

GOP analysis centre – 2013/2014

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GOP tropospheric production & support

Operational status:

- Regional GPS solution (official solution)
- Global hourly solution (official solution)
- Regional GPS+GLONASS solution (testing)
- Real-time solution (demonstration campaign)

Progress

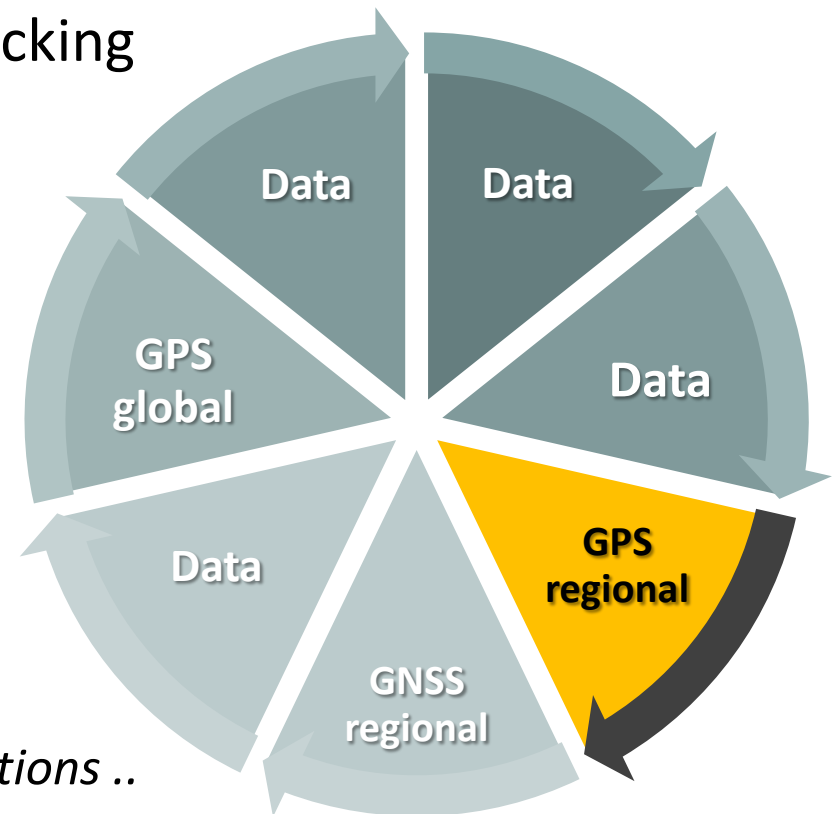
- Trop-NET solution (distributed system)
- GOP TropDB (tropospheric parameters evaluation)
- GOP TropModel (online service)
- GOP EUREF Repro1+, Repro2 (homogeneous reprocessing)

GOP1: NRT regional GPS solution

- ❑ Bernese GNSS software v5.0 (BSW v5.2 ready)
- ❑ Data: hourly RINEX
- ❑ Orbits: official IGS ultra-rapid GPS orbits (IGU)
- ❑ Stations (80): Czech Rep, SuperSites, fiducial stations
- ❑ 4 hourly data batches for stacking
 - ❑ NEQ: 12-hour for ZTDs
 - ❑ NEQ: 28-day for coordinates

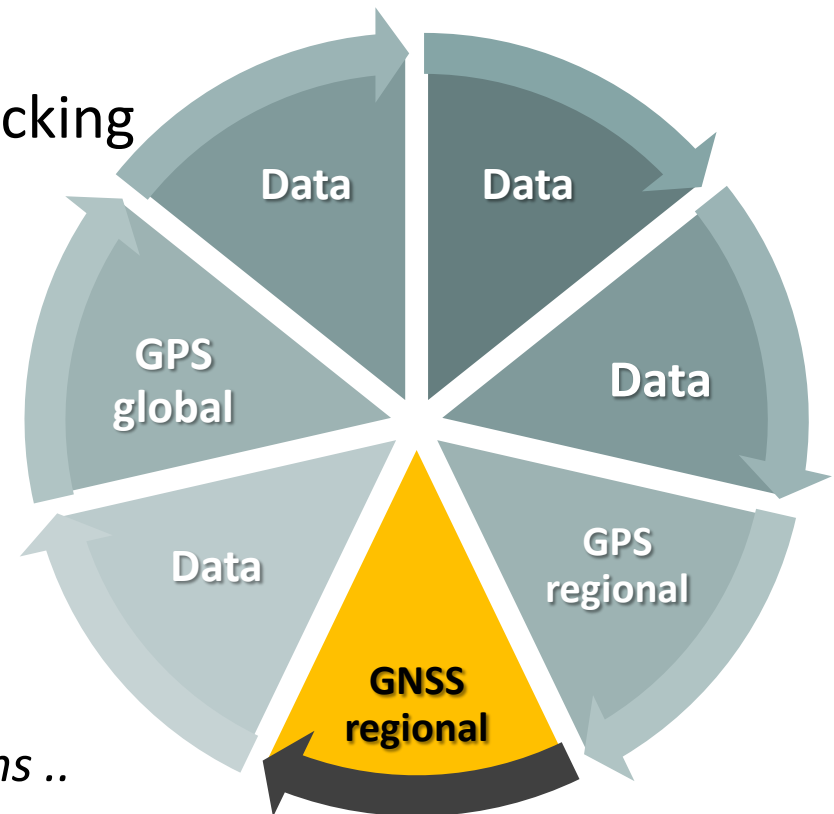
NOTE: *GOP2 is testing using ambiguity-fixed solution in ZTD*

During summer 2014, the change of internet domain at GOP caused many missing national stations ..



GOP3: NRT regional GPS+GLO

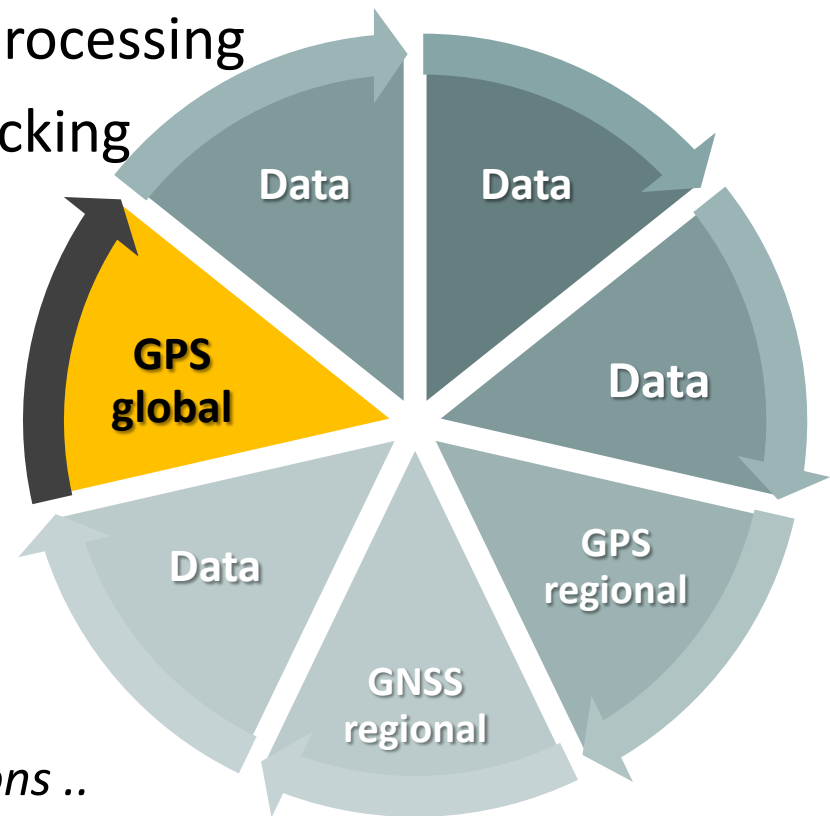
- ❑ Bernese GNSS software v5.0 (BSW v5.2 almost ready)
- ❑ Data: hourly RINEX
- ❑ Orbits: testing IGS ultra-rapid GPS+GLONASS orbits (IGV)
- ❑ Stations (100): Czech Rep, Latvia, *Bulgaria*, *Greece*, SuperSites, fiducial stations
- ❑ 4 hourly data batches for stacking
 - ❑ NEQ: 12-hour for ZTDs
 - ❑ NEQ: 28-day for coordinates



During summer 2014, the change of internet domain at GOP caused many missing extra stations ..

GOPG: NRT global GPS solution

- ❑ Bernese GNSS software v5.0 (BSW v5.2 ready)
- ❑ Data: hourly RINEX
- ❑ Orbits: official IGS ultra-rapid GPS orbits (IGU)
- ❑ Stations (120): global stations, SuperSites
- ❑ Specific features for robust processing
- ❑ 4 hourly data batches for stacking
 - ❑ NEQ: 12-hour for ZTDs
 - ❑ NEQ: 28-day for coordinates



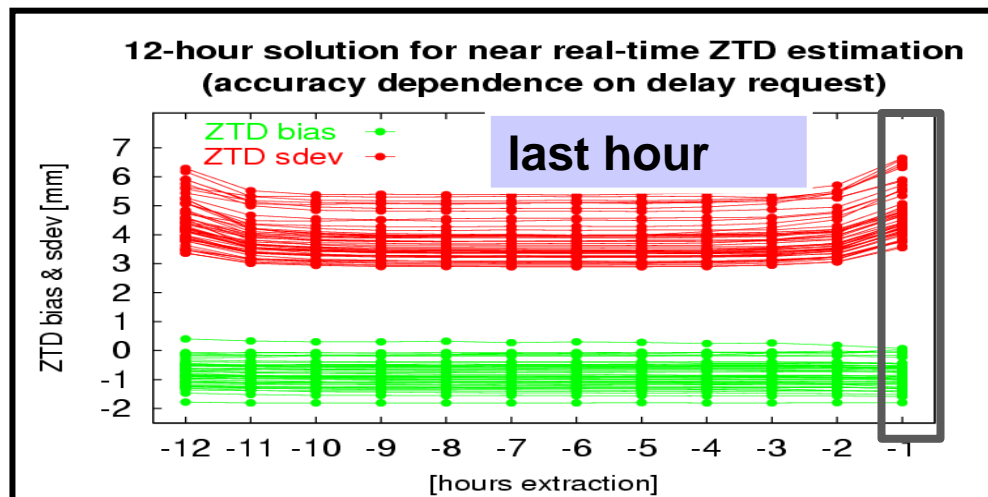
During summer 2014, the change of internet domain at GOP caused many missing global stations ..

GOP NRT tropospheric products

Basic characteristics

- **ZTDs** represented as a piece-wise linear function every hour
 - (HH:00 + HH:59)
- **coordinates** (reported in COST-716 format) are heavily constrained to the estimated values realizing the IGS-yy reference frame
- **active QC** (filtering) for regional ZTD product:
 - *Sites with less than 4h of data in ZTD solution are excluded from the product*
 - *Sites with less than 2 days of data in coordinate solution are excluded*
- + global solution filtering
 - *Formal error filtering applied*

Note: ZTDs estimated and provided at the end of observation window



GOPR: real-time demonstration

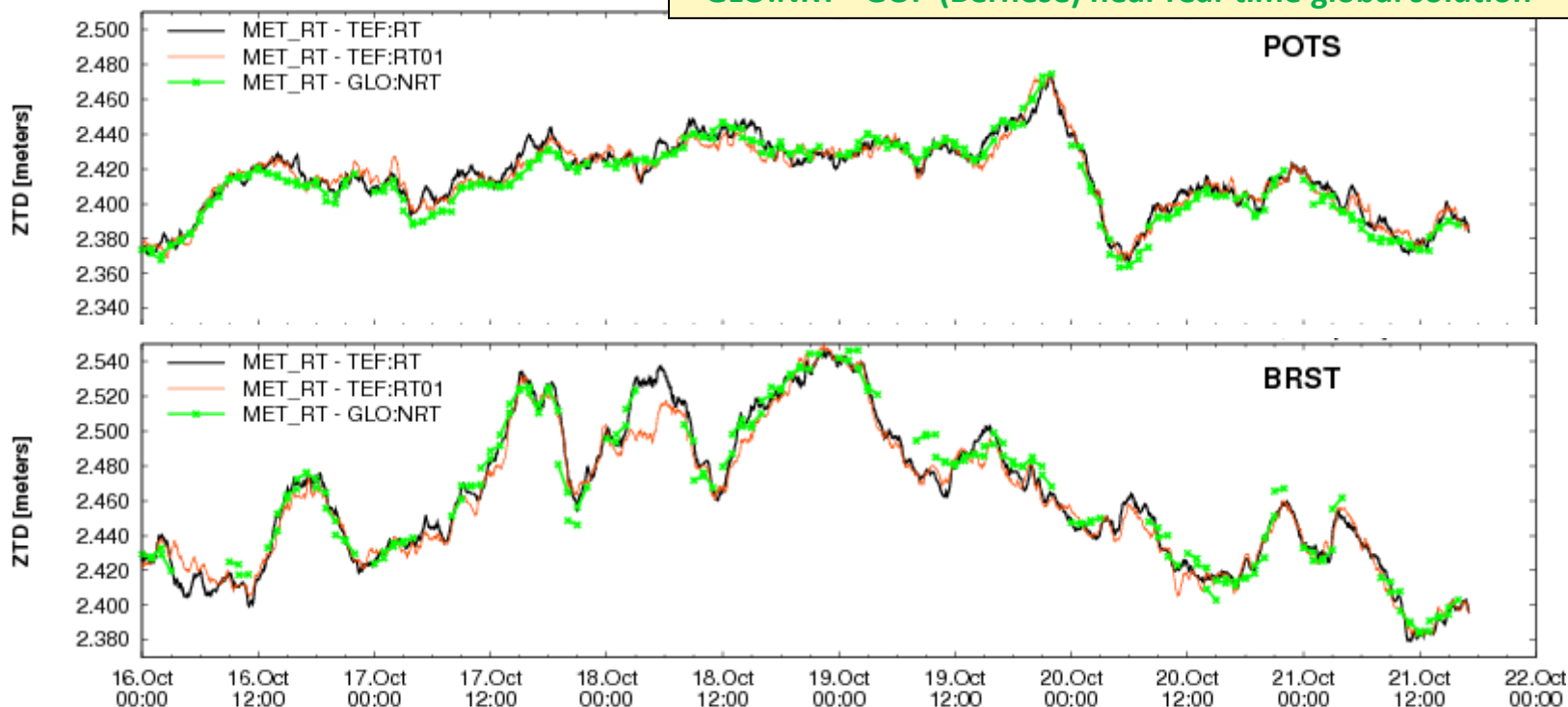
G-Nut/Tefnut: *in-house PPP software, real-time products: IGS01, IGS02, IGS03, CNES*

- GPS, GPS+GLONASS (preparing full multi-GNSS)
- ZTD, ZTD + gradients (preparing slant delays)
- Preparing conversion to COST-716
- Preparing a sub-hourly estimation
- GNSS4SWEC - coordinating a common RT demonstration campaign
- Availability > 95 %

TEF:RT - GOP (Tefnut) PPP real-time ZTD solution using IGS01

TEF:RT01 - GOP (Tefnut) PPP real-time ZTD solution using IGS02

GLO:NRT - GOP (Bernese) near real-time global solution



Summary for GOP troposphere products

Near real-time products - traditional approach

NRT regional product (GPS) – Bernese GNSS software (2001-today)

NRT global product (GPS) – Bernese GNSS software (2010-today)

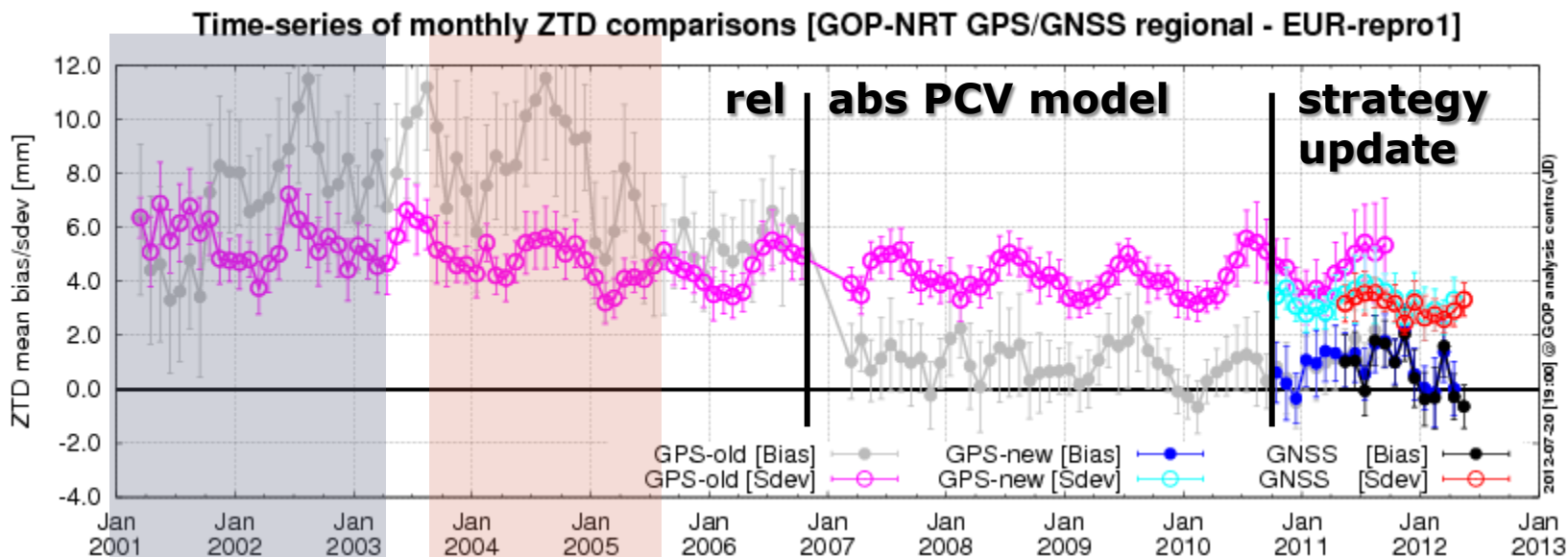
NRT regional product (GPS+GLONASS) – Bernese GNSS software (2011-today)

New products - PPP

Real-time product (2013, demonstration)

Sub-hourly product (2014, development)

vs. final ZTD	AbsBias	StdDev
ZTD regional	0-3 mm	3-6 mm
ZTD global	0-1 mm	3-9 mm
ZTD real-time	~0-20 mm	5-10 mm

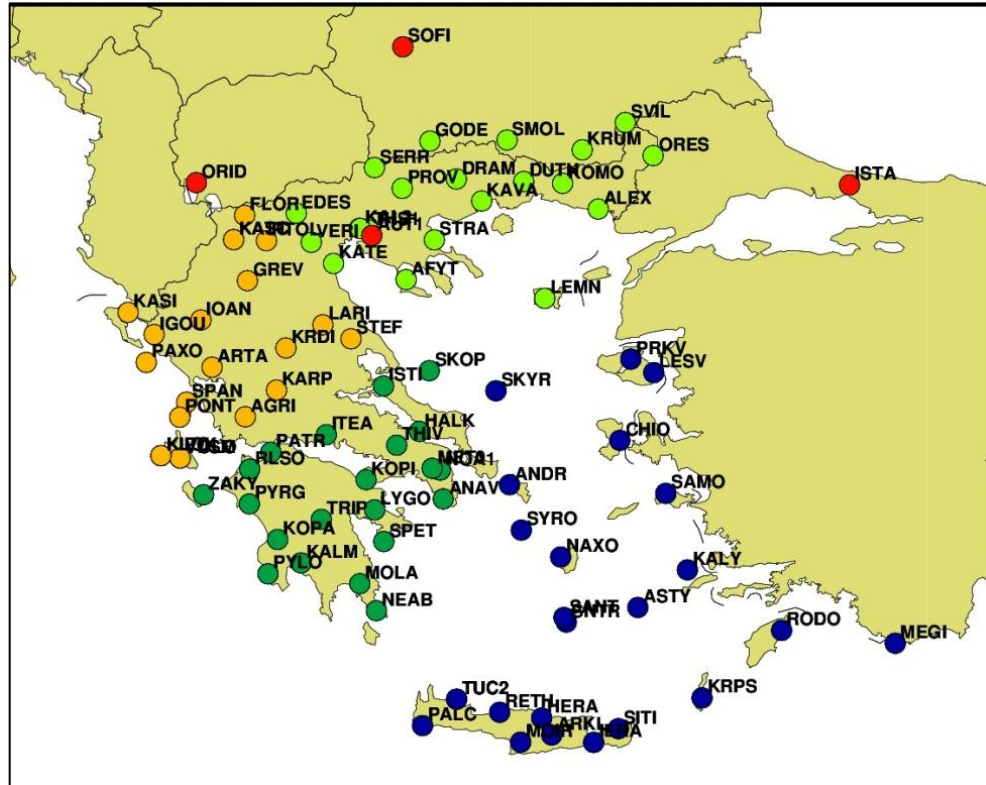


Trop-Net: a new co-operation project

- Develop distribute NRT Troposphere network solution
- Easy support for new analysis centre, networks
- Close cooperation for coordinated and shared development
- Initiated by JD during STSMs in support of AUT, KTU & BEU, ...
- Implemented as a flexible modular system
- GNSS processing: Bernese GNSS software + BPE (V5.0/V52)
- Developed by GOP exploiting 15-year experience in the domain
 - GPS NRT solution since 1999
 - GLONASS-only solution (2008-2010)
 - GPS+GLONASS NRT solutions since 2011
 - Global NRT solution since 2010
 - GPS ultra-rapid orbits since 2004
 - GPS + GLONASS ultra-rapid orbits since 2008

nd Cartography

-



Implemented modules for Trop-Net

Individual nodes

- Downloads & mirroring
 - Universal modules for data/product collections
- NRT GNSS processing (Bernese GNSS software)
 - Converting duplicate stations
- Upload of products
 - Support of last COST-716 format incl. new file naming
- *IWV conversion (to be implemented at AUT)*
- *Specific monitoring (e.g. IWV visualization)*

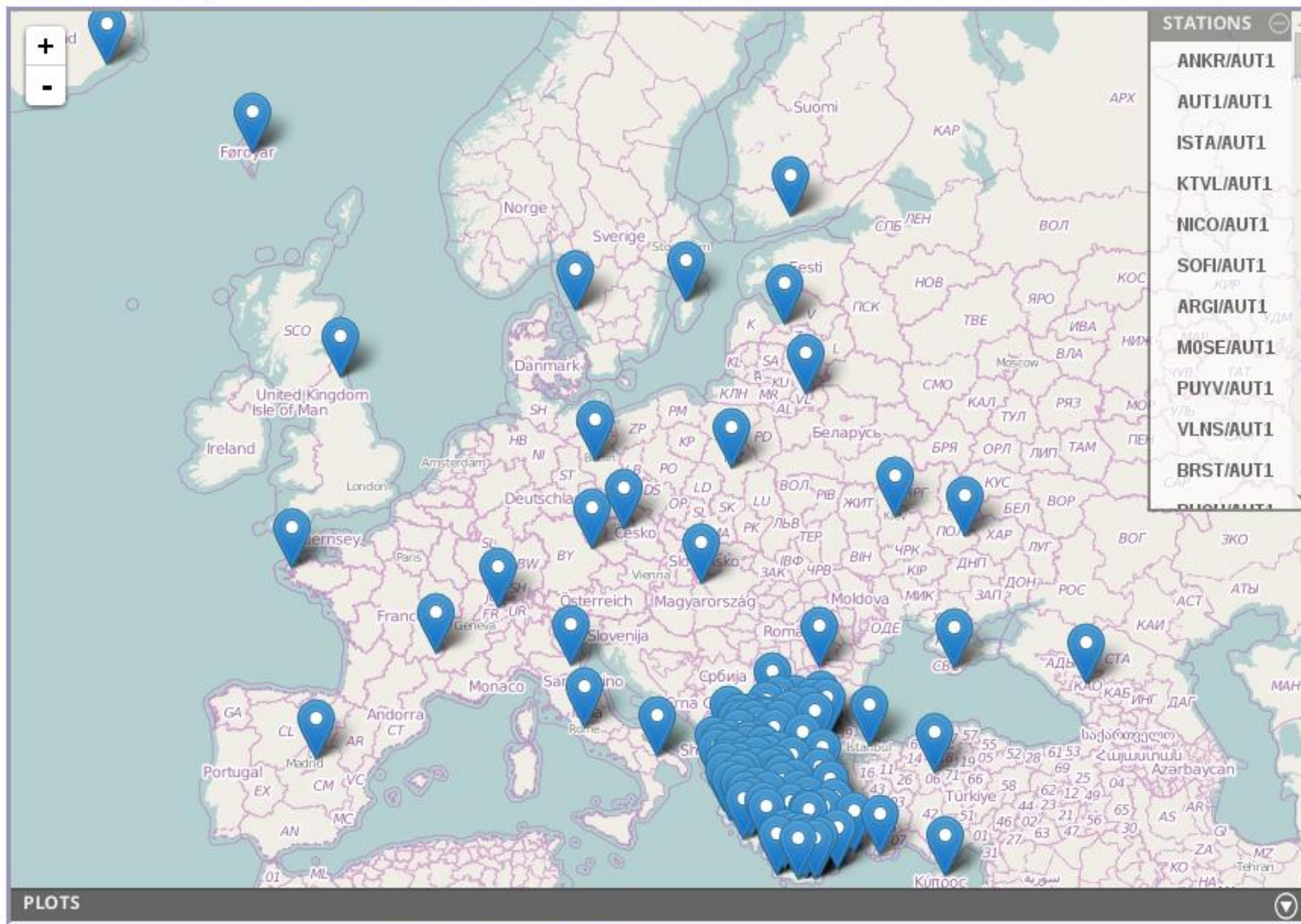
Central (currently at GOP)

- Versioning repository & software archive
- Real-time monitoring & inter-comparison
- Archive + long-term assessment
- *Installation/operation manual and documentation*



Main Menu

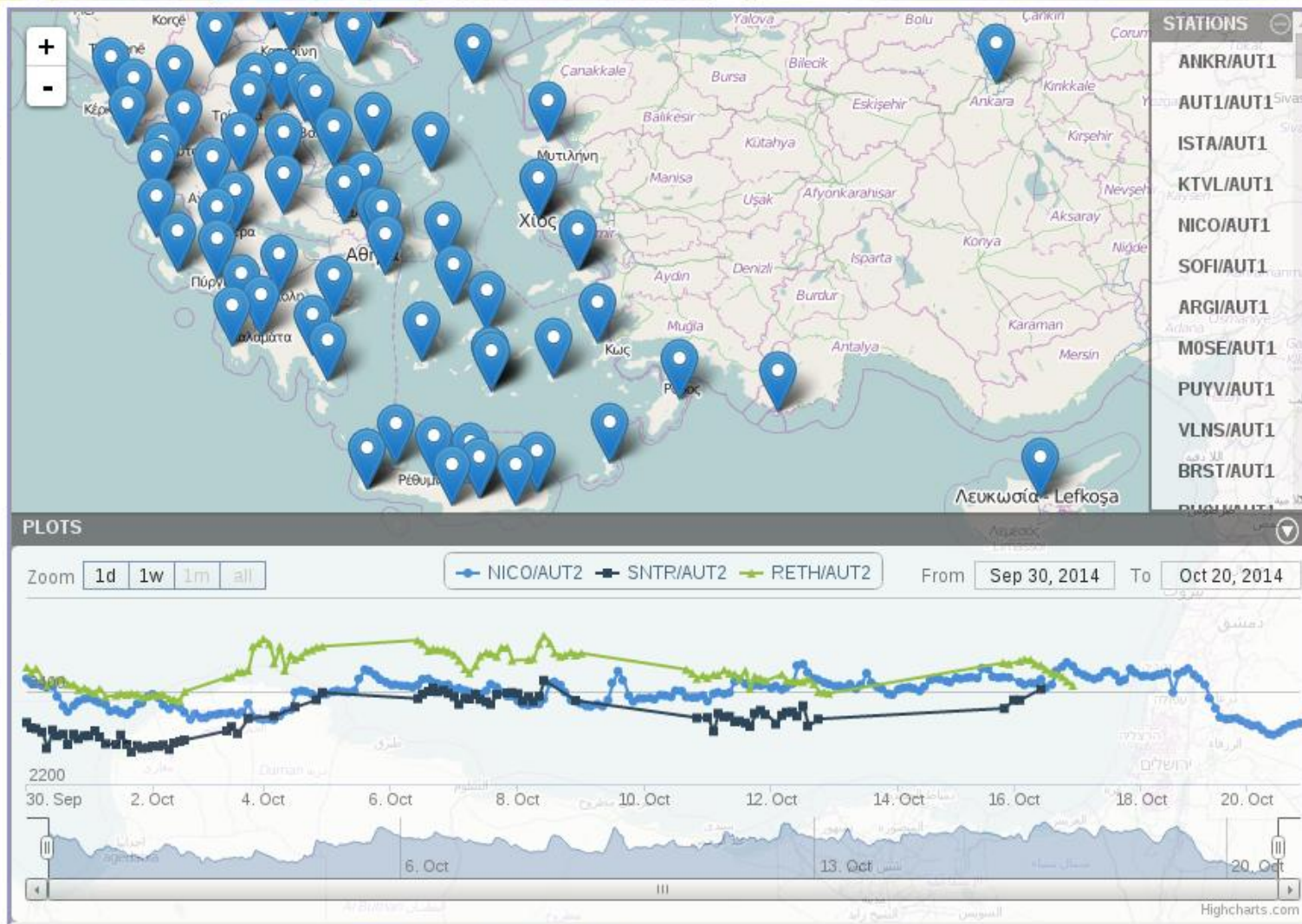
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GOP-TropDB – tropo evaluations

Intra-technique comparison (currently GNSS)

- **Reference products:** IGS, EUREF (legacy, Repro1, Repro2)
- **IGS Individual ACs:** CODE Repro2 (COF/COD), interests ?
- Other individual contributions from EUREF, GNSS4SWEC, interests ?
- **GOP products:** Repro1, Repro2, Multi-GNSS NRT, Global NRT, Real-time etc.

Inter-technique comparison

- **VLBI** – IVS combined products (preliminary → need for better tropospheric ties!)
- **DORIS** – GOP internally only (study of SAA), lack of official products
- **RAOBS** – BADC/MetOffice global data set, **IGRA** (*preliminary*), ...
- *WV Radiometers – GOP WVR (no other available)*
- **NWM – ERA-Interim** (NCEP GFS) a global background NWM data set (1990-present)
- potential **other NWMs** in Europe within E-GVAP/GNSS4SWEC projects

Additional sources (auxiliary)

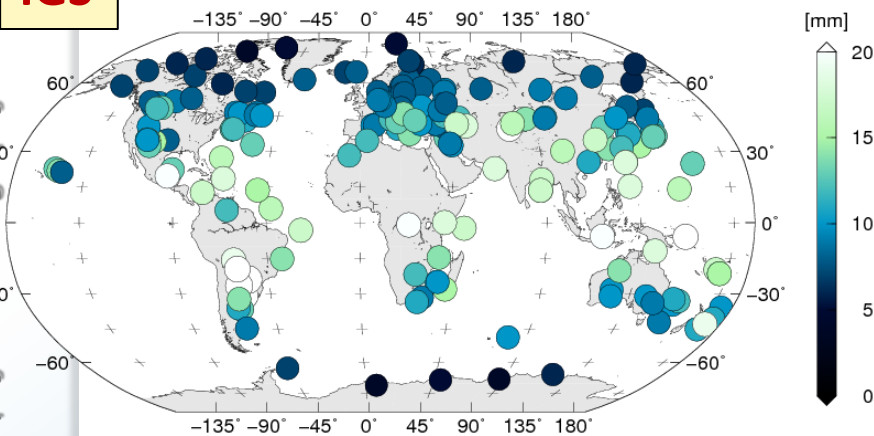
- **GPT2** – Global Pressure and Temperature model, (grid) + geoid, ...
- **EGM2008** – geoid model (grid)
- (ERA-Interim orography + land/sea mask)
- Temporal and spatial interpolations

ERA-Interim long-term evaluation

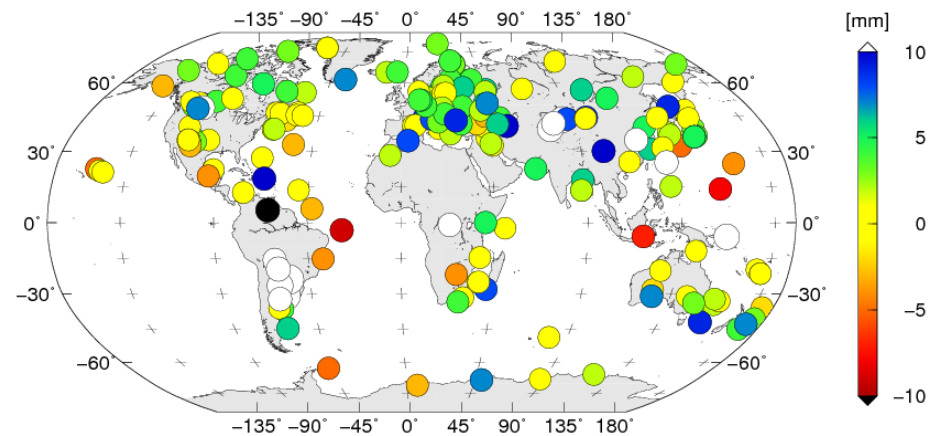
... total statistics of ZTD from ERA-Interim compared to IGS (top) and EUREF (bottom)

IGS

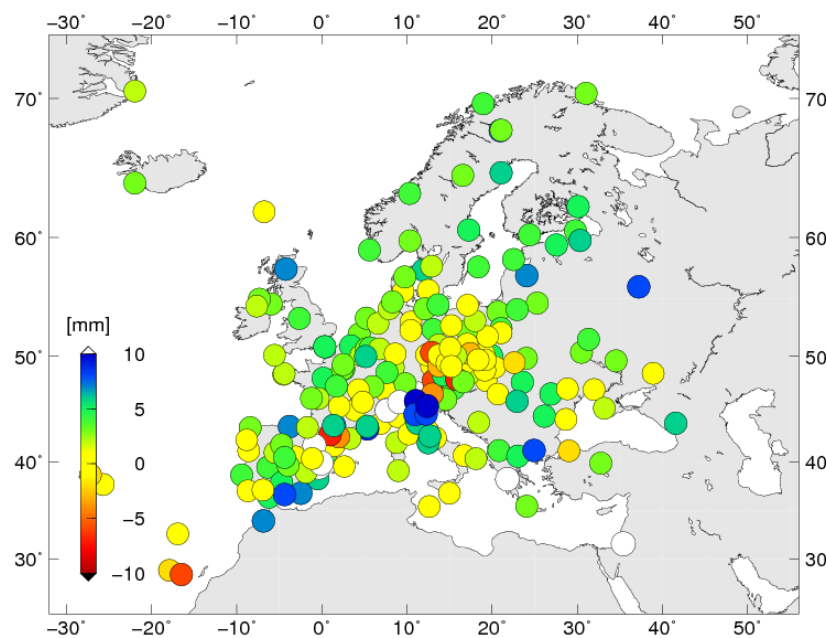
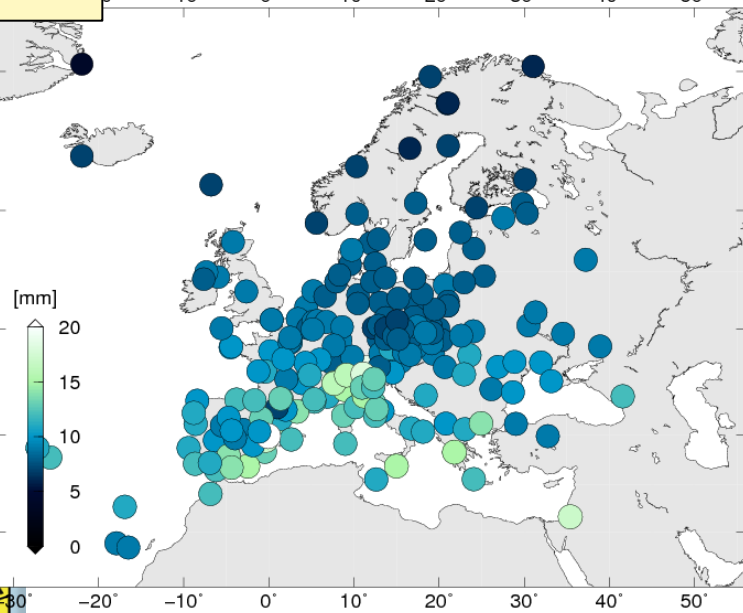
ZTD Sdev: ERA-Interim - IGS (final)



ZTD Bias: ERA-Interim - IGS (final)

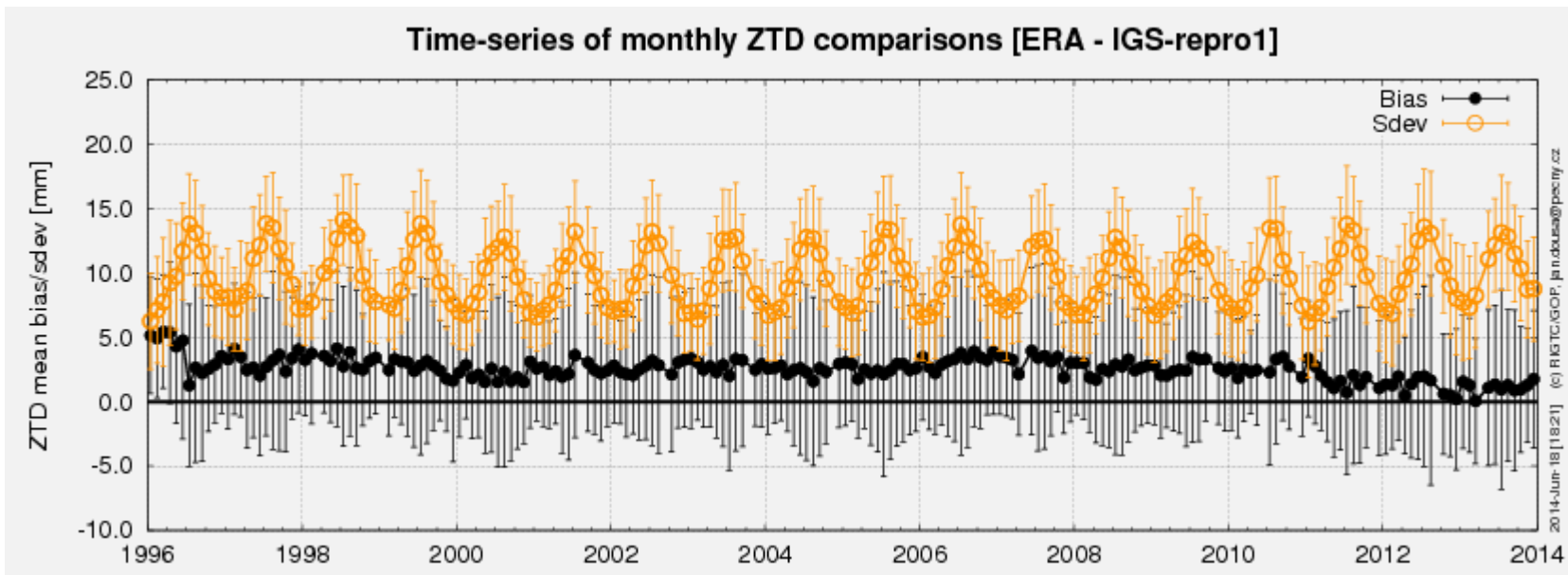


EUREF

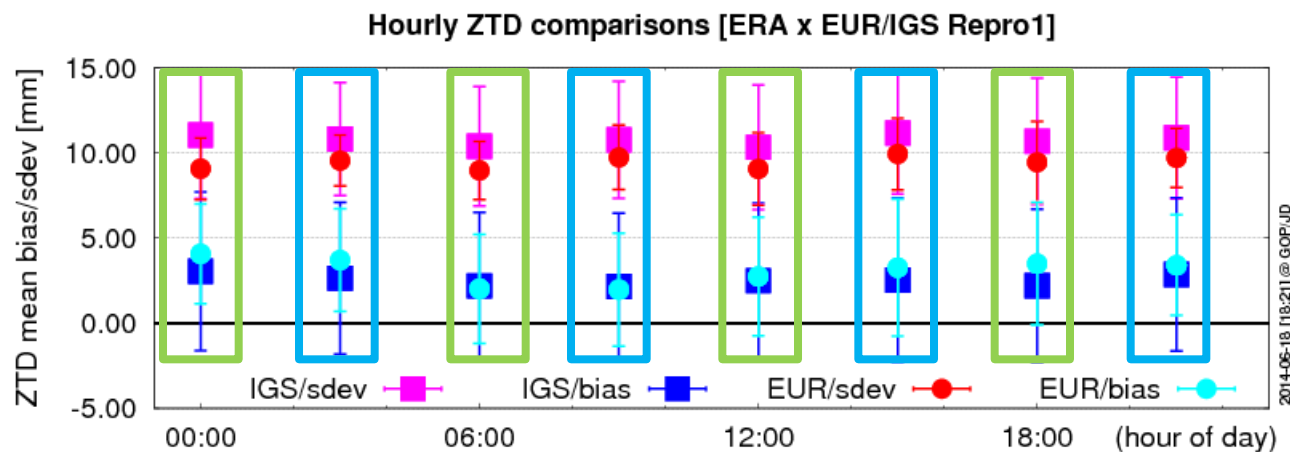



ERA-Interim long-term evaluation

... monthly statistics of ZTD from ERA-Interim compared to IGS (top) and EUREF (bottom)




*Estimated
Interpolated*







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www.pecny.cz/joomla25/index.php/gop-tropdb/tropo-model-service

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GOP-TropDB - TropModel online service

The formular serves for calculation of site-specific tropospheric parameters, conversion factors or other auxiliary meteorological parameters for scientific applications.

Currently, the following limitations for the service are applied:

- Scope: 20 sites
- Period: 366 days (1 year)
- Interval: 1990 - present (delayed by 3-4 months)
- Sampling: 1s - 21600s (6h)

Notes: This is an **experimental** service! Any feedback is appreciated at jan.dousa@pecny.cz. We acknowledge the availability of the ERA-Interim dataset provided by [ECMWF](#).

E-mail

Parameters

ZTD☒

ZWD☒

T☒

ZHD☒

P☒

Tm☒

Period

from:

to:

YYYY-MM-DD

Sampling rate

integer [seconds] ... for parameter sampling

Model

Era-Interim ▼

Coordinates

TRON	2820171.00407	513485.97238	5678935.84085	OTH	<div>site_id X Y Z [remark]</div>
TUBI	4211317.86783	2377865.53031	4144663.00278	OTH	
TUBO	4001470.42730	1192345.39606	4805795.45025	EPN08	
TUC2	4744543.75201	2119411.81089	3686258.92183	EPN08	
UNPG	4555145.87427	997822.27681	4337432.63361	EPN08	
UNTR	4590764.42302	1032366.87627	4291666.50767	OTH	
UPAD	4389531.31394	923253.58380	4519256.30347	OTH	
USAL	4627542.08529	1513540.81881	4106448.15576	EPN08	

Job notice:

[request comment](#)

Submit

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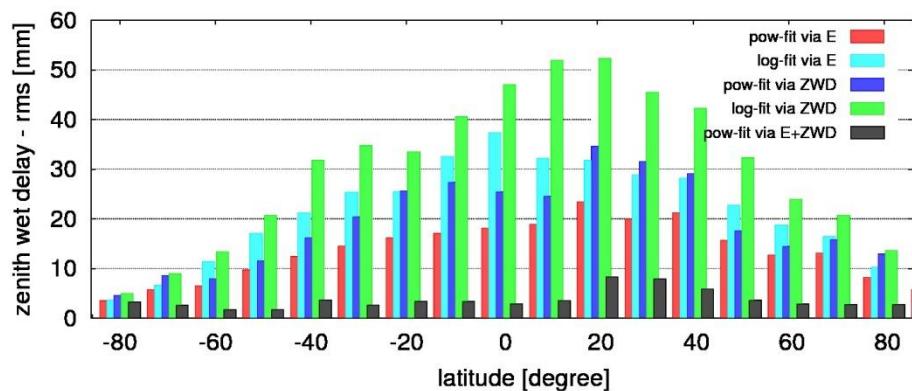
TropModel - output

```
honzaj@janek: ~  
nwm@cert:/kaca/nwm/WWW/job-2014-09-06-540a3612ae4c3$ head -30 TRON-2013-01.out  
#ver: G-Nut/Shu [1.0.0] compiled: Sep  3 2014 15:01:34 ($Rev: $)  
#sit: TRON  
#xyz: 2820171.0041 513485.9724 5678935.8409  
#blh: 63.3714 10.3192 317.7196  
#----  
#YEAR-MM-DD HH:MM:SS p[hPa] T[K] ZHD[m] ZWD[m] Tm[K]  
2013-01-01 00:00:00 944.3550 272.1241 2.1468 0.0749 266.9972  
2013-01-01 02:00:00 945.0995 272.4506 2.1485 0.0747 267.1106  
2013-01-01 04:00:00 945.8441 272.7771 2.1502 0.0745 267.2241  
2013-01-01 06:00:00 946.5886 273.1036 2.1519 0.0743 267.3376  
2013-01-01 08:00:00 948.1261 273.9027 2.1553 0.0689 267.5297  
2013-01-01 10:00:00 949.6635 274.7017 2.1588 0.0634 267.7219  
2013-01-01 12:00:00 951.2010 275.5008 2.1623 0.0580 267.9140  
2013-01-01 14:00:00 952.4779 274.8730 2.1652 0.0555 267.9598  
2013-01-01 16:00:00 953.7547 274.2451 2.1681 0.0530 268.0057  
2013-01-01 18:00:00 955.0316 273.6173 2.1710 0.0505 268.0515  
2013-01-01 20:00:00 956.5223 273.1019 2.1744 0.0521 267.9788  
2013-01-01 22:00:00 958.0130 272.5865 2.1778 0.0536 267.9060  
2013-01-02 00:00:00 959.5037 272.0712 2.1812 0.0552 267.8333  
2013-01-02 02:00:00 960.9816 272.8569 2.1846 0.0587 267.8836  
2013-01-02 04:00:00 962.4594 273.6427 2.1879 0.0621 267.9338  
2013-01-02 06:00:00 963.9373 274.4284 2.1913 0.0656 267.9841  
2013-01-02 08:00:00 965.8586 274.6091 2.1957 0.0624 267.2317  
2013-01-02 10:00:00 967.7799 274.7897 2.2000 0.0593 266.4794  
2013-01-02 12:00:00 969.7012 274.9704 2.2044 0.0561 265.7270  
2013-01-02 14:00:00 970.1714 274.6663 2.2055 0.0576 265.3189  
2013-01-02 16:00:00 970.6417 274.3622 2.2065 0.0591 264.9109  
2013-01-02 18:00:00 971.1120 274.0581 2.2076 0.0606 264.5028  
2013-01-02 20:00:00 969.7129 273.3568 2.2044 0.0626 264.5918  
2013-01-02 22:00:00 968.3138 272.6555 2.2012 0.0645 264.6808  
nwm@cert:/kaca/nwm/WWW/job-2014-09-06-540a3612ae4c3$
```

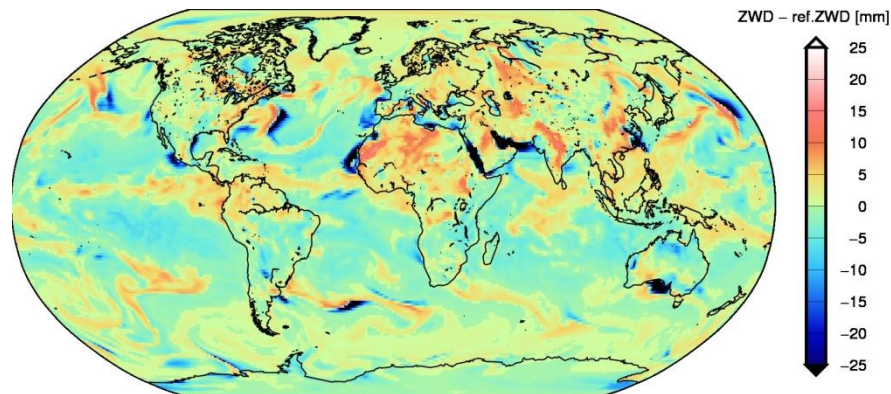
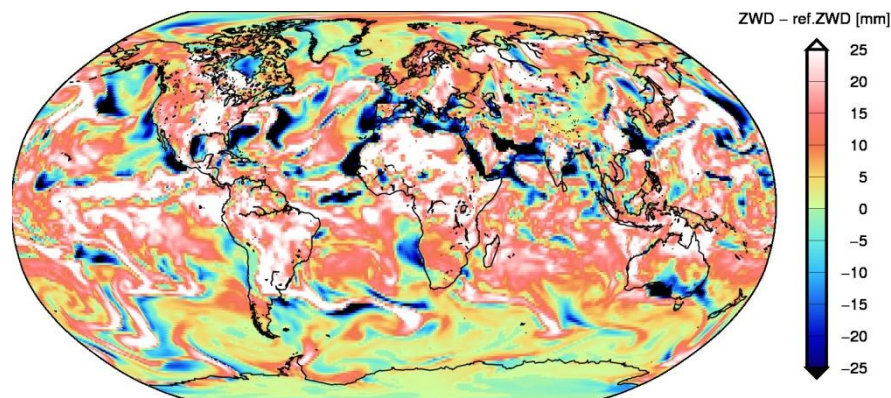
New tropo model for positioning

- Improved ZWD physical model of Askne and Nordius (1987)
- Needs for assessment various NWM models as a potential input for GNSS real-time positioning
- Enhanced ZWD vertical approximation → used in GOP-TropDB tropo-ties

Douša and Eliaš (2014) An improved model for tropospheric wet delay, Geophys. Res. Lett. 41



Global ERA-Interim data (2005-06-05:00)



References

G-Nut library

Václavovic P, Douša J, Györi G (2013), G-Nut software library - state of development and first results, Acta Geodynamica at Geomaterialia, pp 431-436, Vol. 10, No. 4 (172), doi:10.13168/AGG.2013.0042.

GOP near real-time solution - long-term evaluations

Douša J, Václavovic P (2013), Long-term evaluation of new ground-based GNSS tropospheric products, submitted to IAG Symposia Series - Proceedings of the IAG 2013 held in Potsdam, September 1-6, 2013

G-Nut/Tefnut - real-time ZTD product

Douša J, Václavovic P (2013), Real-time zenith tropospheric delay estimates in support of nowcasting, submitted to Advanced Space Research, 2013.

Global near real-time ZTD product

Douša J, Bennitt GV (2013), Estimation and evaluation of hourly updated global GPS Zenith Total Delays over ten months, GPS Solution, Springer, 17:453-464, doi:10.1007/s10291-012-0291-7, (ISSN online:1521-1886 printed: 1080-5370)

GLONASS near real-time ZTD product

Douša J (2012), Developments of the GLONASS ultra-rapid orbit determination at Geodetic Observatory Pecný, In: Geodesy of Planet Earth, S. Kenyon, M.C. Pacino, U. Marti (eds.), International Association of Geodesy Symposia, Vol 136, pp.1029-1036. (<http://www.springer.com/978-3-642-20337-4>)

GOP Tropospheric database

Gyori G, Douša J (2013), GOP-TropDB developments for tropospheric product evaluation and monitoring -- design, functionality and initial results submitted to IAG Symposia Series - Proceedings of the IAG 2013 held in Potsdam, September 1-6, 2013

GOP Troposphere modelling

Douša J, Eliaš M (2014), An improved model for tropospheric wet delay, Geophys. Res. Lett. 41, doi:10.1002/2014GL060271.