EPN Repro2: a reference tropospheric dataset over Europe

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Abstract

The availability of about 19 years of GNSS data belonging to the European Permanent Network (EPN, http://www.epncb.oma.be/) is a valuable database for the development of a climate data record of GNSS tropospheric products. In the framework of the EPN-Repro2 campaign, five EPN Analysis Centres (AC) are providing homogenously reprocessed solutions, for the period 1996-2013. Three ACs homogenously reprocessed the entire EPN network, using three different software packages: Bernese 5.2, GAMIT 10.5 and GIPSY 6.2. Smaller subnetworks based on Bernese 5.2 are also provided. Reprocessed orbit and clock parameters, which are either provided by CODE and JPL, are used. A huge effort is currently on going for providing solutions that are the basis for deriving new coordinates, velocities and troposphere parameters over Europe. The Working Group 3 (Use of GNSS tropospheric products for climate monitoring) of the COST Action ES1206 (GNSS4SWEC) addresses to the evaluation of existing and forthcoming GNSS tropospheric products and to the assessment of their potential for climate research. This task needs a cooperation between geodesists and climatologists, to agree on diagnostics for assessing the data records and on recommendations on equipment, data reprocessing and data formats. In this scenario, EPN-Repro2 long term time series of homogeneously reprocessed troposphere parameters will provide a GNSS climate data record over Europe with high potential for monitoring trend and variability in atmospheric water vapour, improving the knowledge of climatic trends of atmospheric water vapour and being useful for global and regional NWP reanalysis as well as climate model simulations. We describe the EPN-Repro2 activities, on the results of the first combined solutions and how by the climate community can take benefit.

EPN Working Group on Reprocessing

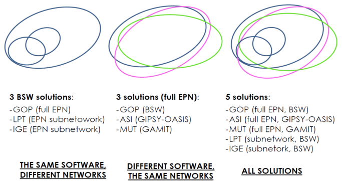
EPN Working Group on Reprocessing established in 2009 during the 49thEUREF Technical Working Group.

- Repro1: First Reprocessing Campaign 1996-2006
  - 16 ACs: ASI BEK BKG DEO GOP IGE IGN LPT MUT NKG OLG ROB SGO SUT UPA WUT
  - Each processing an EPN sub-network (3 ACs for each site)
  - Results presented at the EUREF 2011 symposium
- Repro2: Second Reprocessing Campaign 1996-2013, with extension to 2014
  - 5 ACs: ASI GOP IGE LPT MUT (Figure1 and Table1)
  - At least 1 solution for AC
  - Tropospheric Parameters: ZTDs & Horizontal Gradients

Combination of EPN Positions: Military University of Technology, Poland (MUT)

Combination of EPN Troposphere Parameters: Centro di Geodesia Spaziale, Italy (ASI)

Coordination: Bavarian Academy of Sciences and Humanities, Germany (BEK)



3 BSW solutions:
-GOP (full EPN)
-LPT (EPN subnetowork)
-IGE (EPN subnetwork)
3 solutions (full EPN):
-GOP (BSW)
-ASI (GIPSY-OASIS)
-MUT (GAMIT)
5 solutions:
-GOP (full EPN, BSW)
-ASI (full EPN, GIPSY-OASIS)
-MUT (full EPN, GAMIT)
-LPT (subnetwork, BSW)
-IGE (subnetork, BSW)
THE SAME SOFTWARE, DIFFERENT NETWORKS
DIFFERENT SOFTWARE, THE SAME NETWORKS
ALL SOLUTIONS

Figure 1. GNSS Solutions: Software used and Network coverage

	AS0	GO0	GO1	GO4	IG0	LP0	LP1	MU4
SW	GIPSY 6.2	BSW 5.2			BSW 5.2	BSW 5.2		GAMIT 10.5
GNSS	G	G			G + R	G + R		G
SOLUTION TYPE	PPP	NET			NET	NET		NET
STATIONS	ALL EPN+ IGS CORE	ALL EPN			PART EPN	PART EPN + IGS(8)		ALL EPN
ORBITS	JPL R2 (prelim.)	CODE R2			CODE R2	CODE R2		CODE R2
ANTENNAS	IGS08	IGS08 + IND.			IGS08 + IND.	IGS08	IGS08+ IND	IGS08
IERS	2010	2010			2010	2010		2010
GRAVITY	EGM08	EGM08			EGM08	EGM08		EGM08
TROPOSPHERE Estimated Param	ZTD (5min) GRAD (5min)	ZTD (1h) GRAD (6h)			ZTD (1h) GRAD (6h)	ZTD (1h) GRAD (24h)		ZTD (1h) GRAD (24h)
MAPPING FUNCTION	VMF1	GMF	VMF1	VMF1	GMF	GMF	VMF1	VMF1
ZTD/GRAD time stamp	hh:30 24 estimates/day	hh:30 (and hh:00) 24(+24) estimates/day			hh:30 24 estimates/day	hh:30 (and hh:00) 24(+24) estimates/day		hh:30 24 estimates/day
IONOSPHERE	(HOI included)	CODE (HOI included)			CODE (HOI included)	CODE (HOI included)		CODE IONEX + IGRF11 (HOI included)
REF. FRAME	IGb08	IGb08			IGb08	IGb08		IGb08
OCEAN TIDES	FES2004	FES2004			FES2004	FES2004		FES2004
T-ATML	NO	NO			YES	YES	YES	YES
NT-ATML	NO	NO	NO	YES	NO	NO	YES	NO
ELEV. CUTOFF	3	3			3	3		5
Delivered SNX_TRO Files [from week to week]	0835-1772	0836-1771			0835-1816	0835-1772		0835-1771

Table 1. GNSS Solutions: Processing Set-Up

Features of the Solutions

Even though each contributing solution has been homogeneously reprocessed, there are a few difference among them in the applied processing set-up (see Table 1). These differences are evaluated prior to run the combination.

Impact of GLONASS: GLONASS observations are available starting from 2002, however only in 2008 there were enough EPN operational GPS+GLONASS stations (Figure 2). As far as the ZTD trend is concerned, the difference GPS – GPS/GLO, computed over 111 sites, shows no significant rate, with small standard deviation and no bias effect (Figure 3).

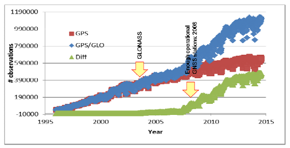


Figure 2. GPS and GLONASS available data

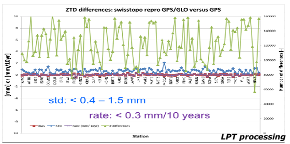


Figure 3. ZTD trends

Impact of Individual versus Type Mean Calibration: Within EPN not only Type Mean but also Individual antenna calibration models are used. Figure 4 shows the time series of the ZTD difference obtained applying 'Individual' and 'Type Mean' antenna calibration for the EPN station KLOP (Germany). Although a jump is clear visible in the time series, it is not large enough to be capture during the combination process where 10 mm ZTD (about 1.5 kg/m^2 IWV) threshold is set to flag stations/ACs.

PERIOD	Diff . Up	Diff. ZTD	Anntena + Radome	
2002-07-02 : 2007-06-27	- 5.2 mm	0.4 mm	TRM29659.00	NONE
2007-06-27 : 2013-06-28	8.7 mm	– 1.3 mm	TRM55971.00	TZGD
2013-06-28 : 2013-12-31	5.1 mm	-1.4 mm	TRM57971.00	TZGD

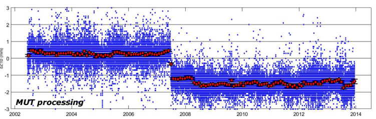


Figure 4. KLOP (Germany): differences between 'Individual' versus 'Type Mean' calibration

Impact of Non-Tidal Atmospheric Loading: In Figure 5 shows the ZTD and H differences between two time series obtained with and without Non-Tidal Atmospheric Loading for the ENP stations KIR0 (Sweden) and ARGI (Faroe Islands). The effect seems to be negligible at the ZTD level.

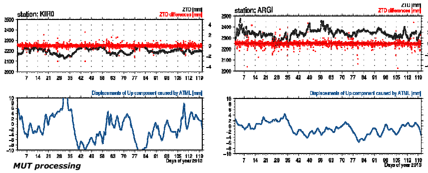


Figure 5. differences between ZTD computed with/without Non-Tidal Atmospheric Loading

	IWV		
	Threshold	Breakthrough	Goal
Horizontal Domain	Regional (e.g. Europe, N. America)		
Horizontal Sampling	200 km	25 km	10 km
Observation Cycle	6 h	4 h	3 h
Accuracy	3 kg.m^{-2}	1.5 kg.m^{-2}	1 kg.m^{-2}
Timeliness	60 days	14 days	7 days

Table 2. Observational requirements for Regional Climate (E-GVAP II Product Requirements Document)

EPN Repro2 Combined Solution

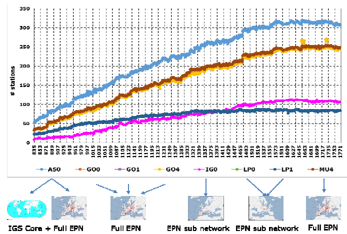


Figure 6. # of reprocessed stations

We reprocessed more than 900 GPS weeks with an increasing number of stations, starting from 50 up to 250 (in GOP/MUT solutions)/300 (in ASI solutions) (see Figure 6). The combination is done station by station, if and only if 3 different input solutions are available for that specific stations (see Figure 7).

A first tropospheric combined solution for the period 1996-2013 has been carried out considering all the eight available homogenously reprocessed contributions (see Table 1) delivered by the five ACs. This preliminary combined solution gives the possibility to assess each contributing solution and to investigate on station/AC specific bias prior to the final combination. Figure 8 shows the weekly mean bias (left) and standard deviation (right) of each contributing solution w.r.t. the combination. With some exception, the bias is in the range [-2 mm, +2 mm] while the standard deviation below 2.5 mm.

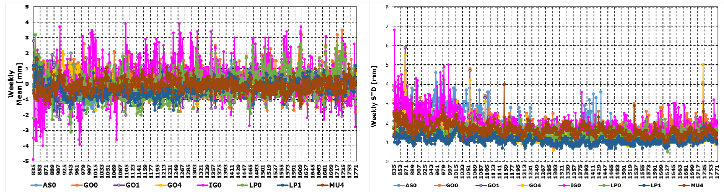


Figure 8. Weekly Mean Bias (left) and Standard Deviation (right) w.r.t. the combination.

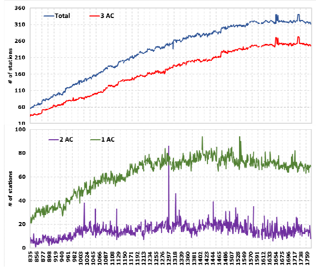


Figure 7. Station redundancy

Since horizontal gradients are available, we performed an intra-technique (AS0 as reference solution) and inter-technique (ERA-Interim as reference solution) evaluation on a subset of EPN stations (Figure 9) for the whole 2013. An example is shown for the EPN station ZIMM (Switzerland) in Figure 9 and Figure 10.

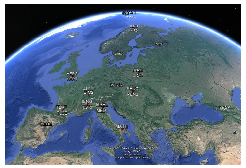


Figure 8. EPN sub-network used for gradient evaluation, made by twin stations or GPS and VLBI stations

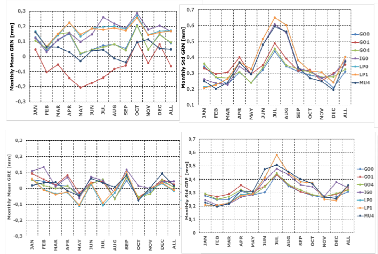


Figure 9. Intra-technique Monthly Mean and Standard deviation GRN (up) and GRE (bottom)

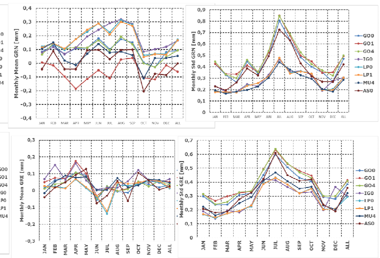
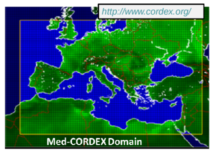


Figure 10. Inter-technique Monthly Mean and Standard deviation GRN (up) and GRE (bottom)

EPN Repro2 End Users

Water vapour is under-sampled in the current meteorological and climate observing systems. Obtaining and exploiting more high-quality humidity observations is essential to weather forecasting and climate monitoring.

Climate community only now starting to use GNSS tropospheric products to document climate trends and variability and to evaluate climate models (CMIP, CORDEX, EC-Earth, GEWEX, HYMEX…).



For the assessment of Med-CORDEX, Euro-CORDEX climate model simulation IGS Repro1 (1996-2010) is used as reference reprocessed GPS solution.

The climate groups expressed the need for:

- more spatially dense GPS ZTD/IWV data over Europe;
- data after 2010

EPN repro2 will be compliant to both requests and is expected soon!!

This activities are carried out in the framework of WG 3 'GNSS for Climate Monitoring' of the COST Action ES 1206 and will continue in the JWG 'GNSS tropospheric products for Climate' of the Sub-Commission 4.3: Atmosphere Remote Sensing under IAG Commission 4 "Positioning and Applications".

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