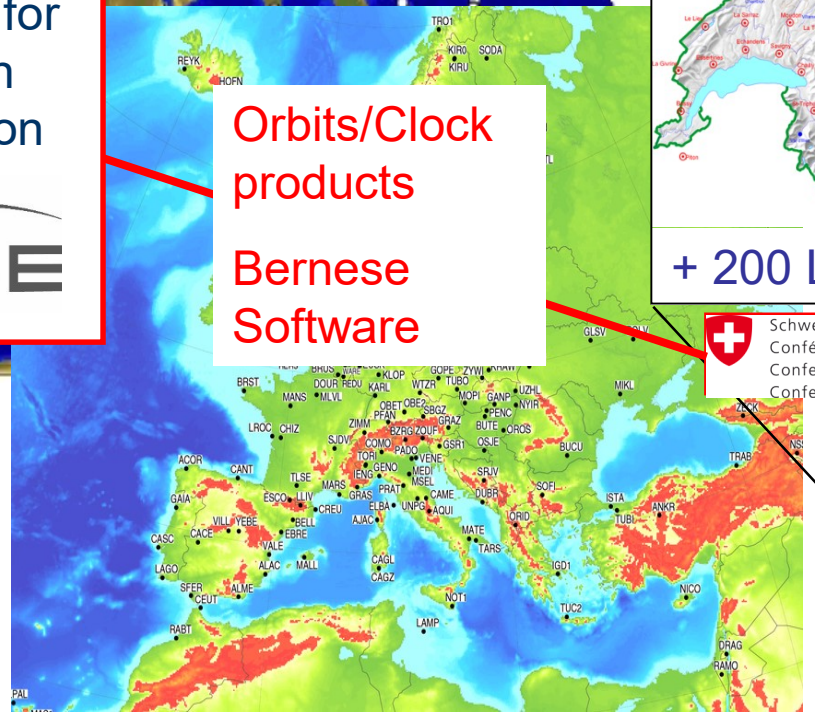
Univ. Bern: Center for Orbit Determination (CODE): contribution to IGS and EUREF

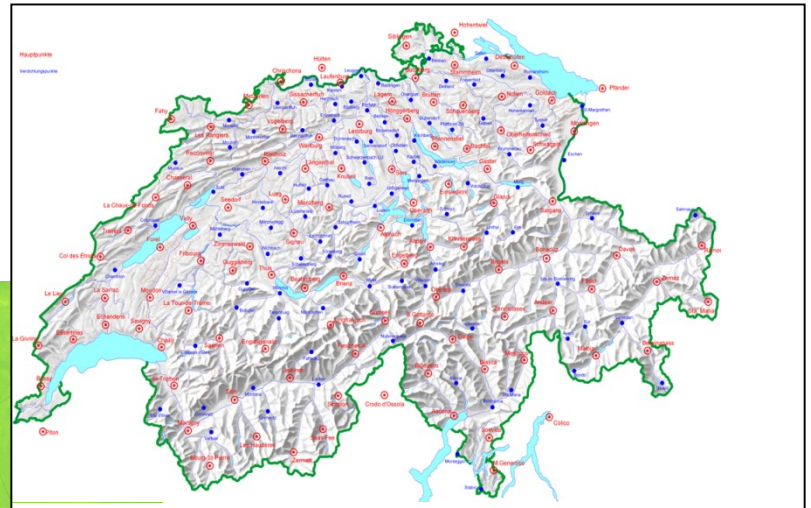
Global: IGS
(400 stations)

Continental: EUREF
(200 stations)

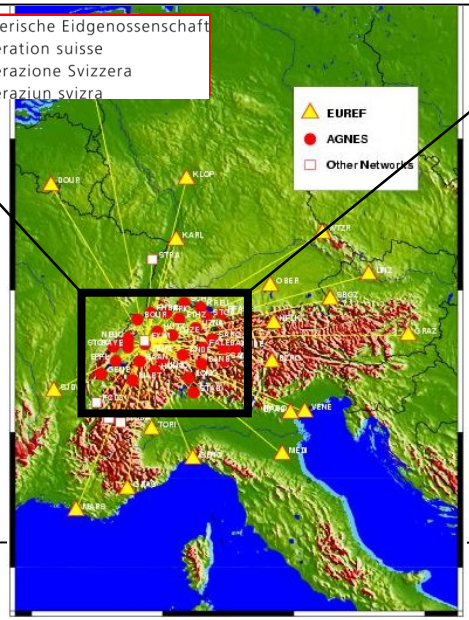
Orbits/Clock products

Bernese Software





+ 200 LV95 control points; not perm.



National: AGNES
(30 stations)

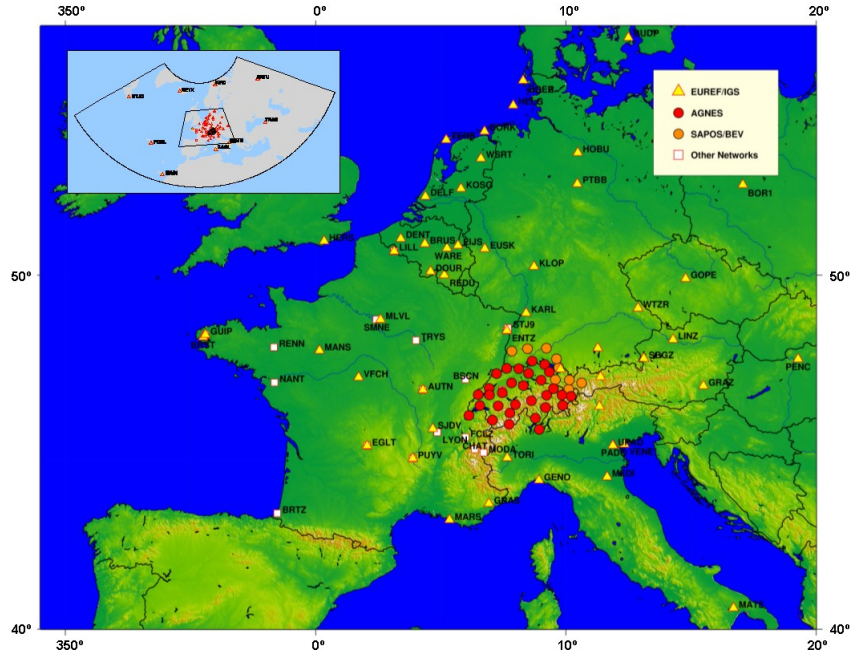
Analyses using Bernese GNSS Software at swisstopo

BSW53
July 2016
GREC
MGEX FINAL

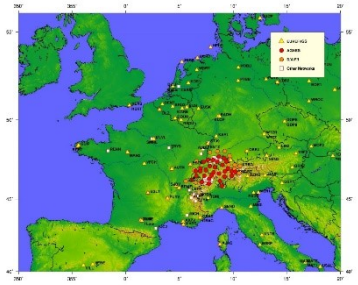
11/17 EPNACs
May 2019
GREC
MGEX FINAL

BSW53
GR July 2016
GRE Sep 2019
ULTRA

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

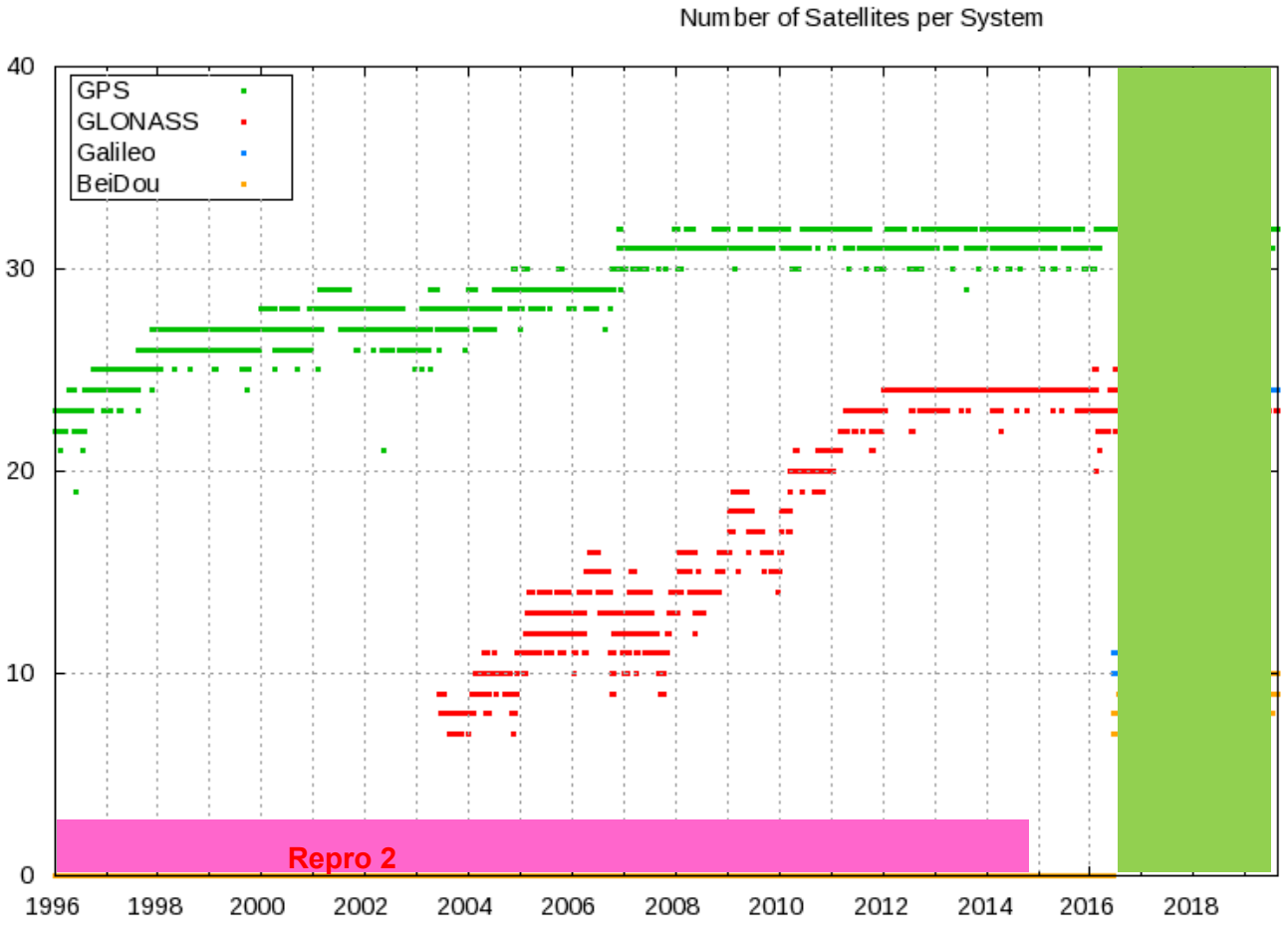


Evolution Multi-GNSS at swisstopo Permanent Analysis Center (PNAC)



Monitoring System:

http://pnac.swisstopo.admin.ch



GPS: 32

Glonass: 24

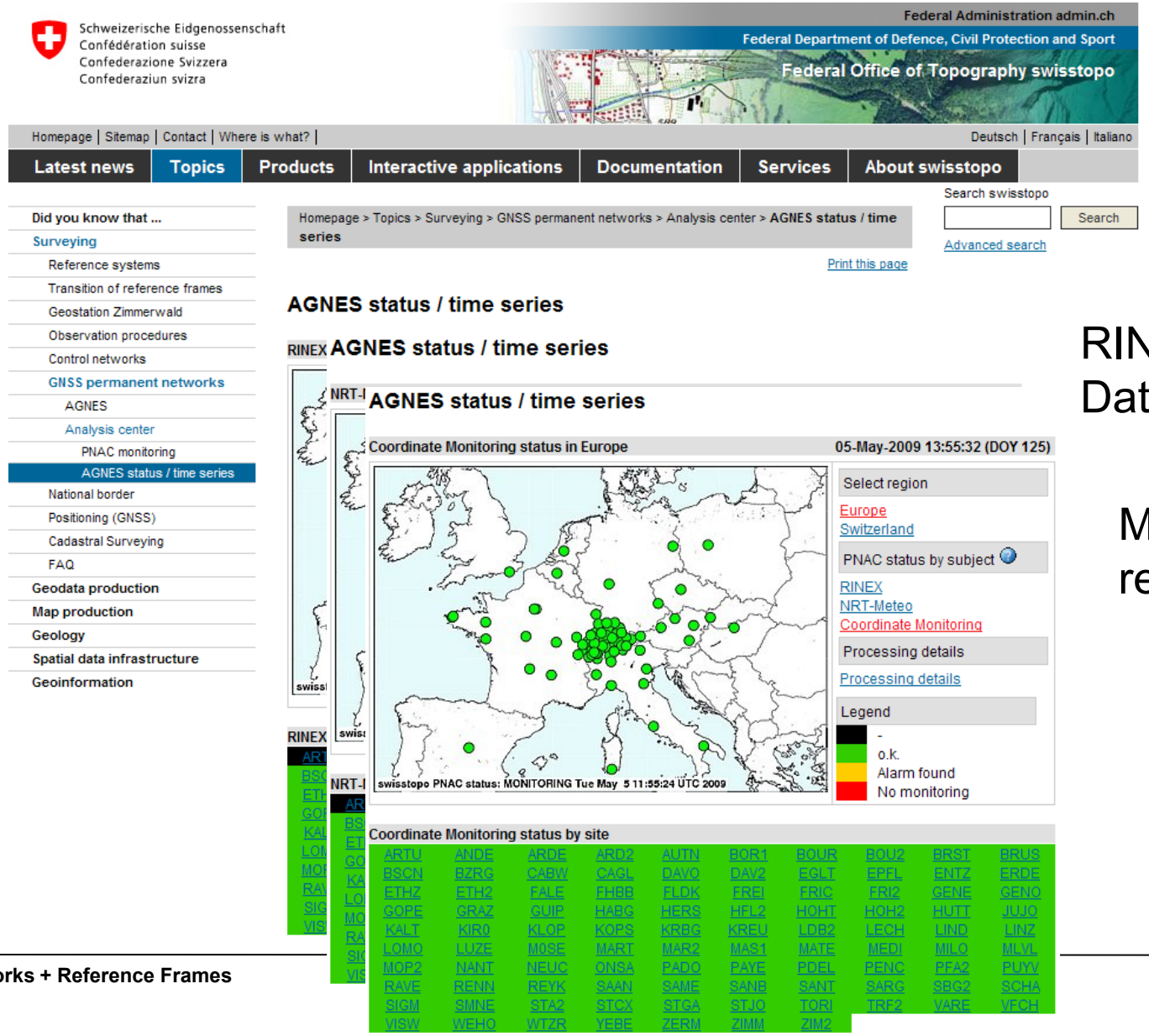
Galileo: 24

Beidou (BDS3 not yet): 10

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

Monitoring web-pages

http://pnac.swisstopo.admin.ch



RINEX Data

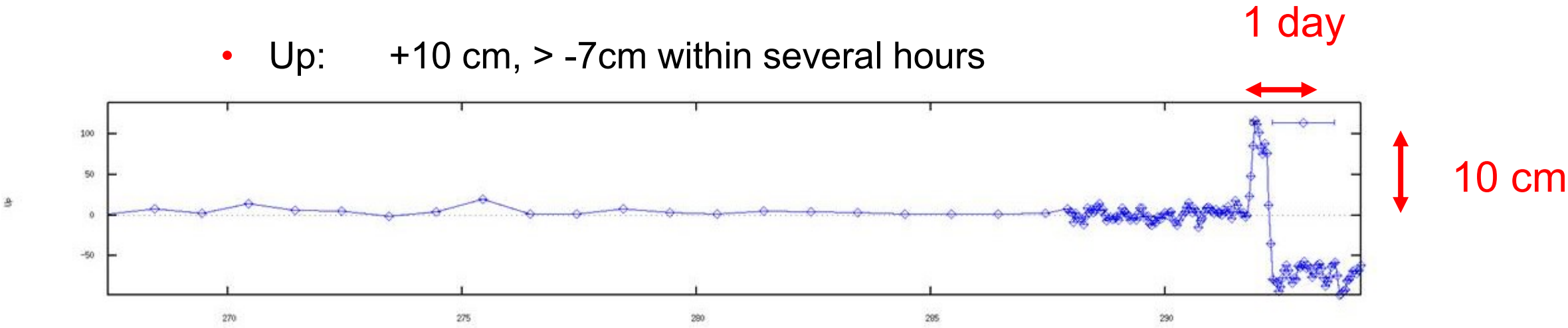
Meteo results

Coordinate results

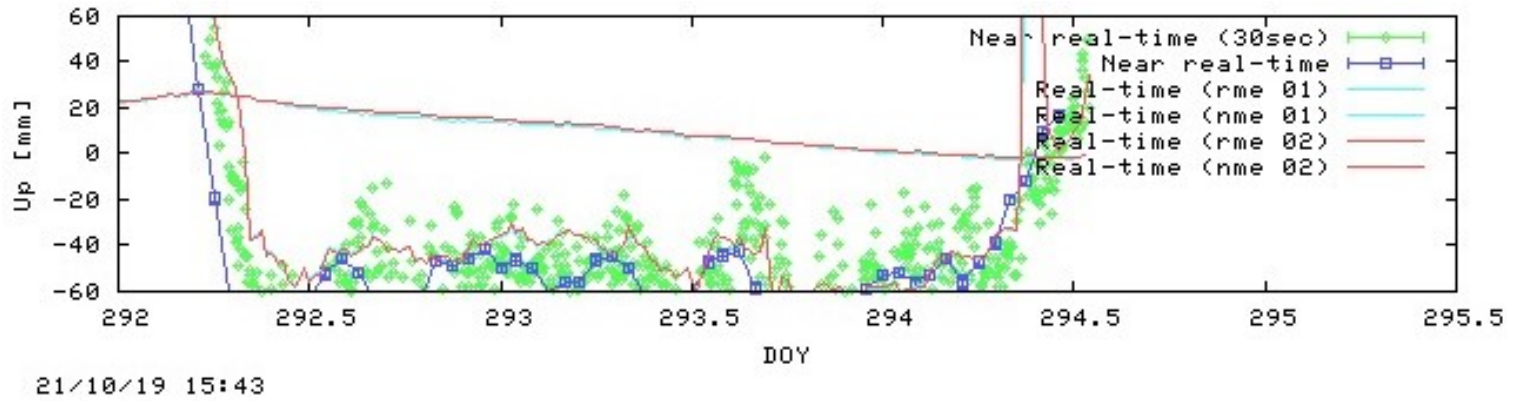
Example: NEUC (20.10.2019)

Sa. 19.10.2019 01:55
pnac@swisstopo.ch
STA/19/01:55(lt02105a): ALARM_OUTLIER_NEUC: http://pnac.swisstopo.admin.ch/pages

- Up: +10 cm, > -7cm within several hours



water in inner choke ring



Reference for Multi-GNSS observations

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

4 ●

or

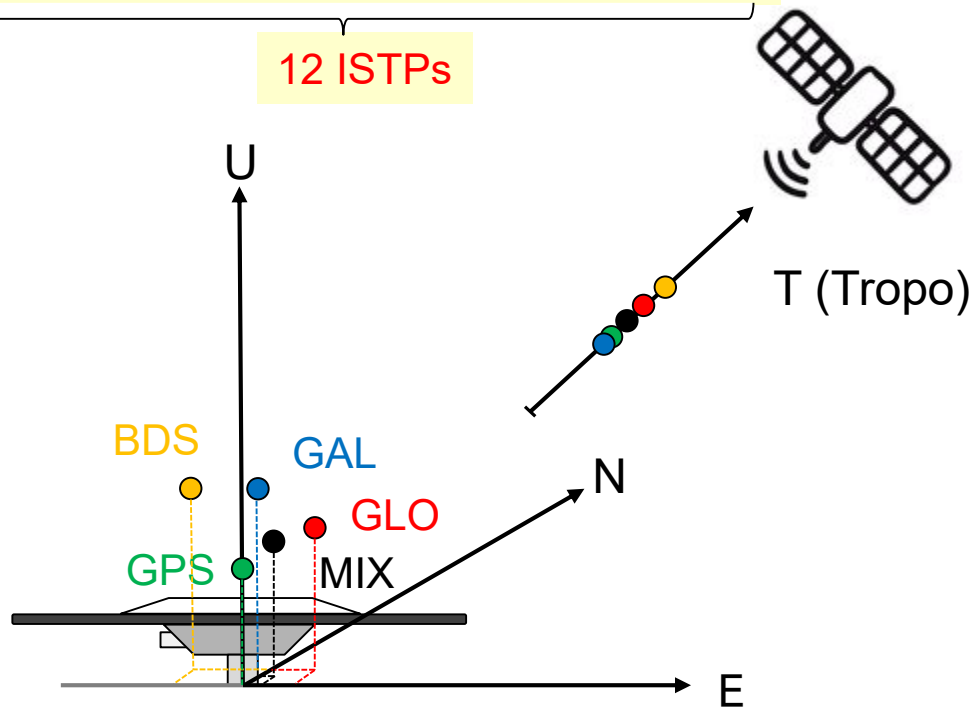
- per satellite system one coordinate (+TRP):
  N,E,U,T | N,E,U,T | N,E,U,T | N,E,U,T

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

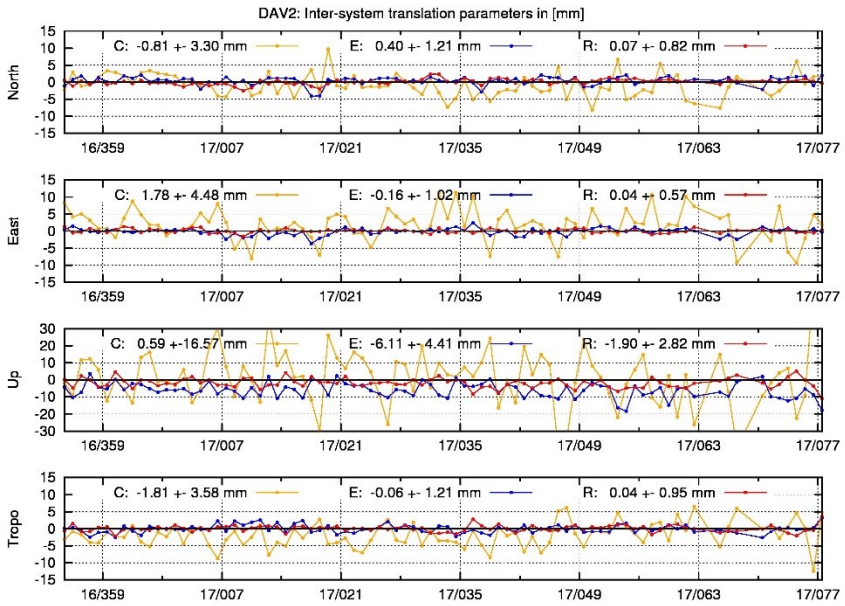
Multi-GNSS analysis: Intersystem parameters

- AGNES processing using Multi-GNSS
- Since Nov. 2016 on pnac web
- Differences worst case 1-2 cm e.g. GPS - GLO

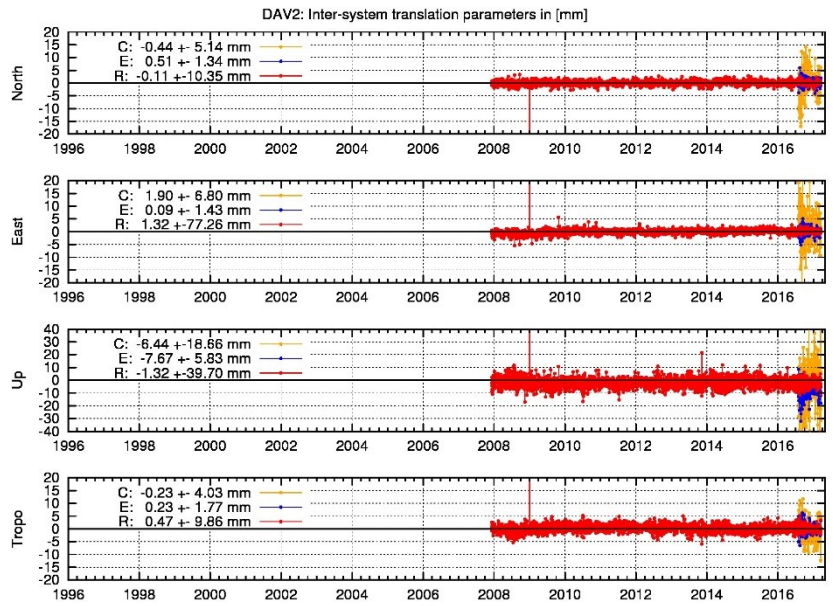
GPS (Ref)
GLO
GAL
BDS

Daily: last month

DAV2



Daily: Long-term



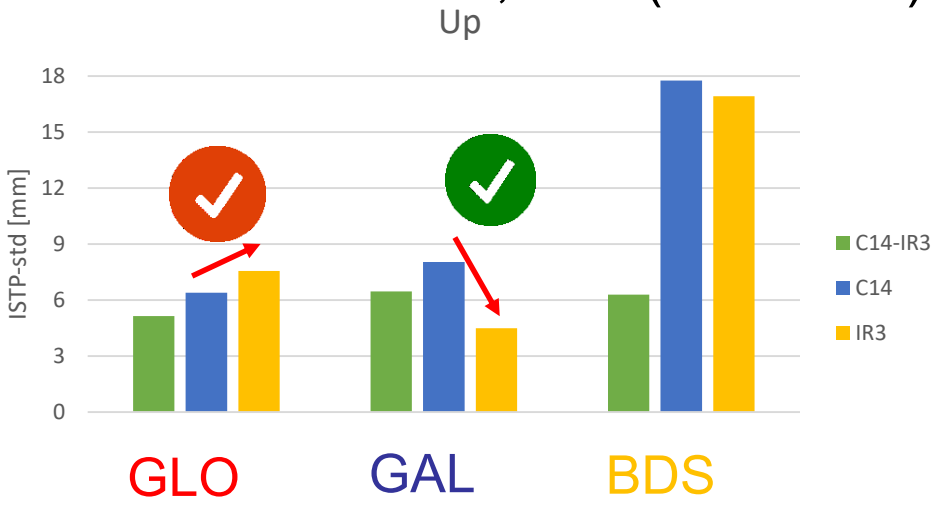
GPS/GLO from repro2

Multi-GNSS BSW53

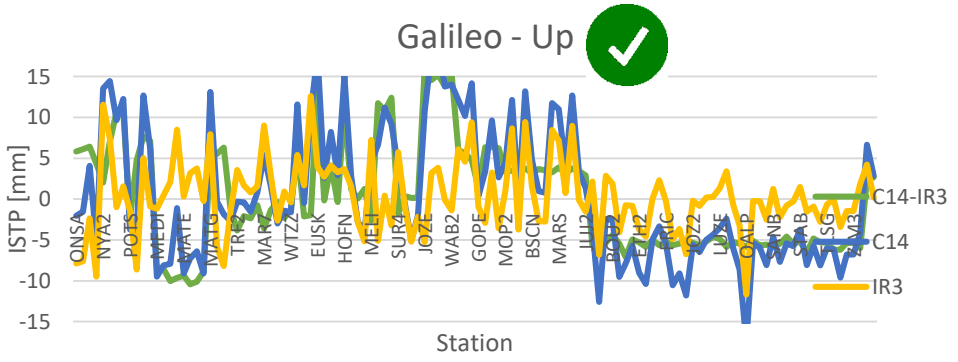
Galileo robot calibrations from Geo++

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) solved, now (Oct. 2019)

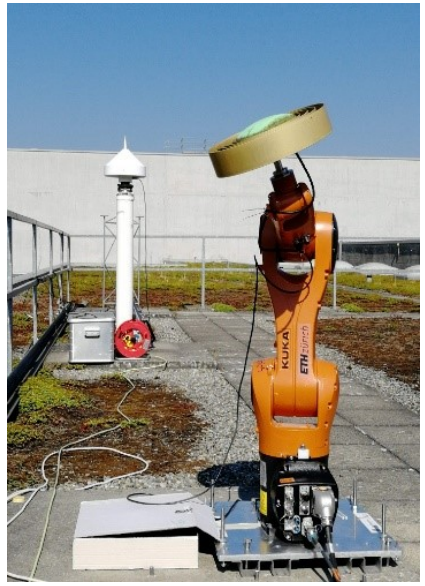


Not a GLO problem, but GPS+GAL

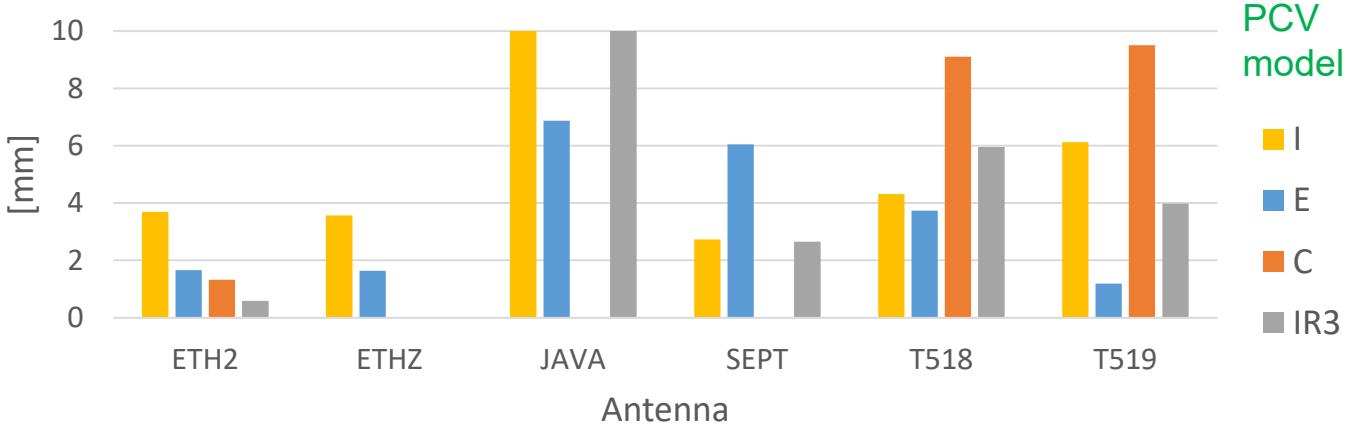


Multi-GNSS antenna calibrations

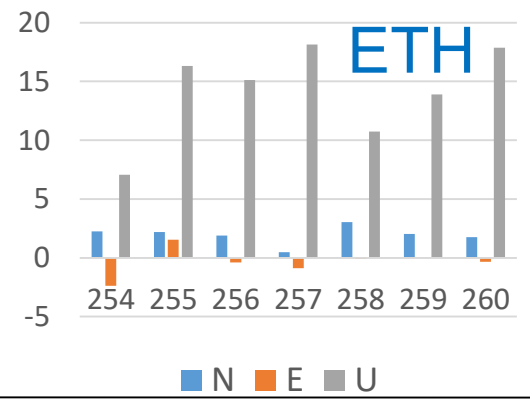
- Collaboration with ETHZ (phd D. Willi)
- Validation campaign with 2 swisstopo field antennas 518, 519 using 4 PCV mod.
  - ground truth comparison
  - Intersystem parameter checks
- New geo++ values Galileo IR3 show good agreement with GPS – will be used from now on…



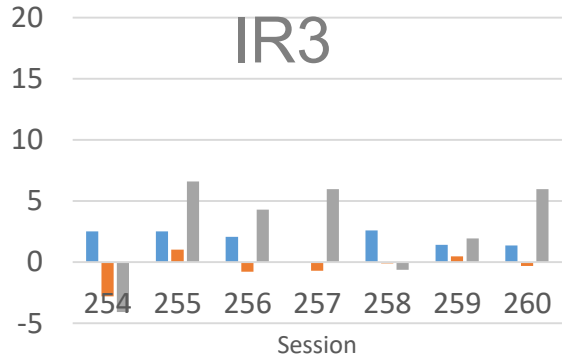
L3Y: 3D Differenz Ground Truth (GE, by antenna, 10 degree): E,I,C,IR3 PCVs



519 ETH PCV: GPS-Gal coordinates [mm]

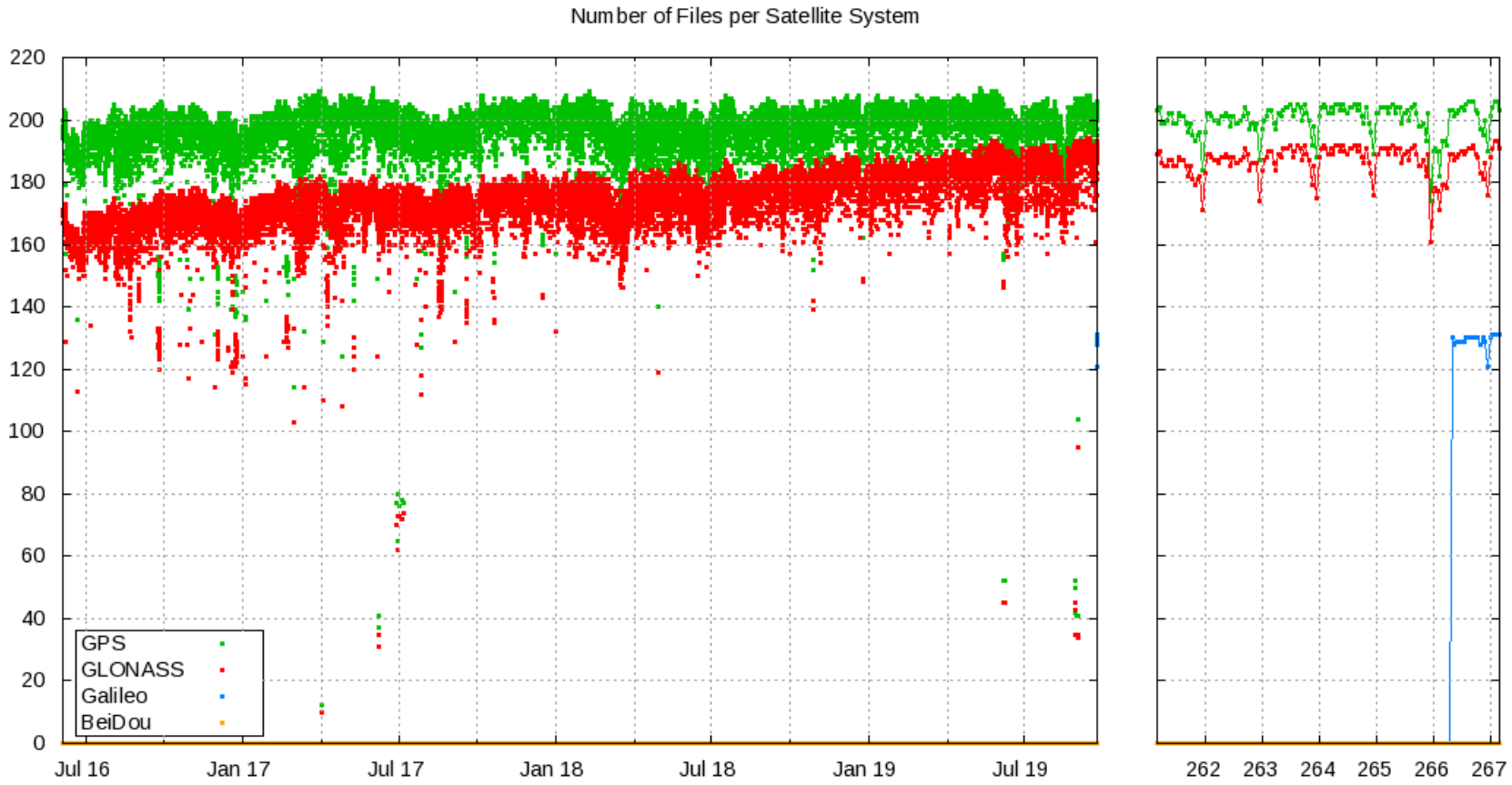


ISTPs G-E T519 IR3 PCV [mm]

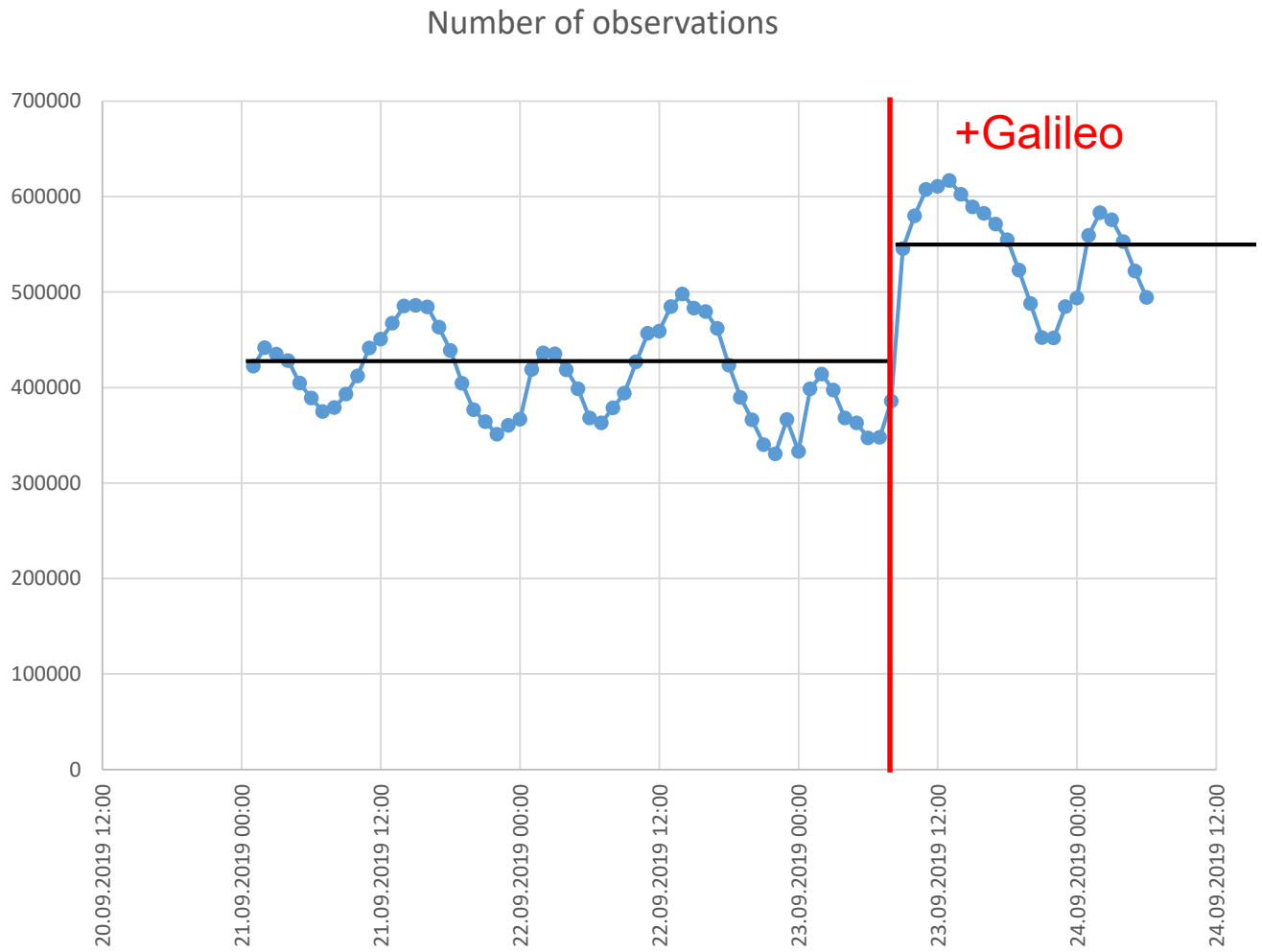


Galileo in Rapid and Ultra-Rapid products

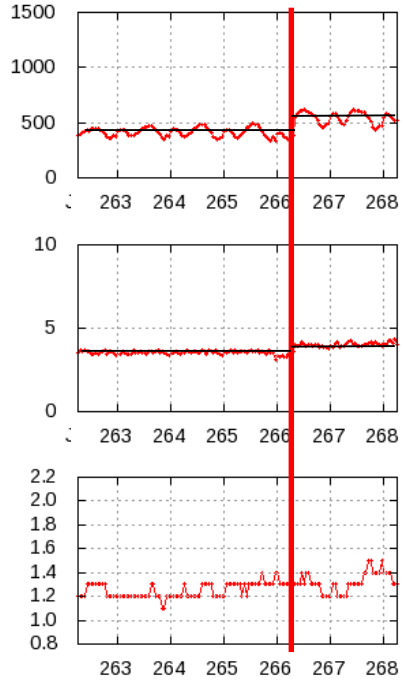
CODE products inclusing Galileo since 23.9.2019 (Tag 266)



Impact: # of observations



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



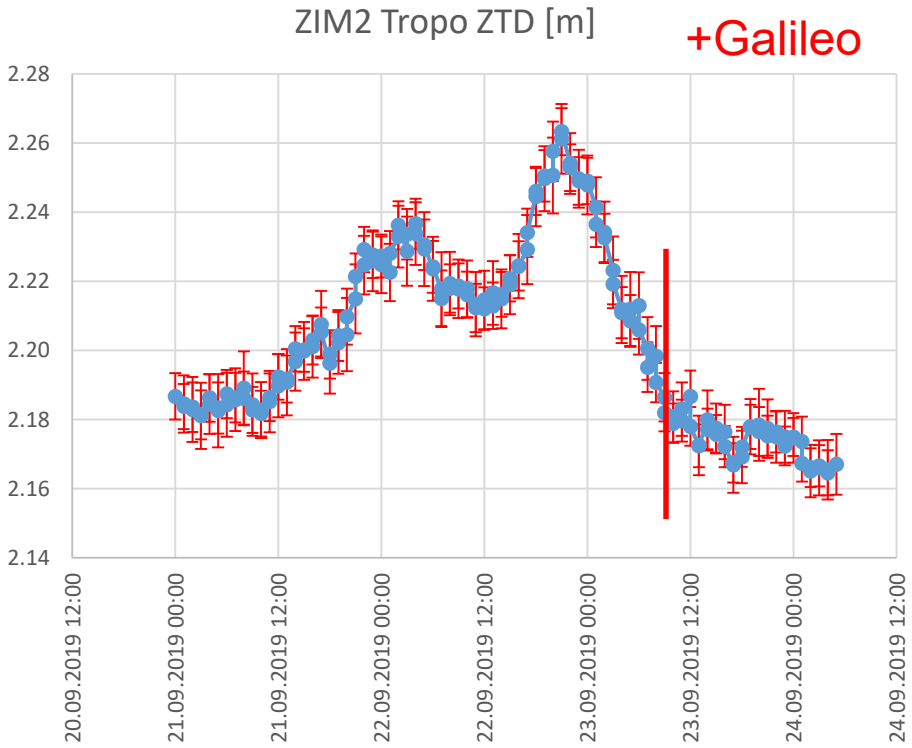
#OBS/1e3

#PAR/1e3

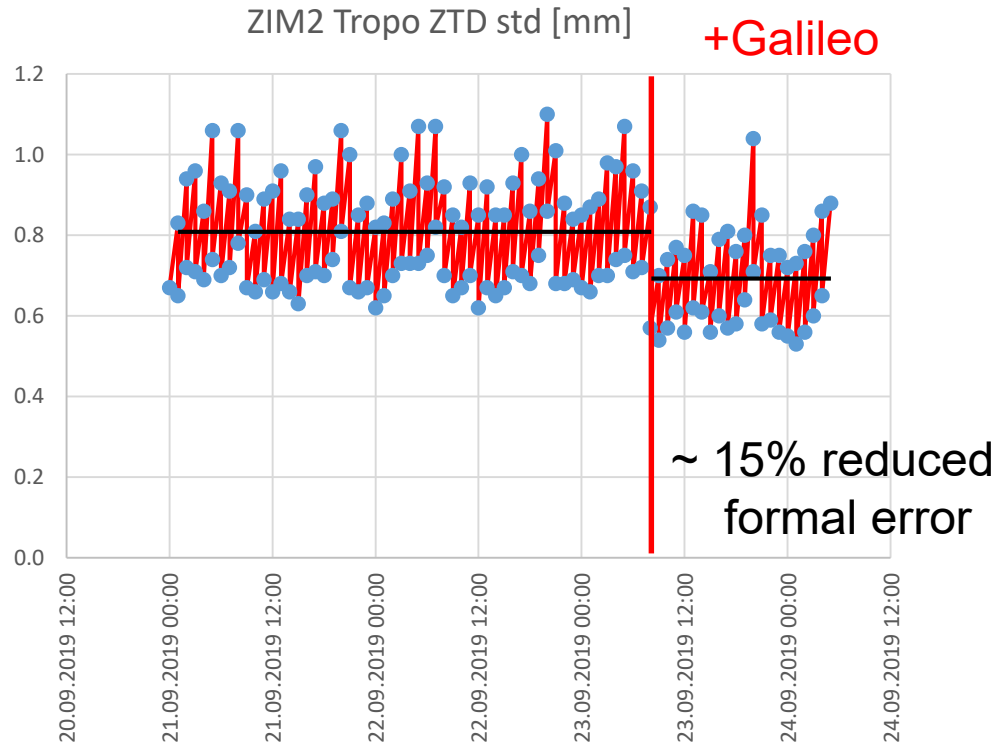
RMS [mm]

Troposphereparameter: ZIM2

Impact ZTD (+ std as error bar)



Impact standard deviation (formal error)



kPPP (kinematic Precise Point Positioning)

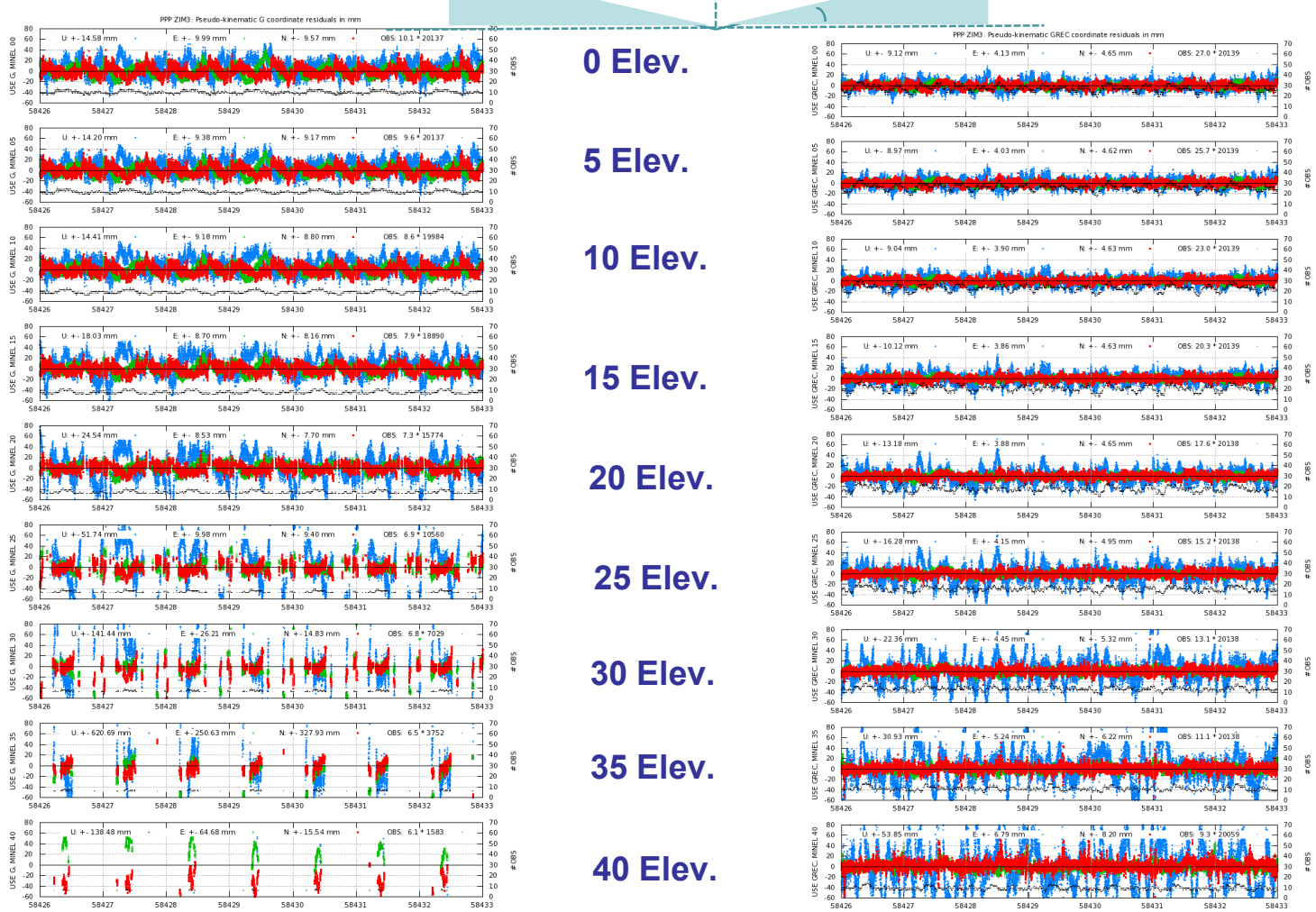
Nov. 2018

BSW53:
ZIM3
1 week
PPP-kinematic

GPS CODE MGEX

GPS + GLO + GAL + BDS CODE MGEX

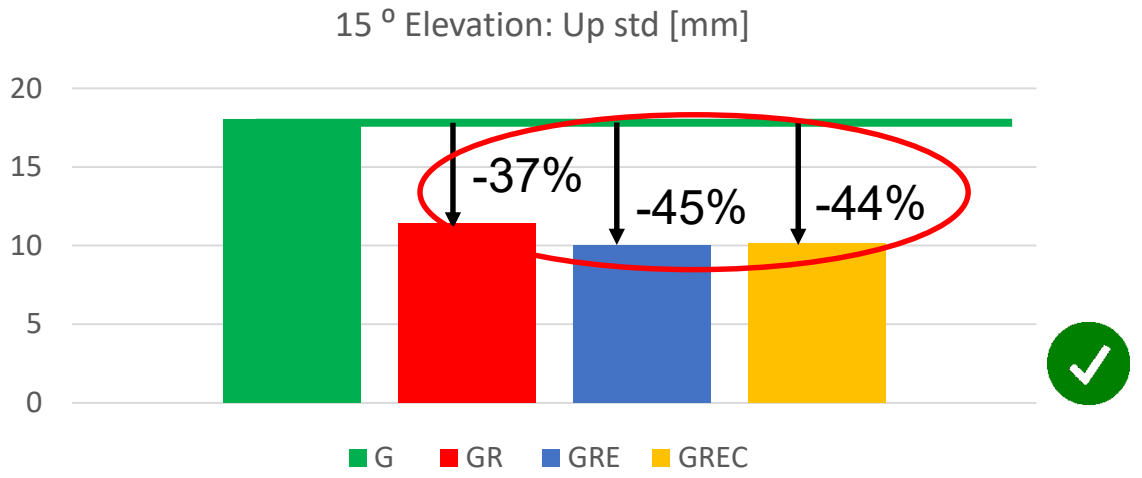
0-40 Elev.



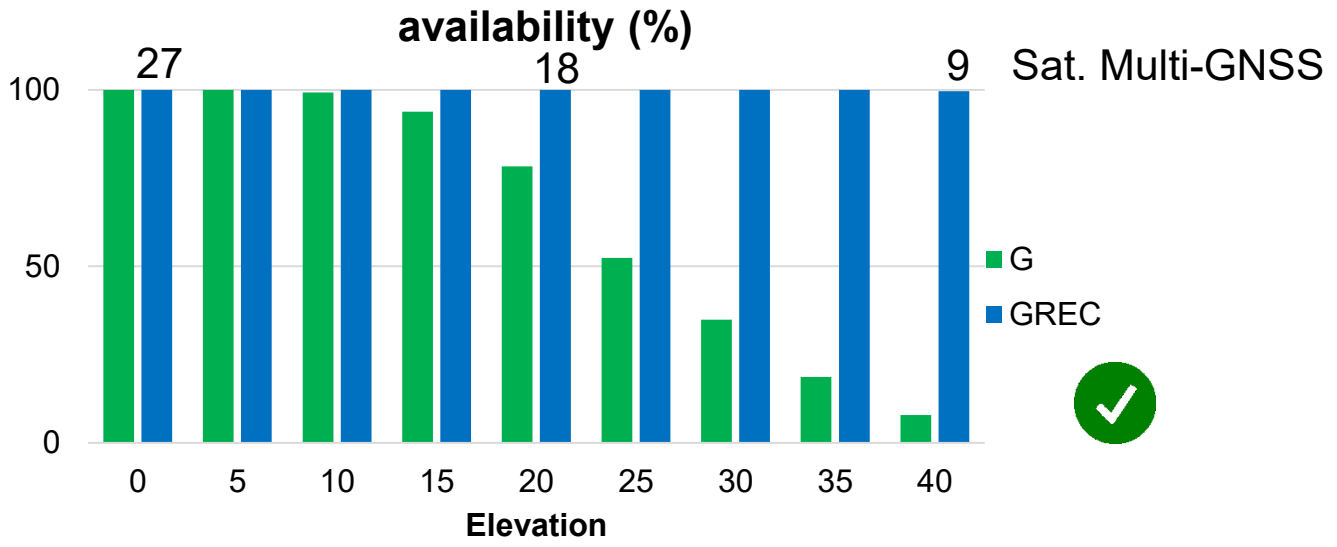
Availabilty under bad conditions only for kinematic GREC

kPPP: Improvement with Multi-GNSS

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

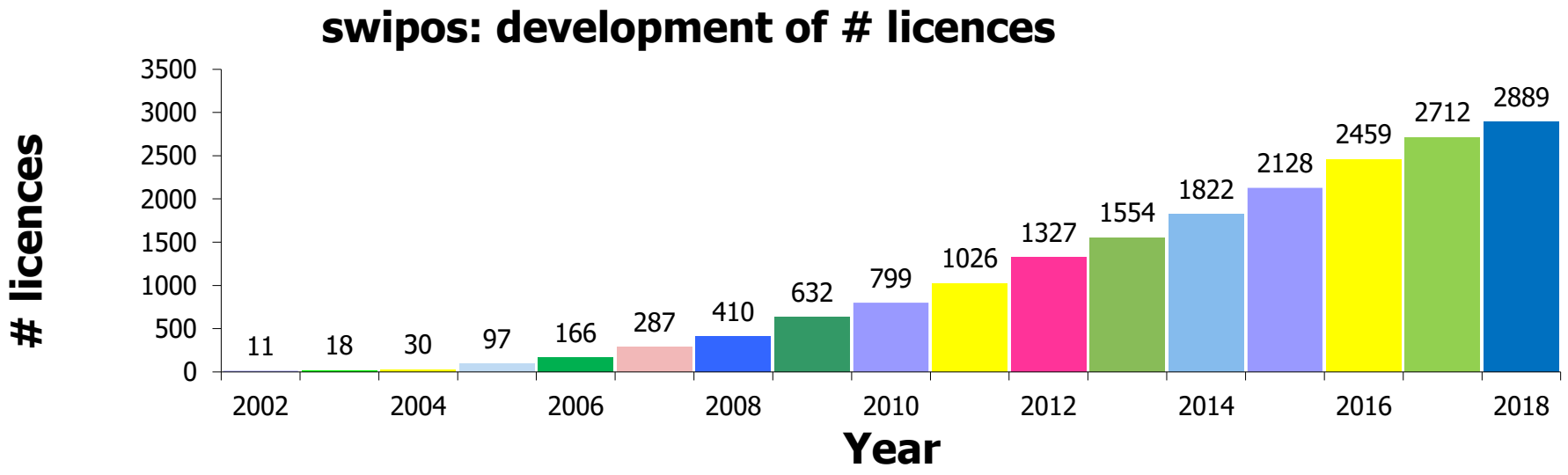


- Availability (20-40º) w.r.t. GPS
  - Multi-GNSS allows coordinate results even under very bad conditions



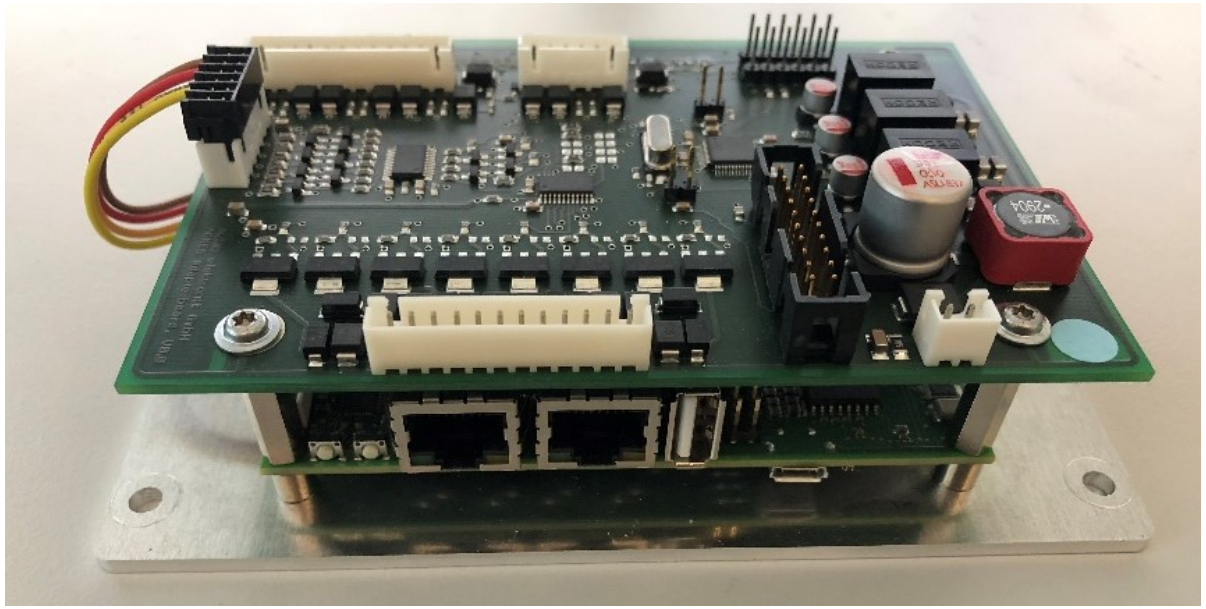
Swiss Positioning Service swipos

- Integration of BeiDou and Galileo in the Trimble Pivot Platform – Software (TPP 3.10) in June 2017; Trimble RTXNet – Processor Trimble RTX Real-time Orbits; currently TPP 4.1.3
- New RTCM 3.2 MSM mountpoints (GPS/GLO/BDS/GAL) are used by 20-25% users (status 27. Aug. 2019, 550 simultaneous user)



Infrastructure AGNES stations

- New IO-Controller -> Single Board Computer
- 5 units installed successfully, currently installed site-by-site («Zimmerwald first»…)



AGNES UPS CONTROLLER - web interface -

ioControl server version: 1.0

AGNES station DACH

swisstopo AGNES

Input

#	Current	Pin alias	Pin function
1	OFF	IN 1	general purpose input
2	OFF	IN 2	general purpose input
3	OFF	IN 3	general purpose input
4	OFF	IN 4	general purpose input
5	OFF	IN 5	general purpose input
6	OFF	IN 6	general purpose input
7	OFF	IN 7	general purpose input
8	OFF	IN 8	general purpose input
9	OFF	-	unused
10	OFF	CHARGER_FAIL	charger:processor_fail
11	OFF	POWER_FAIL	charger:power_fail
12	OFF	BAT_FAIL	charger:battery_fail

read now ☐ read continously 5 sec

Output

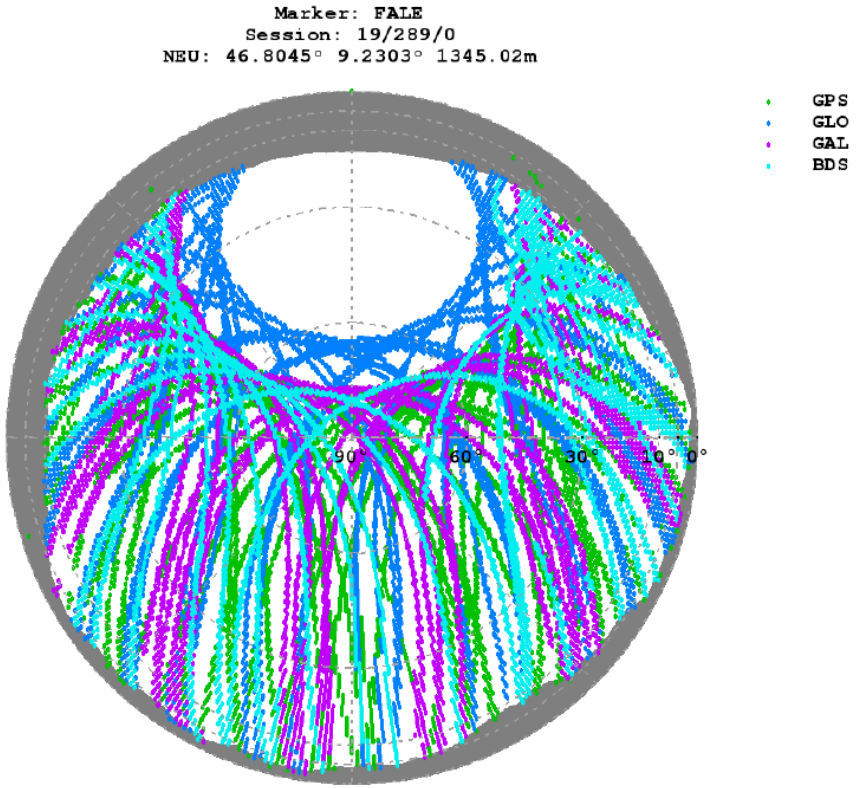
#	Current	Desired	Pin alias	Pin function
1	ON	☑	1-S	24V,relay
2	ON	☑	2-S	24V,relay
3	ON	☑	3-S	24V,relay
4	ON	☑	4-S	12V,relay
5	ON	☑	5-S	24V,relay
6	ON	☑	6-S	24V,relay
7	ON	☑	7-S	24V,relay
8	ON	☑	8-S	12V,relay

write now ☐ write immediately

Server connection okay

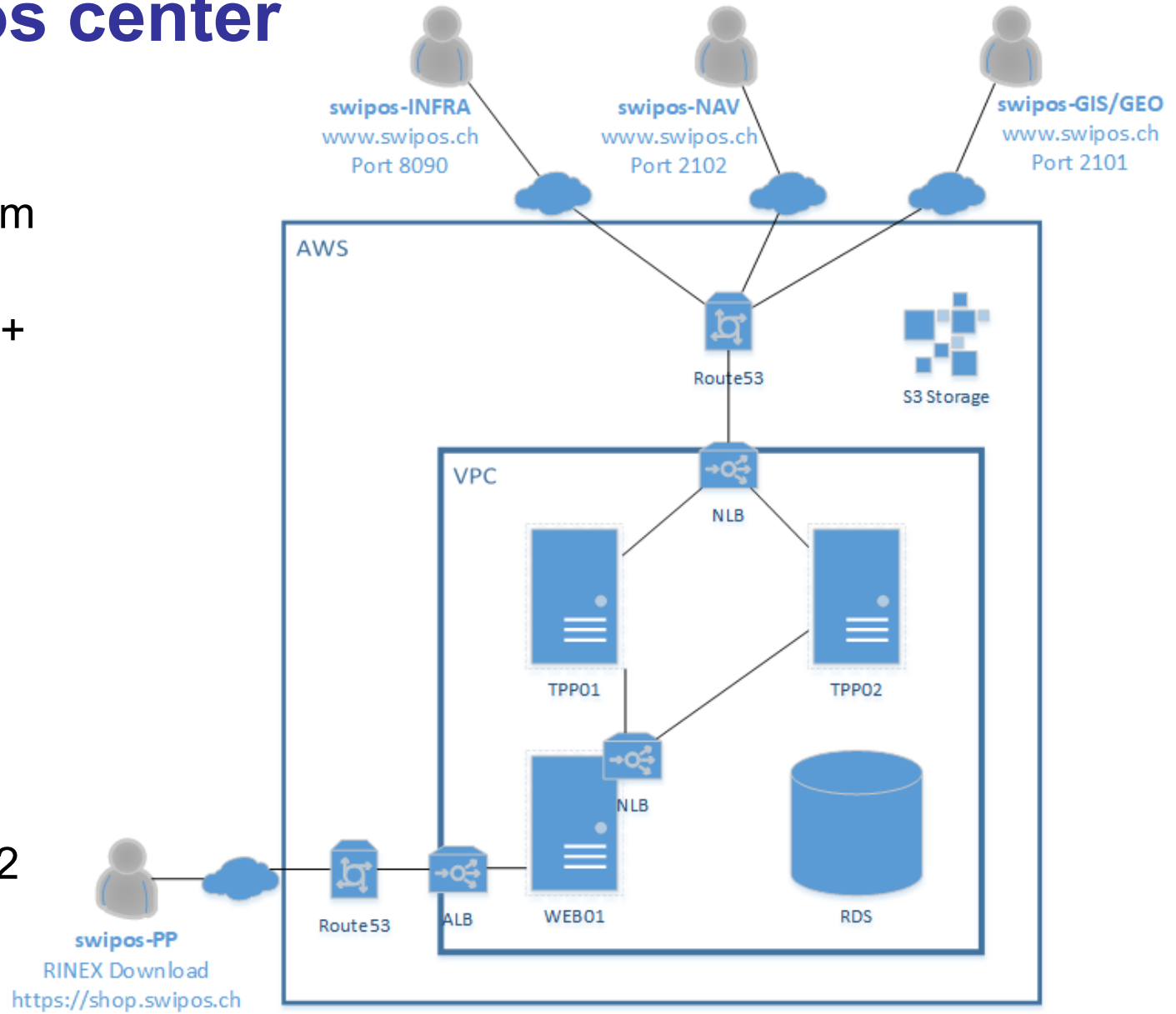
Falera: «On Air»: 16.10.2019

- No observation degration visible (yet) …



New operational swipos center

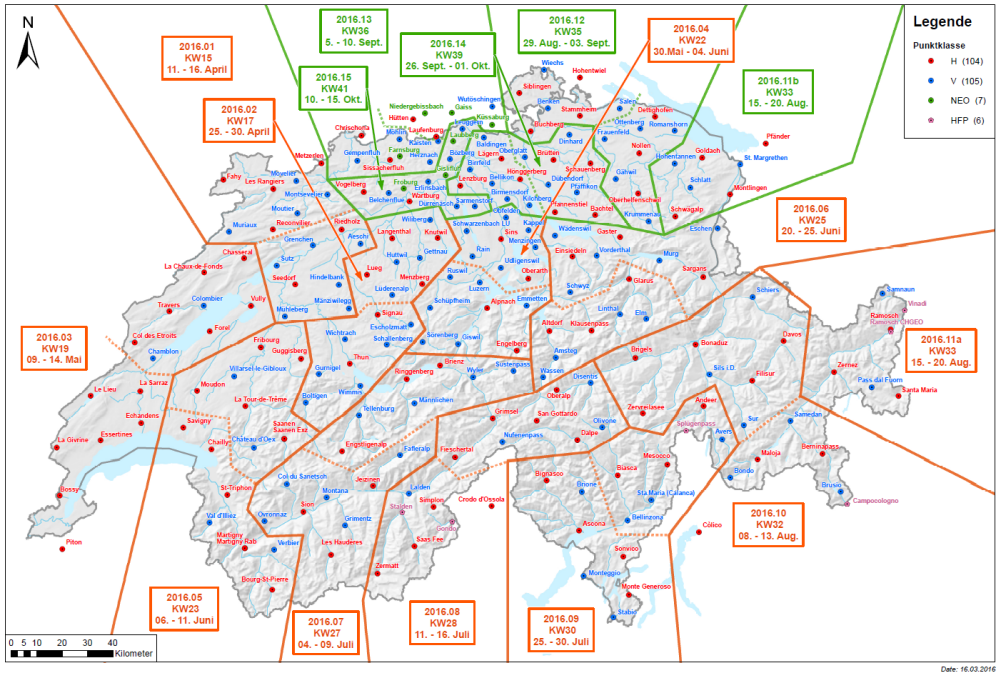
- Design principles
  - Infrastructur as code in git -> terraform & packer; generates OS image
  - Redundance: identical setup TPP01 + TPP02 (only Mac address an hostname)
- Amazon web service aws (Frankfurt)
- TPP 4.1.3. (production+ test)
- Mountpoints for data exchange D-A-F-I ready
- Rinex-3 data flow supported
- Communication station – operational center as well as swipos-INFRA: NTRIP2
- Go-Live: 20.11.2019



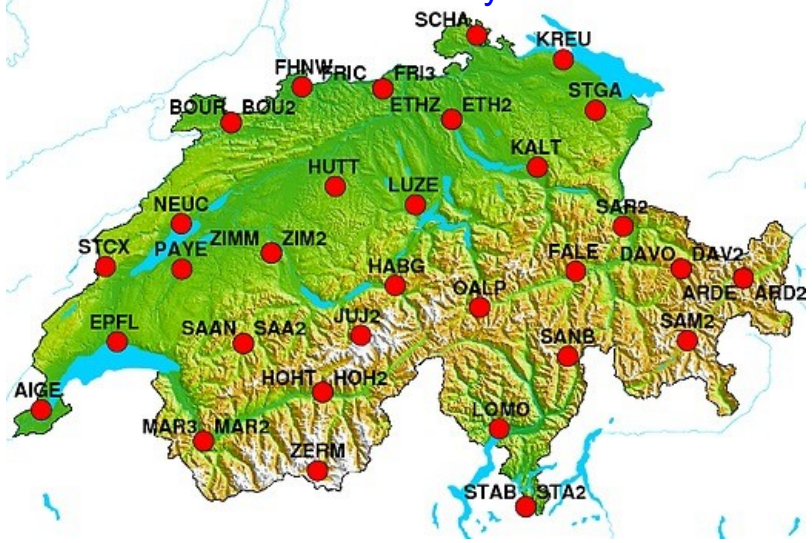
CHTRF2016: Multi-GNSS field campaign and AGNES permanent network

- All ~200 reference points measured in summer 2016 (1988-1995 establ., 1998, 2004, 2010 remeasured every 6 years)
- Multi-GNSS knowledge extension (permanent analysis later because campaigns are less time-critical)

LV95; passive; ~200 stations, Multi-GNSS since 2016

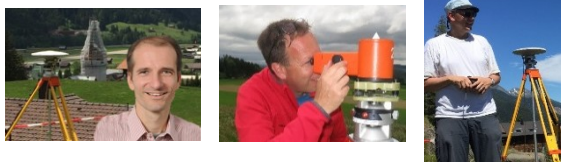


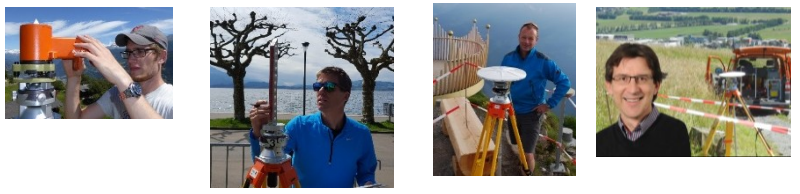
AGNES; active; 42 stations, Multi-GNSS since Feb-May 2015



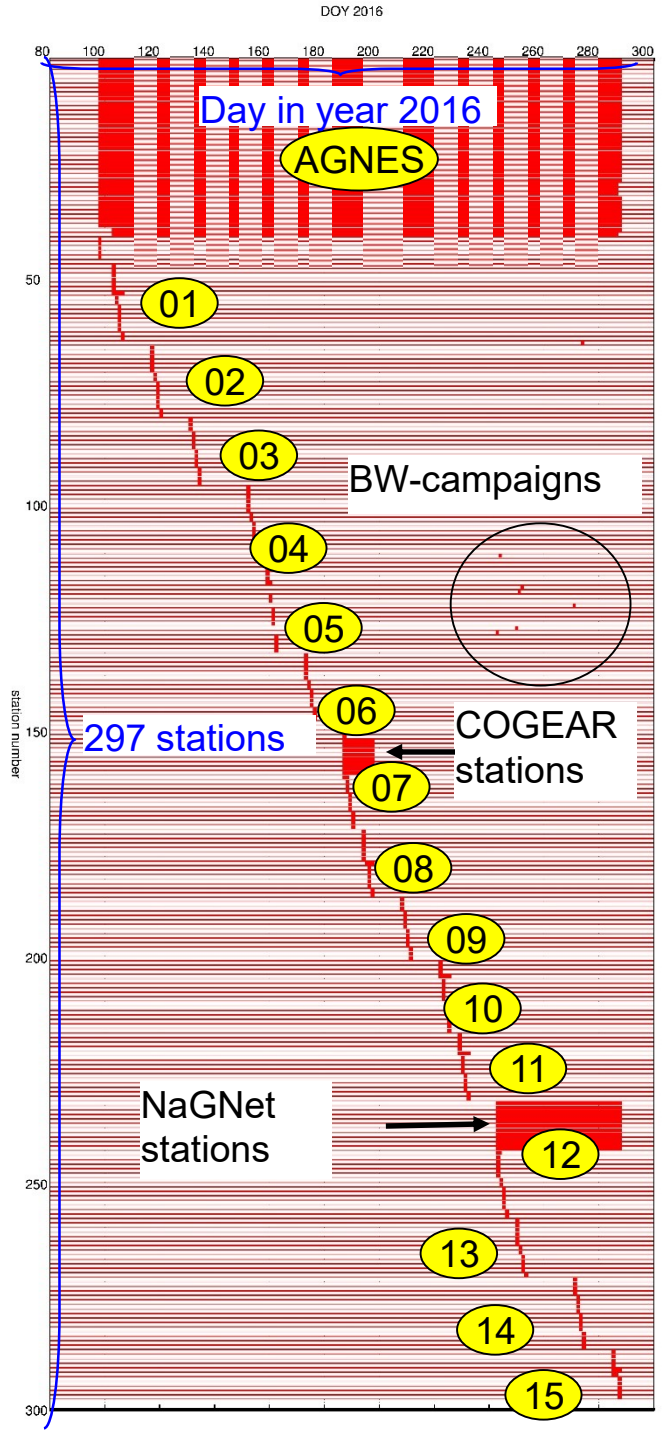
Campaign 2016

- 10 observers
- 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)

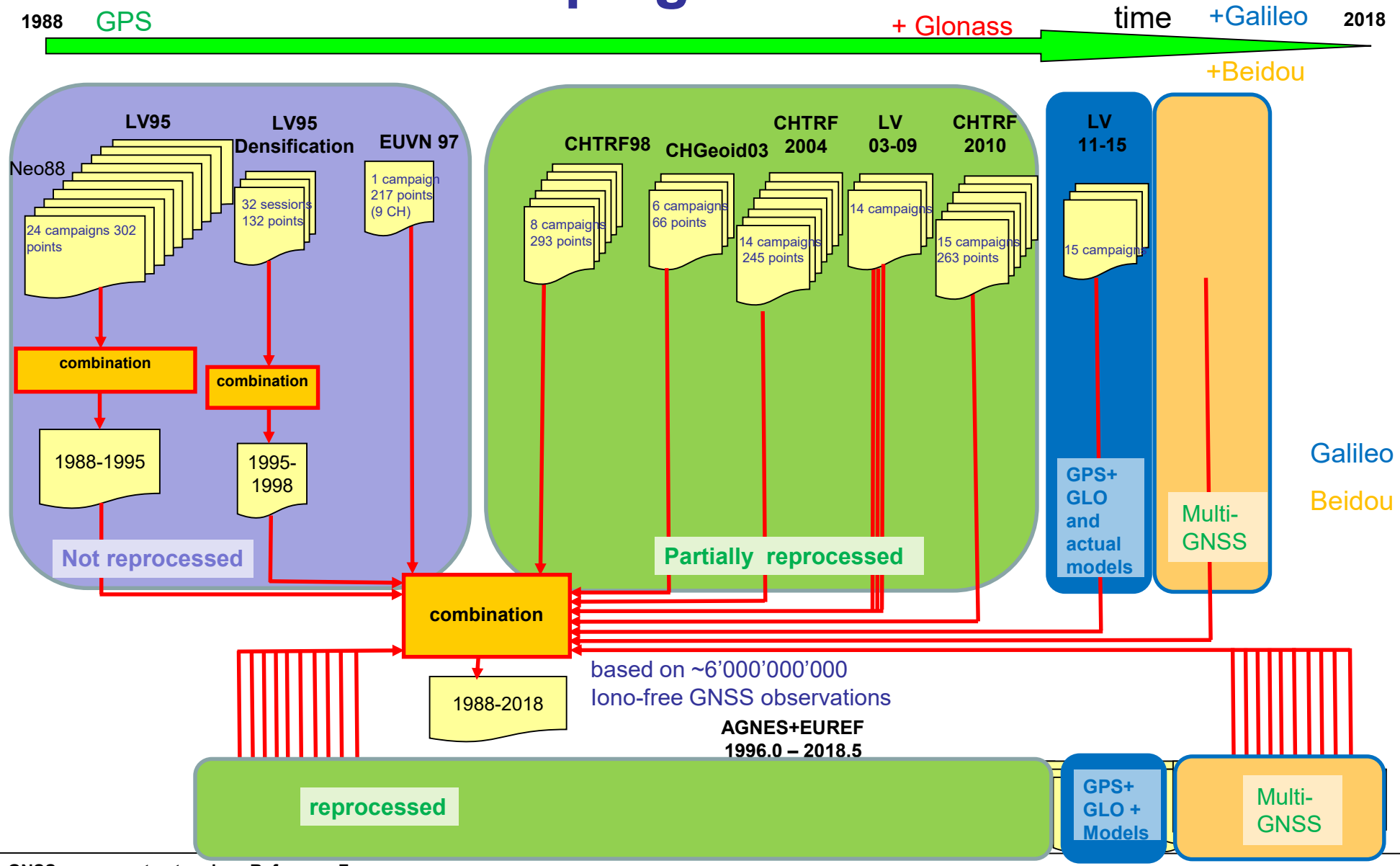




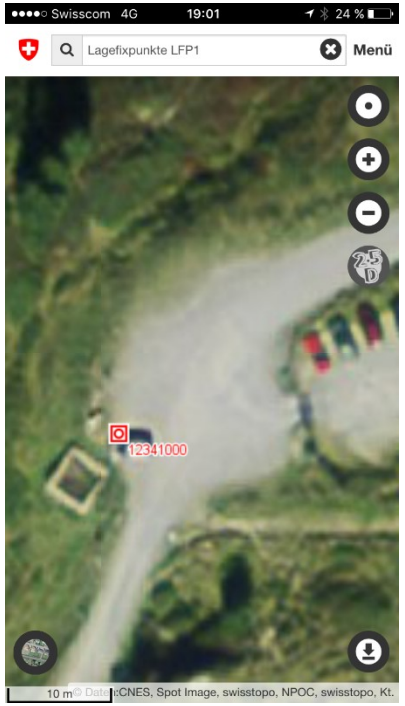
- Analysis using BSW5.3 (development version)
- Analysis delay 1-2 months – CODE Multi-GNSS orbits not operational in 2016

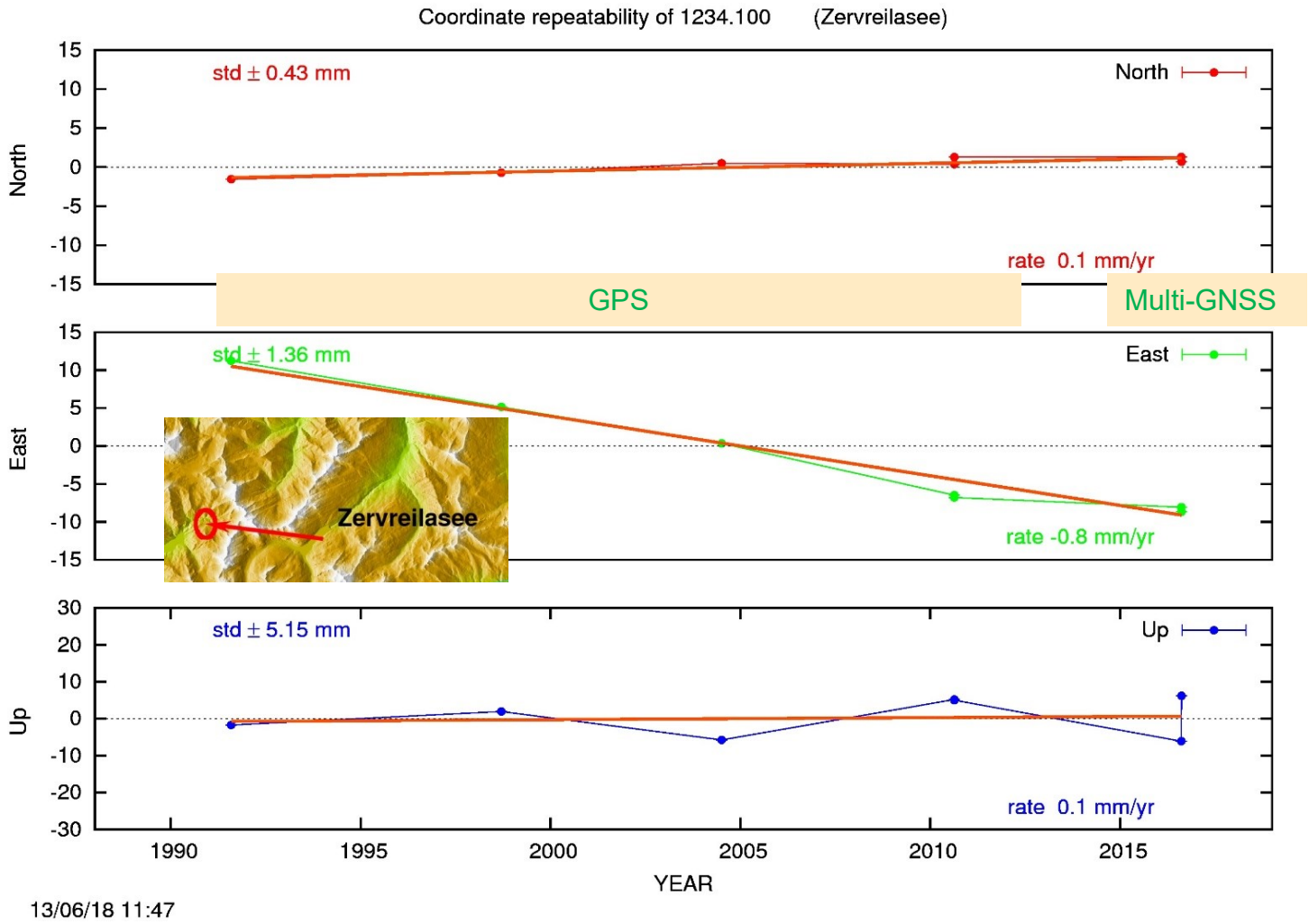


Combination Campaigns + Perm. Net

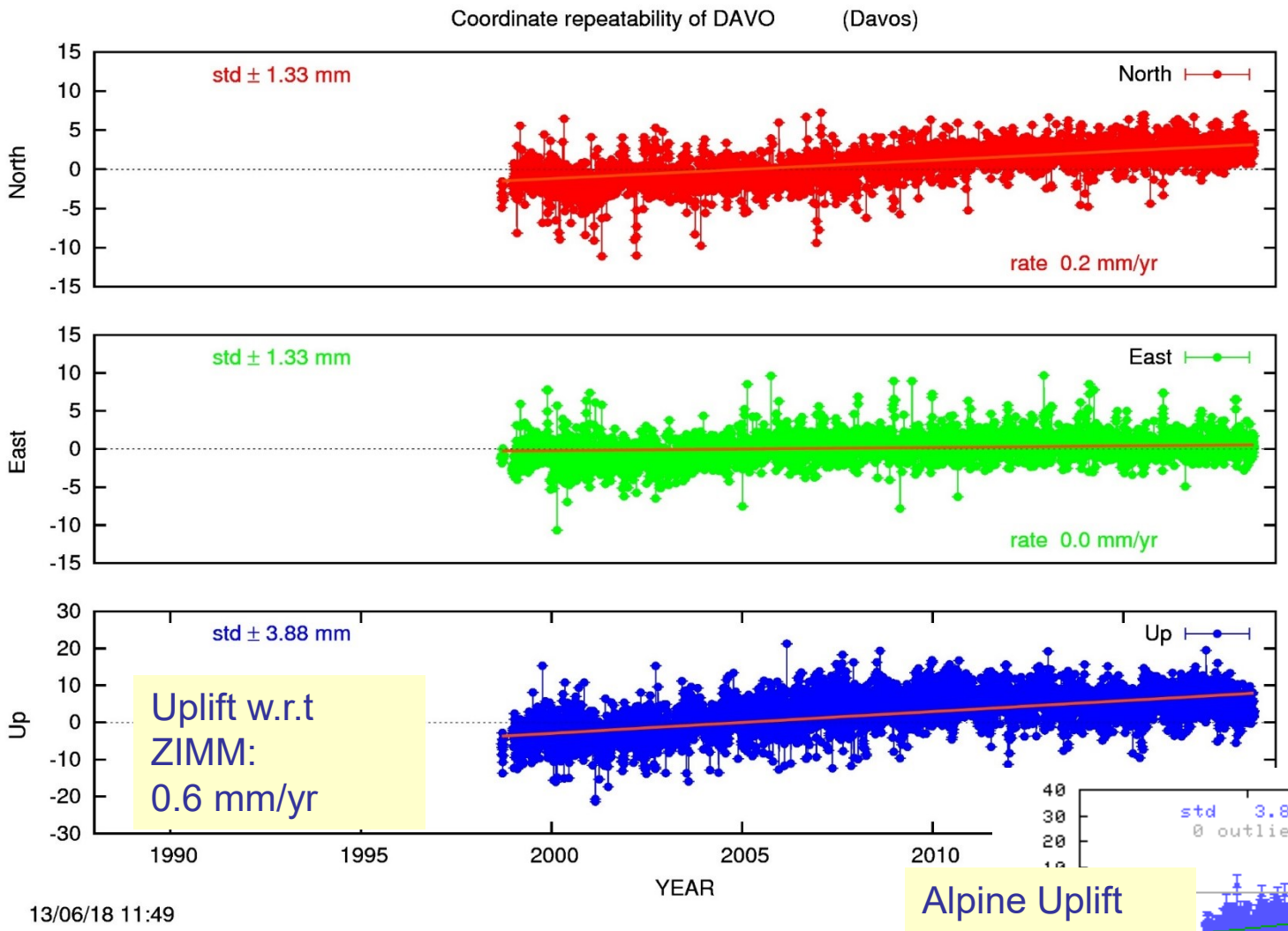


Example Zervreilasee

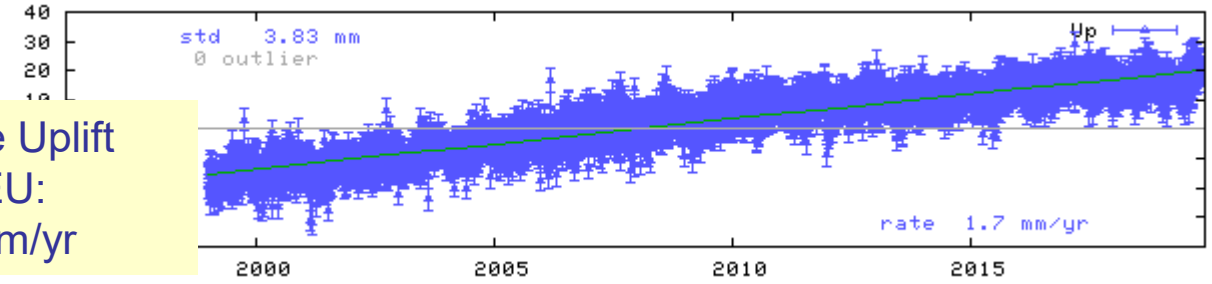




Repeatabilities: Example Davos



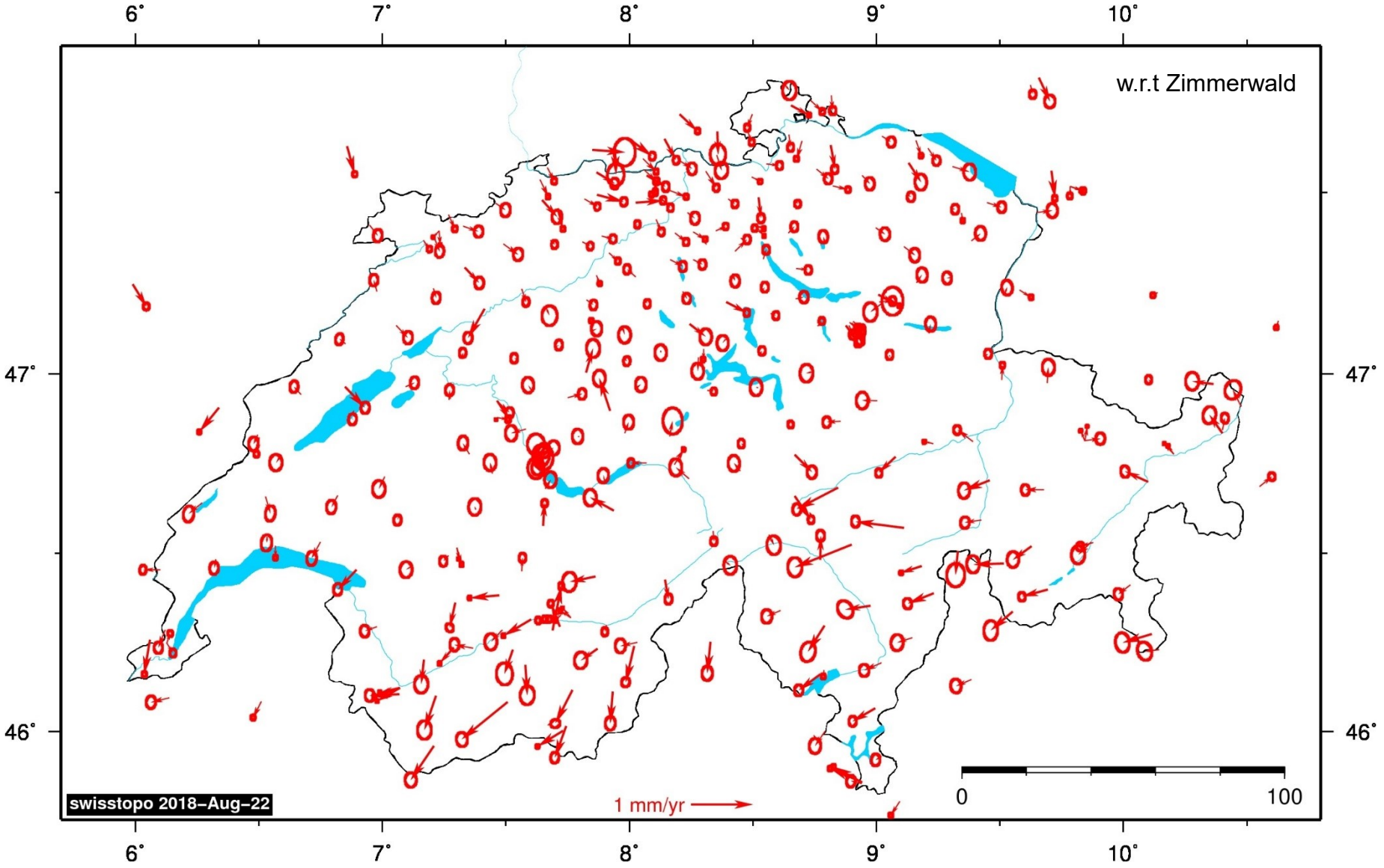
Uplift w.r.t ZIMM: 0.6 mm/yr



Alpine Uplift w.r.t EU: 1.7 mm/yr

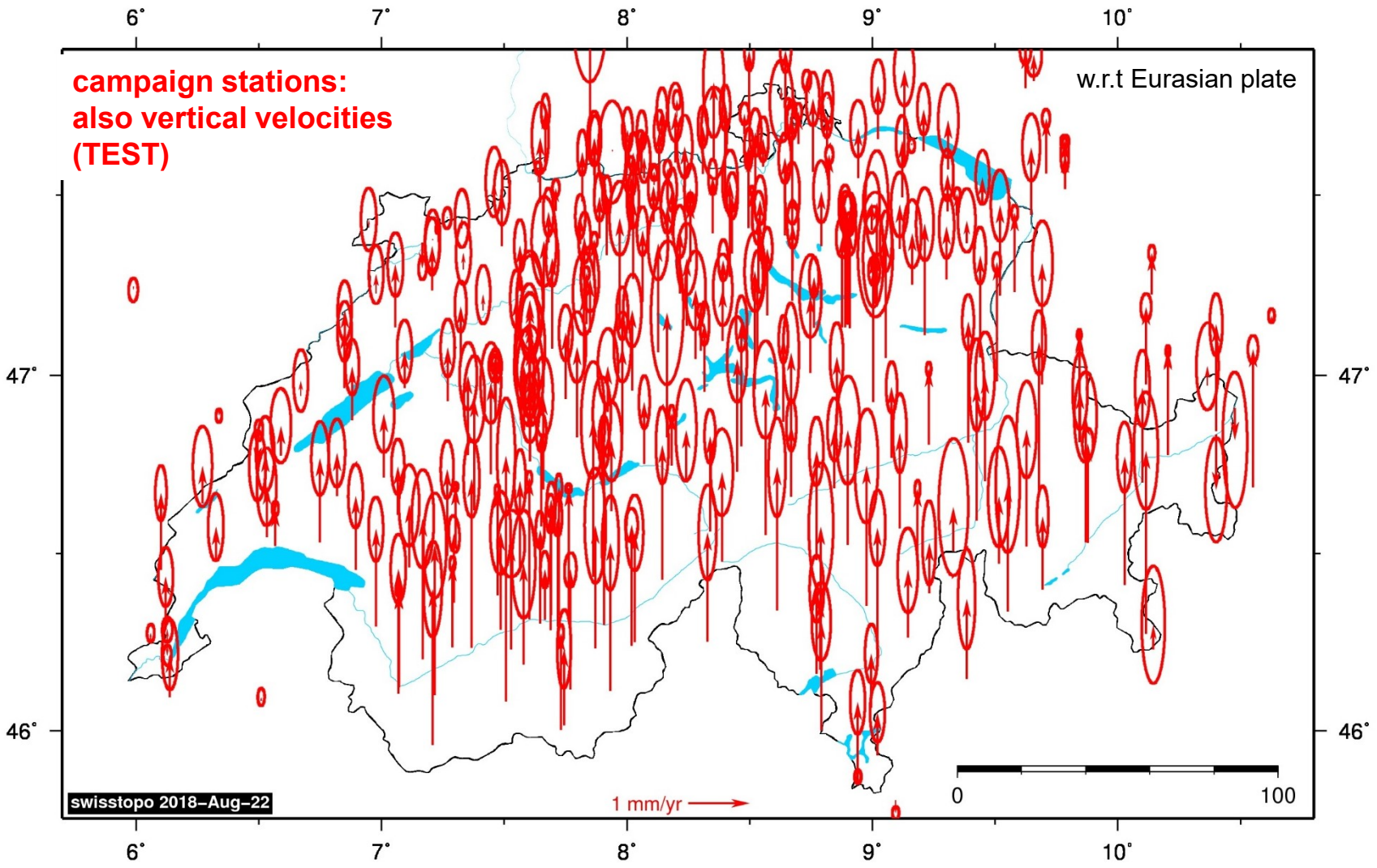
Velocity Fields

ALL_DAY_EU



Velocity Fields Vertically

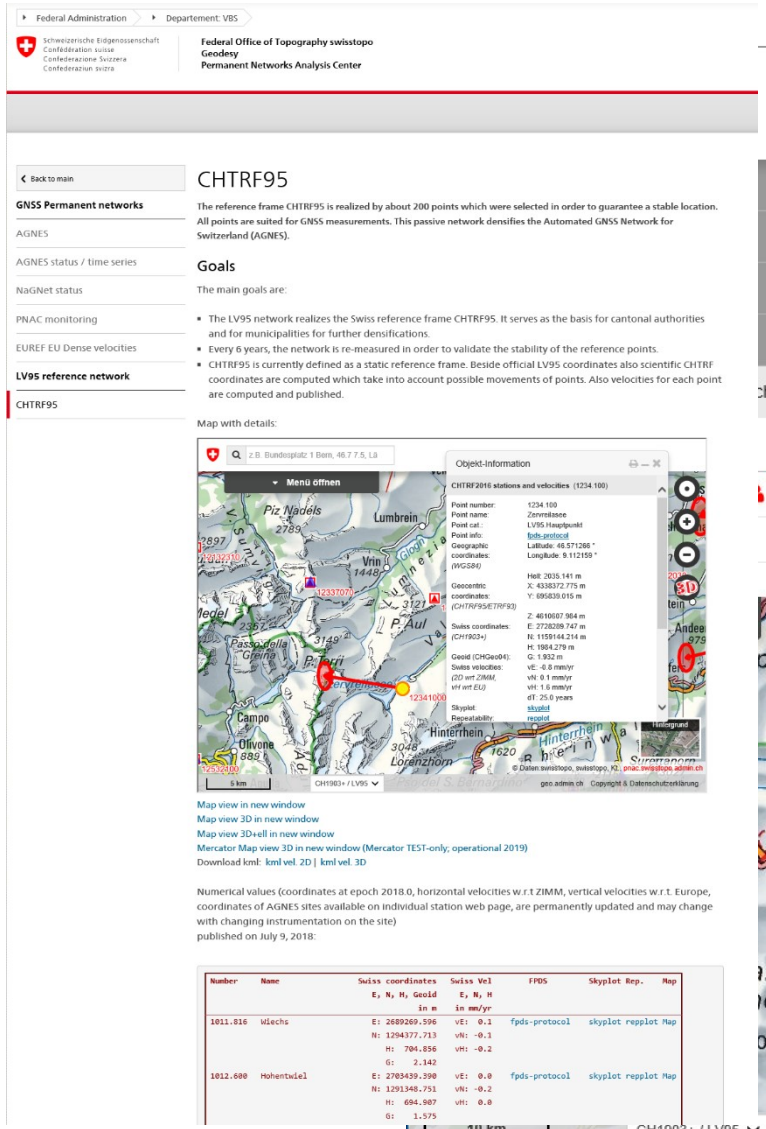
ALL_DAY_EU

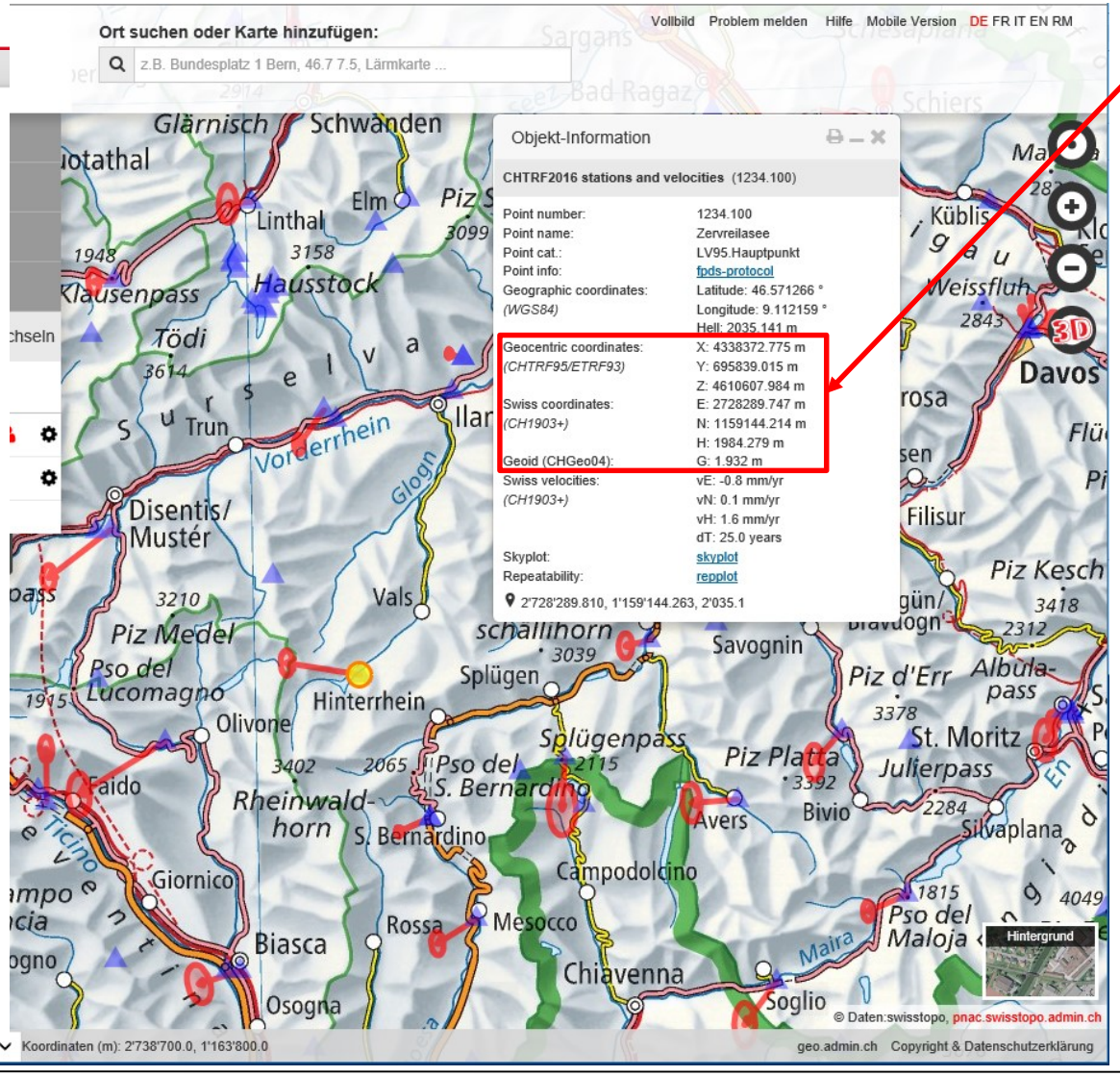


Publication on pnac web

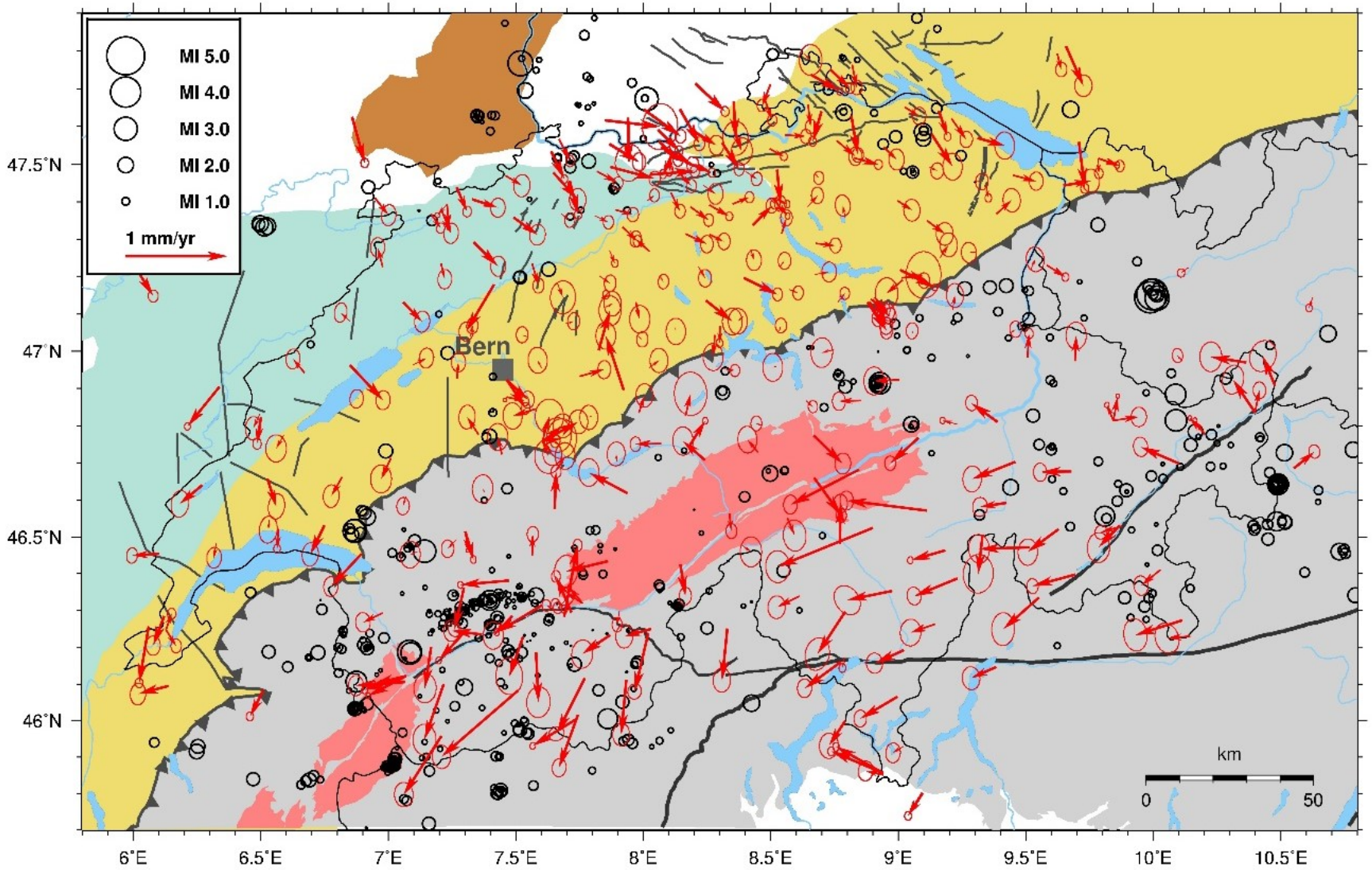
CHTRF2016 coordinates in reference system CH1903+ at epoch 2018.0

http://pnac.swisstopo.admin.ch/pages/en/chtrf.html





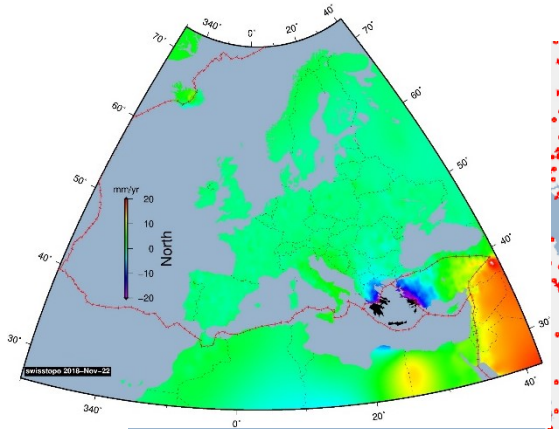
Correlation with Geology / Seismic



Geological information from Swiss Seismological Sercice (T. Diehl)

EU Dense Velocity Project

28 contributors, since 2017
~6000 station velocities
~0.2-0.3 mm/yr hor. standard deviation
~0.4-0.7 mm/yr up std



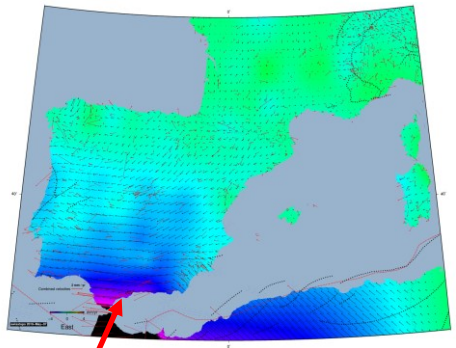
3-4 mm/yr: Italy

3-4 cm/yr: Greece/Turkey

EU Dense Velocity Project

horizontally

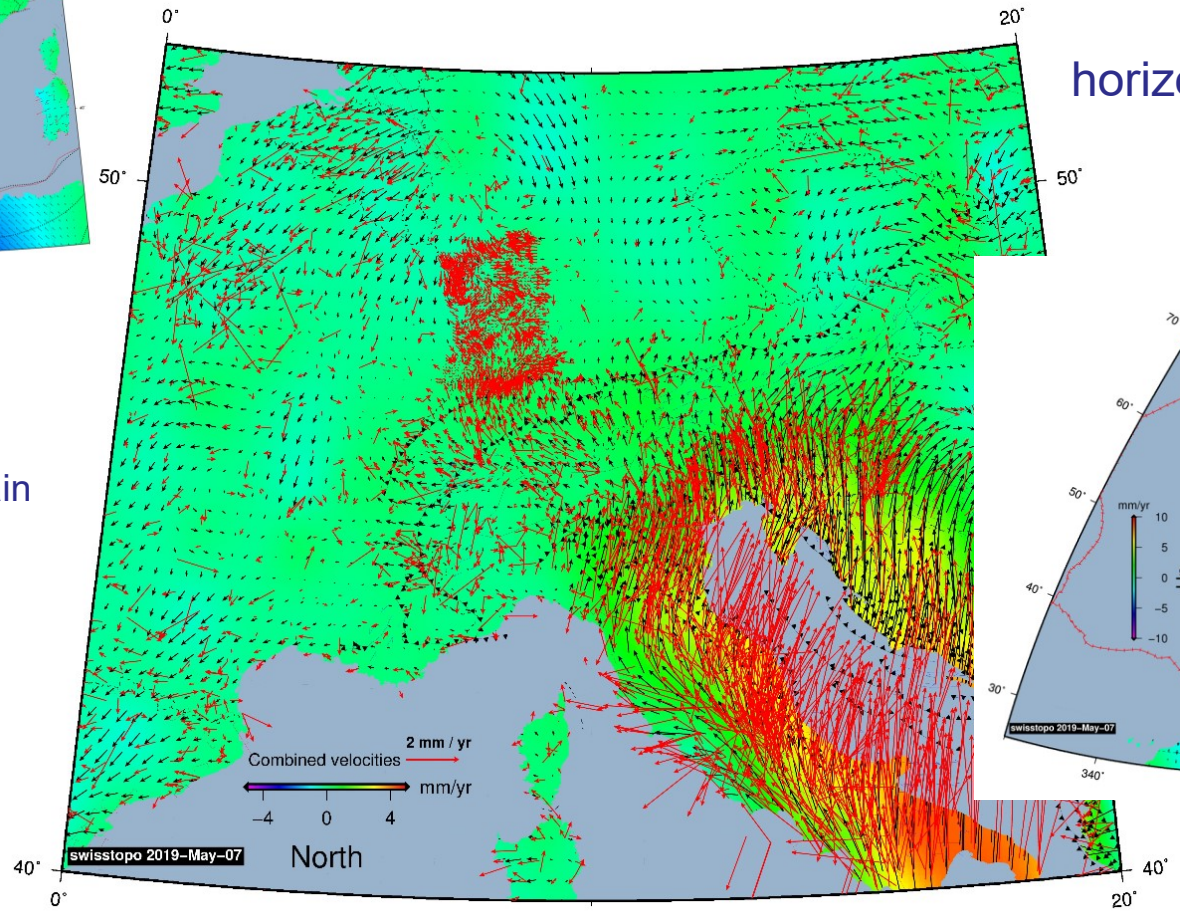
observed
model
colored grid



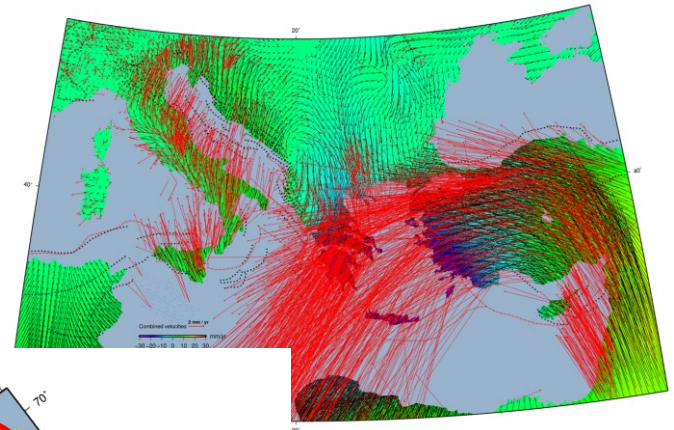
South-Spain

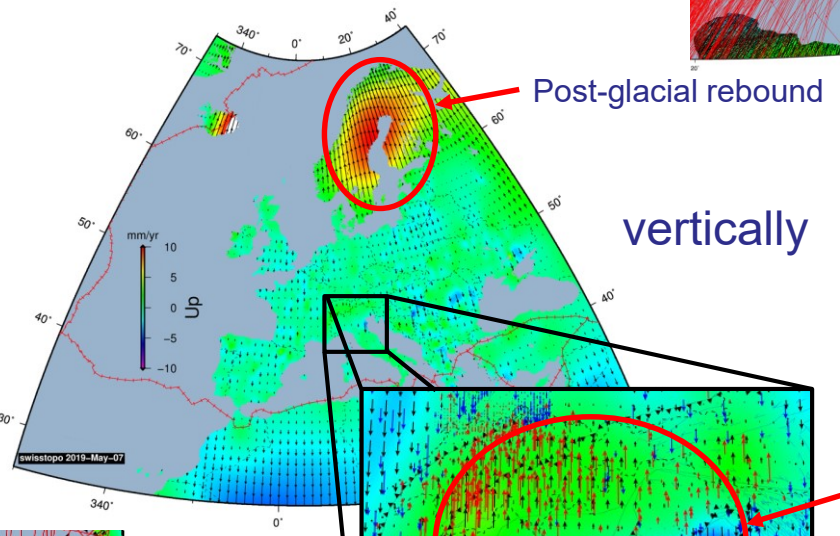
East velocities
~4 mm/yr
w.r.t. ETRF + North Spain

Static reference frame
newly defined
1.1.2017 : < 1 mm
July 2019 : < 10 mm
1.1.2022 : < 20 mm



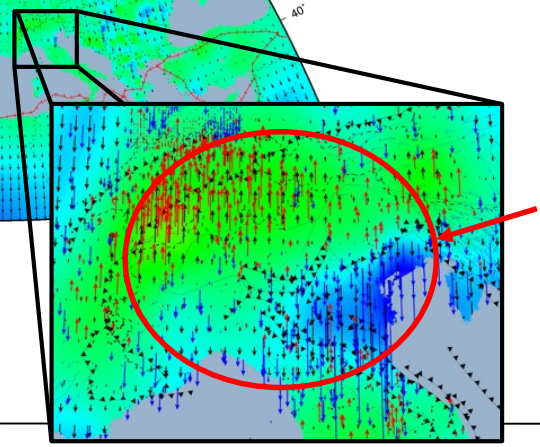
horizontally





Post-glacial rebound

vertically



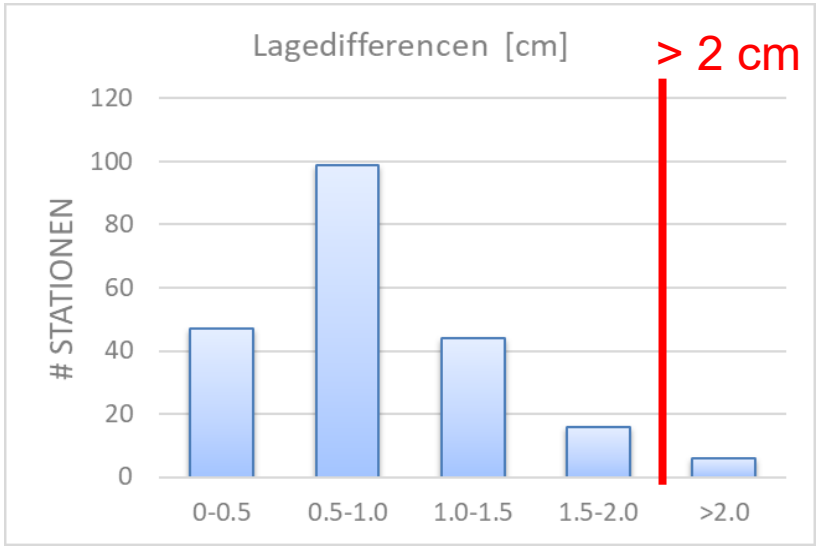
Alpine rise +
Po-basin
subsidence

http://pnac.swisstopo.admin.ch/divers/dens_vel/000.html#VELOCITIES

Static reference frame – how long?

- Limits of 2 cm horizontal accuracy of LV95 reference points will soon be exceeded.

Status 2016 (200 points) horizontally



«Nachführungskonzept Landesvermessung»
6 (2.8 %) of main- and densifikation points > 2 cm (Hohentwil, Les Haudères, Santa Maria, Siblingen, Zernez, Zervreilasee).

In 3 years (every 6 years) much more…

- A kinematik model (currently zero) need to be developed (in collaboration with EU) to maintain static reference frame on a longer view without changing coordinates. Solution (grid and software) must be easy to be implemented for all users.