EPN-Repro2:
A Reference Tropospheric Dataset over Europe

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Outline

- EPN-Repro2: 2nd Reprocessing Campaign of the EPN (1996-2014)

    Features of the Individual Solutions

    Combined ZTD Solution

- Evaluation versus radiosonde and ERA-Interim data

- Evaluation of ZTD trends

- EPN-Repro2 exploitation

- Summary

EPN-Repro2: A reference GNSS tropospheric data set over Europe, R. Pacione, A. Araszkiewicz, E. Brockmann, J. Dousa, Atmos. Meas. Tech., 10, 1689-1705, https://doi.org/10.5194/amt-10-1689-2017, 2017

GNSS Solutions: SW & Network coverage

- **Period:** 1996-2014
- **5 ACs:** ASI GOP IGE LPT MUT
- **5 (+3)** input solutions available
- **Tropo Parameters:** ZTDs & Gradients
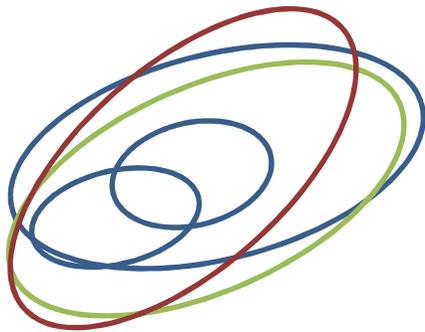
5 (+3) Solutions

- ASI (GIPSY, Full EPN)
- GOP (Bernese, Full EPN)
- LPT (Bernese, EPN sub-net)
- IGE (Bernese, EPN sub-net)
- MUT (GAMIT, Full EPN)

- **Different software**
- **Different networks**
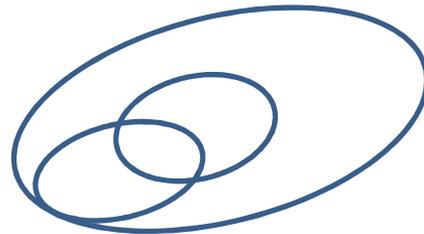
3 Bernese Solutions

- GOP (Full EPN network)
- LPT (EPN Sub-network)
- IGE (EPN Sub-network)

- **Same software**
- **Different networks**
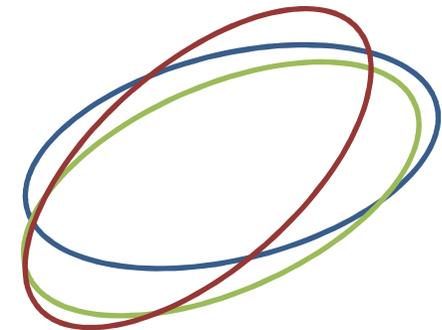
3 Solutions (Full EPN)

- ASI (GIPSY)
- GOP (Bernese)
- MUT (GAMIT)

- **Different software**
- **Same network**

Diversities of the GNSS solutions

- **GLONASS**
  - available since 2003
  - only in LPT and IGE solutions

- **Different PCV corrections**
  - 'type mean' & 'type mean + individual'

- **Non Tidal Atmospheric Loading**
  - Yes/No

- **Orbits**
  - CODE reprocessed: IGE, GOP, LPT, MUT
  - JPL reprocessed: ASI

- **Mapping Function**
  - GMF & VMF1

Impact of GLONASS data

LPT processing

ZTD trend analysis over 111 sites

➢ **No significant rate**
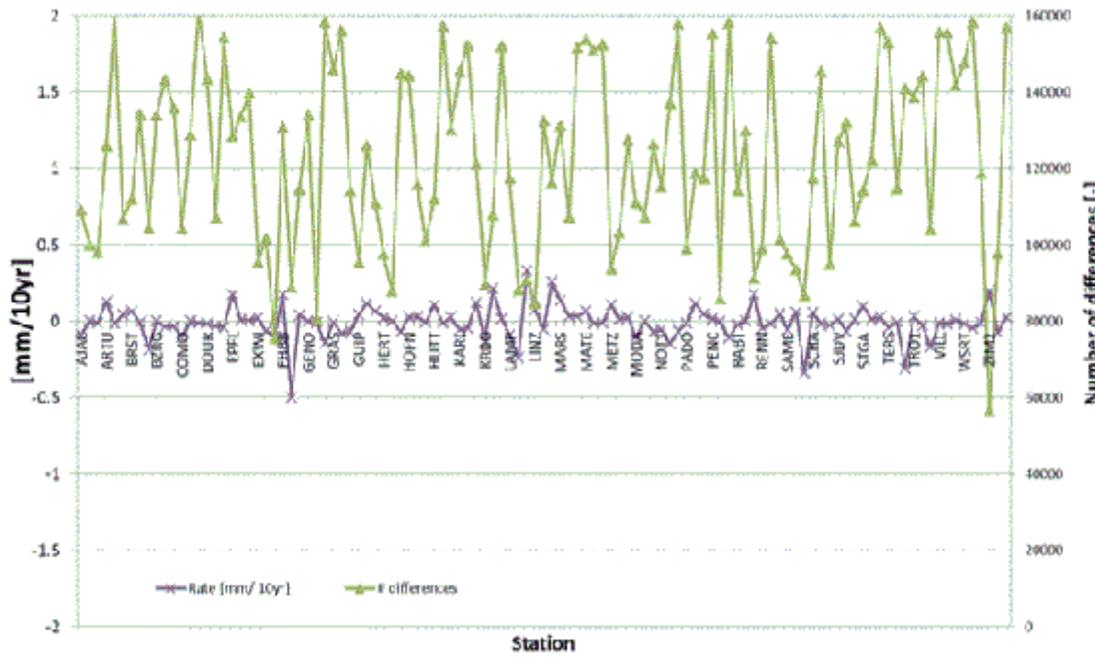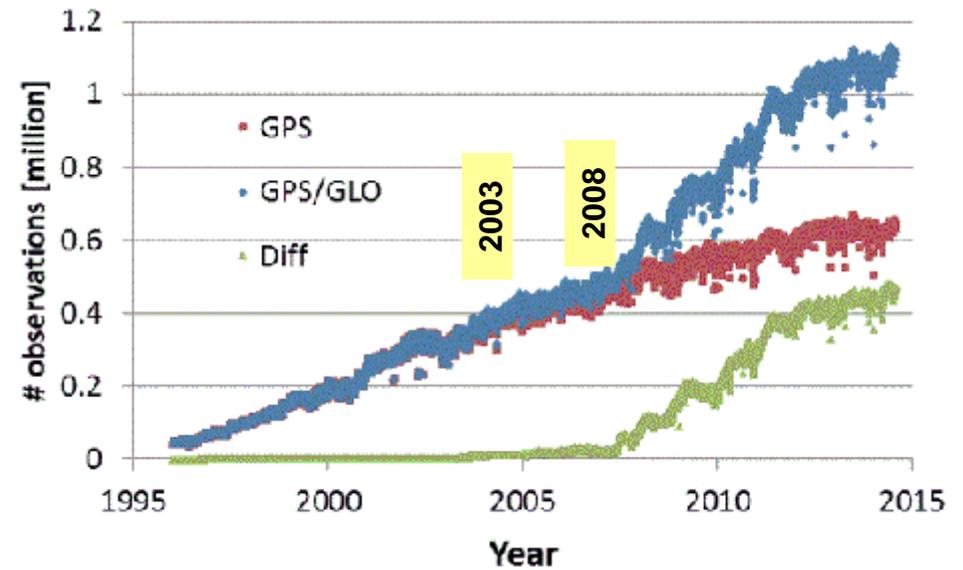
ZTD trends might be determined independently of the satellite systems used in the processing.

IGS Mean Type and EPN Individual Antenna Calibration

KLOP00DEU (KLOP): differences between 'individual' & 'type mean' calibration

PERIOD	Diff . Up	Diff. ZTD	Antenna + 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
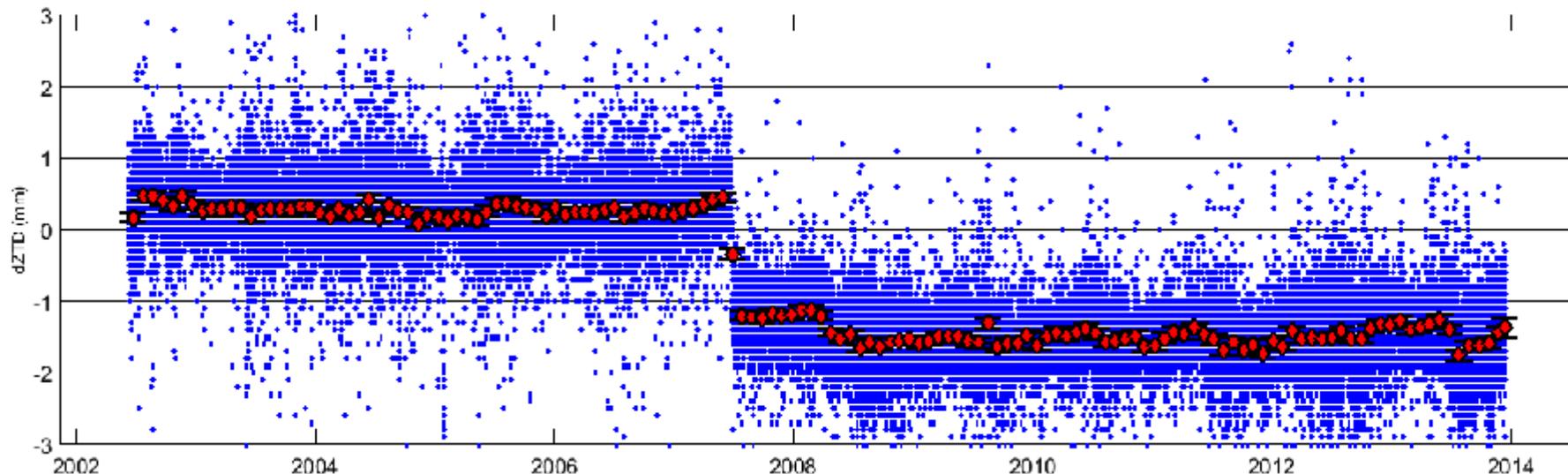
MUT processing

Impact of NT-ATL on ZTD and Height

MUT processing
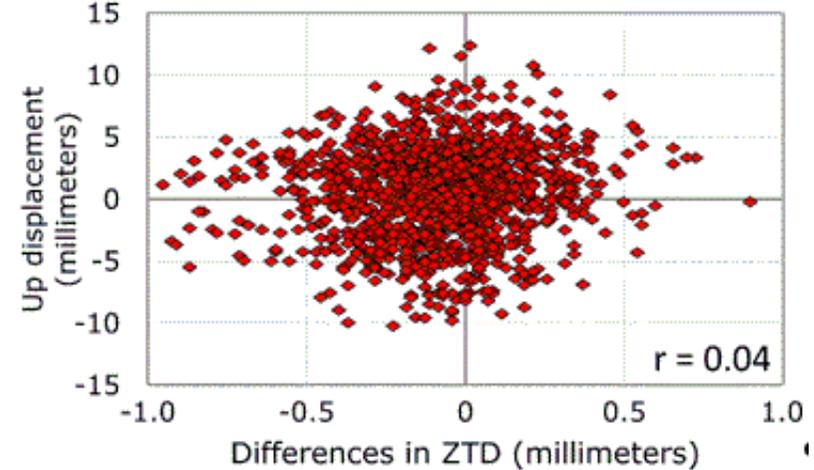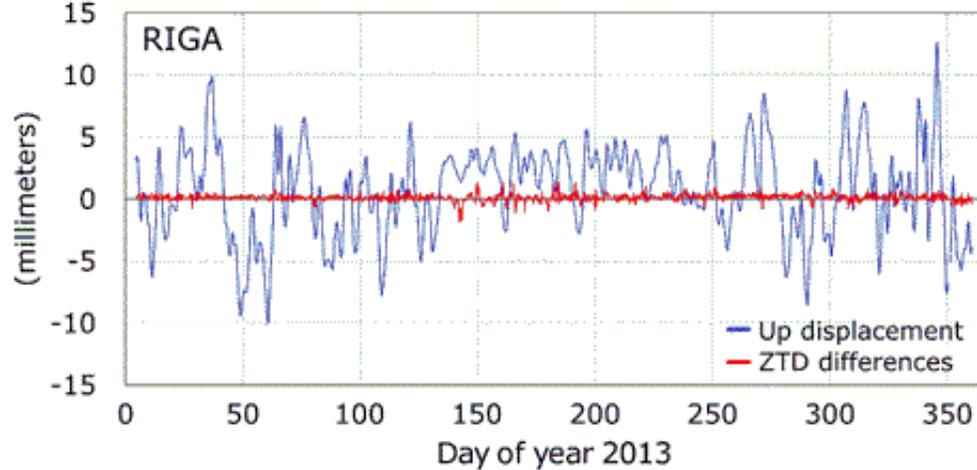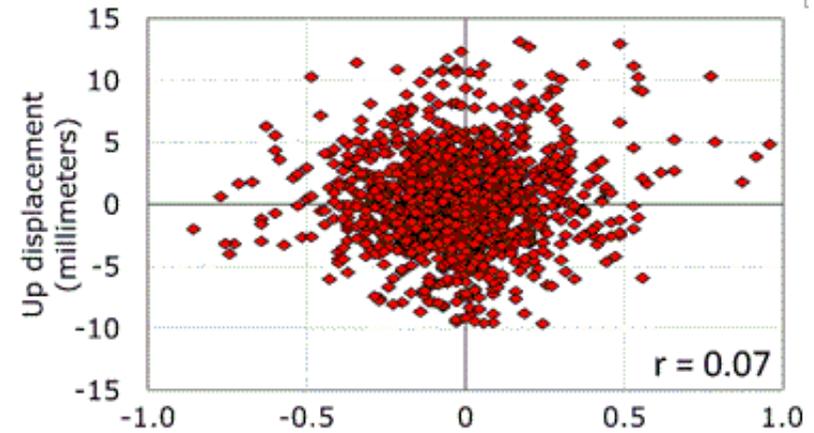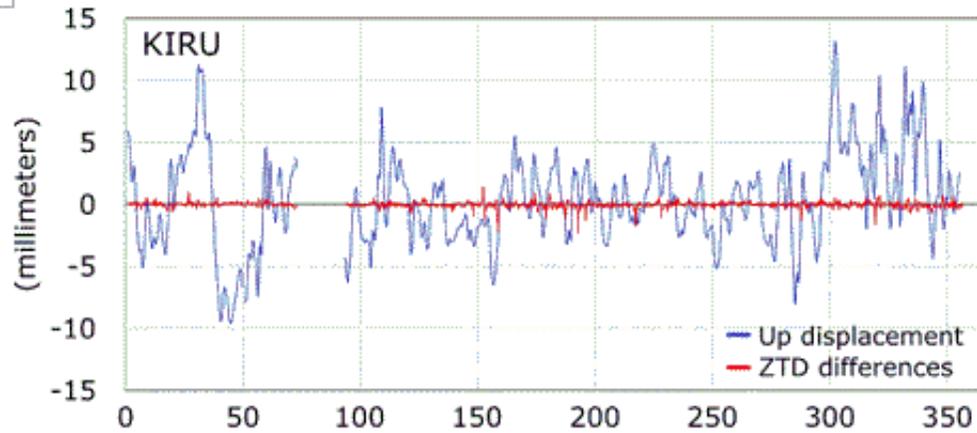
EPN-Repro2 ZTD Combination

➢ 5 input solutions: AS0, GO4, IG0, LP1, MU2

http://www.epncb.oma.be/_productsservices/troposphere/mean_zpd_biases.php?repro2
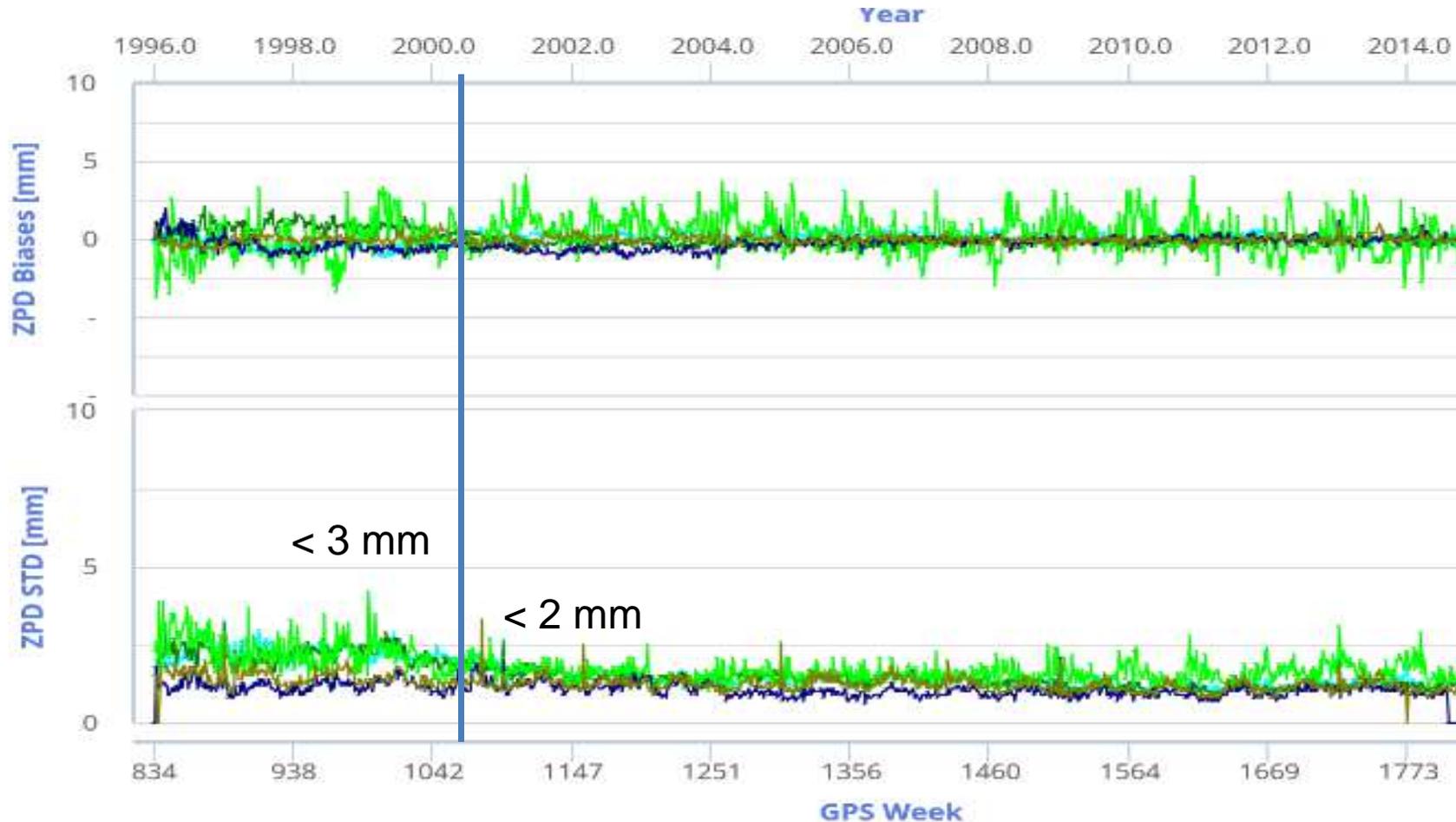
Generalized Least Square Method described in *Pacione et al. Combination Methods of Tropospheric Time Series, Adv. Space Res., 47(2) 323-335 doi:10.1016/j.asr.2010.07.021, 2011*

Internal Quality Metric

➢ Site coordinate repeatability is used as internal quality metric

➢ 9 mm UP repeatability ----> 3 mm ZTD ---> 0.5 kg/m^2 IWV

Stations sorted by names
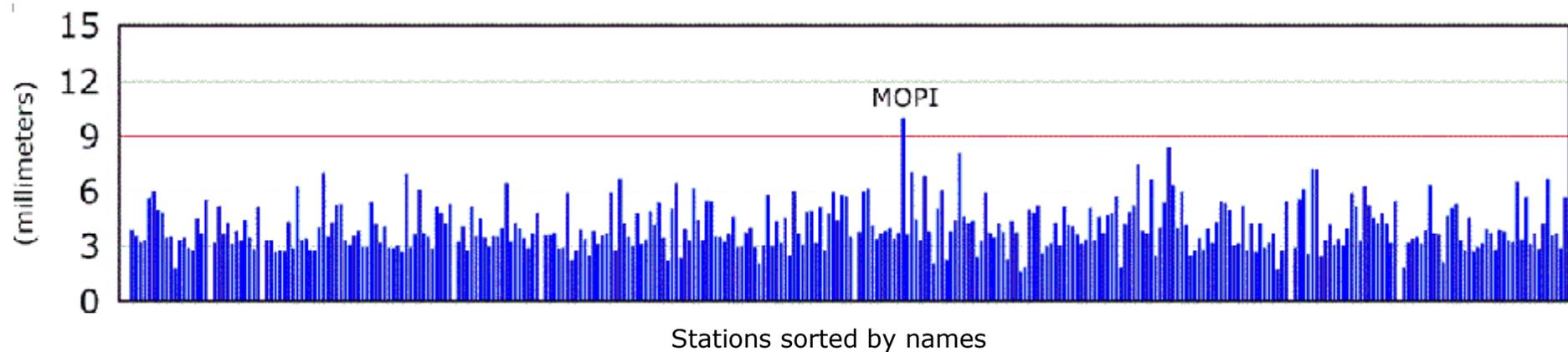
EPN-Repro2 versus Radiosonde

➢ Overall bias and std (RS minus GNSS) at 183 EPN co-located sites;

➢ Bias < 5 mm in ZTD for 75% of the stations (178 pairs);

➢ Sdt increased with distance from the radiosonde launch site;

➢ Improvement of approx. 3-4% if compared to EPN-Repro1.
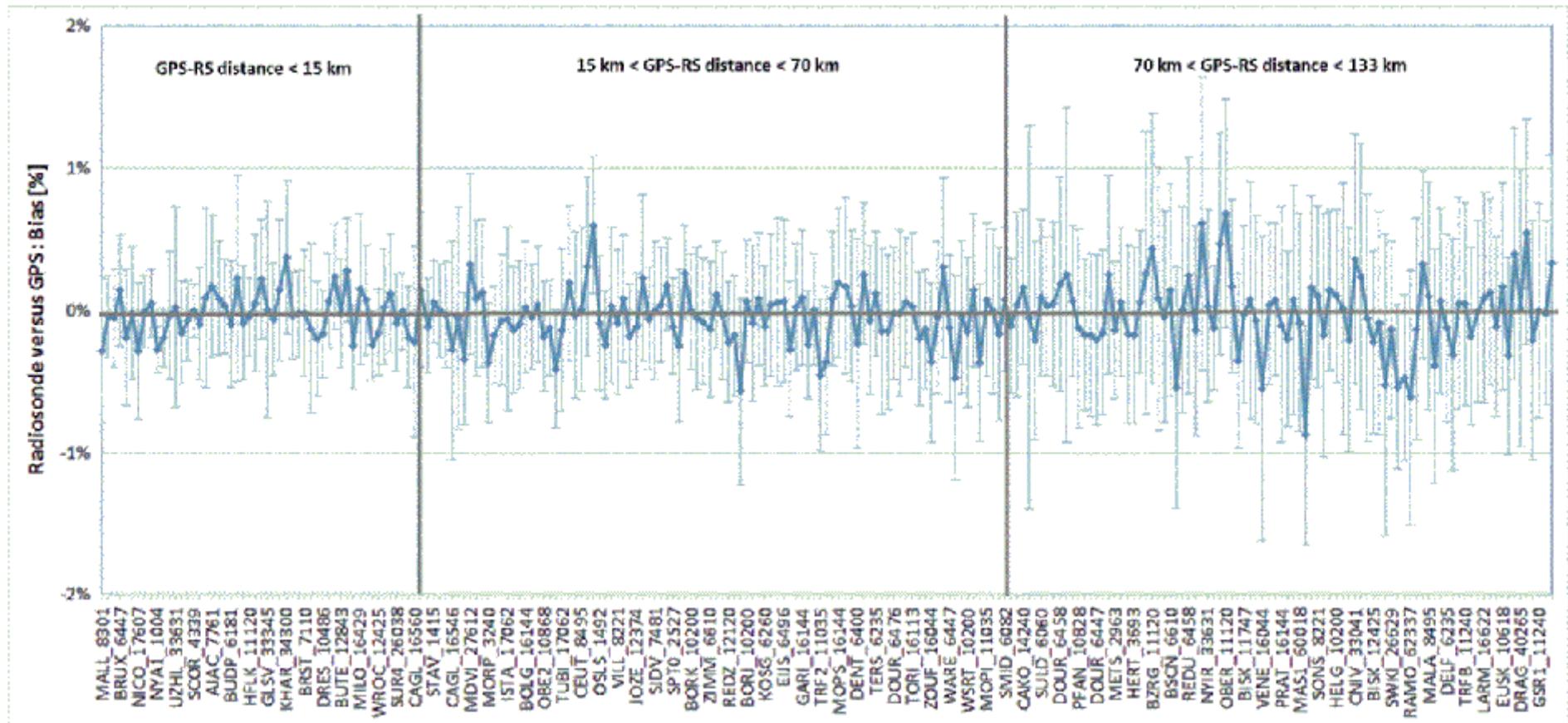
EPN-Repro2 versus ERA-Interim

➢ Positive biases (ERA-Interim minus GNSS) seem to become lower or even negative in mountain areas.

➢ Strong latitudinal dependence for std due to the increase of water vapour content and its variability towards the equator.

➢ Improvement of approx. 8-9% in bias/std if compared to EPN-Repro1
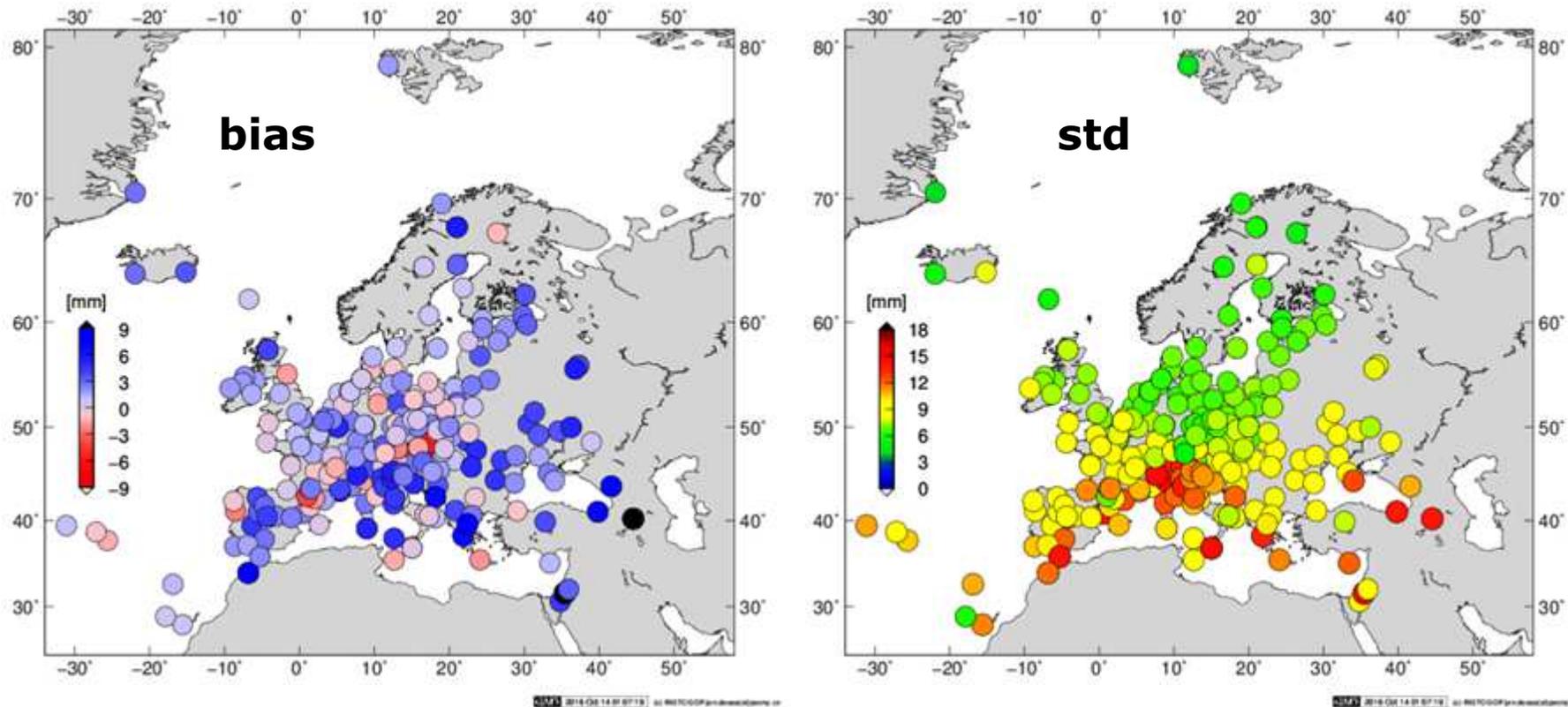
EPN-Repro2 ZTD Trends

➢ ZTD trends are very consistent for the three GNSS data sets;

➢ EPN-Repro2 ZTD trends have lower uncertainty;

➢ Large discrepancy vs RS due to the lack of homogenization of RS data.
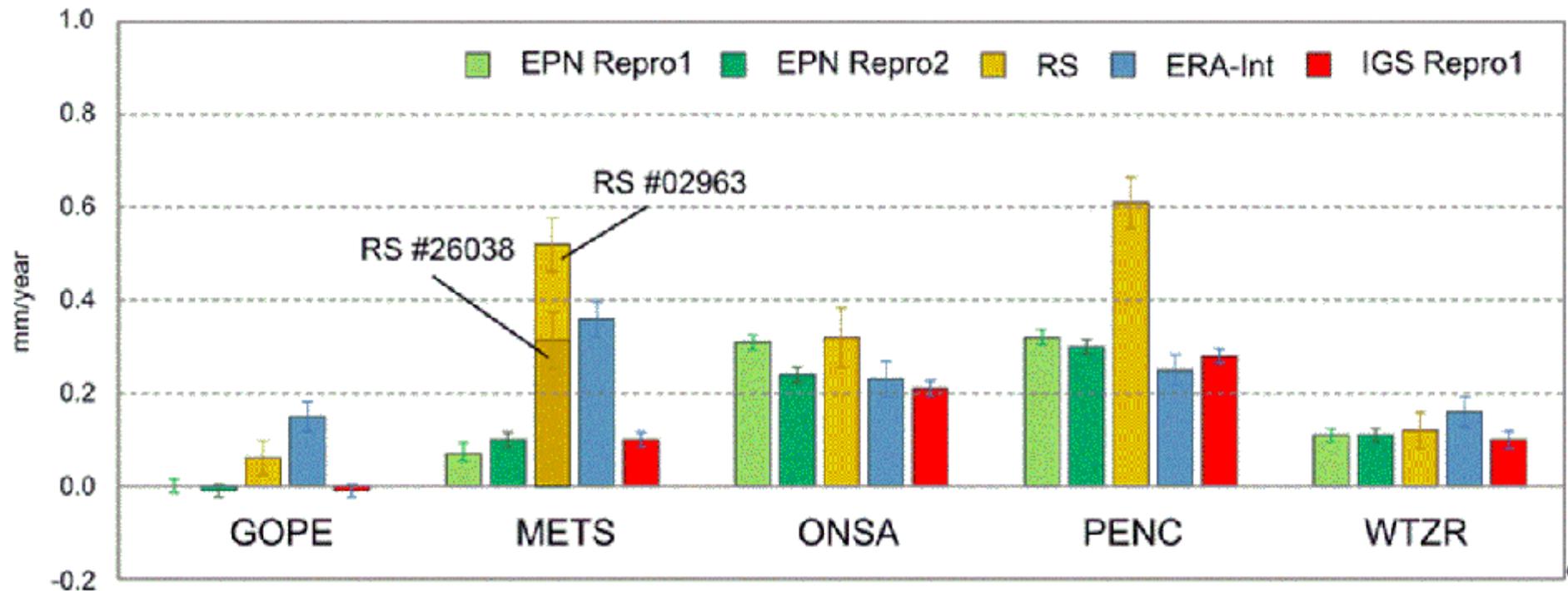
EPN-Repro2 in Climate Model Simulation

ALARO Climate Model

➢ 100 EPN stations in the domain with
min 10 years of data,
min 15 days per months.
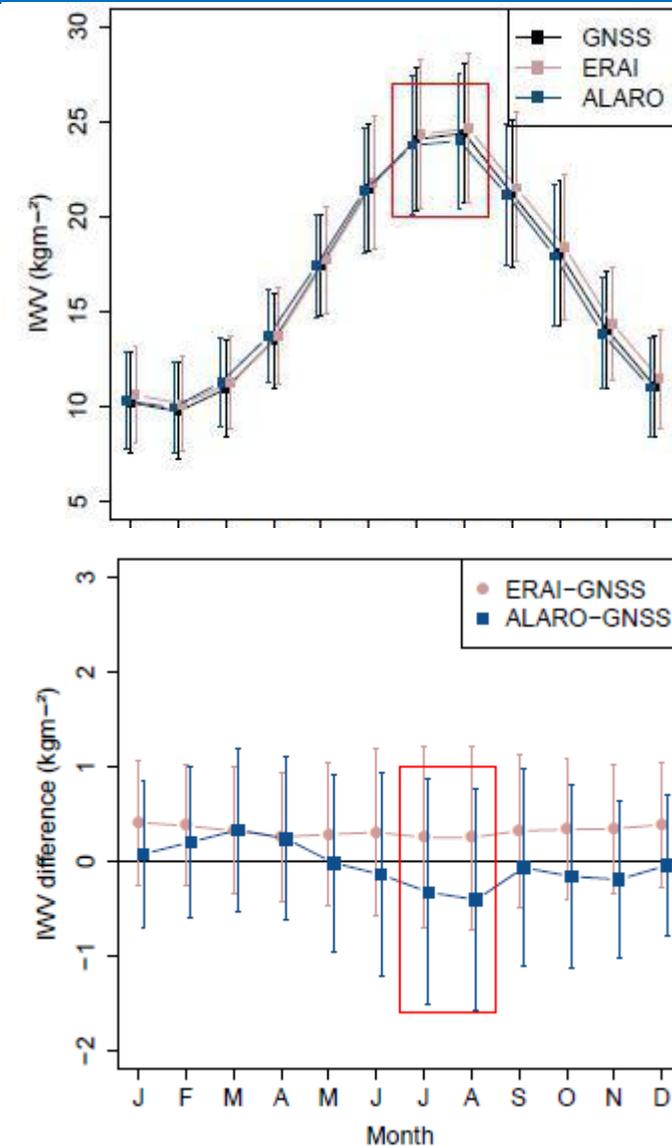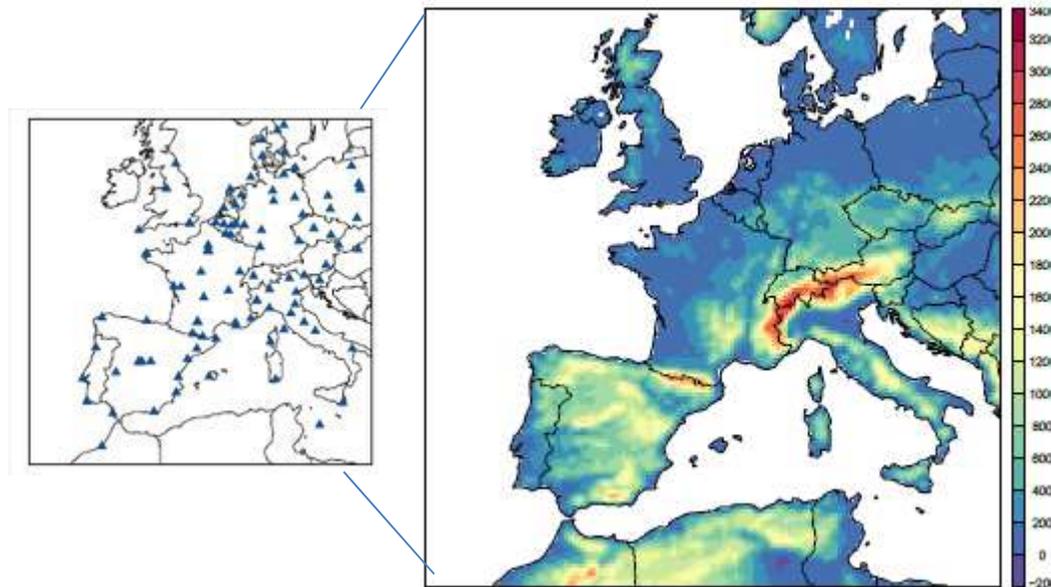
Berckmans J. et al.:' *Evaluation of the atmospheric water vapor content in the regional climate model ALARO-0 using GNSS observations from EPN Repro2*', EUREF Symposium 2017

EPN-Repro2 in Regional ReAnalysis

Uncertainties in Ensembles of Regional ReAnalyses

European reanalysis

- 1978-present
- 4D-VAR hybrid data assimilation
- Data assimilation of reprocessed ZTD with continuously updating bias correction

Repro2 data

*Courtesy G.Halloran,
UK MetOffice*
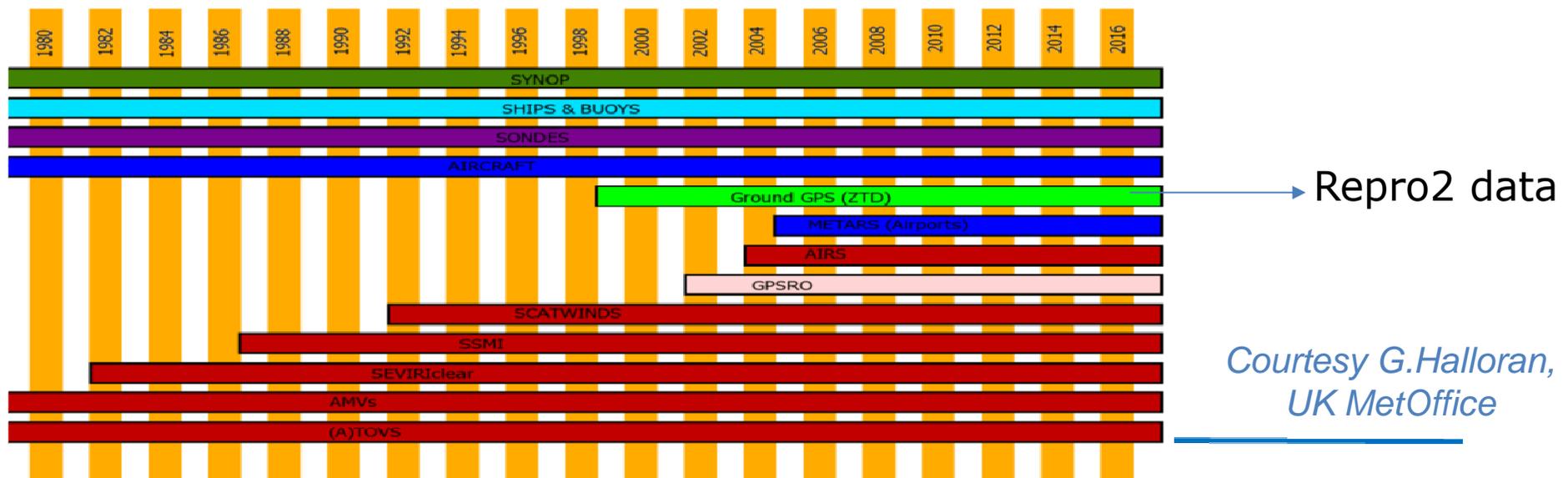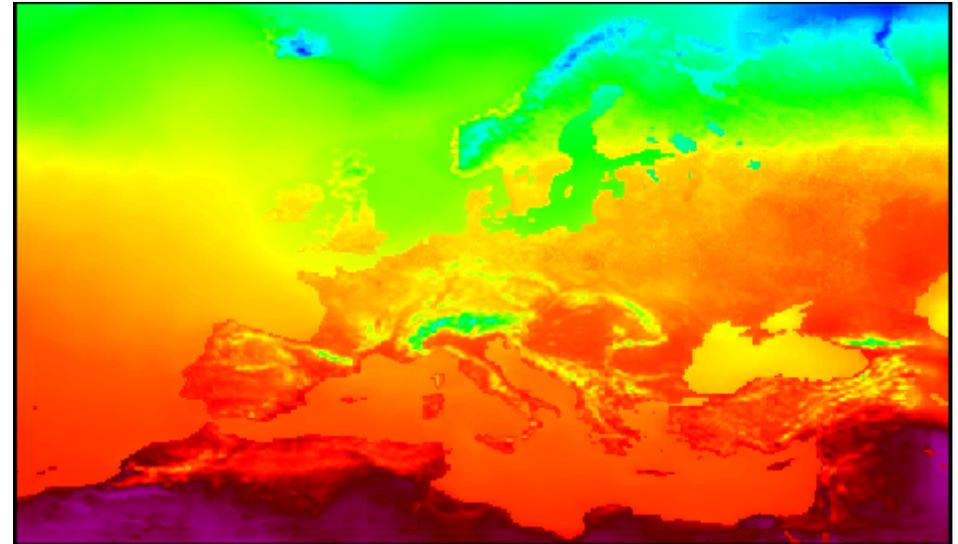
Cooperation

➢ EPN-Repro2 activity has been carried out in cooperation with the WG3 'GNSS for Climate' of the COST Action ES1206 - GNSS4SWEC

http://iag-gnssclimate.oma.be/index.php

➢ EPN-Repro2 dataset will be homogenized in the framework of the IAG WG 4.3.8: "GNSS tropospheric products for Climate"

Summary

➢ EPN-Repro2 Campaign: 1996-2014 homogeneously reprocessing tropospheric products from 5 EPN ACs;

➢ The impact of the diversities of the contributing solutions has been evaluated prior to the combination;

➢ The quality of ZTD combined product is 3 mm before GPS week 1055 (26 March 2000) and 2 mm thereafter;

➢ The evaluation of the combined products vs Radiosonde data shows an improvement of 3-4% in the sdt w.r.t. EPN-Repro1;

➢ The evaluation of the combined products vs ERA-Interim data shows an improvement of 8-9% both in bias and std w.r.t. EPN-Repro1;

➢ SINEX TRO files can be downloaded from the EPN-repro2 product directory at the BKG data centre;

➢ Several plots are available at the EPN Central Bureau http://www.epncb.oma.be/_productsservices/sitezenithpathdelays.

We acknowledge

- the members of the EUREF Working Group "EPN reprocessing";

- CODE and JPL IGS AC for providing the GNSS products used in this work;

- the support provided by COST – (European Cooperation in Science and Technology) for providing financial assistance for the publication of the paper:

  EPN-Repro2: A reference GNSS tropospheric data set over Europe, R. Pacione, A. Araszkiewicz, E. Brockmann, J. Dousa, Atmos. Meas. Tech., 10, 1689-1705, https://doi.org/10.5194/amt-10-1689-2017, 2017

Extra Slide

Gradient Evaluation

Table 4. Mean statistics and uncertainties, calculated from results of individual stations, provided for AC individuals and EUREF combined (EPN-Repro1 and EPN-Repro2) tropospheric parameters compared to the ERA-Interim reanalysis (ERA-Interim minus GNSS). EGRD represents east gradient and NGRD north gradient.

Solution	ZTD bias [mm]	ZTD SD [mm]	EGRD bias [mm]	EGRD SD [mm]	NGRD bias [mm]	NGRD SD [mm]
AS0 (full EPN)	1.7 ± 2.0	7.7 ± 1.9	-0.00 ± 0.06	0.32 ± 0.09	-0.09 ± 0.06	0.33 ± 0.10
GO4 (full EPN)	1.9 ± 2.4	8.1 ± 2.1	0.04 ± 0.09	0.38 ± 0.10	-0.00 ± 0.09	0.40 ± 0.12
MU2 (full EPN)	1.8 ± 2.0	8.3 ± 2.1	0.03 ± 0.32	0.35 ± 2.46	0.01 ± 0.84	0.34 ± 2.37
IG0 (part EPN)	1.6 ± 2.3	10.7 ± 2.2	0.05 ± 0.09	0.33 ± 0.11	-0.04 ± 0.12	0.36 ± 0.12
LP1 (part EPN)	1.7 ± 2.4	7.7 ± 1.7	0.02 ± 0.06	0.28 ± 0.05	-0.03 ± 0.09	0.27 ± 0.06
EPN-Repro2	1.8 ± 2.1	7.8 ± 2.2	–	–	–	–
EPN-Repro1	2.2 ± 2.3	8.5 ± 2.1	–	–	–	–