Research Institute of Geodesy, Topography, and
Cartography – Geodetic Observatory Pecny
Land Survey Office, Prague

EUREF Related Activities in the Czech Republic 2011 - 2012

National Report

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Symposium of the IAG Subcommission for
Europe – EUREF 2012
Paris, France, 06 – 08 June 2012

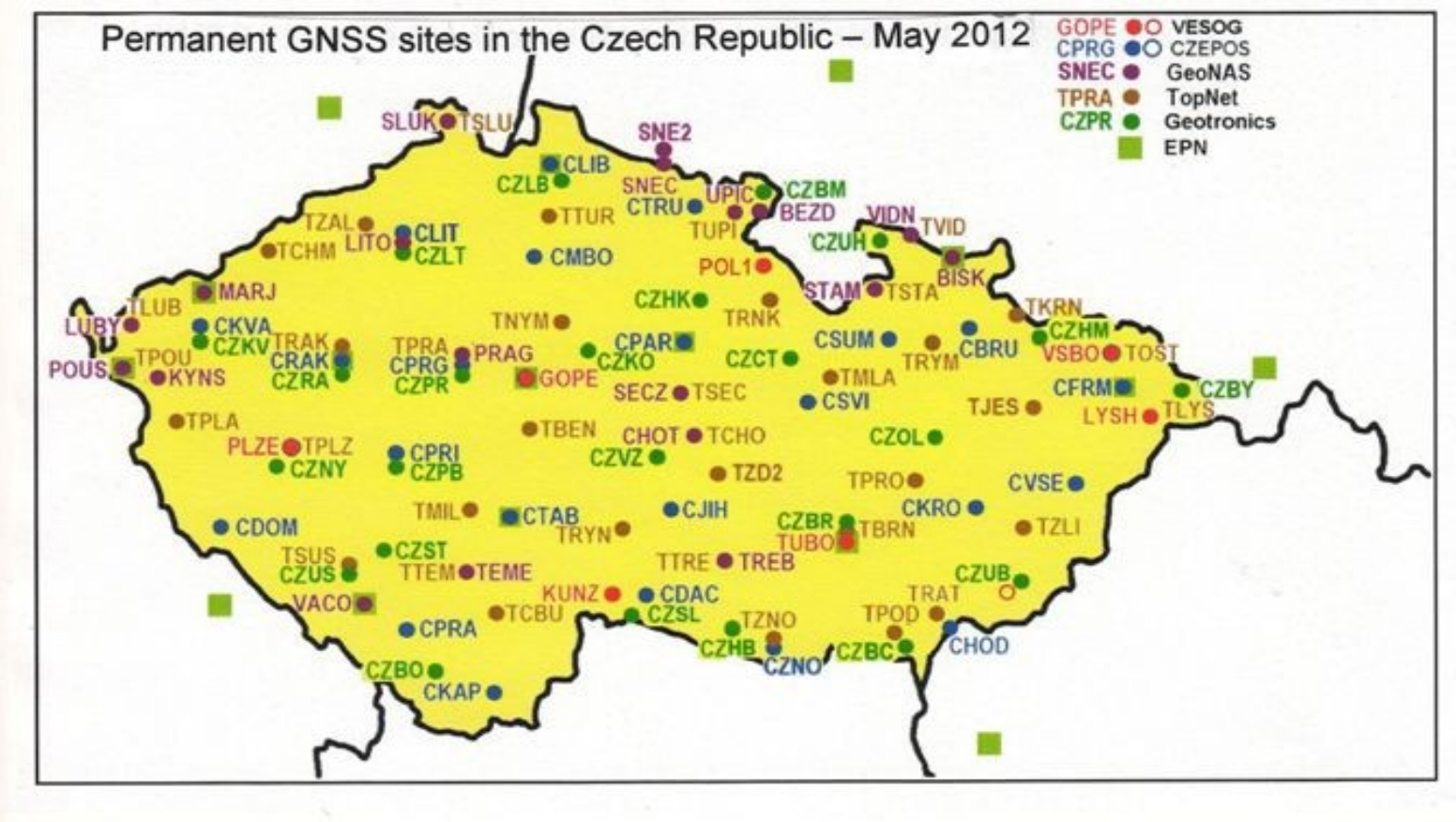
National reference system: S-JTSK/05

- ETRF2000 implemented in the CZEPOS positioning system on January 1st, 2011
- New national S-JTSK/05 system based on ETRF2000 available to users since January 1st, 2011, still not mandatory!
- S-JTSK/05: composed projected coordinate reference system (ISO 19111) – ETRS89 coordinates, planar coordinates (conformal oblique conical projection of the Bessel ellipsoid, normal heights Balt after adjustment
- Conversion between S-JTSK/05 and mandatory S-JTSK by means of correction tables computed for 2 x 2 km grid; improvements in border zones in 2011 – 2012 → rms difference 2 cm
- Conversion of heights by the CR 2005 quasigeoid model (1´x 1.5 ´grid fitted to 1,024 GPS/levelling heights)

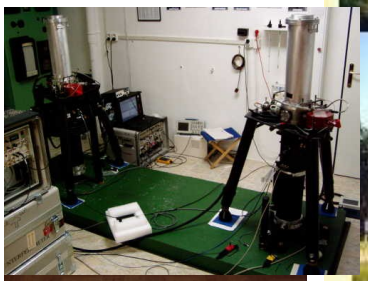
Permanent GNSS Stations and Networks in the Czech Republic

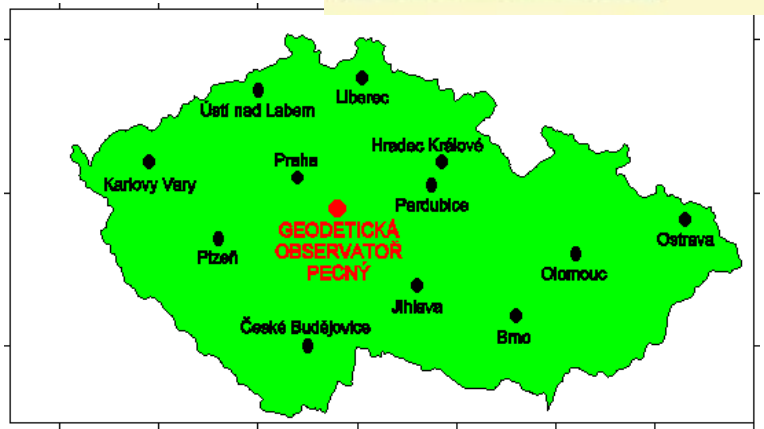
- Fundamental Geodetic Observatory Pecný – GOPE, http://www.pecny.cz (IGS, EPN, CZEPOS, VESOG, E-GVAP II)
- CZEPOS: http://czepos.cuzk.cz, Czech Positioning System, **28 PS**, operated by the Land Survey Office + **27 PS** of neighbour countries
- GEONAS: http://geonas.irsm.asc.cz, **19 PS**, experimental monitoring network operated by the Institute of Rock Structure and Mechanics, Acad. Sci. CR
- VESOG: http://pecny.asu.cas.cz/vesog/, research and experimental GNSS network operated by the RIGTC GOP and academic institutions, **8 PS**
- TopNet: http://www.geodis.cz, **23 PS**, includes also 11 GEONAS and 3 VESOG PS, operated by the private company GEODIS Brno
- Trimble VRS NOW Czech: http://www.geotronics.vrsnow, **24 sites** + 8 sites of Trimble VRS NOW Deutschland, operated by Geotronics Praha, s.r.o. private company
- several smaller networks, operated by private companies, e.g. *byS@T* and others
- **Total: 98 permanent stations, 12 of them EPN**

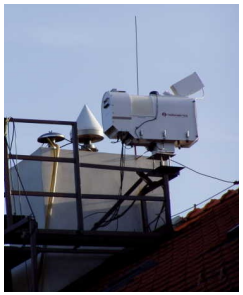
Permanent GNSS networks in the CR (2)



Fundamental Geodetic Observatory Pecný (GOPE) – RIGTC at Ondřejov







GOPE – Fundamental GNSS Station

- Established in 1993, since 1995 has been contributing to IGS (International GNSS Service)
- Topcon Net-G3 receiver, Topcon CR-G3 antenna with a spherical radom TPSH, individual PC calibration
- Tracking the following GNSS: GPS NAVSTAR (L1C, L1P, L2P, L2C), GLONASS (L1C, L2P)
- Post-processing data + real-time data
- Post-processing data downloaded in RINEX 2.10 format in daily files with 30 sec sampling rate, hourly files/ 1 and 30 sec, 15-min files/ 1 sec
- Data are forwarded to the following data centers:

- GOP - RIGTC, Czech Republic (hourly and daily 30 sec data)
- BKG, Frankfurt am Main, Germany (hourly and daily 30 sec data)
- OLG, Graz, Austria (hourly and daily 30 sec data)
- CZEPOS, Land Survey Office, Czech Republic (hourly 1 sec data)
- CDDIS, NASA, U.S.A. (15-minute 1 sec data)

- Real-time RTCM 2.3 and RTCM 3 data streams forwarded in NTRIP protocol to VESOG caster and further to BKG and CZEPOS casters

Permanent GNSS station GOPE

Topcon CR-G3 antenna with TPSH radom

Topcon Net-G3 receiver

GOPE Participation in the M-GEX IGS project

- station GOP6 – excentric site of the main GOPE station in the Multi-GNSS Experiment
- Leica GRX1200+GNSS receiver + Leica AR25.R4 antenna with a spherical radom LEIT and individual PC calibrations
- Satellite tracking: GPS NAVSTAR (L1C, L1P, L2P, L2C, L5), GLONASS (L1C, L2P), Galileo (E1, E5a, E5b, AltBoc), SBAS (L1)
- Post-processing data in RINEX 2.10 (directly generated by the receiver) and RINEX 3.01 (conversion from 2.11 using own software in the operation centre):
  - hourly and daily files/ 30 sec data
  - 15 min files of 1 sec data
- Post-processing data forwarded to:
  - CDDIS, NASA, USA (only RINEX 3.01)
  - BKG, Frankfurt am Main, Germany (only RINEX 3.01)
  - IGN, Paris, France(RINEX 2.10 and 3.01)
  - GOP, RIGTC, Czech Republic (only RINEX 2.10)
- Real-time data streams
  - binary data Leica LB2
  - RTCM 2.3 a RTCM 3
  - NTRIP protocol forwarded to NTRIPcaster VESOG/GOP, RIGTC, Czech Republic, binary data LB2 forwarded to the M-GEX caster of the BKG, Frankfurt/Main, Germany

GOP6 M-GEX Site - antenna

GOPE Participation in the JAXA MGM Project

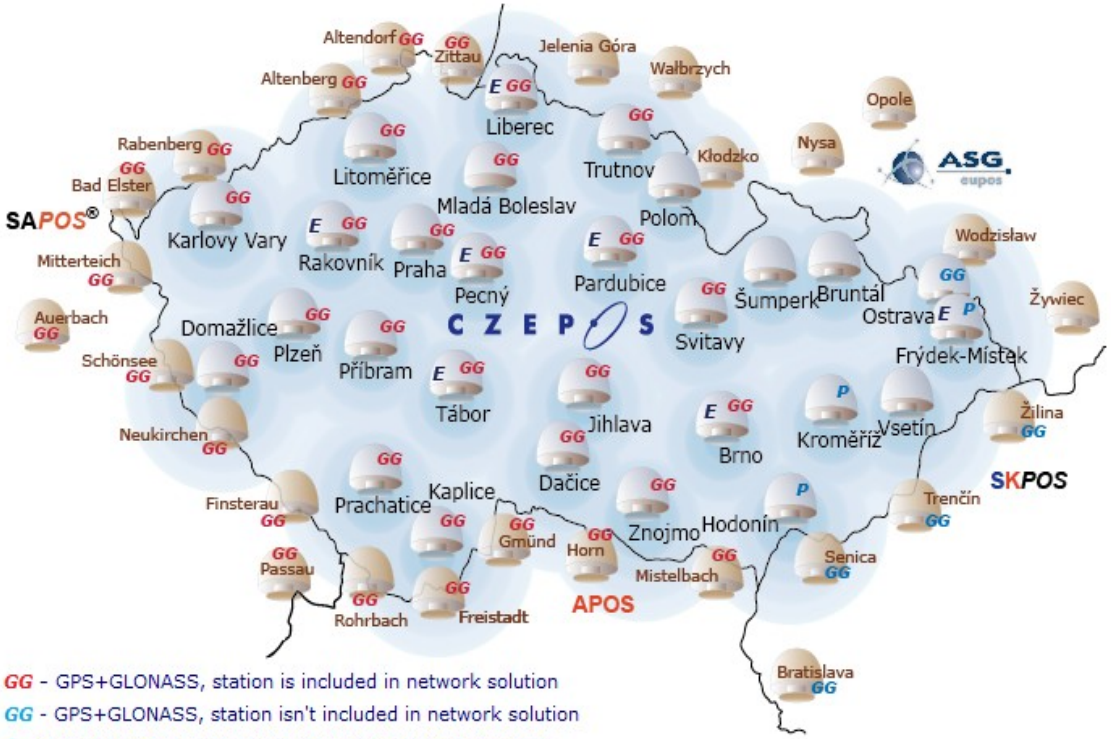
- MGM (Multi-GNSS Monitoring network) Project organized by the Japan Aerospace Agency JAXA – GOPE participates as a hosting station operating a receiver provided on loan by JAXA
- Javad DELTA-G3T receiver is connected through a signal splitter to the Leica AR25.R4 antenna with a spherical radom LEIT installed at the GOP6 site
- Satellite tracking:
- GPS NAVSTAR (L1C, L1P, L2P, L2C, L5)
- GLONASS (L1C, L1P, L2P, L2C)
- Galileo (E1, E5)
- SBAS (L1, L5) including the first QZSS satellite
- Real-time data forwarded to the NTRIP caster of the MGM project in Japan as Javad binary data
- Providing post-processing data generated by the Javad receiver for the M-GEX project under negotiations

GOPE - receivers

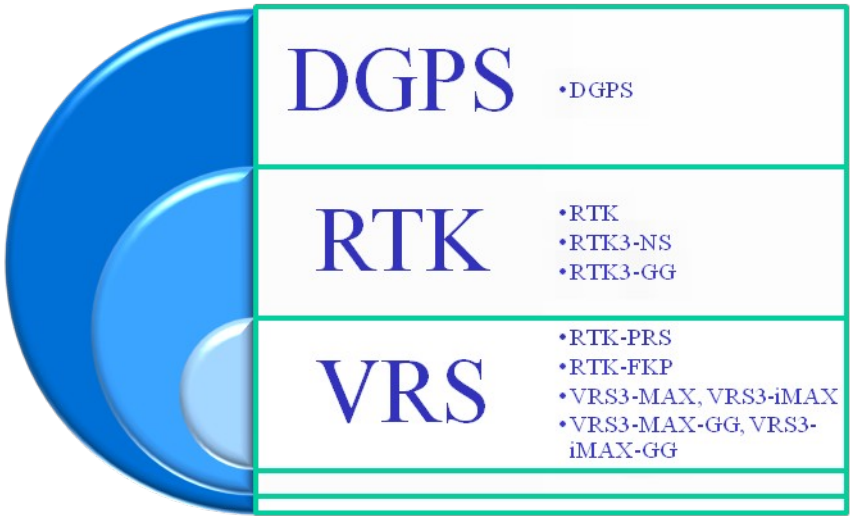
Leica GRX1200+GNSS receiver at GOP6

Javad DELTA-G3T receiver at GOP7/GOP6M

CZEPOS – operated by Land Survey Office since 2004/2005

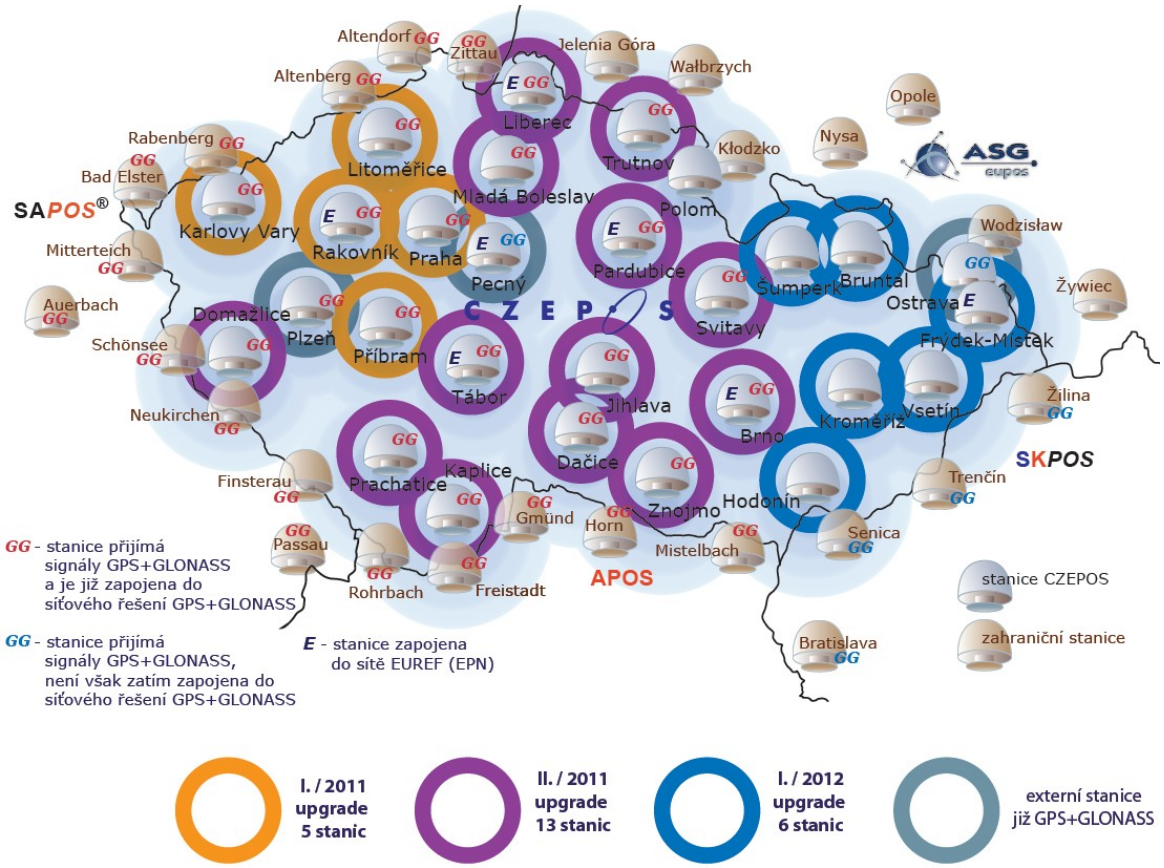


CZEPOS Services

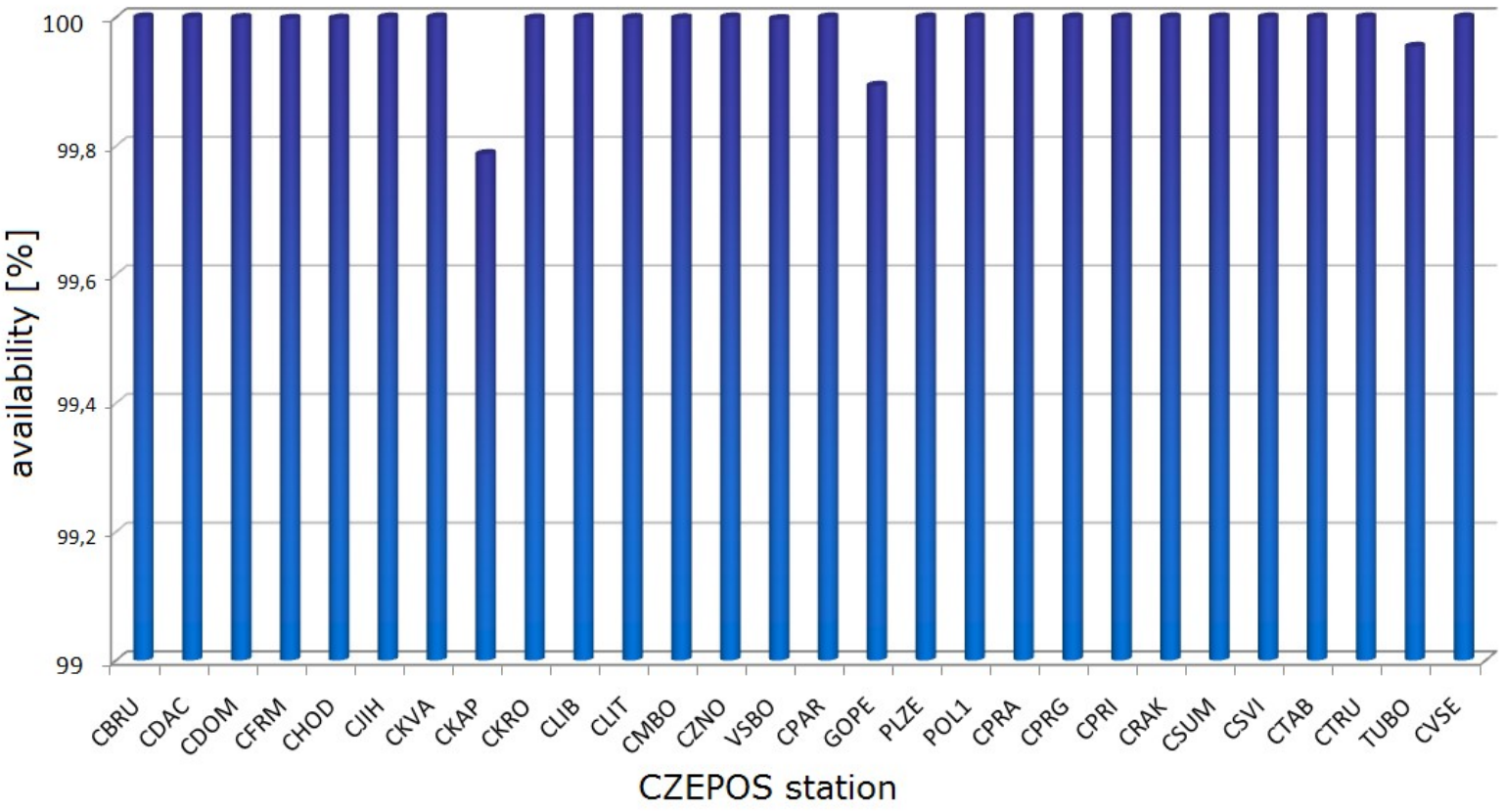


- **Real-time services:** RTK, RTK-FKP, RTK-PRS, RTK3, VRS3 = 80 Kč (3,26 €) / 1 hour, DGPS = 20 Kč (0,82 €) / 1 hour
- **Post-processing:** data interval 1 – 4 sec = 80 Kč (3.26 €), 5 – 9 sec = 16 Kč (0.65 €), 10 – 19 sec = 8 Kč (0.33 €), ≥ 20 sec = 4 Kč (0.16 €)

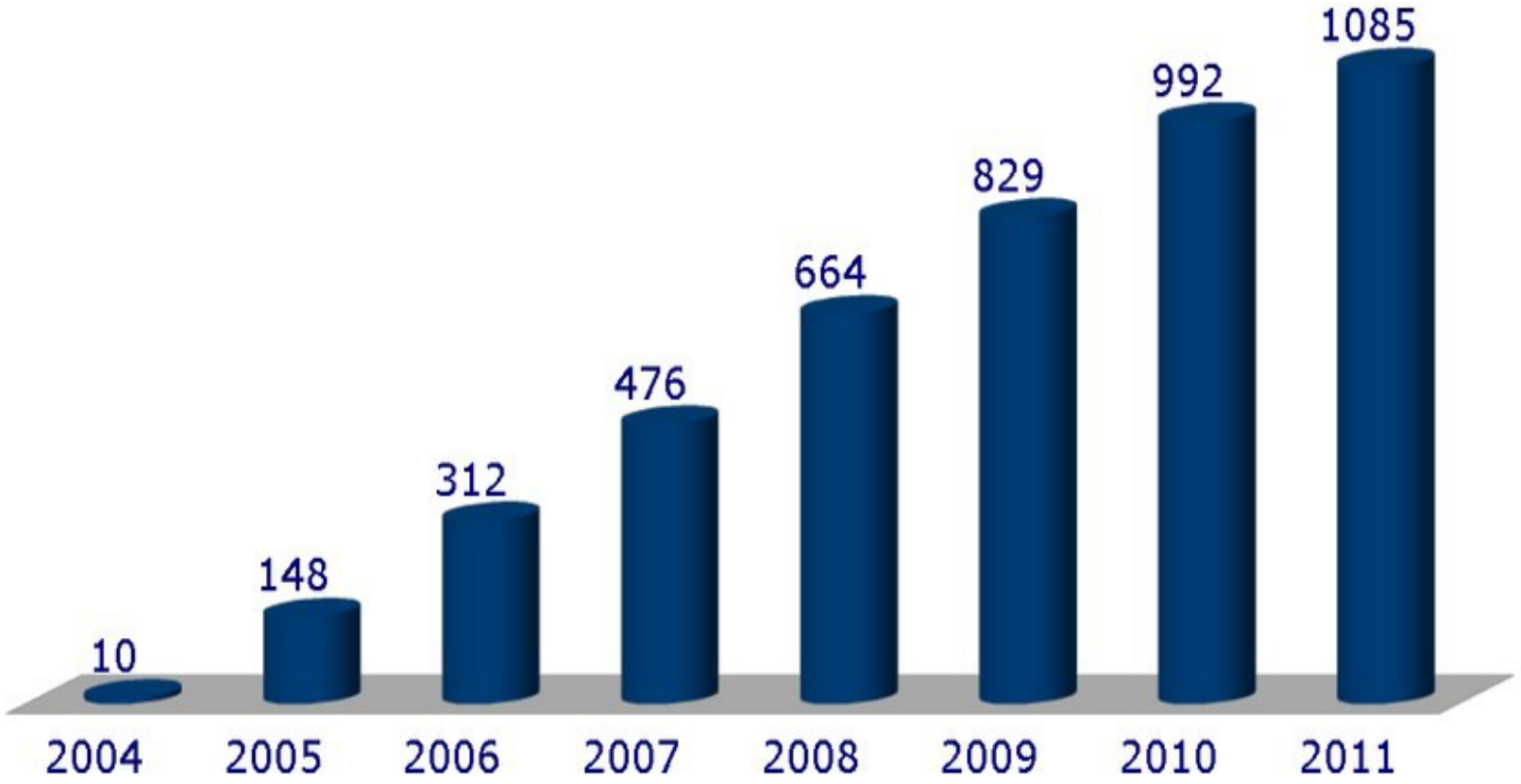
CZEPOS – upgrade schedule



CZEPOS – availability of services



CZEPOS – number of users



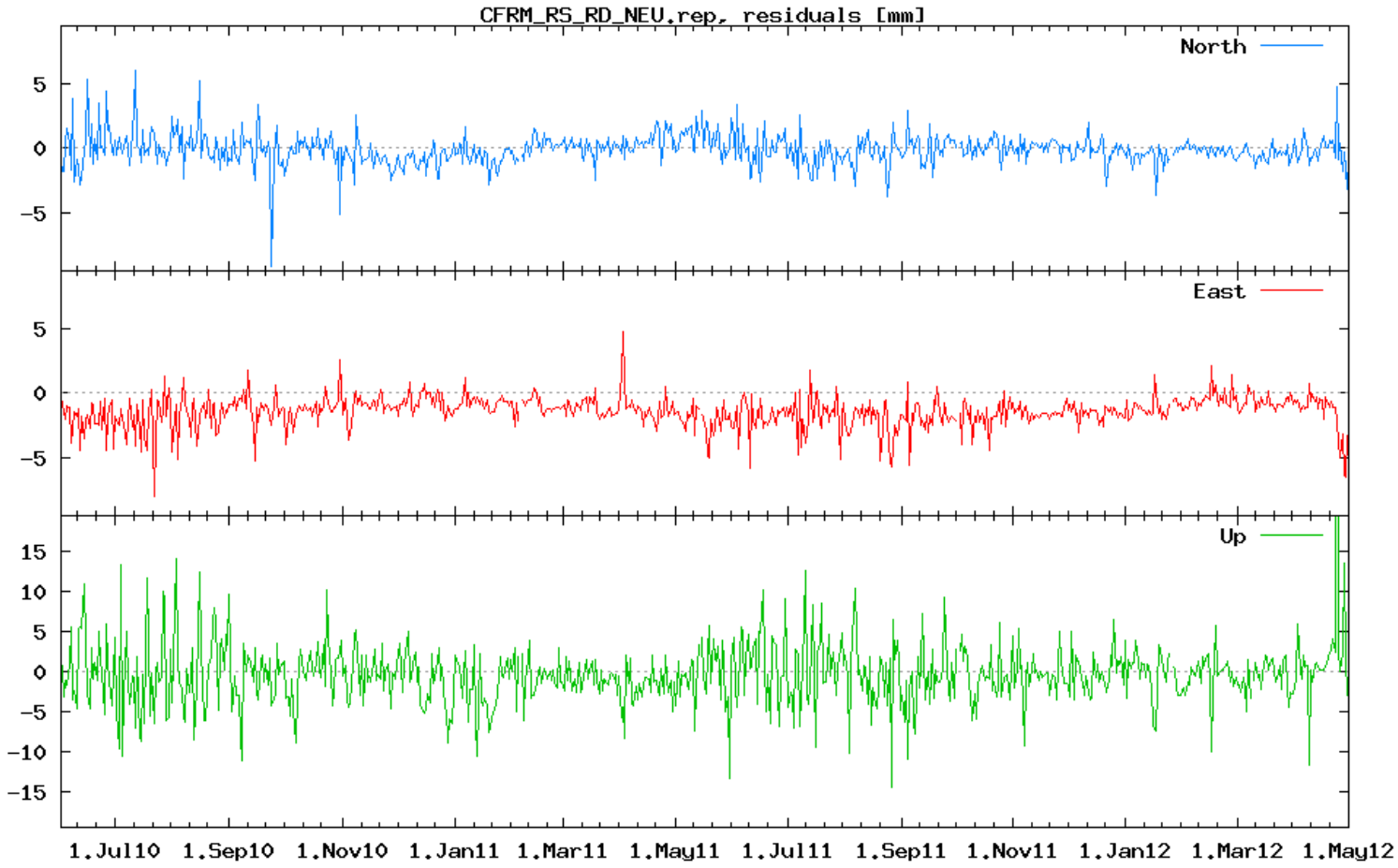
Analysis and Research

- Monitoring of permanent sites in the CR
- EPN Data Center GOP
- EPN Analysis Center GOP
- IGS rapid orbits
- GNSS Ground-based meteorology
- Geodynamics – EPN velocities, CEGRN
- IDS Analysis Center GOP

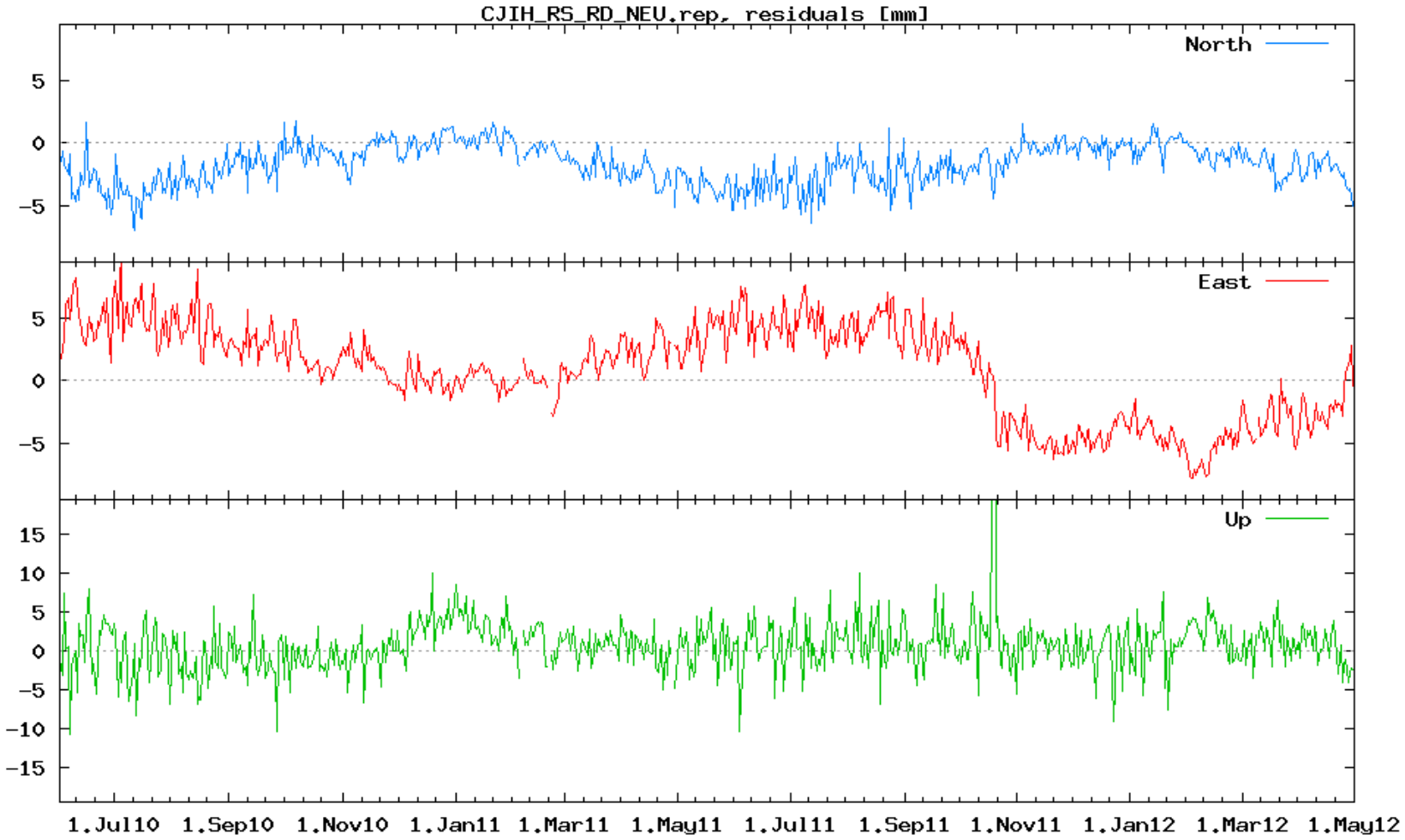
Monitoring of the Czech permanent GNSS sites – Analysis Center GOP

- Check of stability and quality
- Rapid solution used as a basis
- EPN processing standards and guidelines
- 8:00 UTC the daily solution compared with coordinates + statistical test
- Limits: 7mm, 7 mm and 15 mm for N,E,U components

Monitoring results for the site CFRM (good) based on ultra-rapid solution



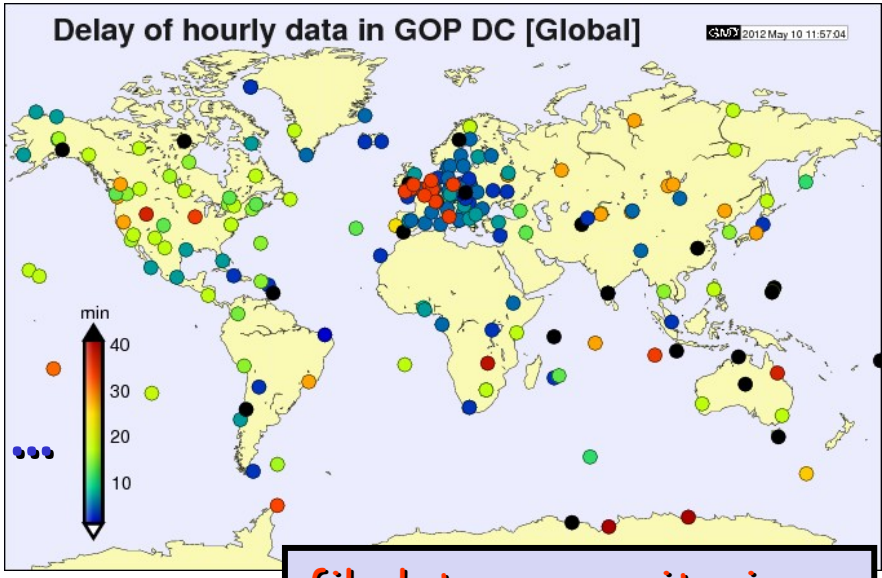
Monitoring results for the site CJIH based on ultra-rapid solution



GNSS data operation/dissemination

GOP operational centre

- GPS, GLONASS, Galileo, QZSS
- hourly, daily, real-time
- 30-sec, high-rate (1Hz)
- EUREF, IGS, VESOG, CZEPOS, …

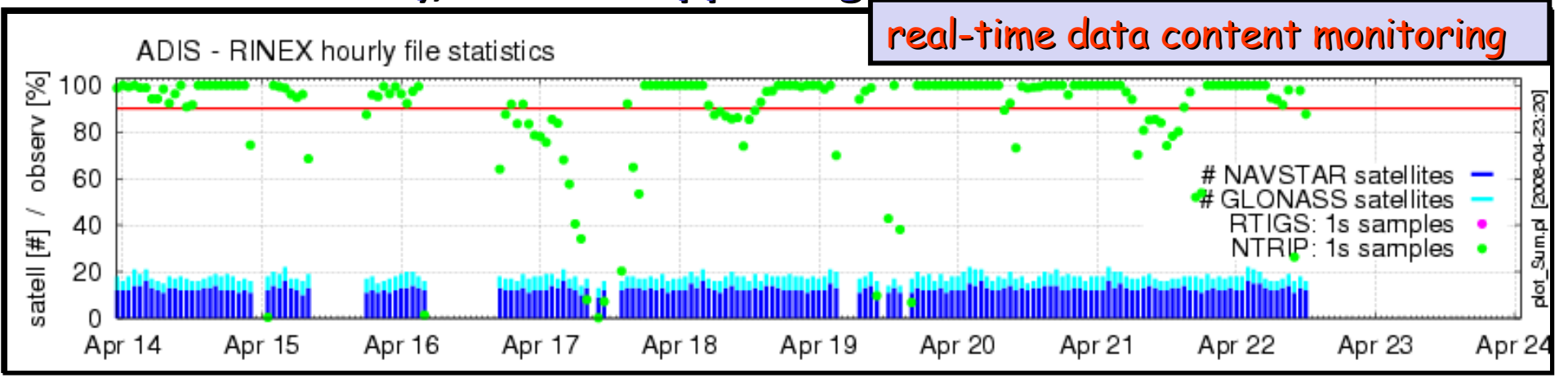


file latency monitoring

GOP Data Centre (EUREF, ..)

- **Files** – GNSS data (daily, hourly and historical), various supporting products

real-time data content monitoring



GPS+GLONASS precise orbit determination

GOP contribution to the International GNSS Service (IGS) – since 2004

software: Bernese GPS sw. V5.0 (GOP modified)

input: **hourly GPS data + navigation messages**

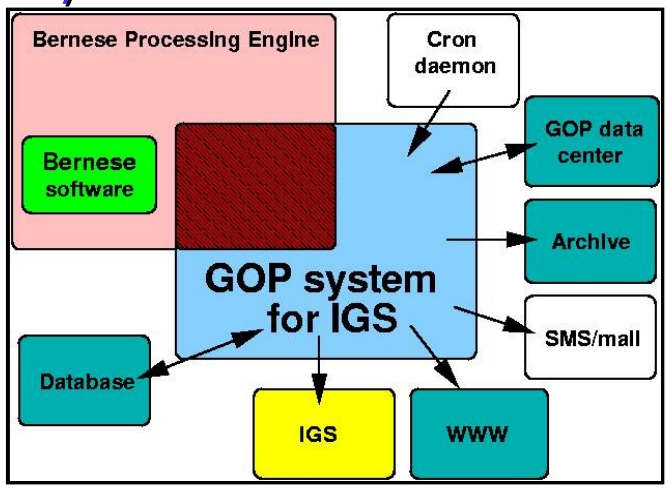
output: **ultra-rapid orbits (GPS+GLONASS)**

product: **2-day arcs fitting, 1-day arc prediction**

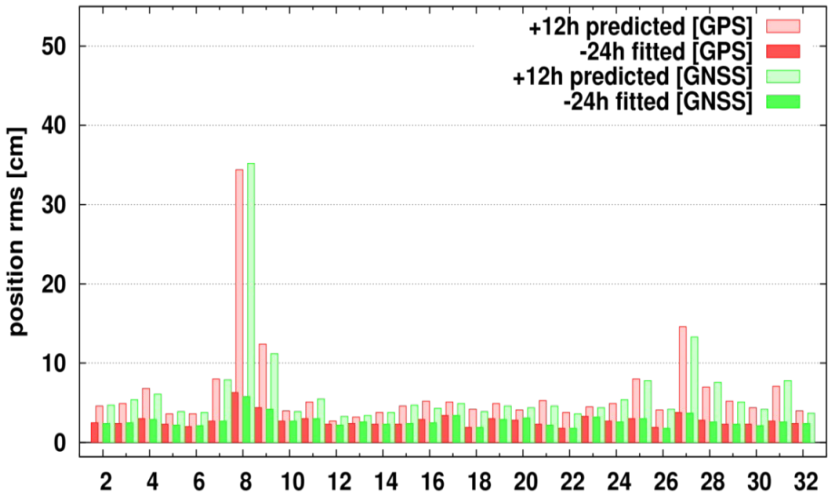
usage: **(near) real-time applications**

processing features:

- LSQ adjustment
- 6-hour update cycle
- double-differenced observations
- efficient strategy with no redundancy
- network split into continental clusters
- self-initializing processing system
- all satellites included, multi-GNSS
- automated manoeuvres detection
- originally developed at GOP



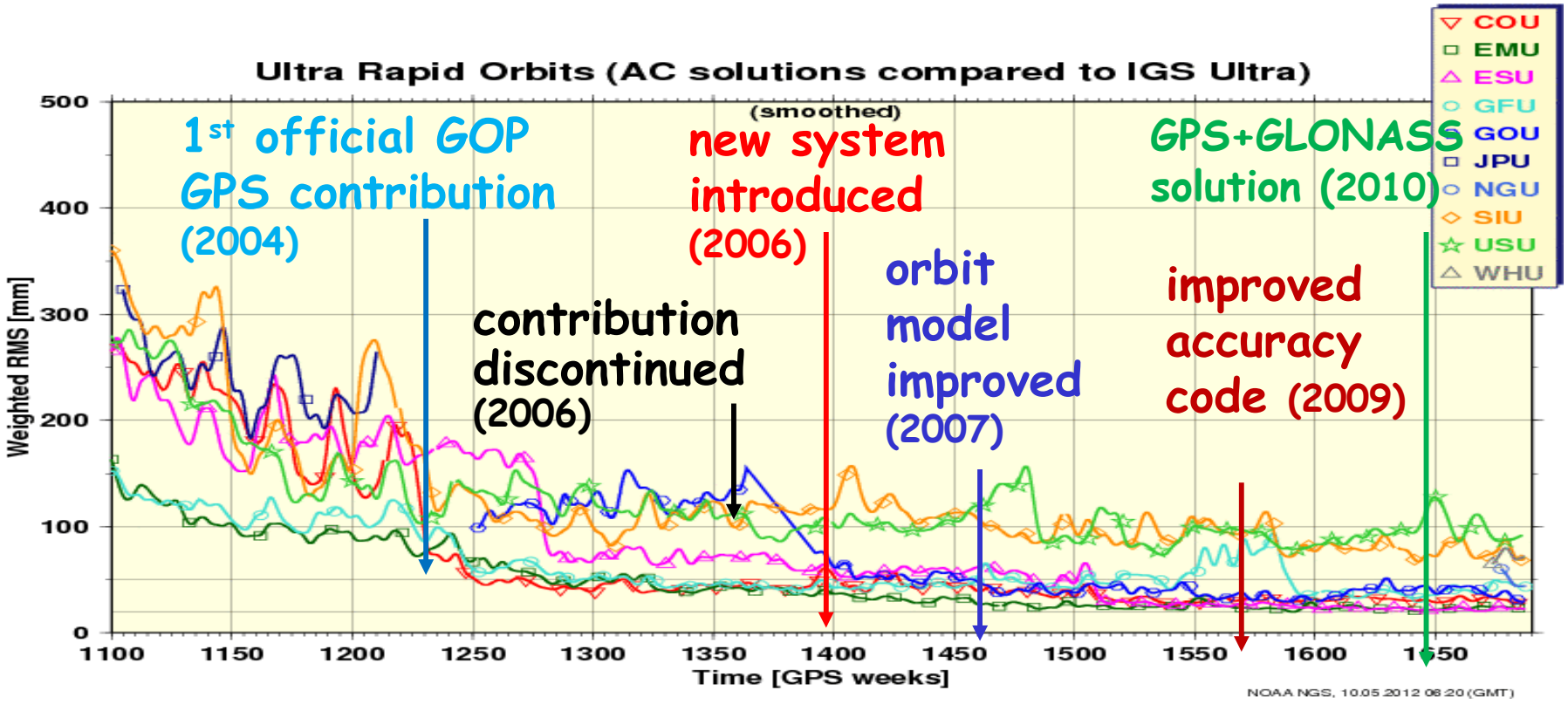
GPS ultra-rapid (GOP) x final orbits (IGS)



GOP orbits/ERP products (milestones)

GOP contribution to the International GNSS Service (IGS) – since 2004

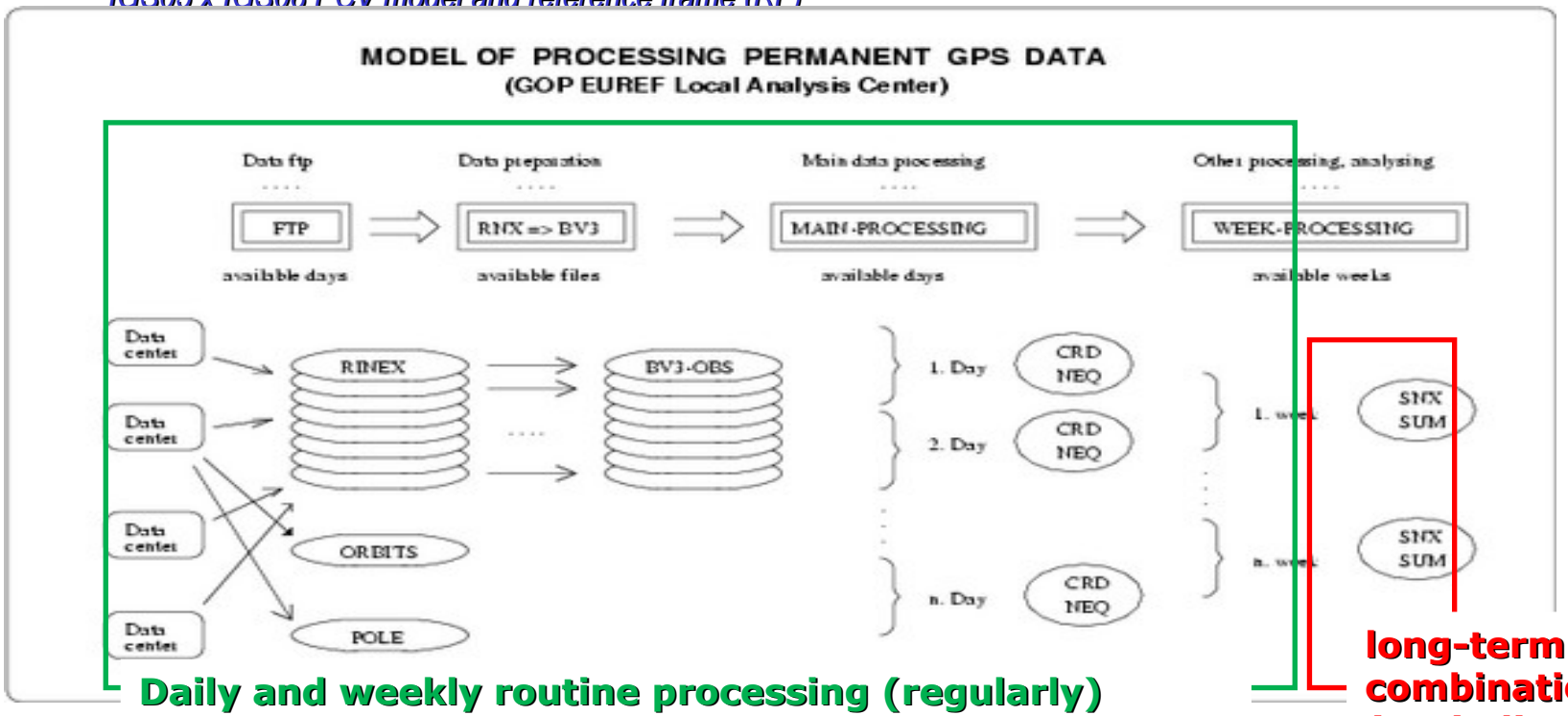
	orbits	clocks	Y,X pole	X,Y pole rates	length of the day
fitted prod.	<5 cm	-	0.1 mas	0.2 mas/day	0.03 ns
predicted prod.	10 cm		0.3 mas	0.3 mas/day	0.07 ns



Terrestrial reference frame realizations

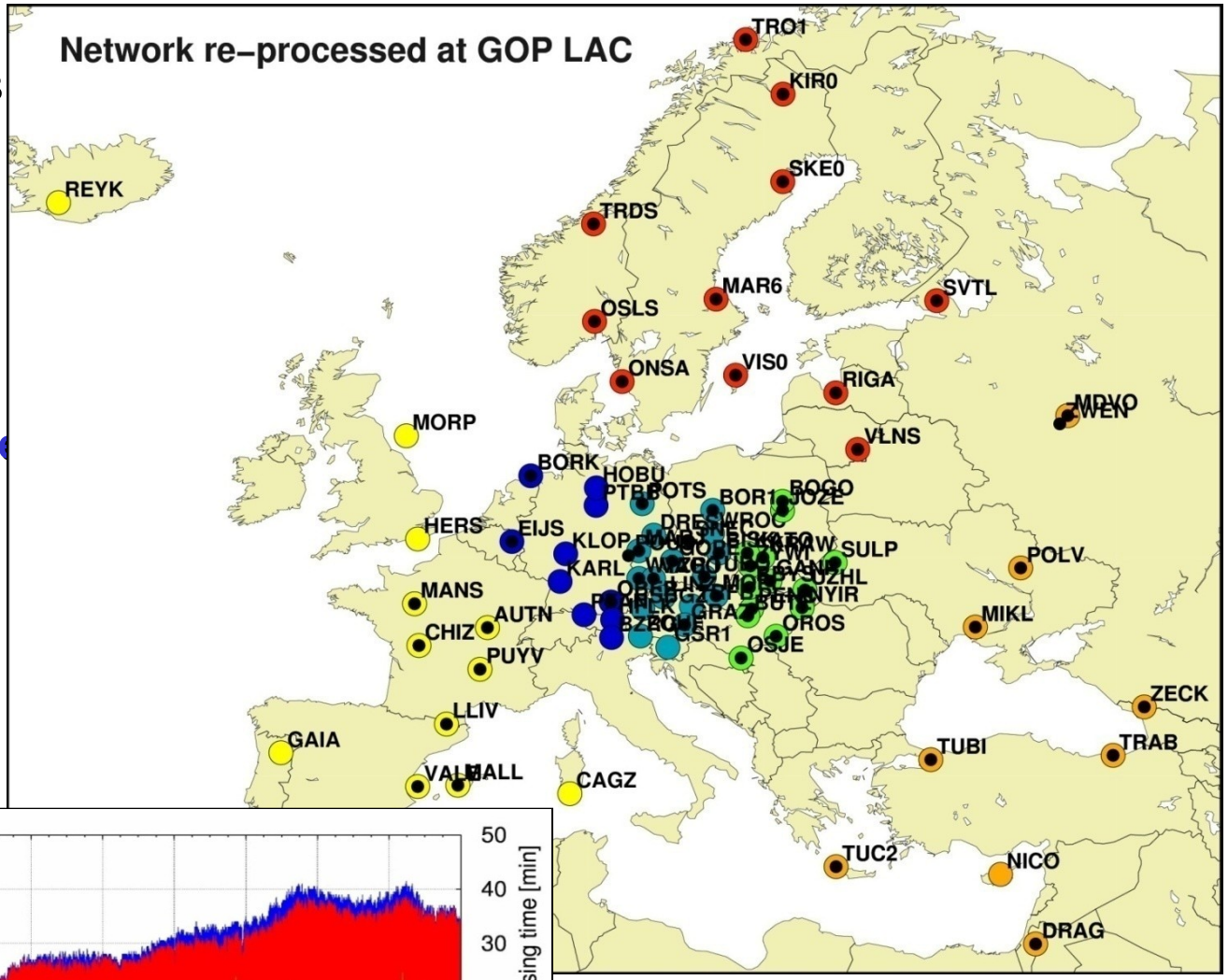
GOP contribution to the EUREF Permanent Network (EPN) – since 1997

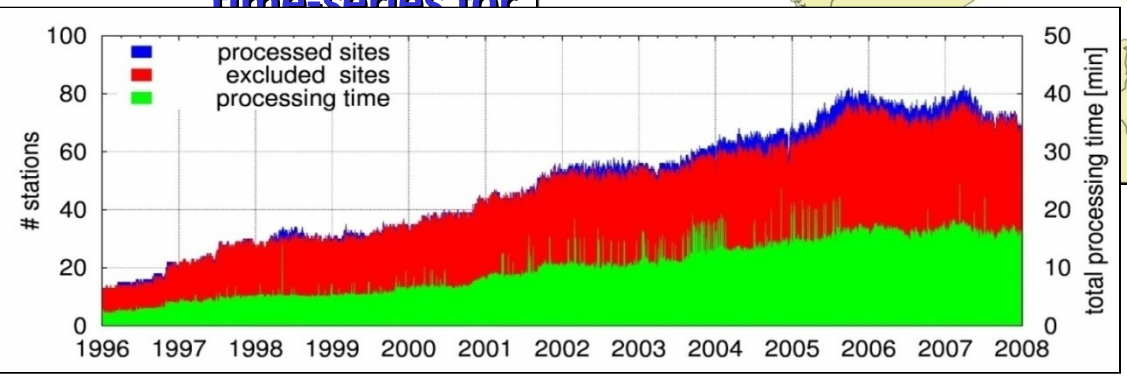
- GOP routinely contributes to EUREF RF maintenance and European ITRFxx realization
- GOP supported EPN reprocessing project (since 1996-2008) – repro1
- GOP daily & weekly full EUREF network reprocessing (~250 sites) using IGS05 and IGS08 - repro1+
- GOP combined full network for the assessment of
  - *EUREF ITRF2008 densification,*
  - *ITRF2008 of EUREF coordinates, velocities and their discontinuities*
  - *IGS05 x IGS08 PCV model and reference frame (RF)*



GOP sub-network re-processing (1996-2008)

- Consistent up-to-date models applied
- A long-term homogeneous solution
- Coordinate time series for geodynamics and reference frame
- Troposphere parameters time-series for

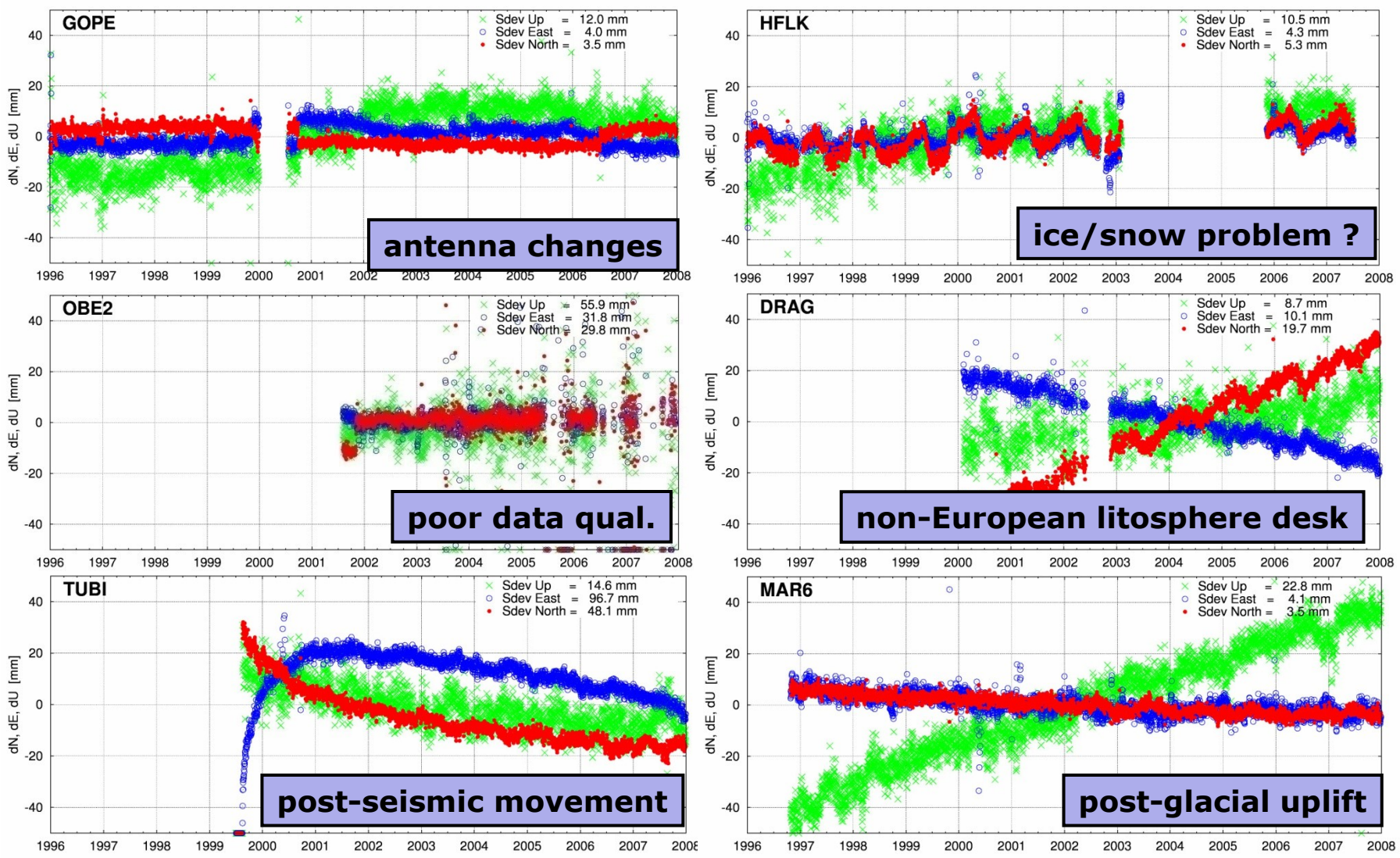




~5475 processed daily sessions
~60 processing days (8 CPUs)

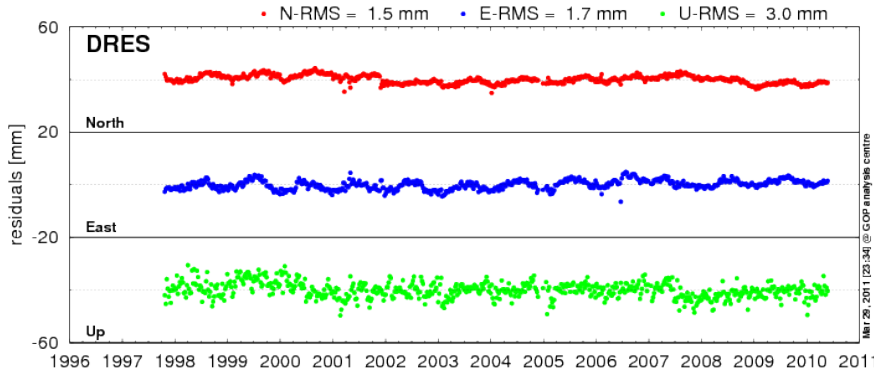
GOP reprocessing - raw coordinate time-series

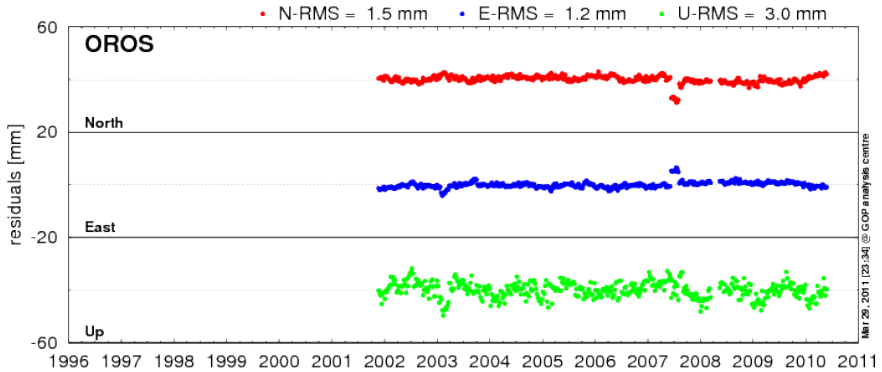
plots of daily-based independent solutions expressed in a single reference frame!

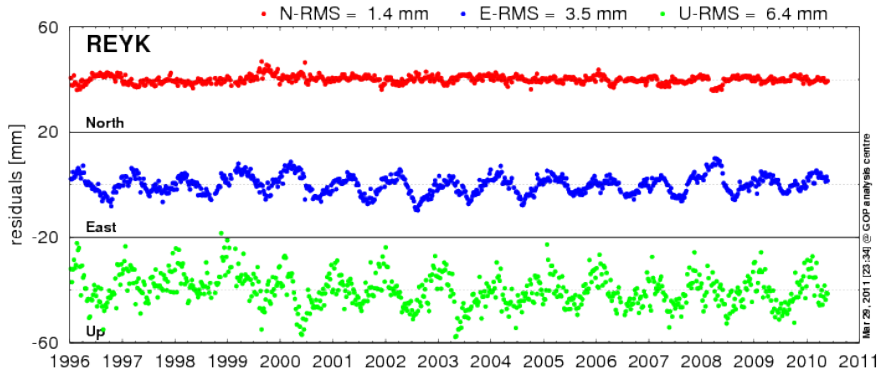


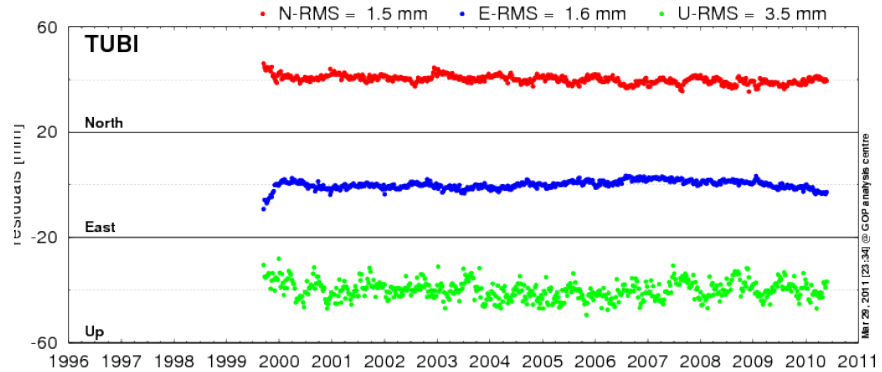
Multi-year combination results

estimation of stations' velocities and coordinates discontinuities

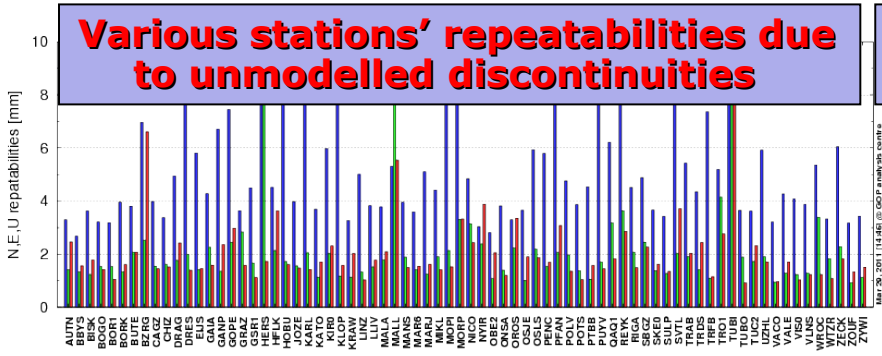




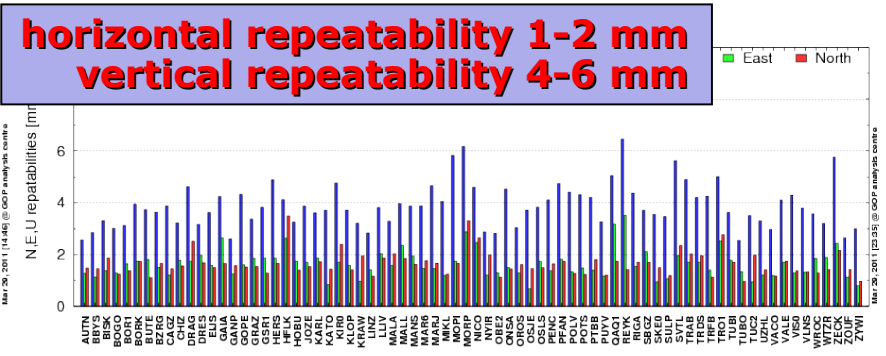




Various stations' repeatabilities due to unmodelled discontinuities

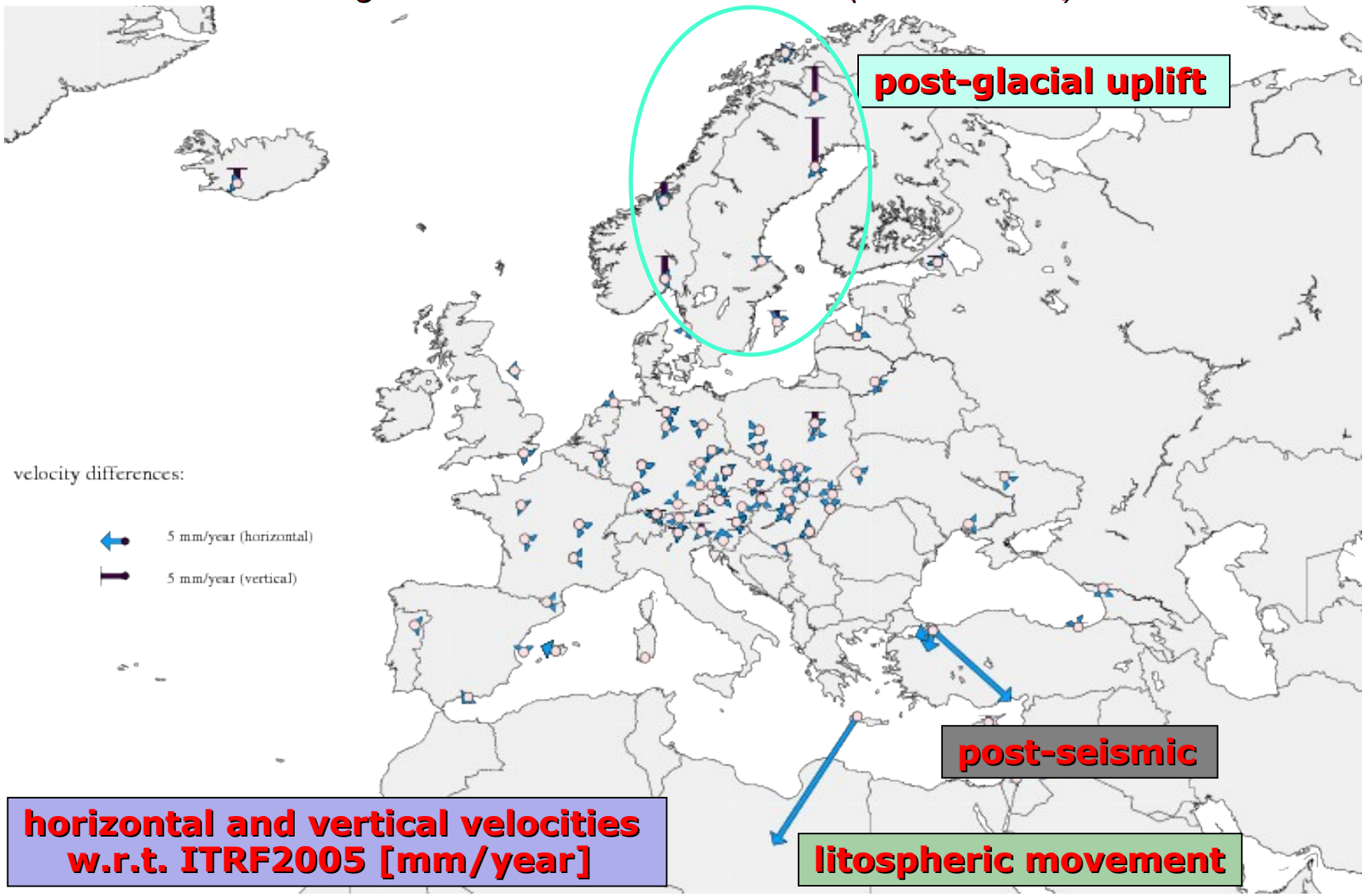


horizontal repeatability 1-2 mm
vertical repeatability 4-6 mm



Velocity estimates based on combination

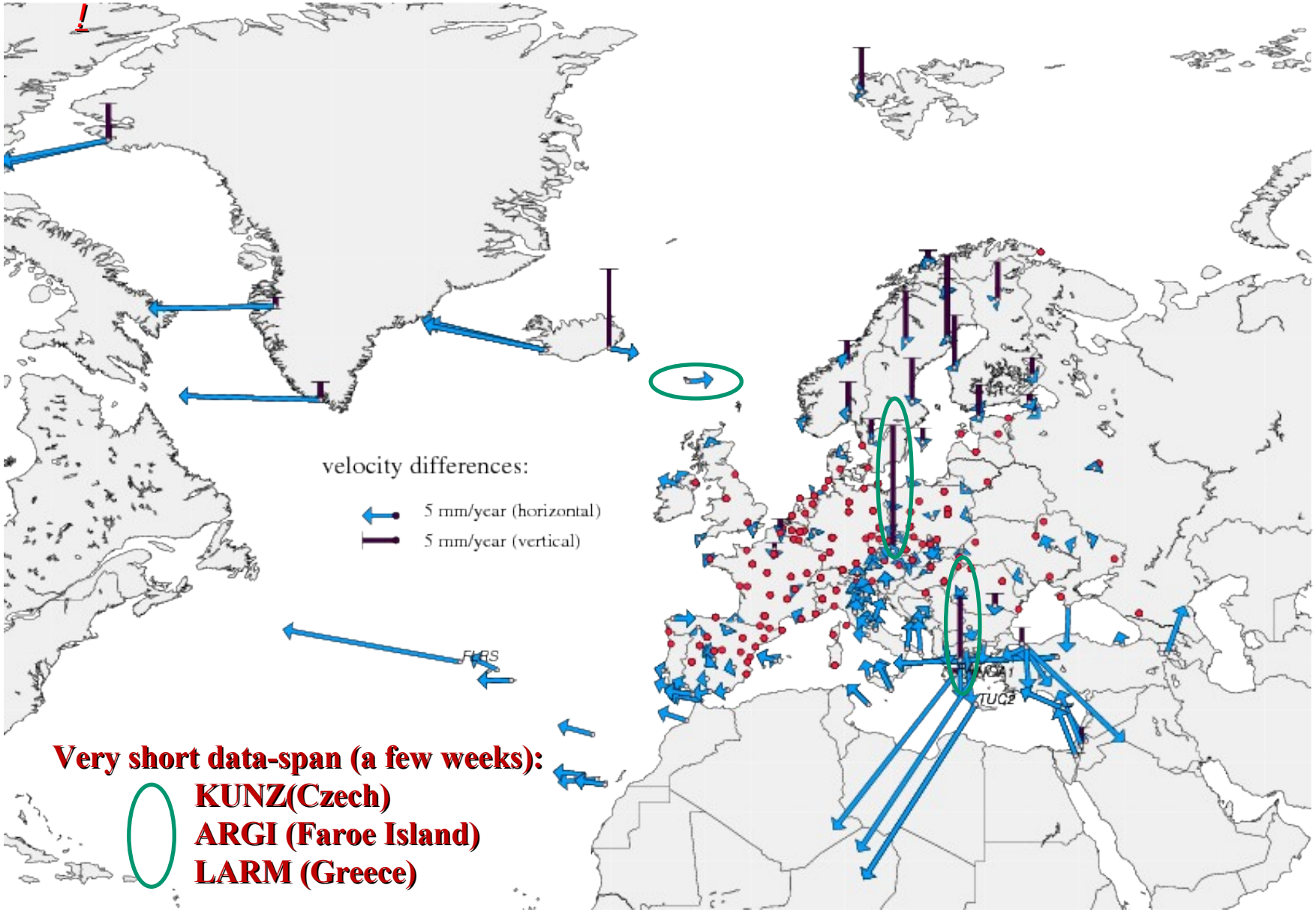
Original GOP EPN sub-network (~70 stations)



horizontal and vertical velocities w.r.t. ITRF2005 [mm/year]

Velocities with respect to Eurasian plate

Based on complete EUREF Permanent network GOP repro1+ solution !

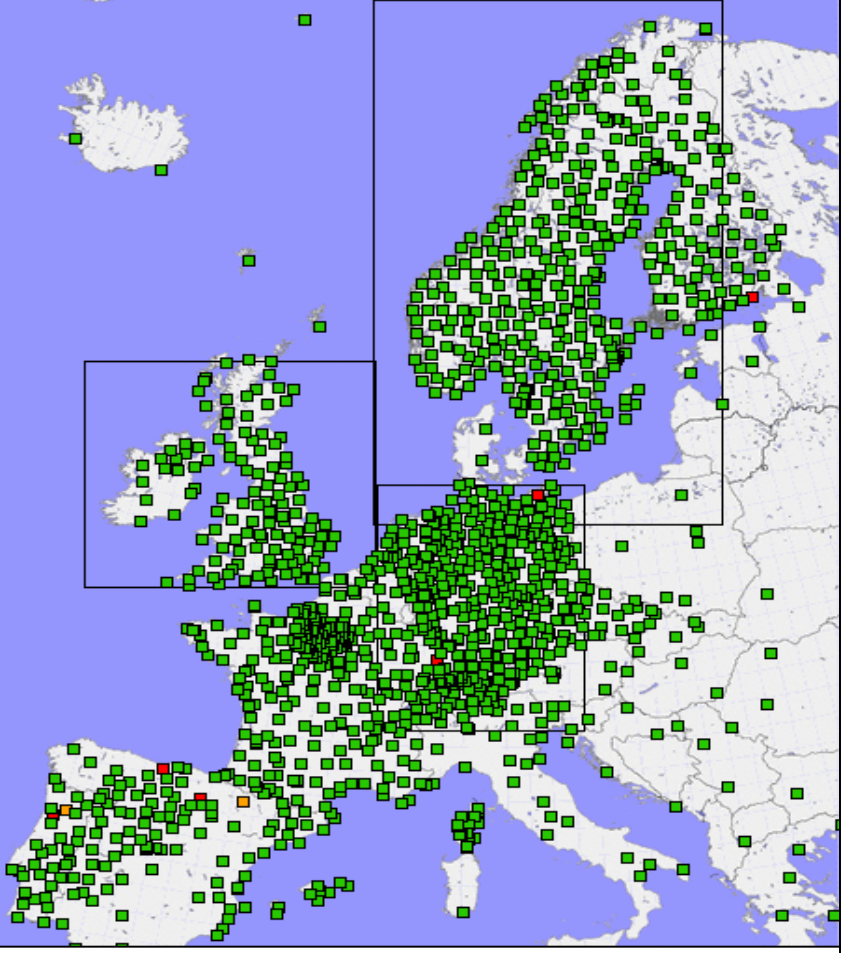


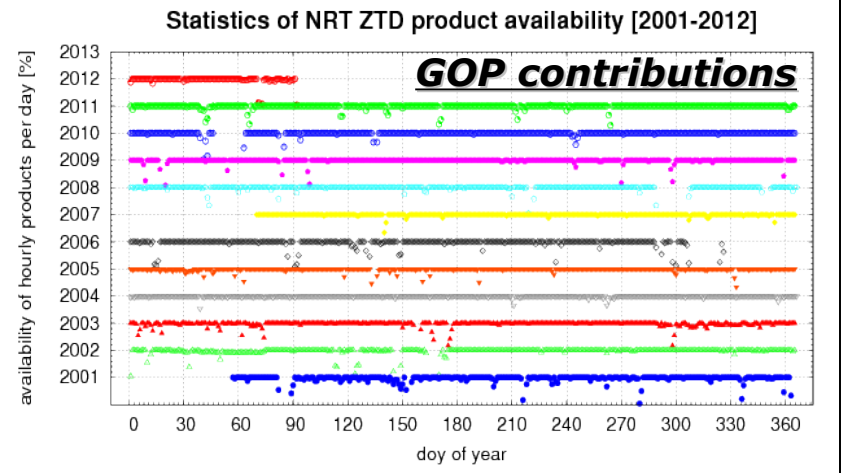
Very short data-span (a few weeks):

KUNZ(Czech)

ARGI (Faroe Island)

LARM (Greece)





GOP activities within GPS-meteorology

……

COST-716 Action (1998-2003): *"Exploitation of Ground-Based GPS for Operational Numerical Weather Prediction and Climate Applications"*

- **15 Institutions, 7 ACs, > 200 GPS sites**

TOUGH (2003-2006): *„Targeting Optimal Use of GPS Humidity Measurements in Meteorology"*

- **15 Institutions, 12 ACs, > 400 GPS sites**

E-GVAP I (2006 - 2009), E-GVAP II (2010-2012)

„The EUMETNET GPS Water Vapor Programme"

- **13 Institutions, 12 ACs, > 1600 GPS sites**

COST Action (pre-proposal) – March 31, 2012

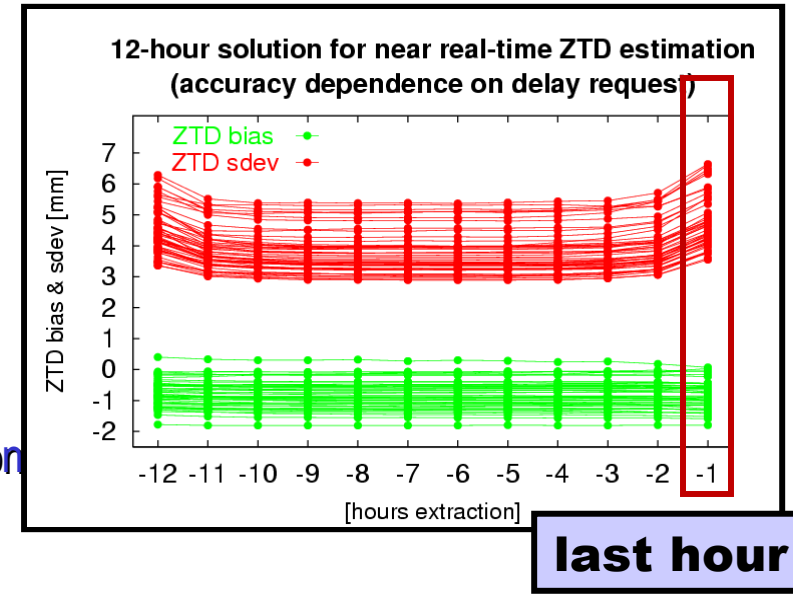
„Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC)"

- **interested 37 institutions from 25 countries**

Near real-time ZTD solutions by GOP

Processing requirements

- hourly GNSS data and precise IGS ultra/rapid orbits

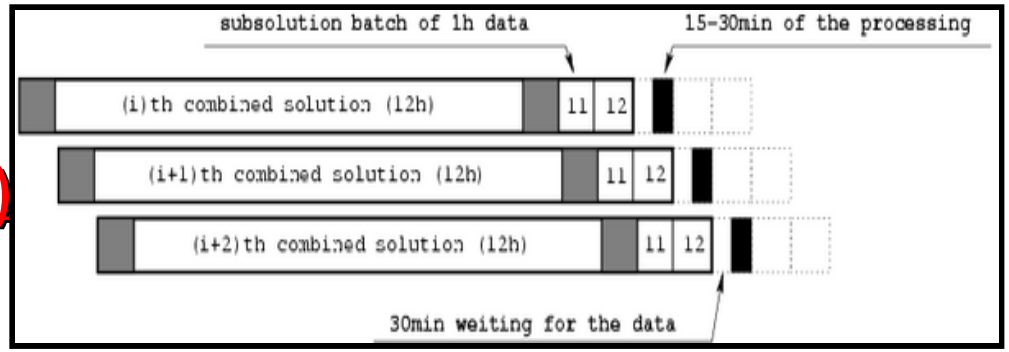


GOP processing features

- processed every hour in HH:20
- 4 hourly data batches and normal equations (NEQ)
- ZTD based on last 12 hours from NEQ combination
- Coordinates based on 28 days from NEQ combination
- processing efficiently distributed in the clusters

GOP ZTD characteristics

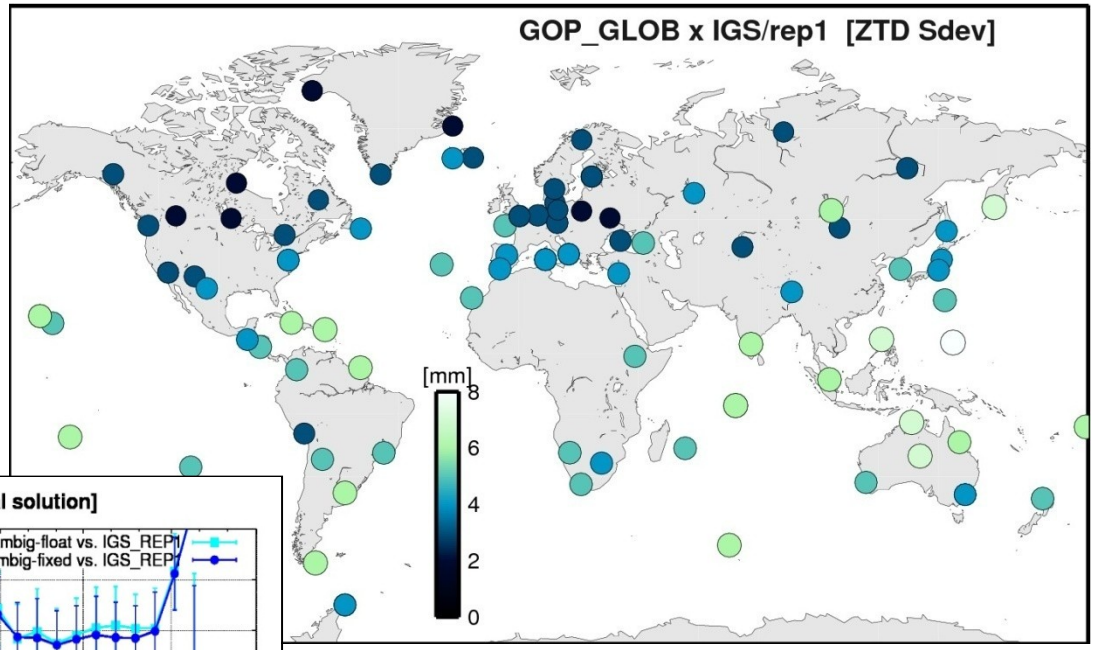
- ZTD product (HH:00 – HH:59) - linear trend model (piece-wise linear function)
- ZTD product filtering:
  - min 4 hours in NRT ZTD solution
  - min 2 days in NRT CRD solution

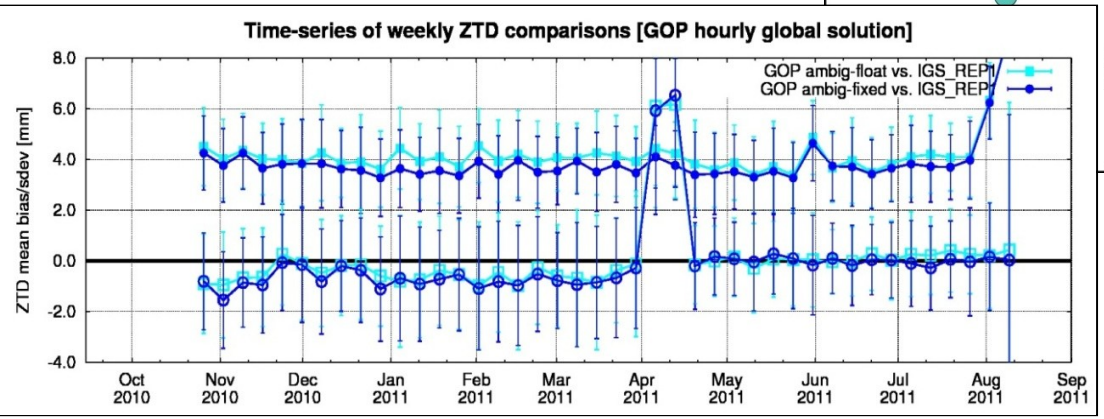


GOP ZTD solutions (E-GVAP)

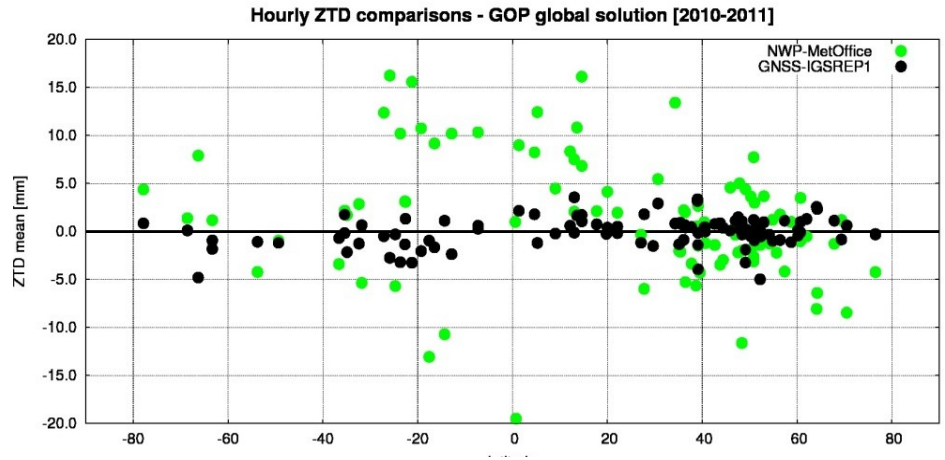
- Regional/national (GPS)
- Regional/national (GNSS)
- Global (GPS)

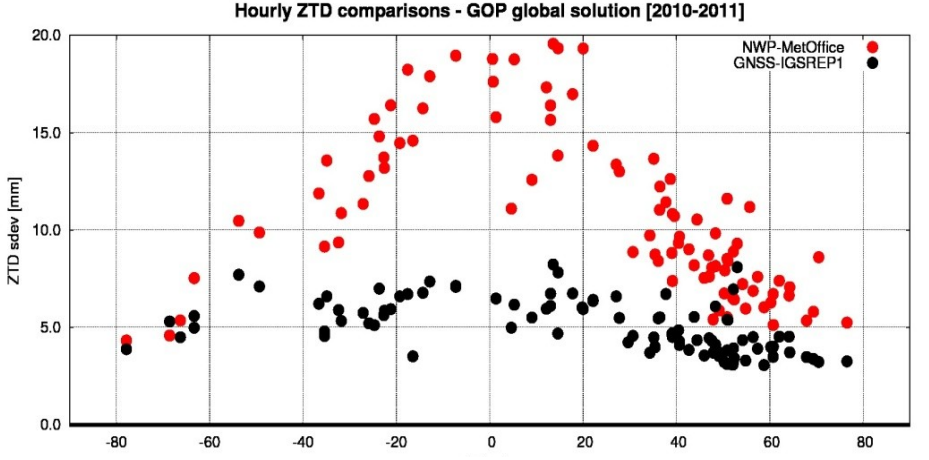
GOP global hourly ZTD 2010-2012





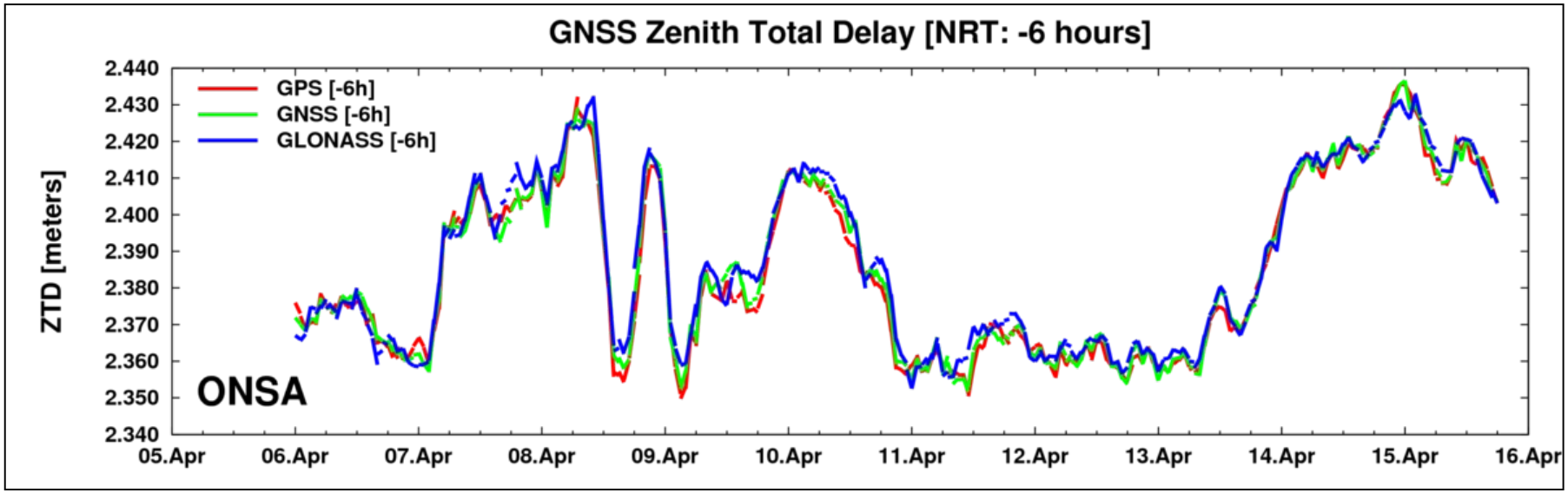
SDEV and BIAS more variable than regional ZTDs, however, still within 3-8 mm and 0-2 mm, respectively





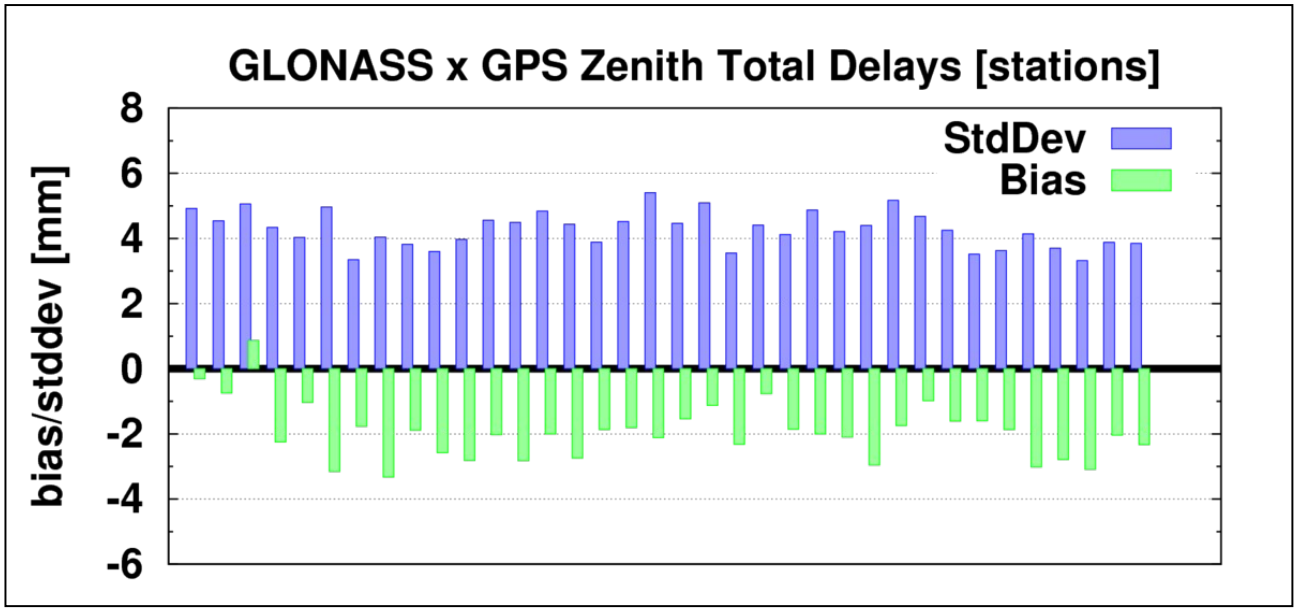
Figures show comparison to UK Met Office global NWM – strong latitude dependence

NRT ZTDs from GPS, GLONASS and multi-GNSS solutions



Using IGS05 APCV model a bias of 0-2 mm observed between stand-alone GPS and GLONASS ZTD solution.

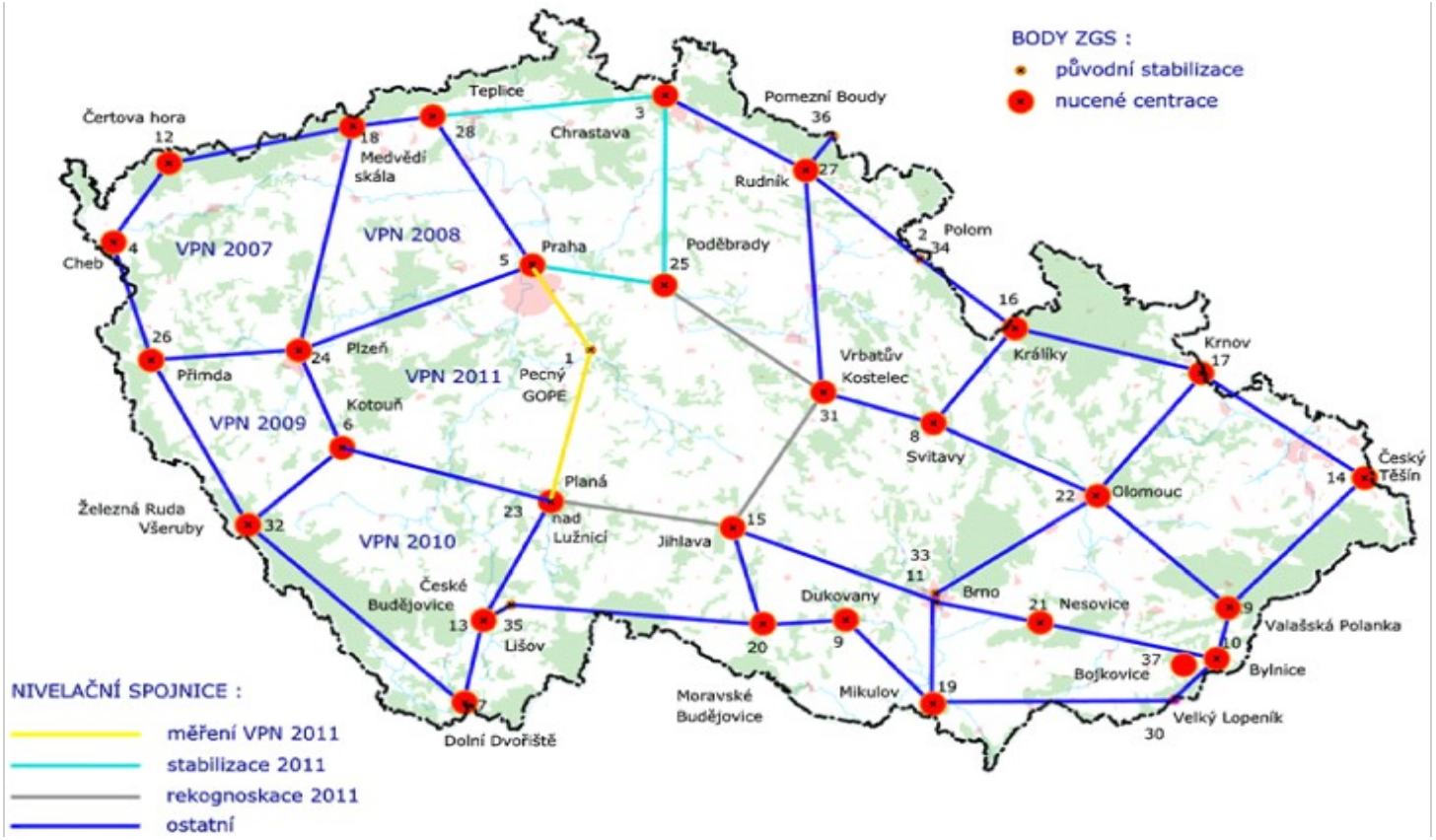
By adopting IGS08 almost disappeared.



ECGN, gravity, geodynamics

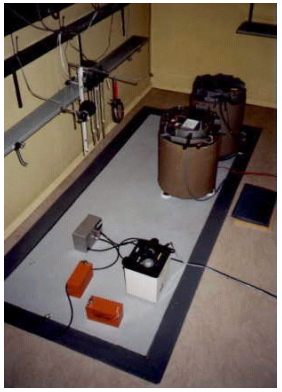
- 180 km of levelling lines in the geodynamic network (long-term rms/1 km error 0.60 mm)
- Gravimetric measurements at 2 stations of the geodynamic network, vertical gradients at 3 sites, local gravity network GOP,
- superconducting (OSG-050) and absolute gravimetry (FG5 No. 215) at GOP, environmental effects on gravity
- ICAG at Walferdange, Nov 2011
- Absolute gravity measurements: Slovakia (3 sites), Hungary (6), Czech Republic (3 sites), GGP station Strasbourg (France)
- Repeated absolute gravity measurements at GNSS permanent stations GOPE (12), POL1 (2), KUNZ (2) and ZDIB (3)

Levelling in Fundamental Geodynamical Network in 2011 – Land Survey Office



Tidal Gravimetry at GO Pecný and Environmental Effects

- gravity time series by GWR OSG-050, Askania Gs15 No. 228 and by LCR 137
- calibration by FG5 No. 215 absolute gravimeter
- very broadband 3-D seismometer
- climatological station
- meteorological parameters
- soil moisture
- ground water level



Thank you for your attention !

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