Global Near Real-Time, Multi-GNSS and Ultra-Fast Troposphere Estimation at Geodetic Observatory Pecny

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arch Institute of Geodesy, Topography and Cartography
etic Observatory Pecný (GOP)

Outline

- Introduction
- Global hourly near – real-time ZTD estimates
- Assessment of multi-GNSS ZTD estimates
- Ultra-fast/real-time estimates of ZTD
- Summary

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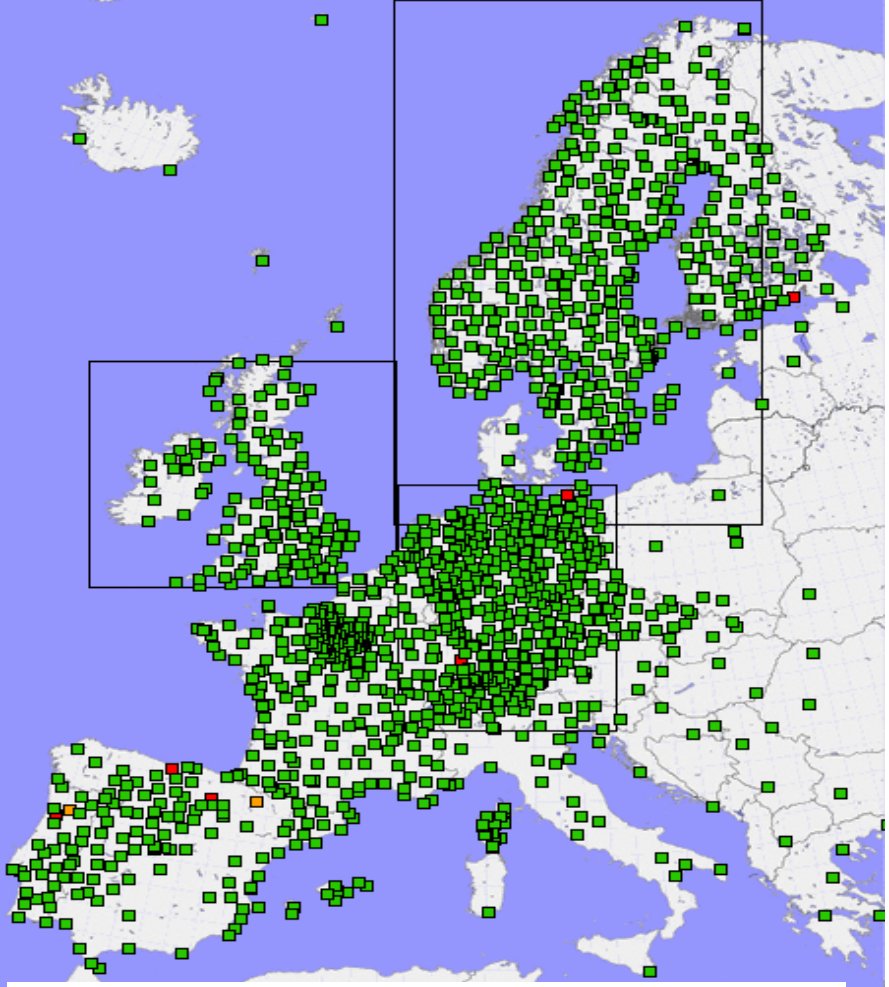
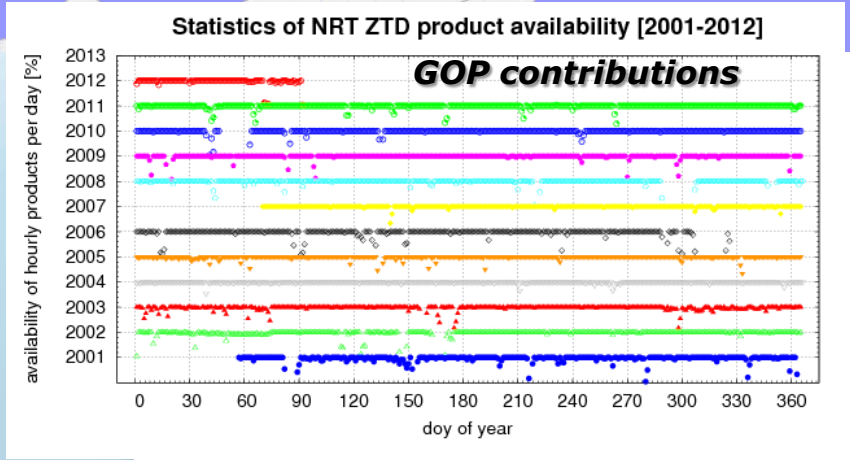
Ground-based GPS-meteorology





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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

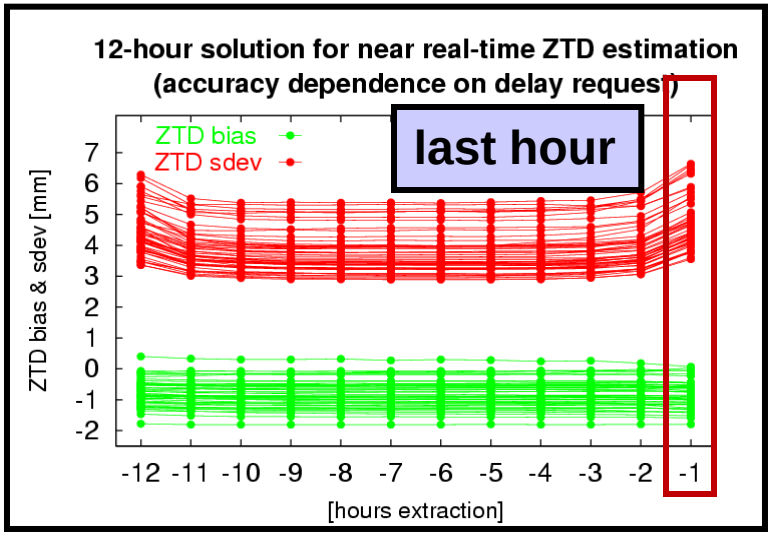
„Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC)"

- **interested 37 institutions from 25 countries**
- **See poster by Jones at al.**

Near real-time ZTD solutions by GOP

Processing requirements:

- hourly GNSS data and precise IGS ultra/rapid orbits



GOP processing features:

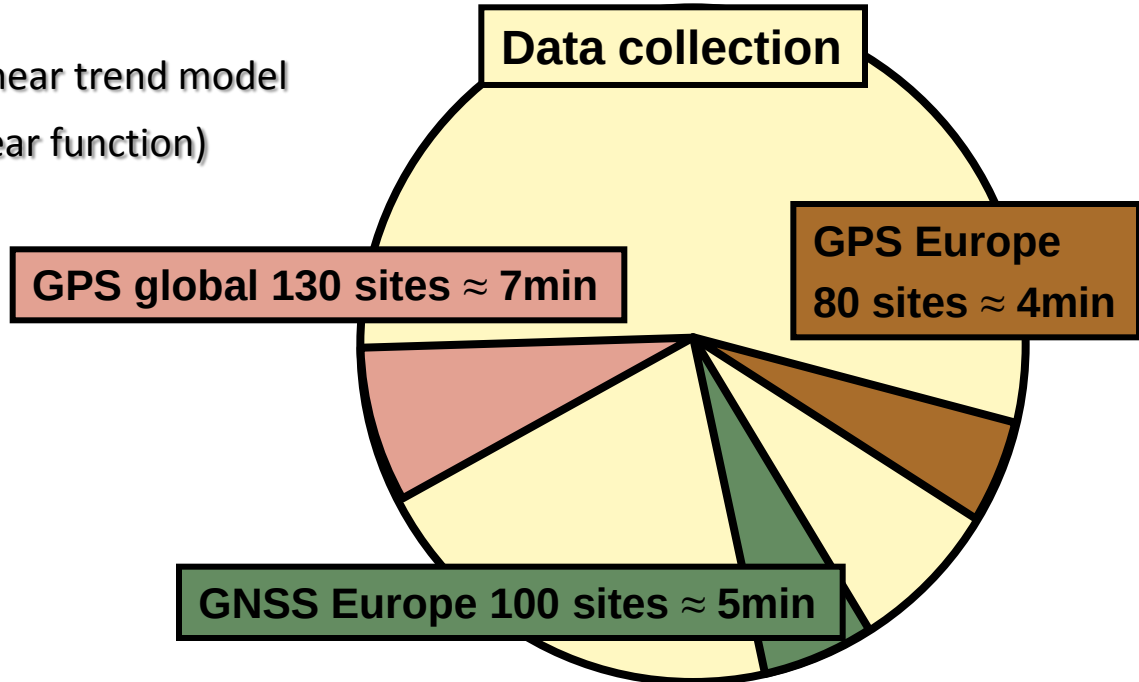
- Bernese GPS software v.5.0
- Process starts every hour at HH:20
- 4 hourly data batches and normal equations (NEQ)
- ZTD based on last 12 hours from NEQ combination
- Coordinates based on 28 days from NEQ combination

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

ZTD solutions (E-GVAP):

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



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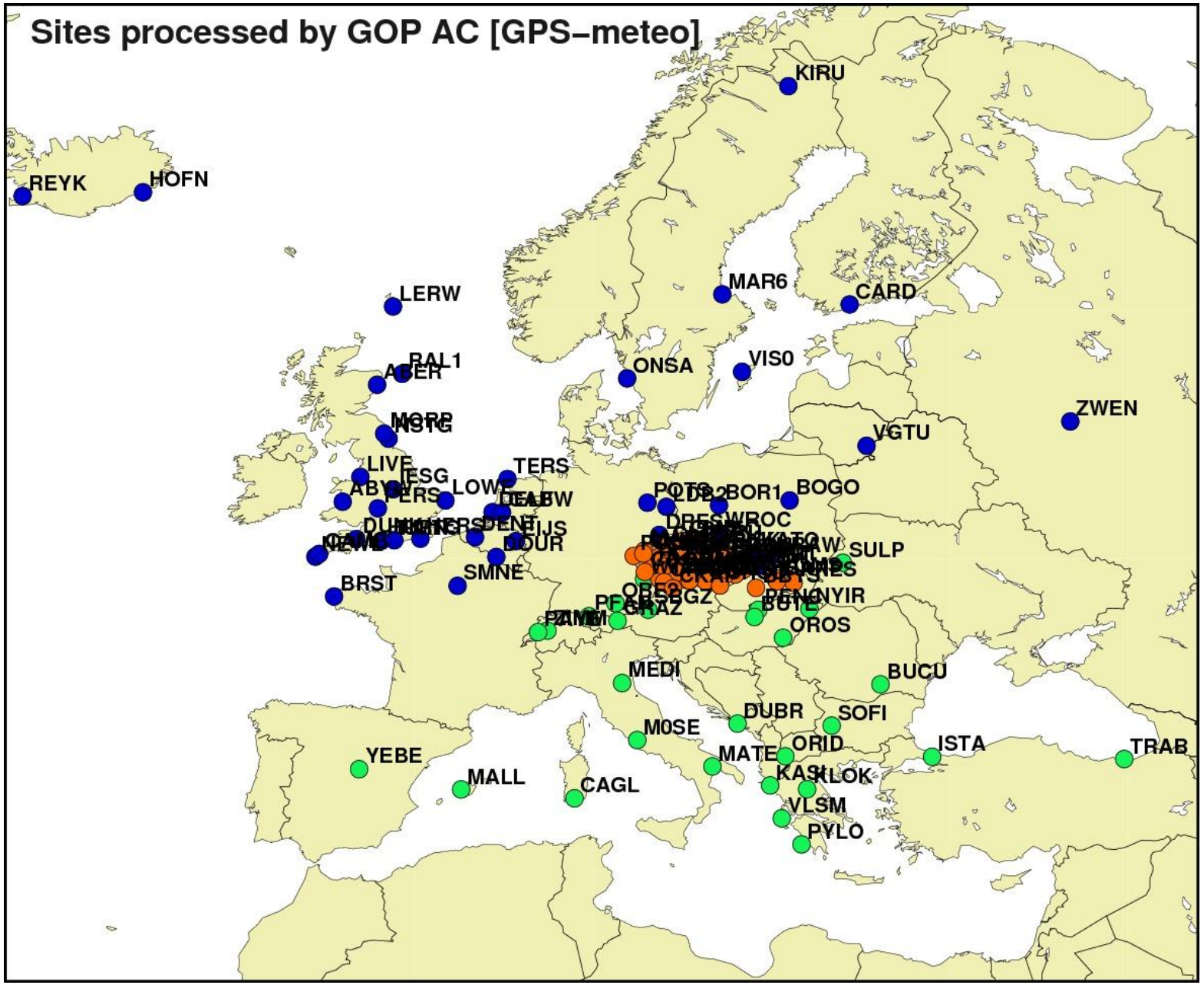
GNSS regional network processed in GOP



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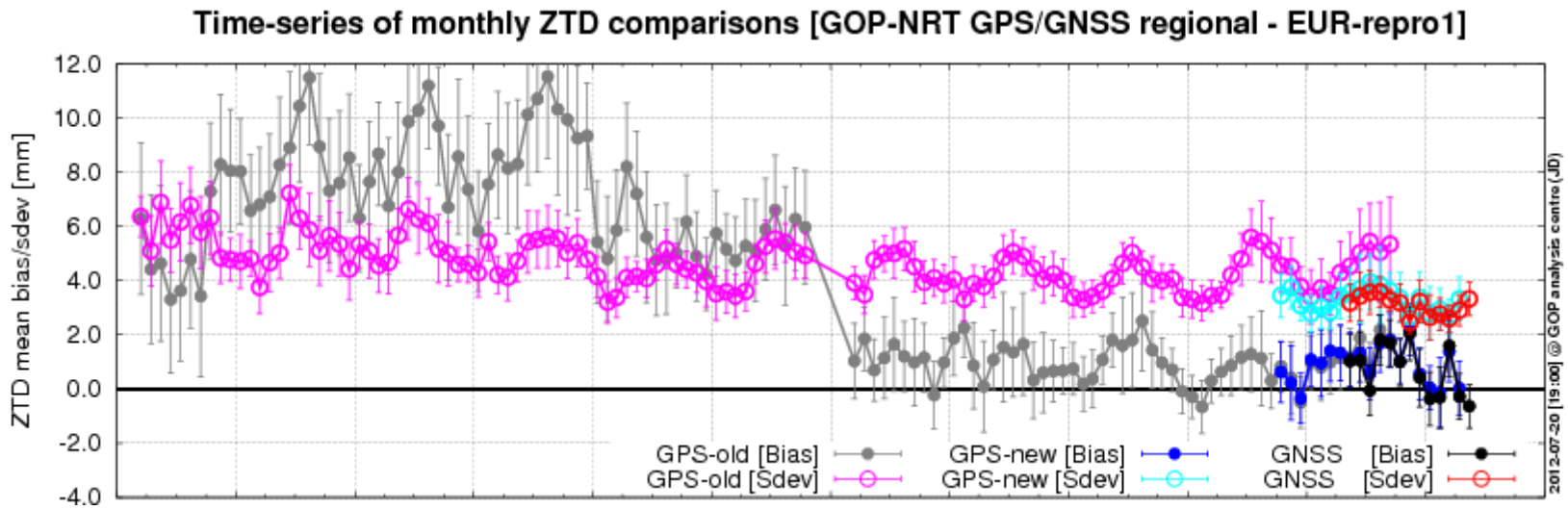
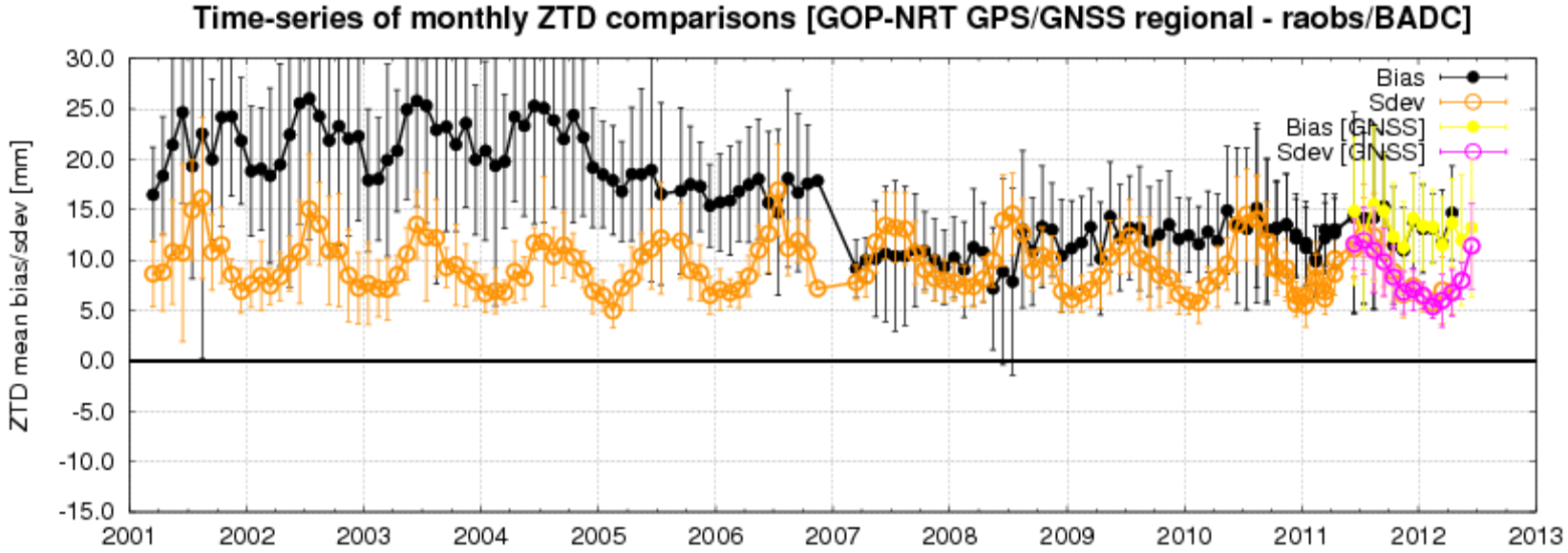
GOP NRT ZTD long-term comparison





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GOP global hourly updated ZTD product

Getting official routine global ZTD solution

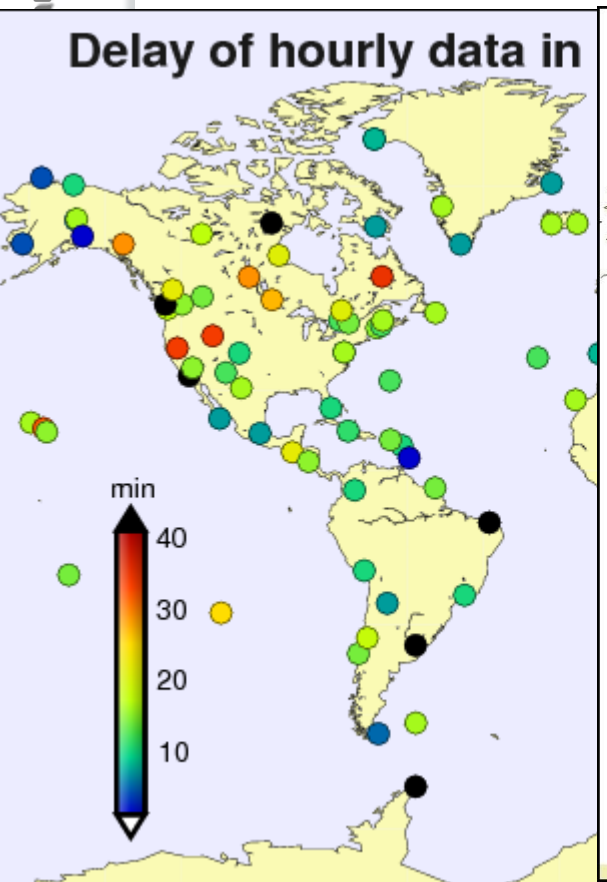
October 1, 2010 – started routine solution (testing status)

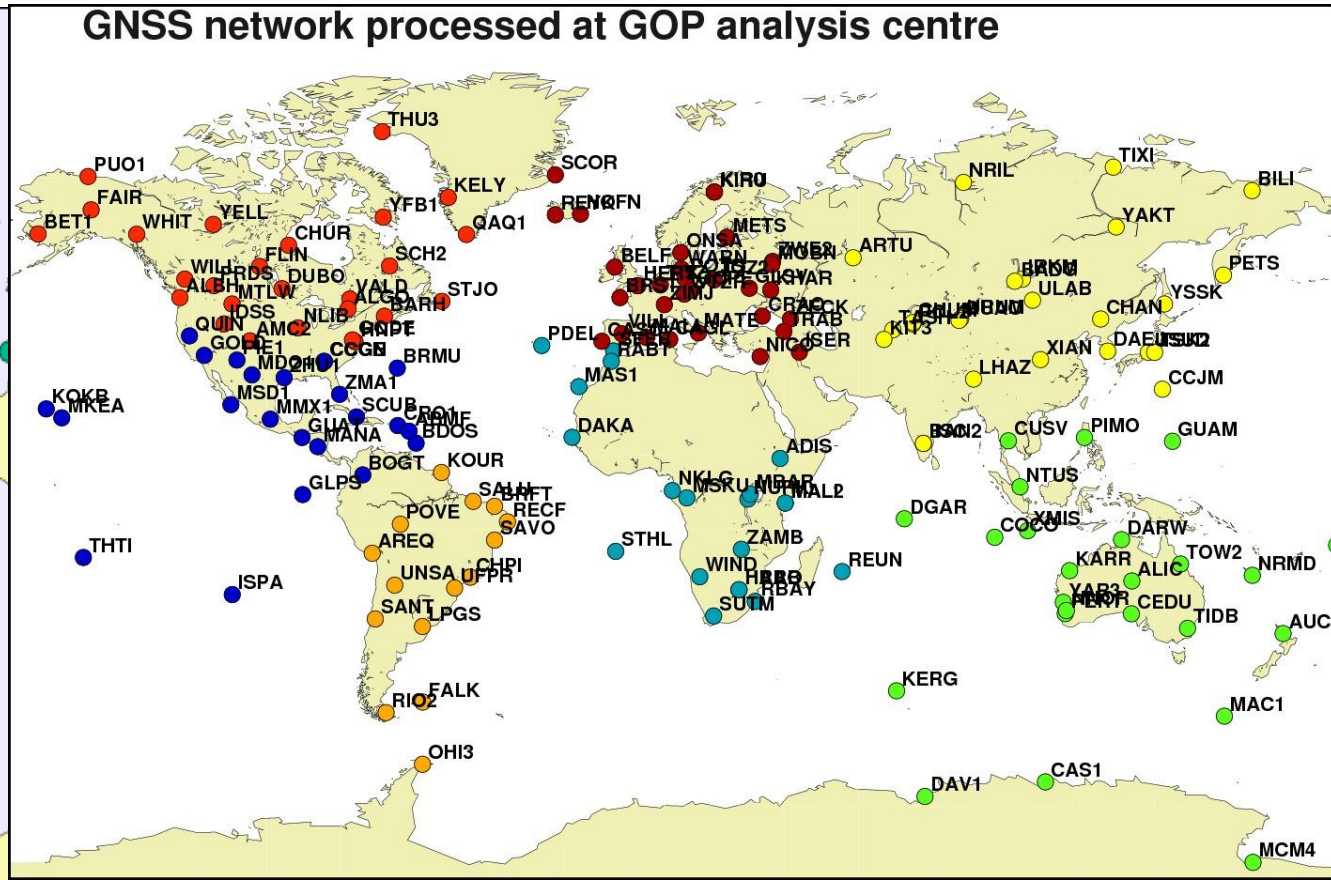
Evaluation 10 months with 80 global stations (IGS/EUREF repro1, radiosonde)

September 10, 2011 – switched to operational mode (UK MetOffice request)

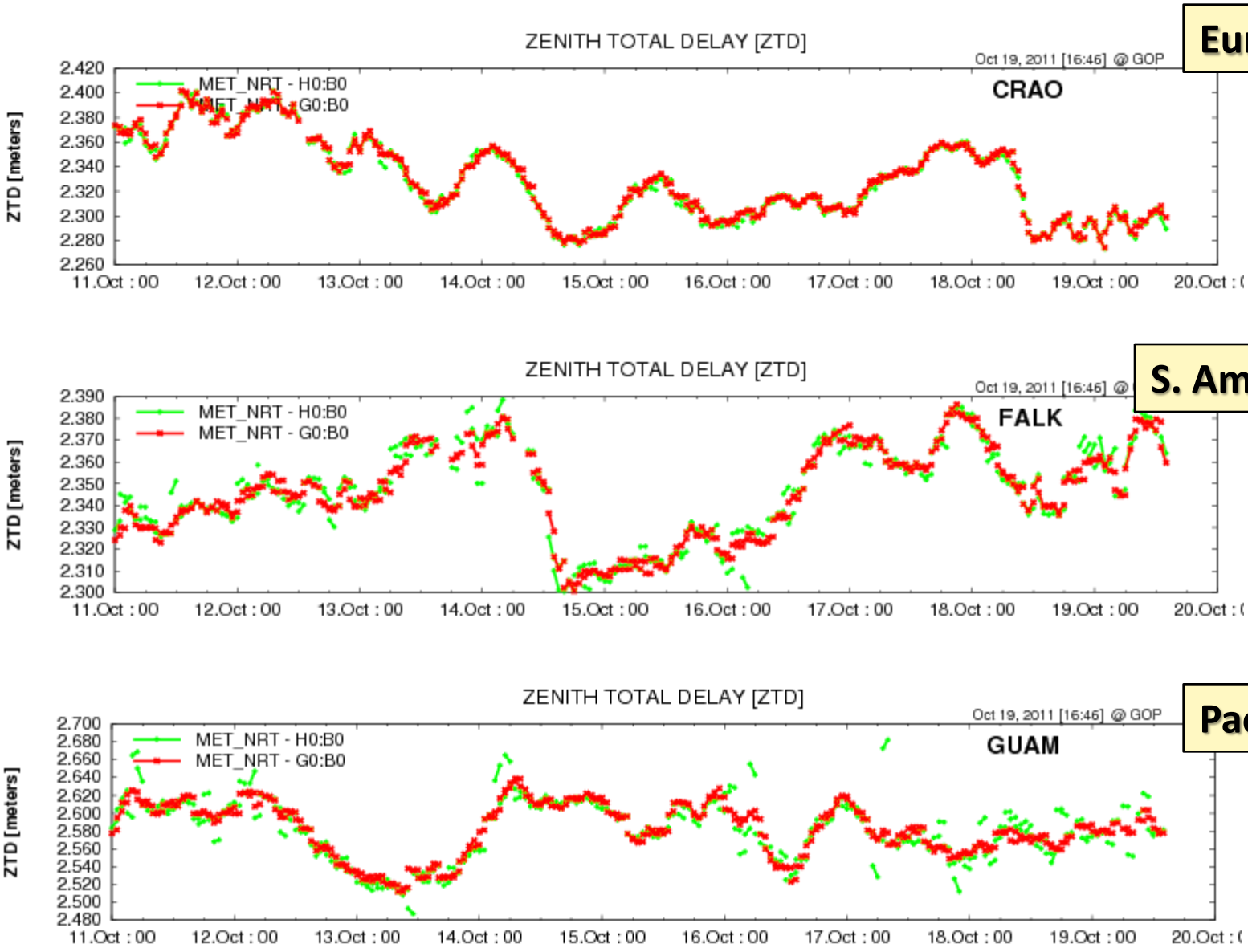
Fig left - hourly files @ GOP DC → global solution started at HH:40

Fig right - a global network extension (80->170), but up to 20% no data

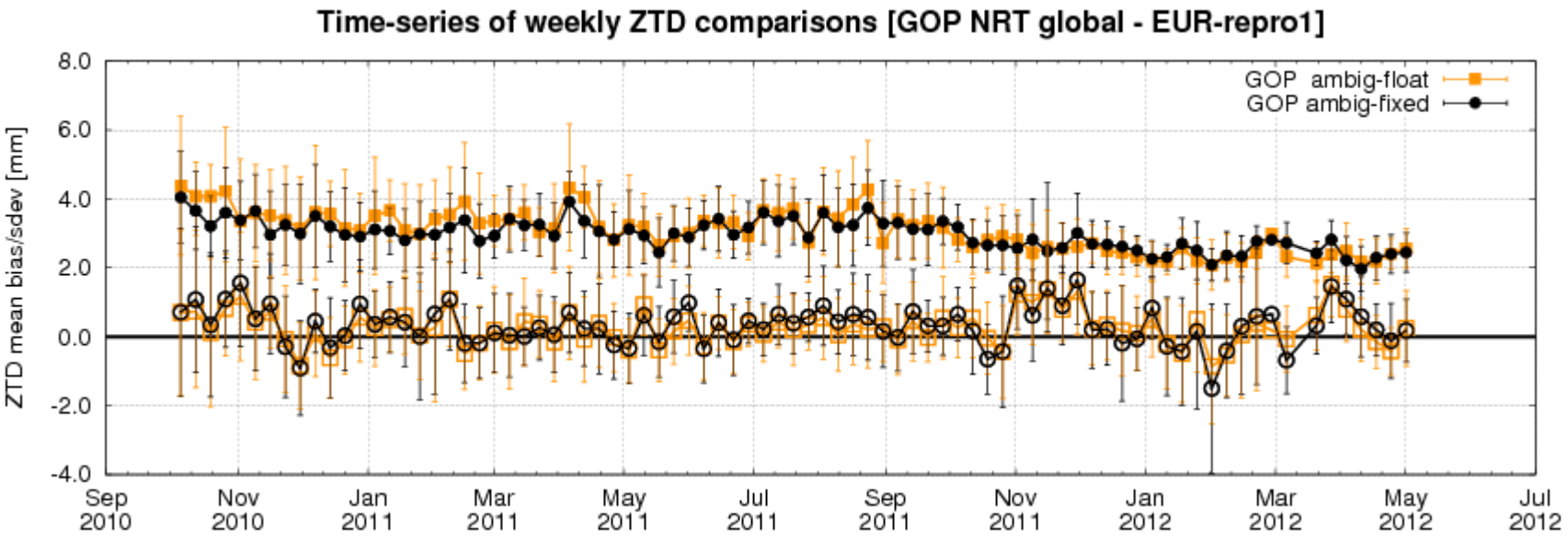


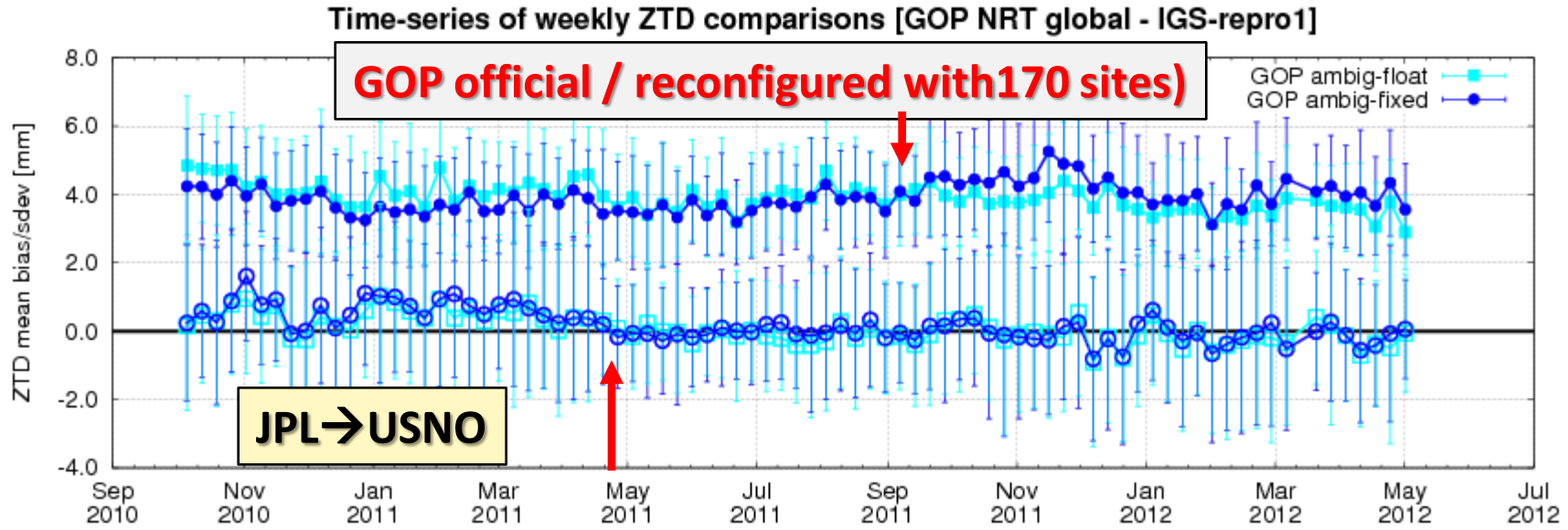


Global GOP ZTD – example time-series



ZTD time-series for European/global stations





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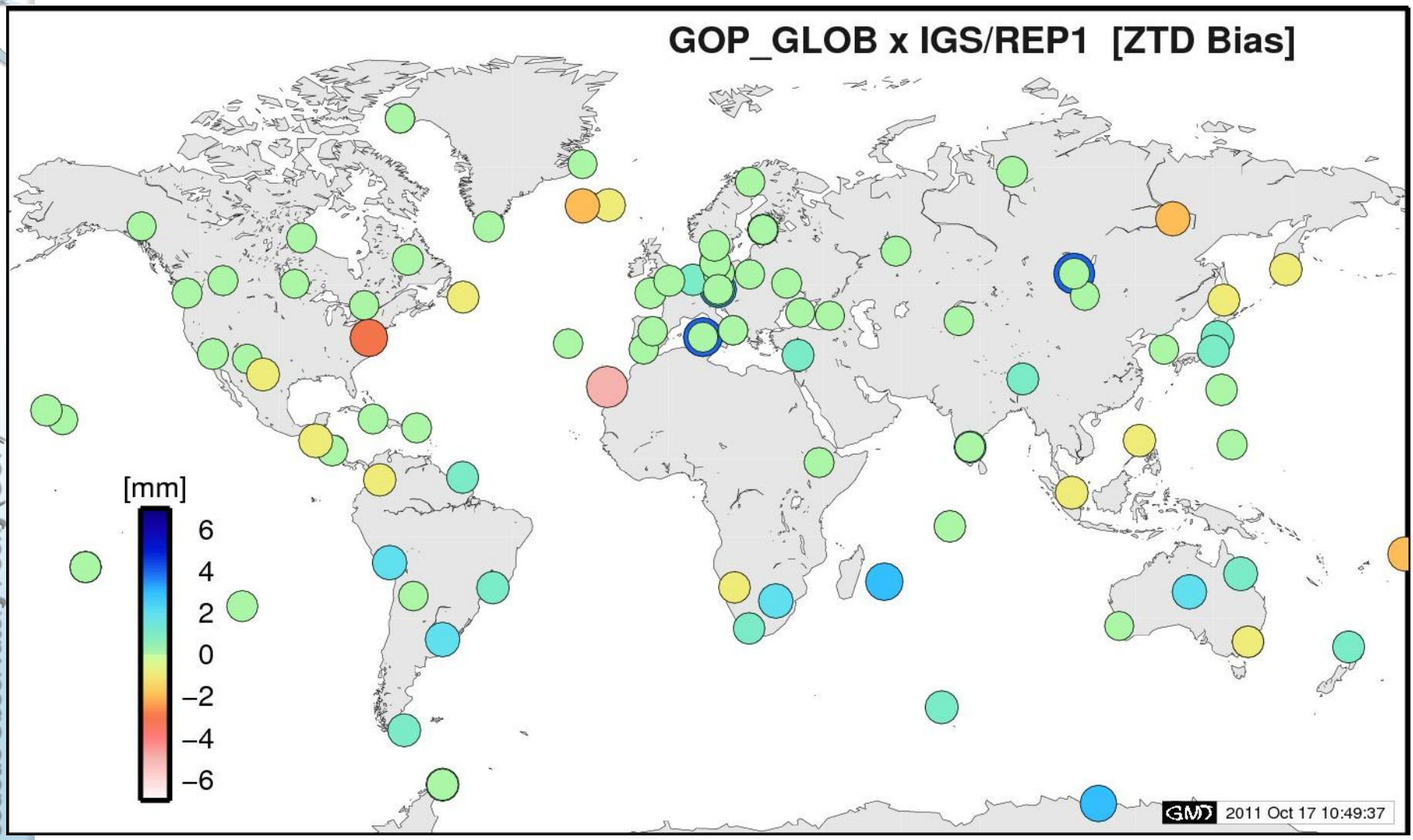
GOP near real-time ZTD products



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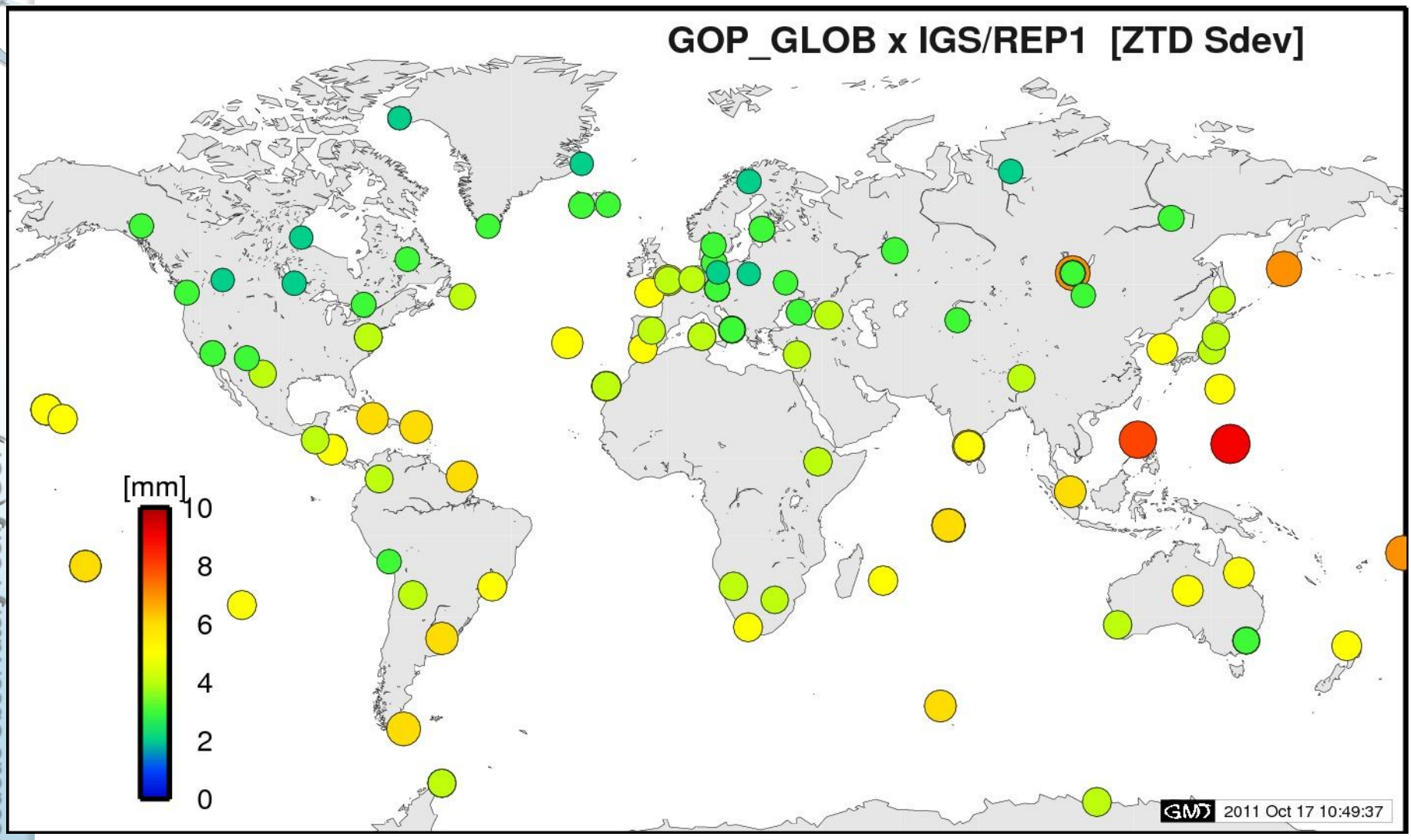

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Global NRT ZTD vs. radiosondes

GPS station	Radiosonde number	Lat [deg]	Lon [deg]	H [m]	dHor [km]	dVer [m]	# pairs GPS-RS	# excl GPS-RS	bias [mm]	sdev [mm]
NRIL	**23078**	69.36	88.35	**48**	**7**	**-16**	**270**	16	**0.4**	**5.2**
YAKT	**24959**	62.03	129.68	**104**	**4**	**0**	**375**	21	**0.2**	**7.1**
PETS	**32540**	53.02	158.65	**102**	**10**	**-18**	**401**	13	**-2.2**	**9.2**
JOZ2	**12374**	52.09	21.03	**153**	**34**	**+58**	**482**	13	**-10.9**	**7.6**
TITZ	**10410**	51.03	6.43	**156**	**72**	**+3**	**367**	13	**21.1**	**9.0**
ULAB	**44292**	47.86	107.05	**1576**	**21**	**+268**	**419**	21	**2.8**	**9.1**
YSSK	**32150**	47.02	142.71	**91**	**8**	**+67**	**356**	19	**-12.3**	**6.7**
CAGL	**16560**	39.13	8.97	**238**	**16**	**+234**	**513**	26	**6.2**	**11.1**
TSK2	**47646**	36.10	140.08	**70**	**7**	**+44**	**294**	16	**11.1**	**7.6**
CCJM	**47971**	27.09	142.18	**209**	**1**	**+205**	**319**	14	**-2.8**	**10.0**
GUAM	**91212**	13.58	144.86	**202**	**16**	**+126**	**329**	7	**-23.3**	**15.3**
IISC	**43295**	13.02	77.57	**844**	**5**	**-76**	**345**	14	**0.0**	**25.2**
HRAO	**68263**	-25.89	27.68	**1414**	**59**	**-108**	**239**	7	**24.0**	**14.4**
PERT	**94610**	-31.80	115.88	**13**	**15**	**-7**	**437**	19	**-13.5**	**7.2**
AUCK	**93112**	-36.60	174.83	**133**	**30**	**+102**	**371**	15	**7.8**	**11.6**

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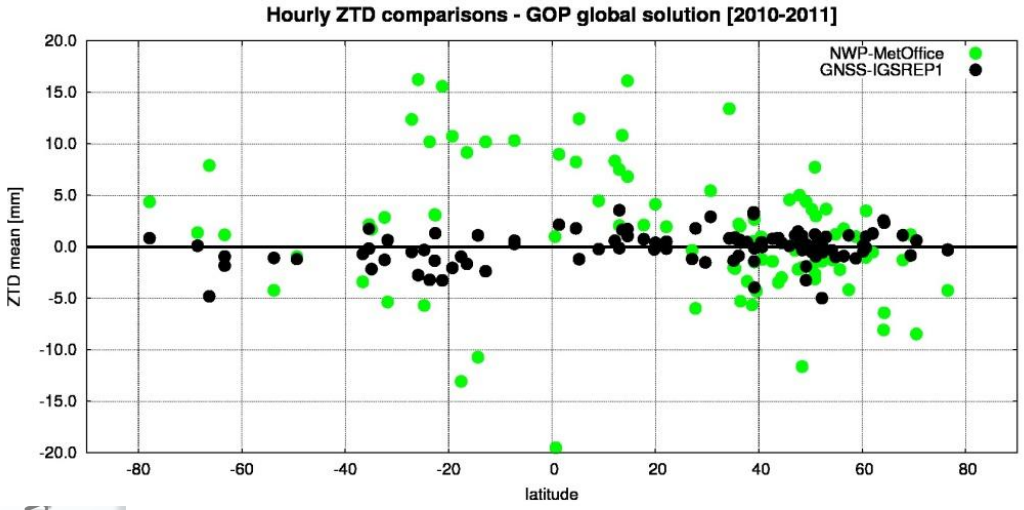
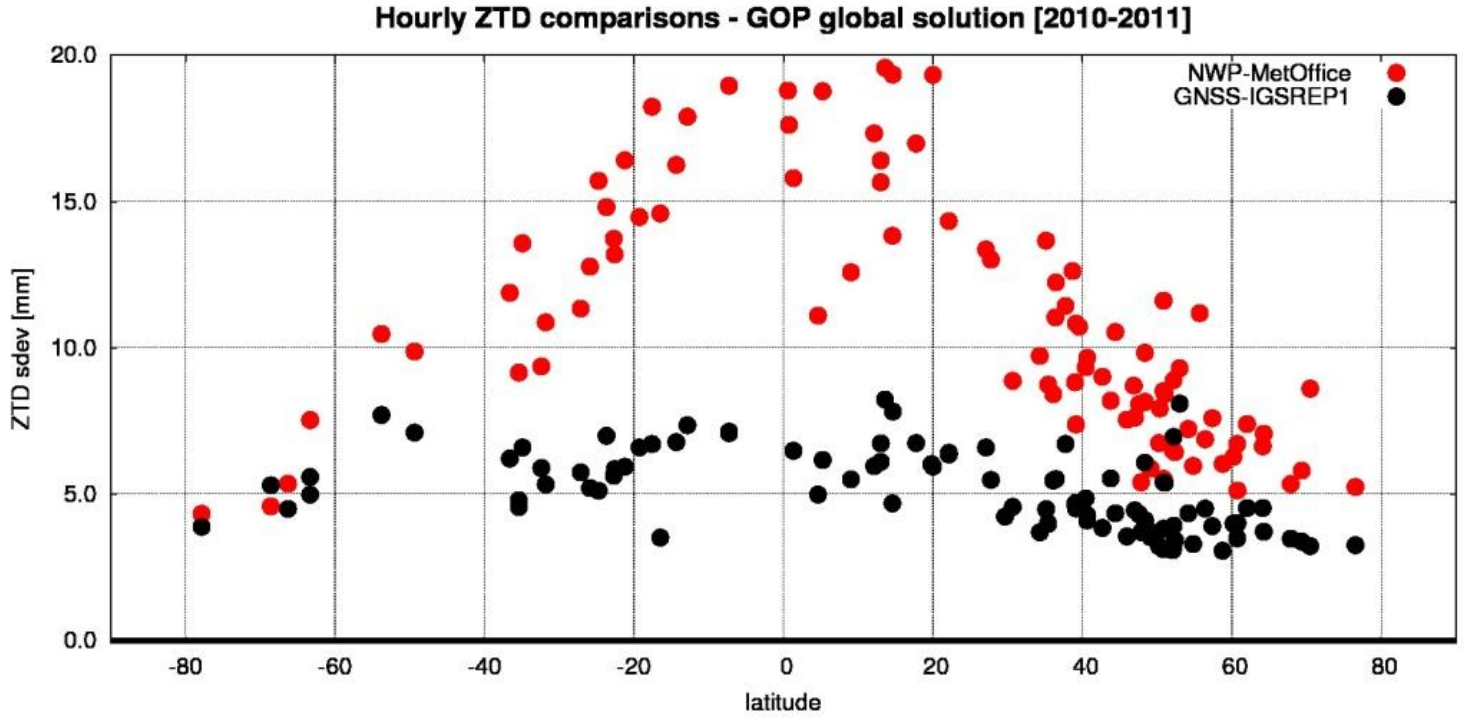
GOP global hourly ZTD (2010-2012)



ZTD NRT global product w.r.t.:

- IGS post-processing ZTD product
- UK Met Office global NWP model

Clear quality latitude dependence to NWP model (usually NWP more dry and quality higher close to equator)



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GOP multi-GNSS evaluation and new NRT ZTD product

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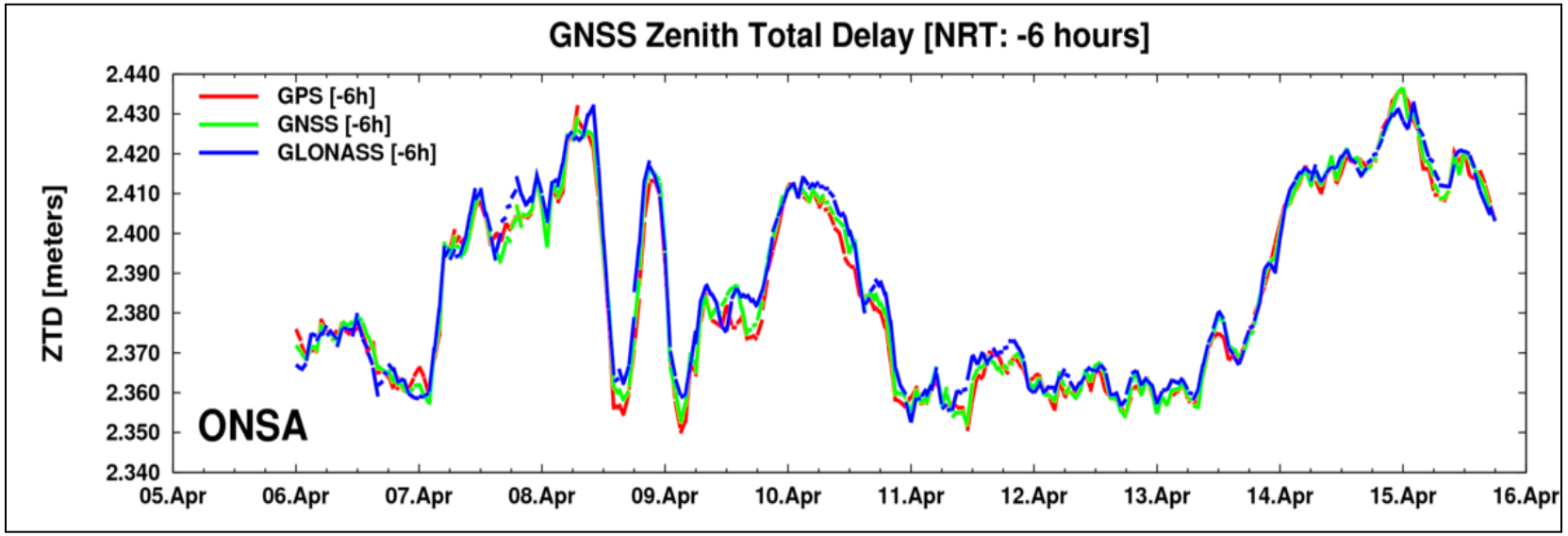
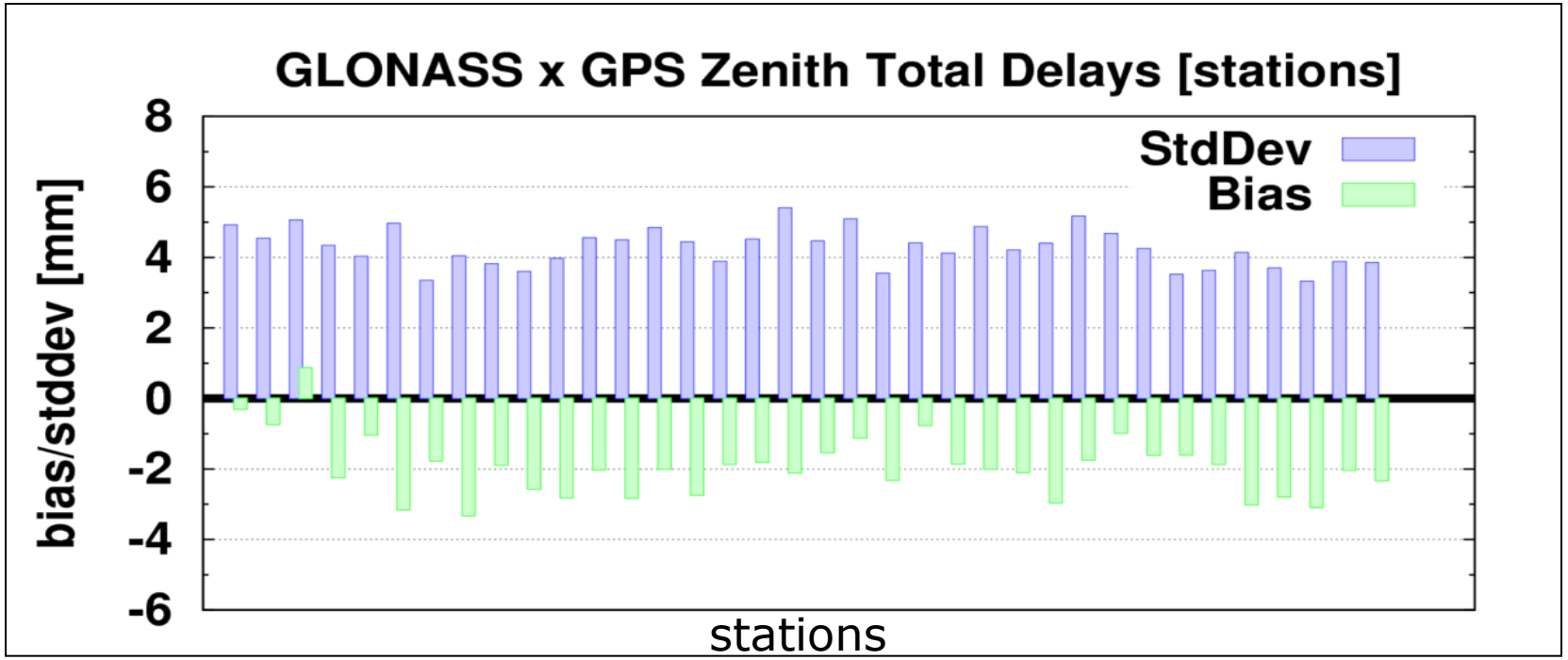
ZTD - GPS, GLONASS, multi-GNSS (2009)





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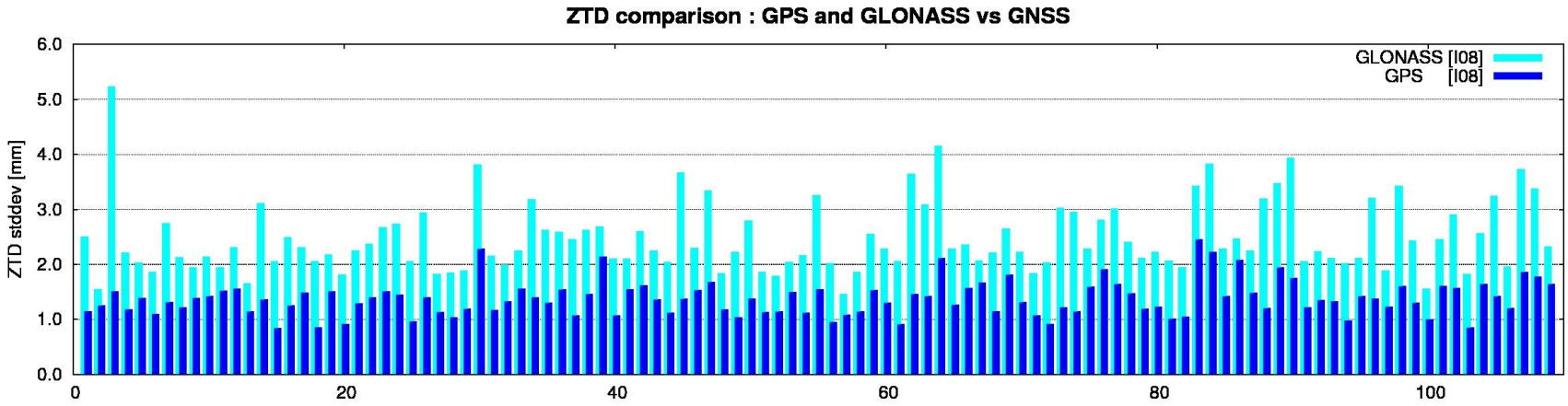
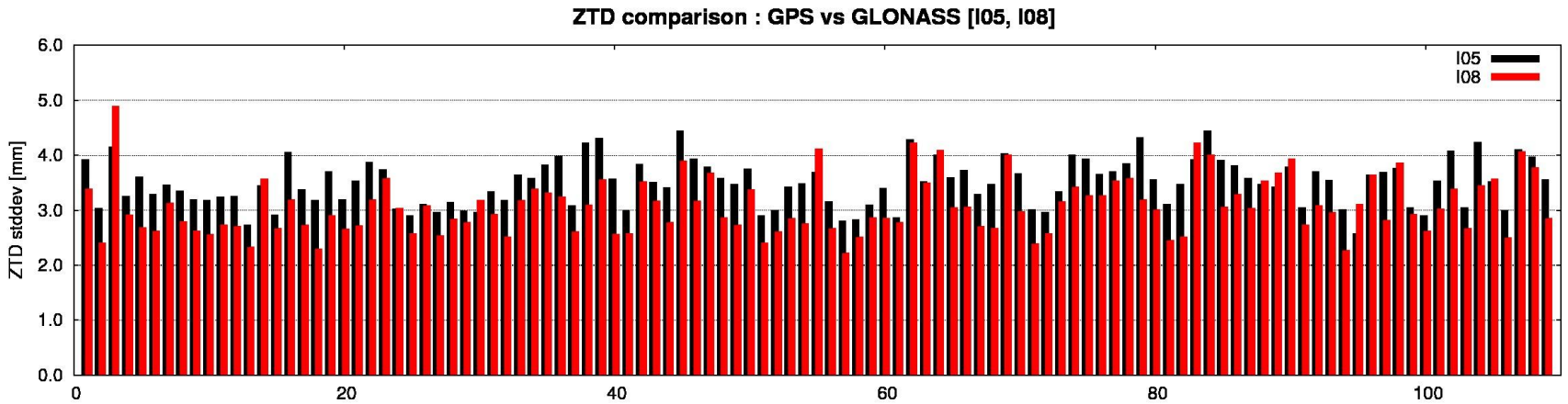
Stand-alone GPS vs. GLONASS - offline

(all EPN multi-GNSS stations, I05 vs. I08 models)

- Processing of all EPN multi-GNSS stations over 2 months (around 1631)
- The GPS data contributes to ZTD product here about the factor of 2/3
- IGS08 PCO+PCV model shows better agreement of GPS with GLONASS





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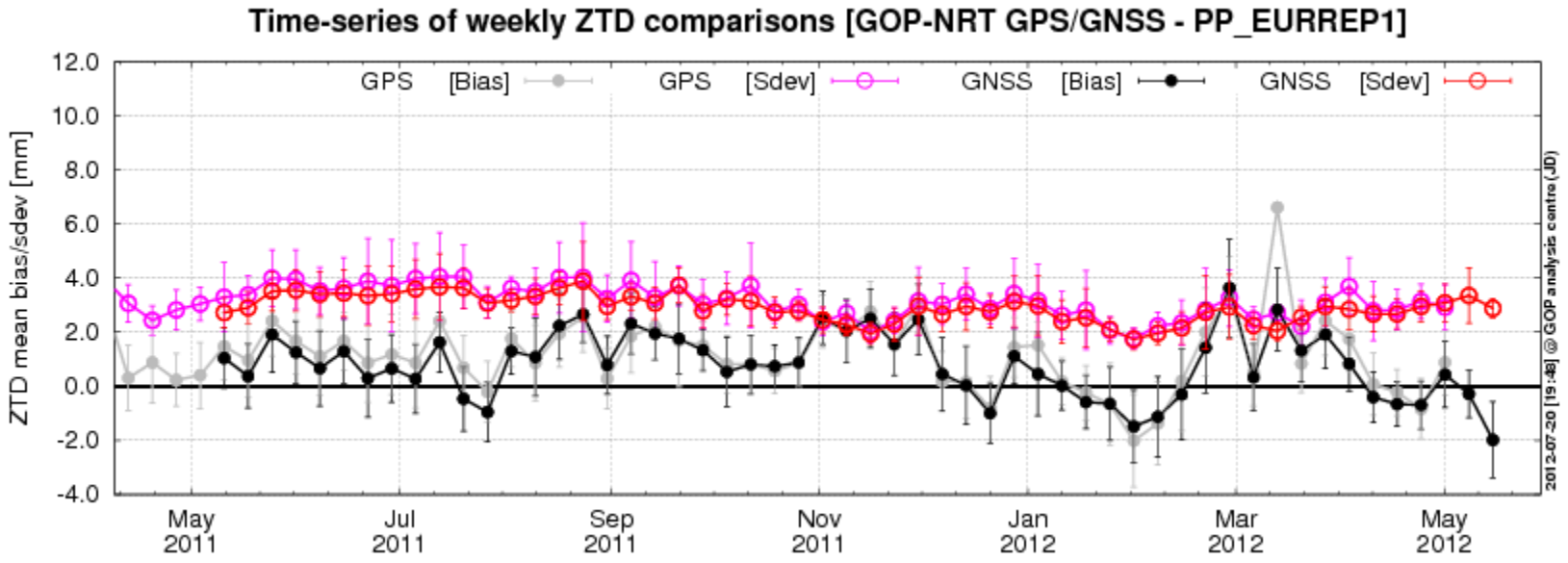
Operational NRT multi-GNSS GOP ZTD

- Multi-GNSS ZTD started after GPS week 1632 (IGS08 PCV+PCO models)
- Using the same strategy as GPS official contribution to E-GVAP, but more frequently exploit robustness of GOP NRT solution than stand-alone GPS
- Testing unofficial IGV (GPS+GLONASS) ultra-rapid orbits
- With exception of June/July (leap second), running continuously
- Compared with GPS (official) shows slightly better Sdev and Bias



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GOP ultra-fast/real-time ZTD product development

G-Nut software library (in-house solution)

- C++, object-oriented, multi-threaded, multi-platform (linux, windows)
- G-Nut library developments (open-source) + applications
- Support filter and LSQ processing (using real-time stream and data-files)
- Support multi-GNSS (GPS, GLONASS, Galileo,.)
- Flexible core library and data/product containers for extension in future
- Sequence of targets:

  Real-time, offline PPP in static & kinematic modes

  Troposphere estimation in quasi real-time for severe weather monitoring

  Precise satellite clock estimations (PPP support)

  Products for PPP ambiguity resolution (in Europe), augmentation,…

  ….

For more details see the poster by Václavovic, Douša and Györi (P07-09)

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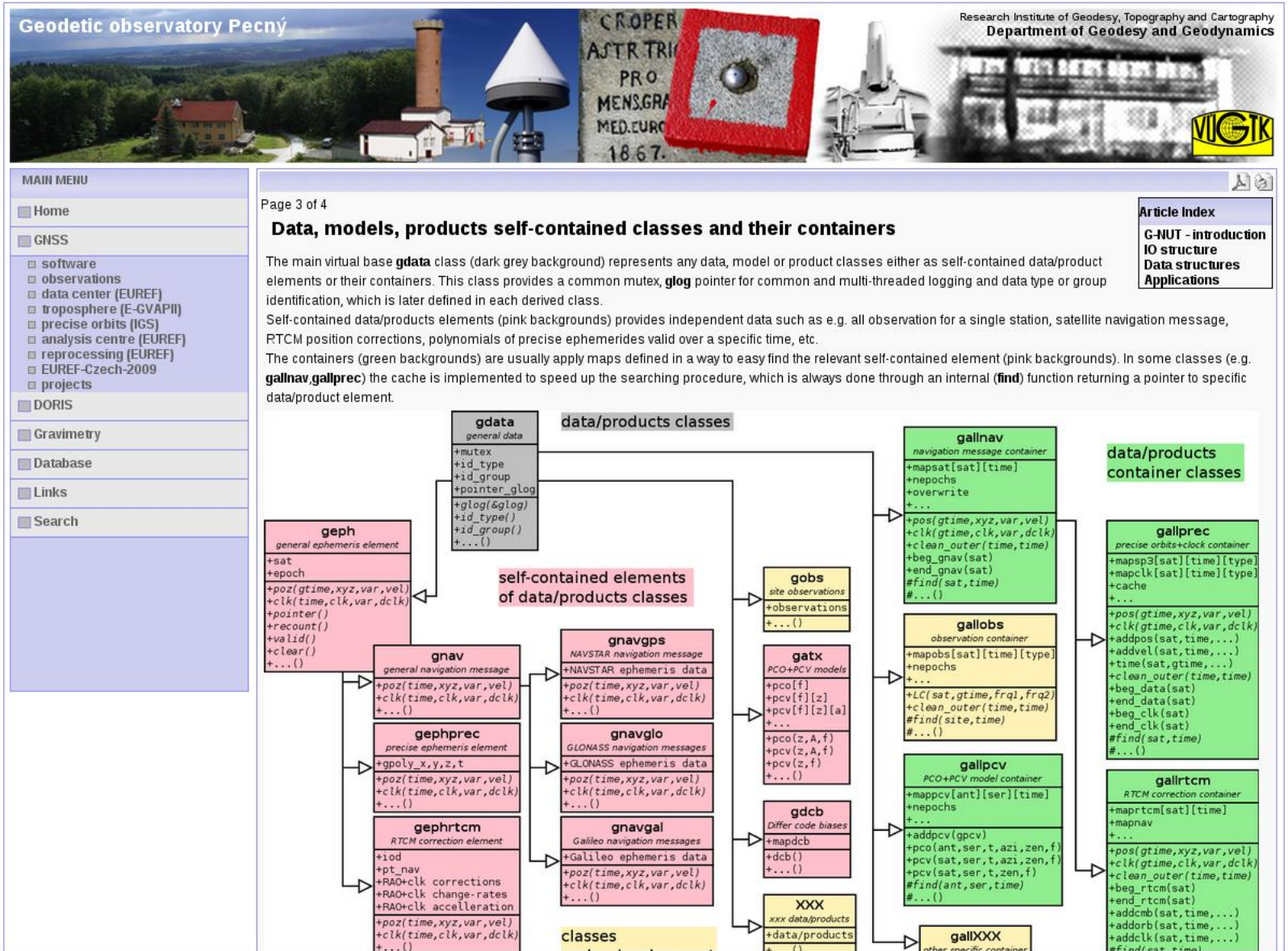
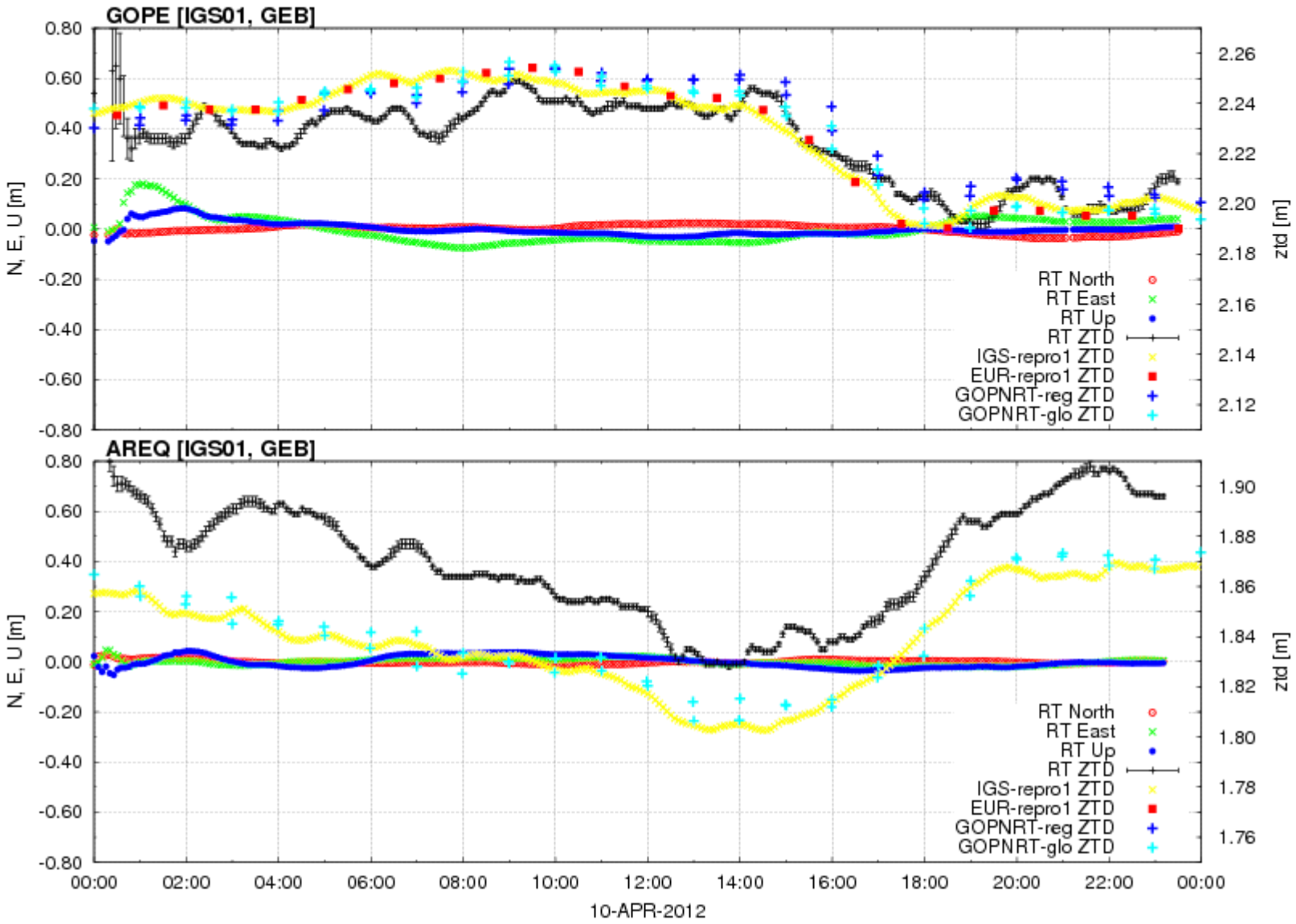
G-Nut software package

- http://www.pecny.cz/ (GNSS, software) … looks here for updates …



Forward filter ZTD processing (SP3+CLK)

Forward filter ZTD estimated with IGS precise orbits and clock during 44 days (April-May 2012), example for GOPE and AREQ sites, April-10, 2012



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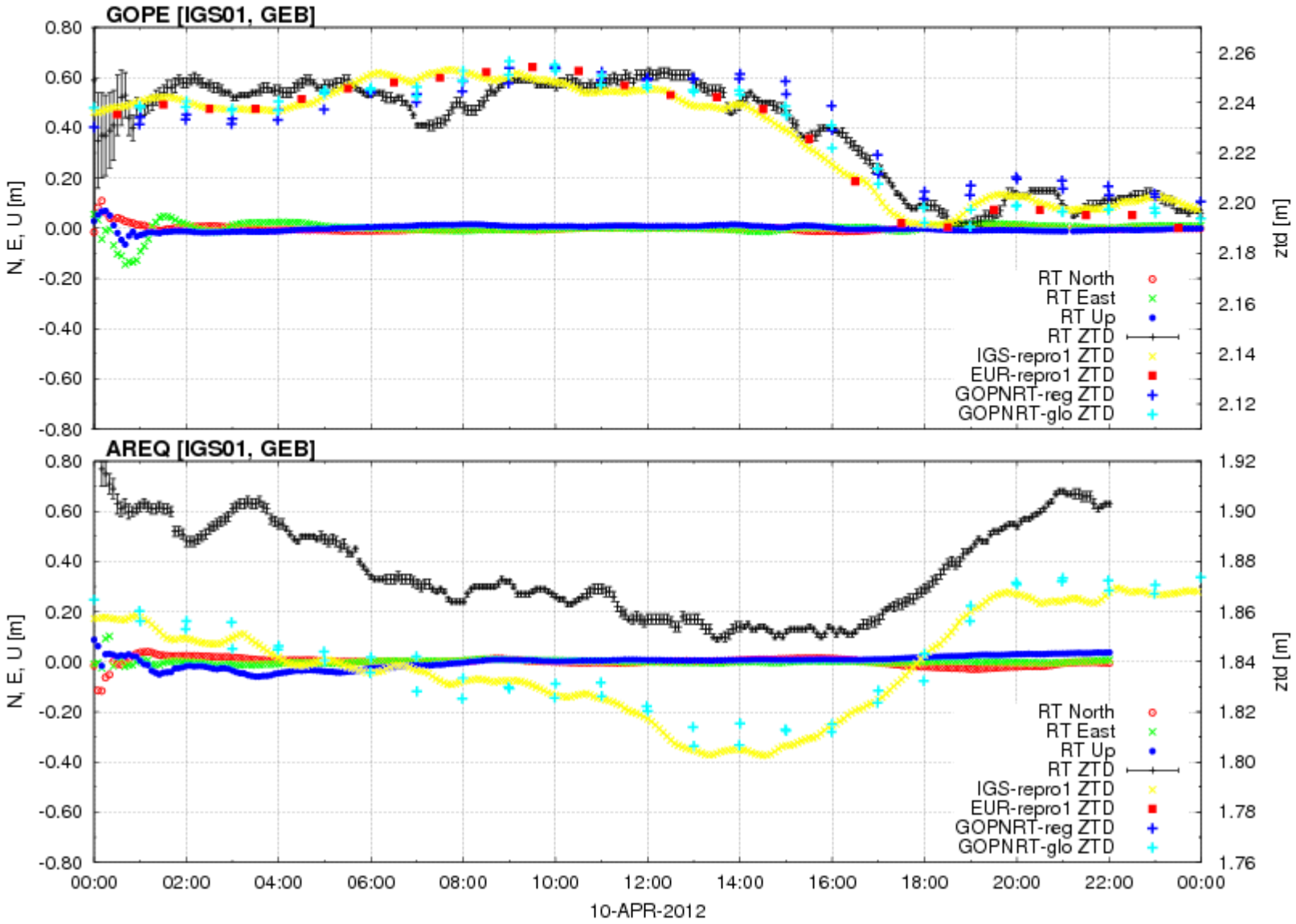
Simulated real-time ZTD (RTCM)

Forward filter ZTD estimation in simulated real-time with IGS01 corrections during 44 days (April-May 2012), example for GOPE and AREQ, April-10, 2012



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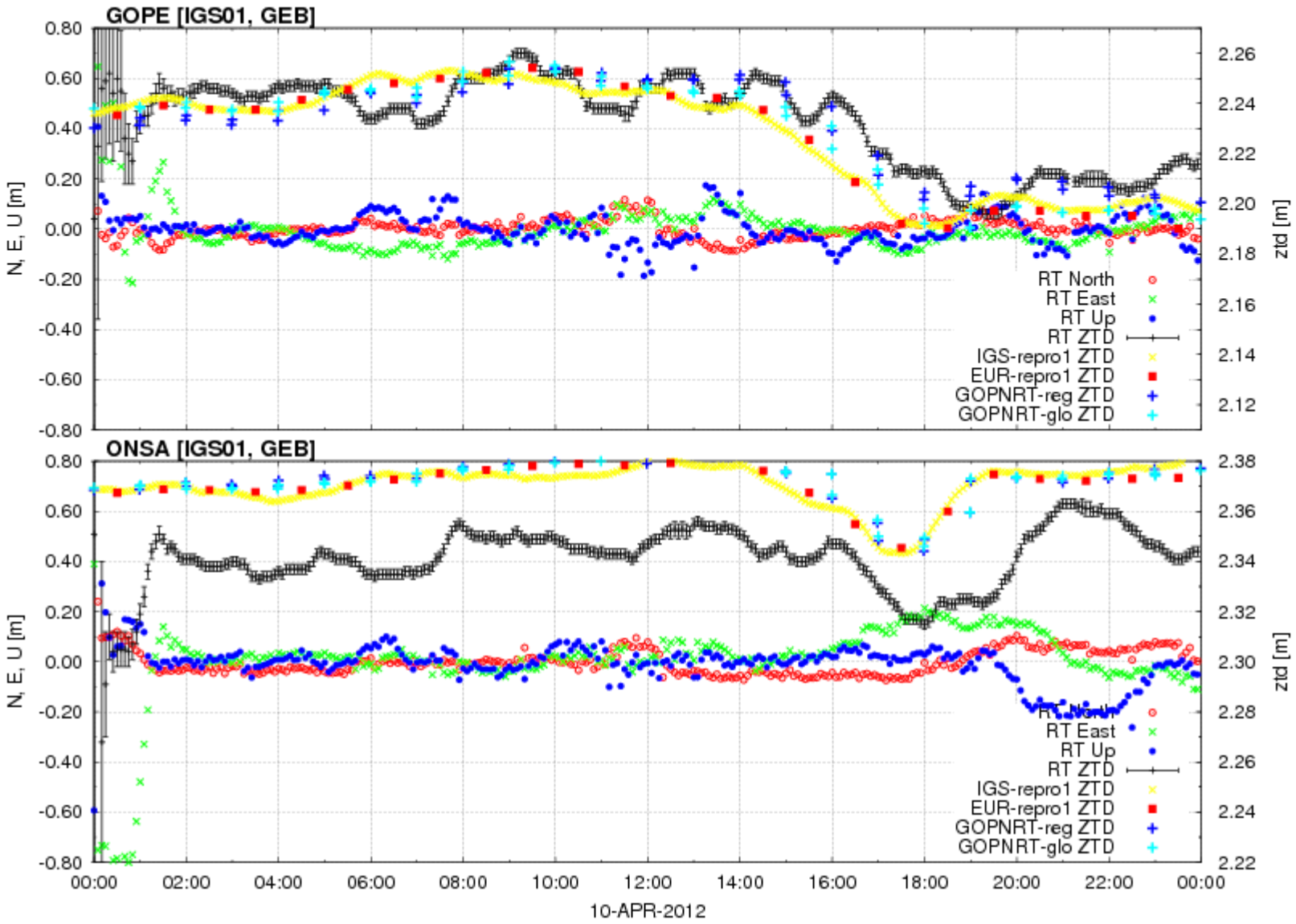
Kinematic real-time solution (RTCM)

Forward filter for ZTD with estimating kinematic coordinates, IGS01 corrections during 44 days (April-May 2012), example for GOPE and ONSA, April-10, 2012



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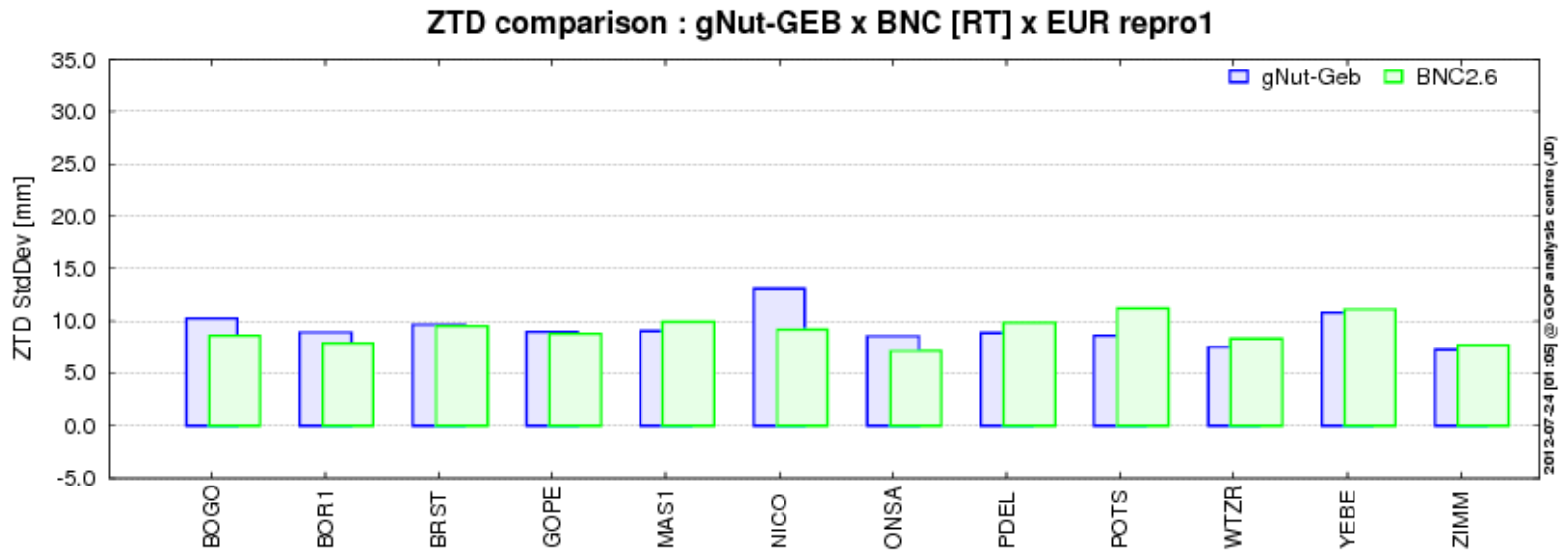
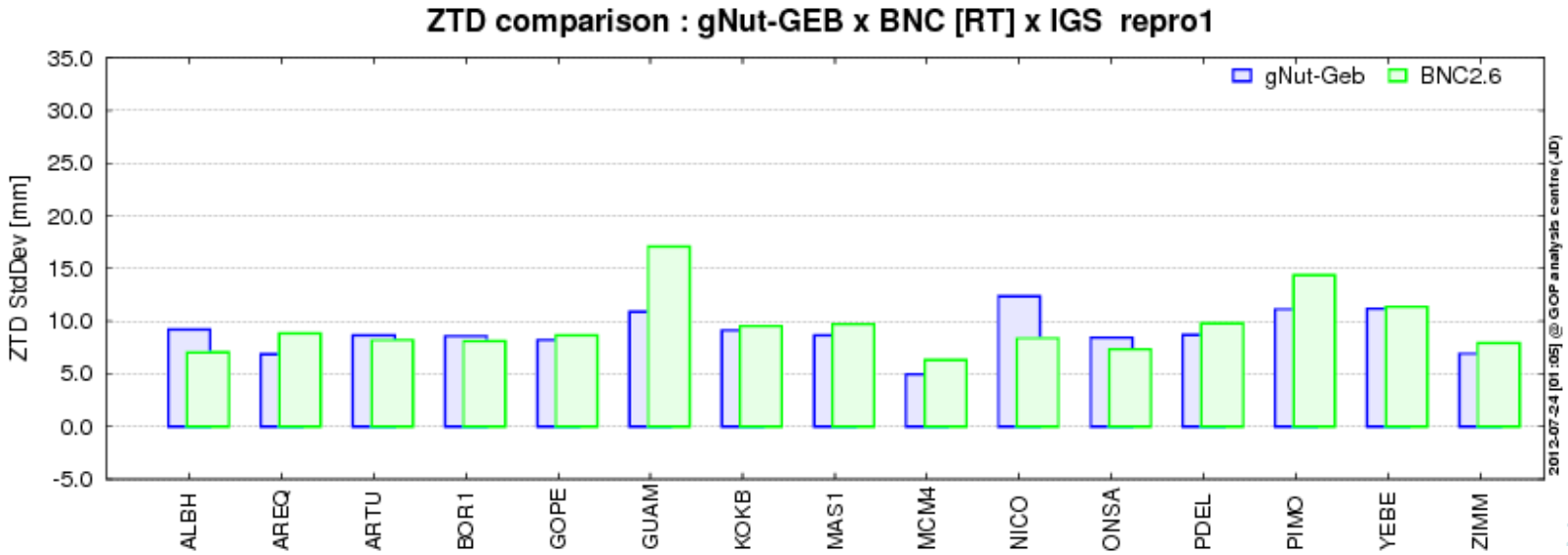
Statistic for ZTD based on two software

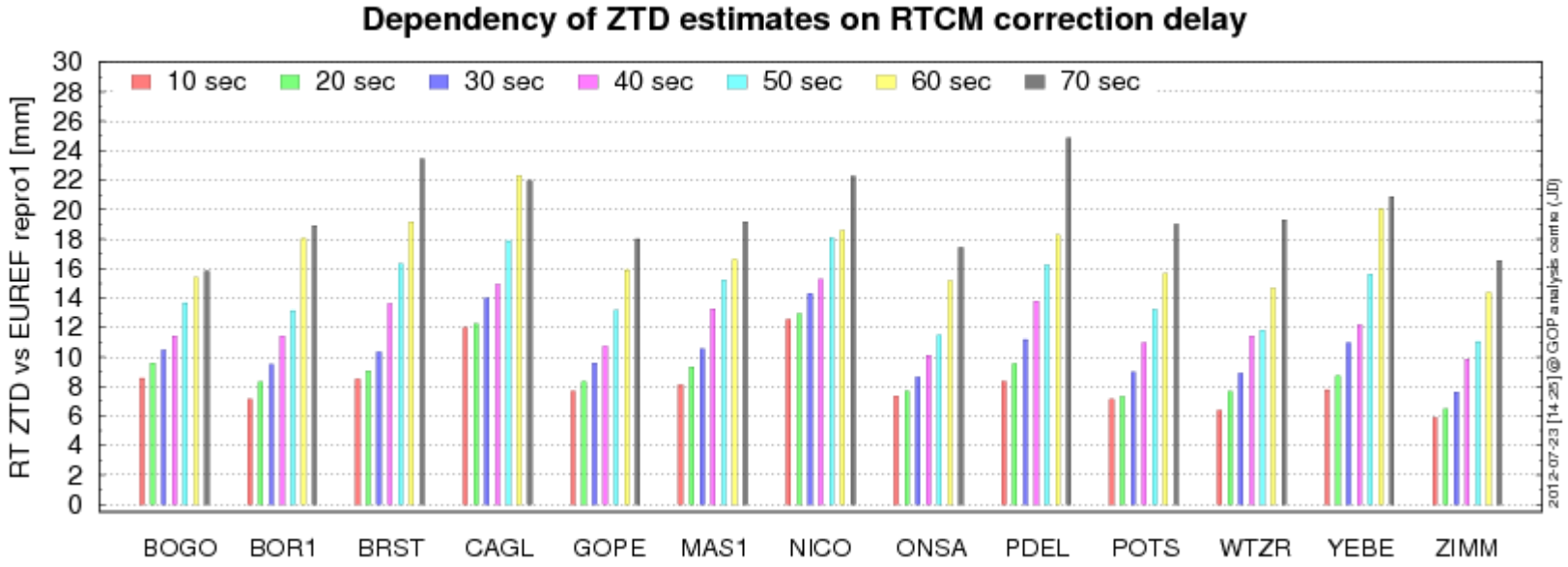
44-days statistics (April-May) from BNC2.6 and gNut-Geb w.r.t IGS/EUR repro1

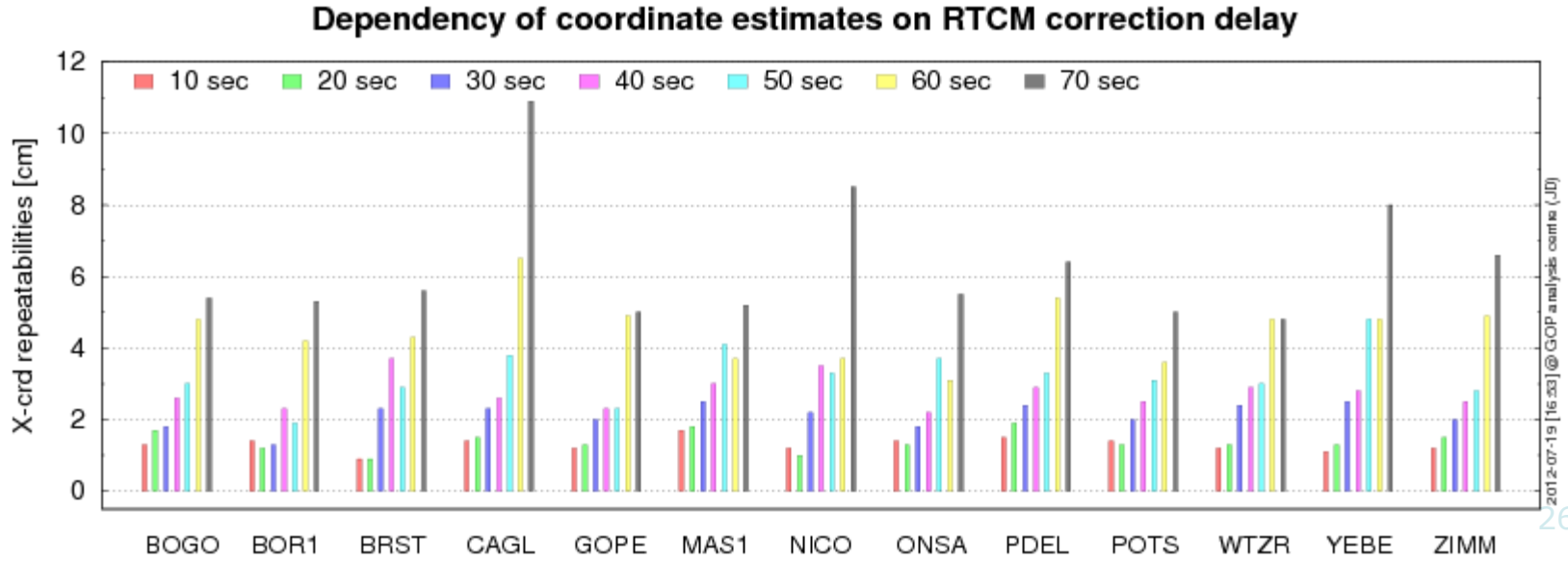




CRD and ZTD dependence on RTCM age

Impact of 10-70s delays of RTCM corrections on troposphere and coordinates





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Summary

- Routine ZTD processing routinely operated at GOP since 2001 - evaluated using EUREF, IGS reference products as well as radiosondes.
- First global hourly ZTD solution developed and evaluated over one year (2010-2011) and, on request, officially accepted in Sept 2011 in E-GVAP. The global product was evaluated with IGS, EUREF ZTD products, global NWP model (UK MetOffice) and radiosondes.
- Multi-GNSS hourly ZTD solution developed, GLONASS and GPS stand-alone products tested and after GPS week 1631 (with adoption of IGS08 models providing much better consistency btw GPS and GLONASS PCV+PCO) routinely provided based on IGU + IGV orbits.
- New core software library under development (G-Nut) and application for real-time or ultra-fast (sub-hourly) ZTD solutions based on IGS RTPP products and using PPP technique. First results were demonstrated.

- Most of the product monitoring can be found at http://www.pecny.cz

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Thank for your attention !

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