Report of the EPN Troposphere Coordinator

Rosa Pacione

Troposphere Coordinator

e-GEOS, ASI/CGS-Matera, Italy

Outline

- Key Milestone in the EPN Tropospheric Product
- Operational Solution:
  - Final weekly combination
  - Multi-year tropospheric solution (1996-2023)
  - Rapid daily combination
- Data exploitation of EPN ZTDs
- Summary and next steps

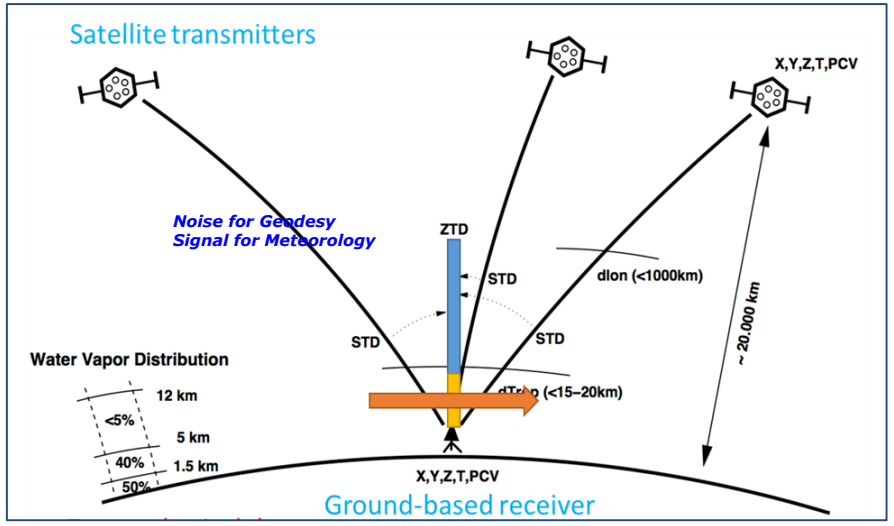
Key Milestones

- 2001: Special Project
- 2008: Routine Operation
- 2012: EPN-Repro1: 1996-2009
- 2014: Troposphere Analysis Coordinator moved from BKG to ASI/CGS
- 2017: EPN-Repro2: 1996-2014
- 2020: IWV added in the EPN combined products

  Solutions delivered in SINEX_TRO V2.0 format
- 2023: Solutions according to IGS20 standards

  Daily Rapid operational products

GNSS-Meteorology Concept



Operational Solutions

AC	Analysis Centre Description	Solutions	Software	GNSS
ASI	Centro di Geodesia Spaziale G. Colombo, Italy	FR	GipsyX-2.1	GRE
BEK	Bavarian Academy of Sciences & Humanities, Germany	FR	BSW 5.4	GRE
BEV	Federal Office of Metrology and Surveying, Austria	F	BSW 5.4	GRE
BKG	Bundesamt für Kartographie und Geodäsie, Germany	FR	BSW 5.4	GRE
COD	Center for Orbit Determination in Europe, Switzerland	F	BSW 5.5	GRE
GFZ	GeoForschungsZentrum, Germany	F	EPOS.P8	GRE
IGE	Instituto Geografico Nacional, Spain	FR	BSW 5.4	GRE
IGN	Institut Géographique National de L'information Geographique et Forestiére, France		–	–
LPT	Federal Office of Topography swisstopo, Switzerland	F	BSW 5.3	GRE
MUT	Military University of Technology, Poland	FR	GG 10.71	GE
NKG	Nordic Geodetic Commission, Lantmateriet, Sweden	FR	BSW 5.4	GRE
RGA	Republic Geodetic Authority, Serbia	F	–	–
ROB	Royal Observatory of Belgium, Belgium	FR	BSW 5.4	GRE
SGO	Lechner Knowledge Center, Hungary	F	BSW 5.4	GRE
SUT	Slovak University of Technology, Slovakia	FR	BSW 5.4	GRE
UPA	University of Padova, Italy	FR	BSW 5.4	GRE
WUT	Warsaw University of Technology, Poland	FR	BSW 5.4	GRE

- **16 ACs** are providing daily final solutions
- **10 ACs** are providing daily rapid solutions
- **Processing Options:** refer to 'Guidelines for EPN Analysis Centres'
- **Distributed Processing**: The EPN stations are distributed among the ACs in such a way that each station is analyzed by at least three ACs. This guarantees the reliability of the EPN products

May 23, 2024: 423 EPN stations

7 ACs	6 ACs	5 ACs	4 ACs	3 ACs
0,5%	3,5%	35%	54%	7%
2	15	150	228	29

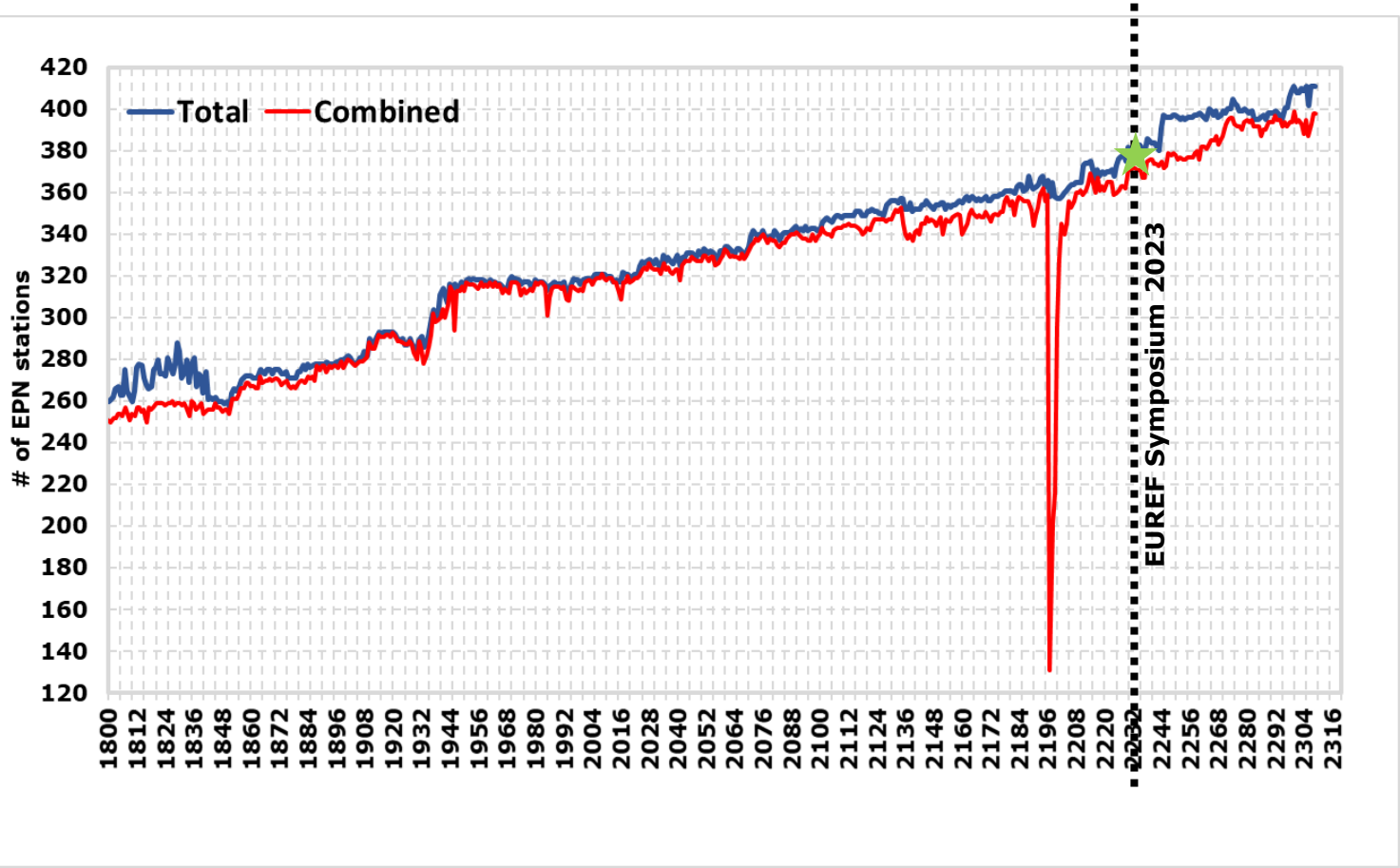
Operational Tropo Combination - Final

- Filename for weekly troposphere solution and summary:
  - EUR0OPSFIN_YYYYDDD0000_07D_01H_TRO.TRO.gz
  - EUR0OPSFIN_YYYYDDD0000_07D_01H_TRO.SUM.gz
- Latency: 5 weeks after the end of observations of the analyzed week
- Combined EPN products available at BKG and BEV data centers:
  - https://igs.bkg.bund.de/root_ftp/EUREF/products/
  - https://gnss.bev.gv.at/at.gv.bev.dc/data/products
- EPNCB web page with AC bias/sdt w.r.t. the combined product
  - https://epncb.oma.be/_productsservices/troposphere/mean_zpd_biases.php

Operational Tropo Combination - Final

Last Combined Solution: GPS week 2309 (23Apr07):

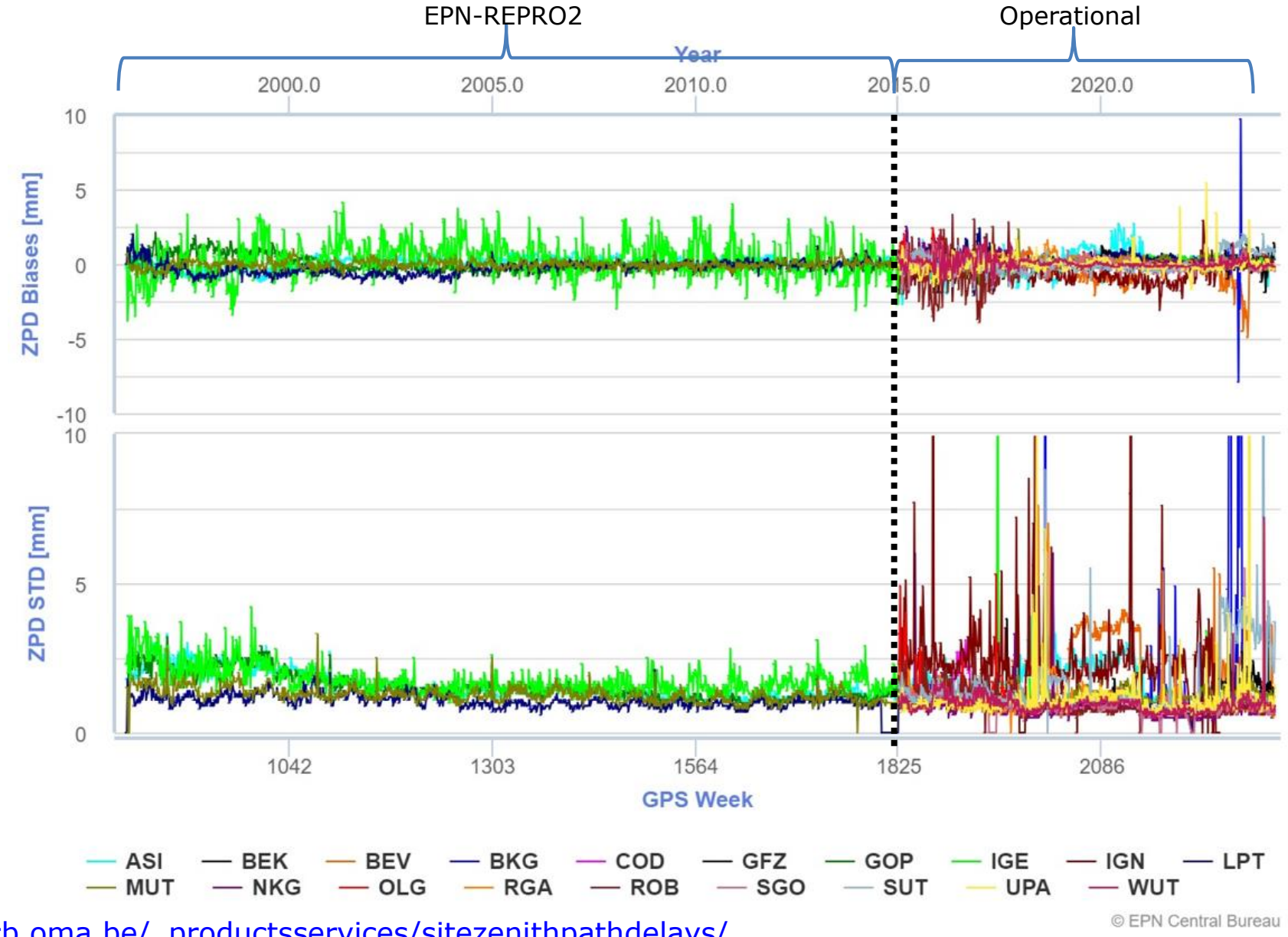
- Total Stations available 411
- Combined Stations 398



20 new stations since the EUREF Symposium 2023

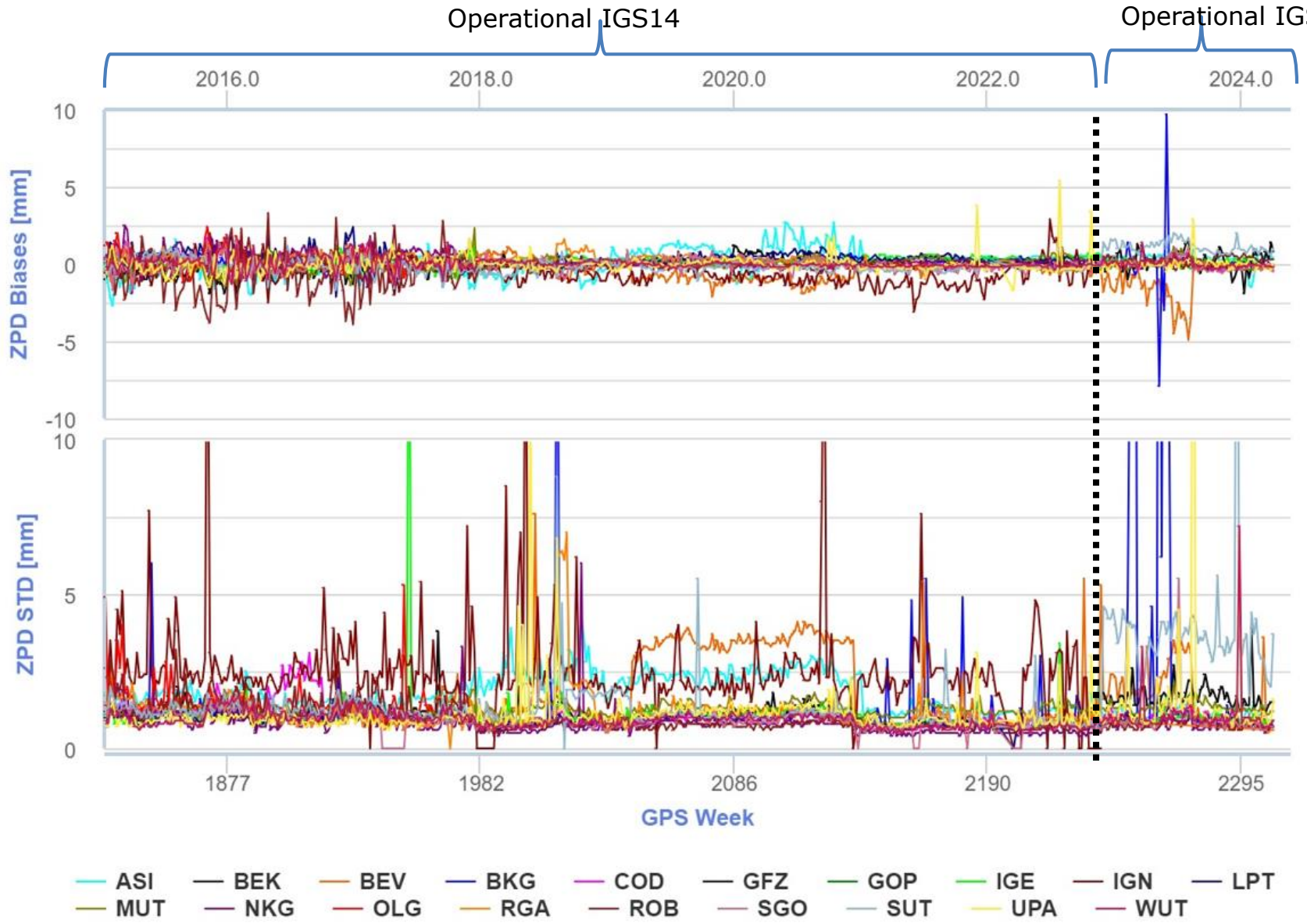
#	Country
16	Italy
2	Greenland
1	Estonia
1	Ireland

Operational Monitoring at AC level - Final



http://www.epncb.oma.be/_productsservices/sitezenithpathdelays/

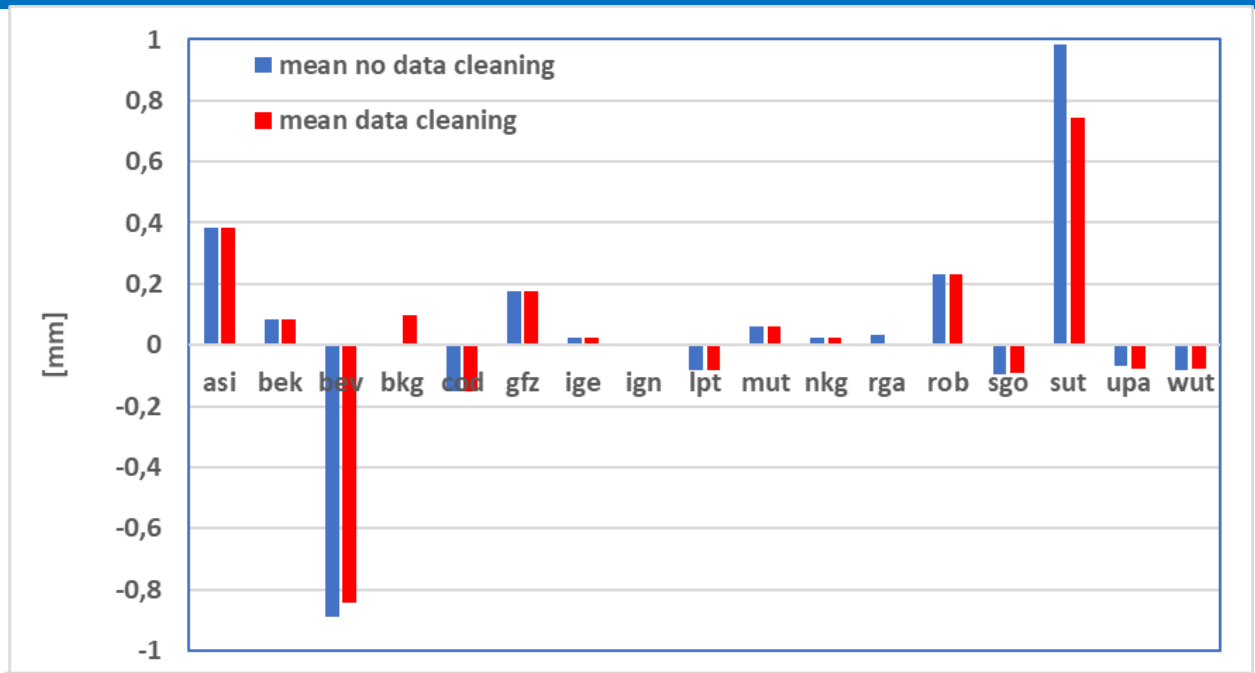
Operational Monitoring at AC level - Final

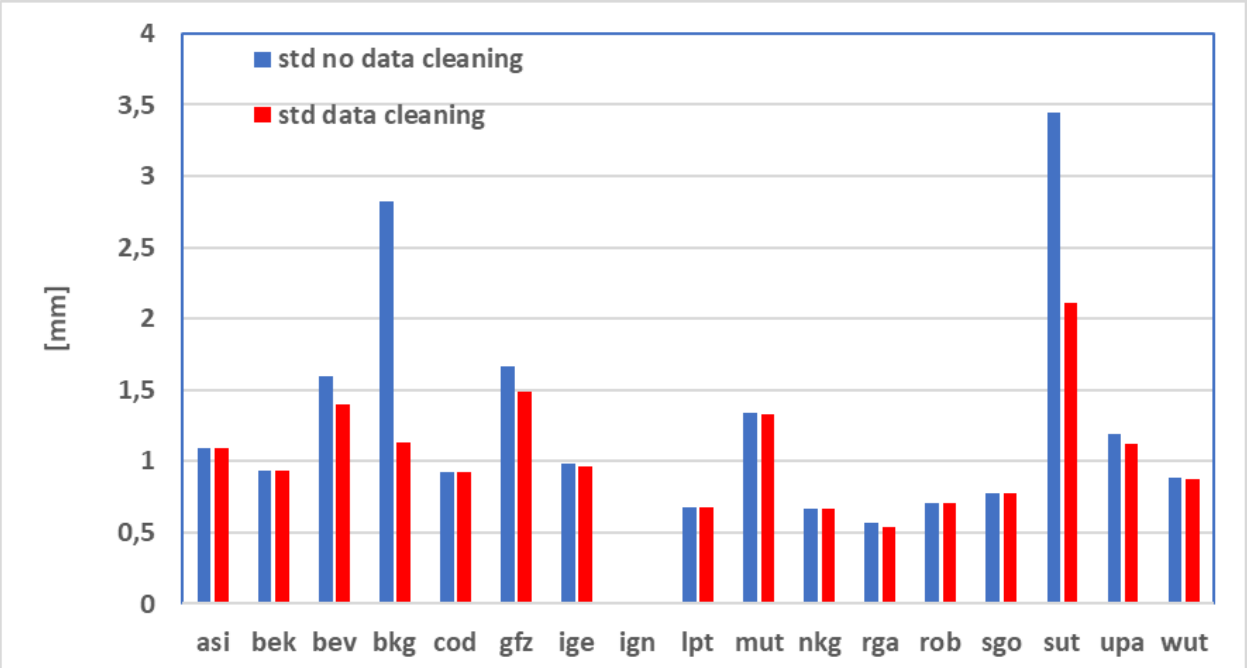


http://www.epncb.oma.be/_productsservices/sitezenithpathdelays/

Operational Monitoring at AC level - Final

- Period: GPS week 2255-2306
  (23MAR26-24MAR23)
- Overall AC mean/std w.r.t. the combined solution
- Data cleaning done at combination level



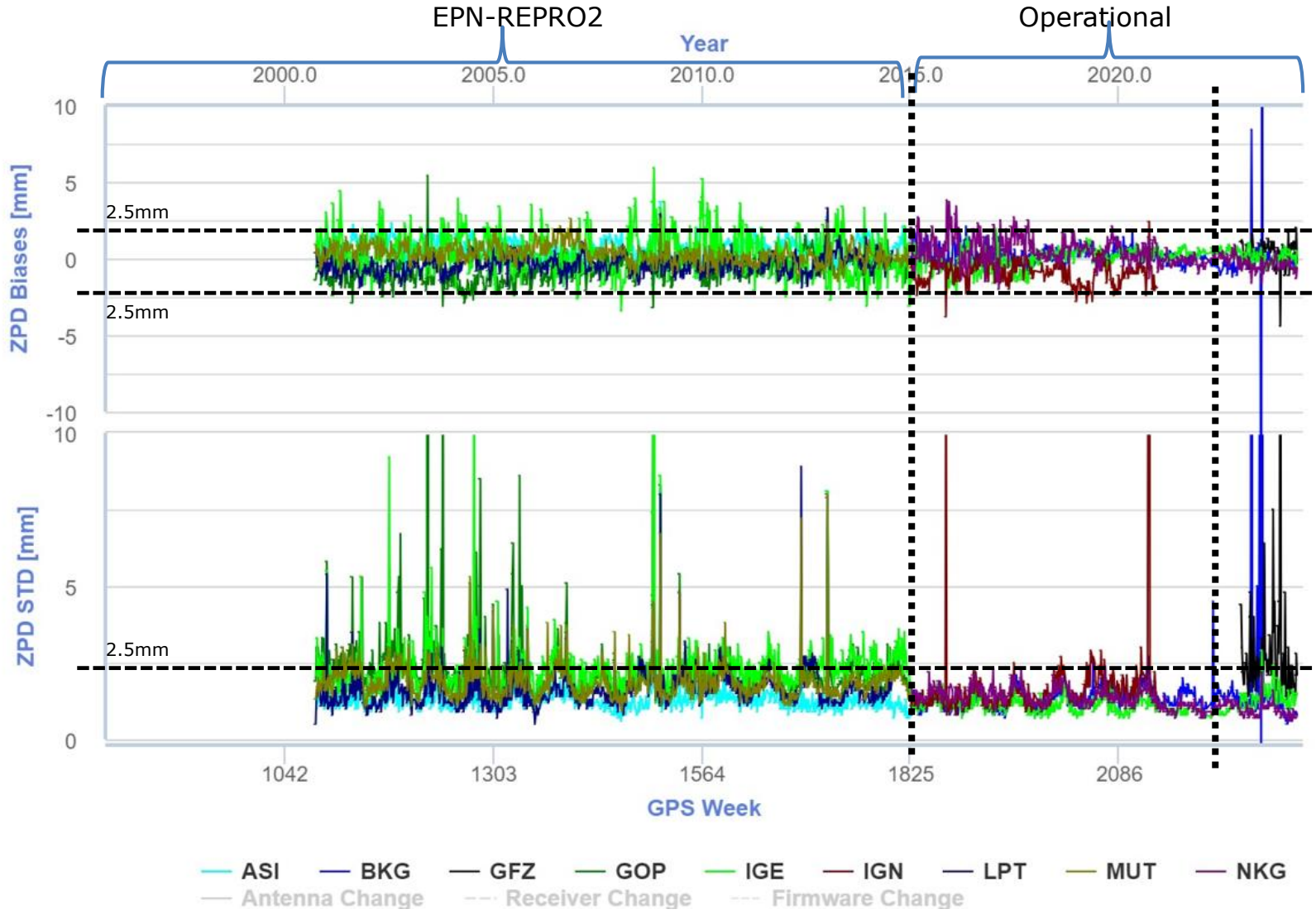


Operational Monitoring at Station level

YEBE00ESP

Analyzed by 5 EPN Acs:

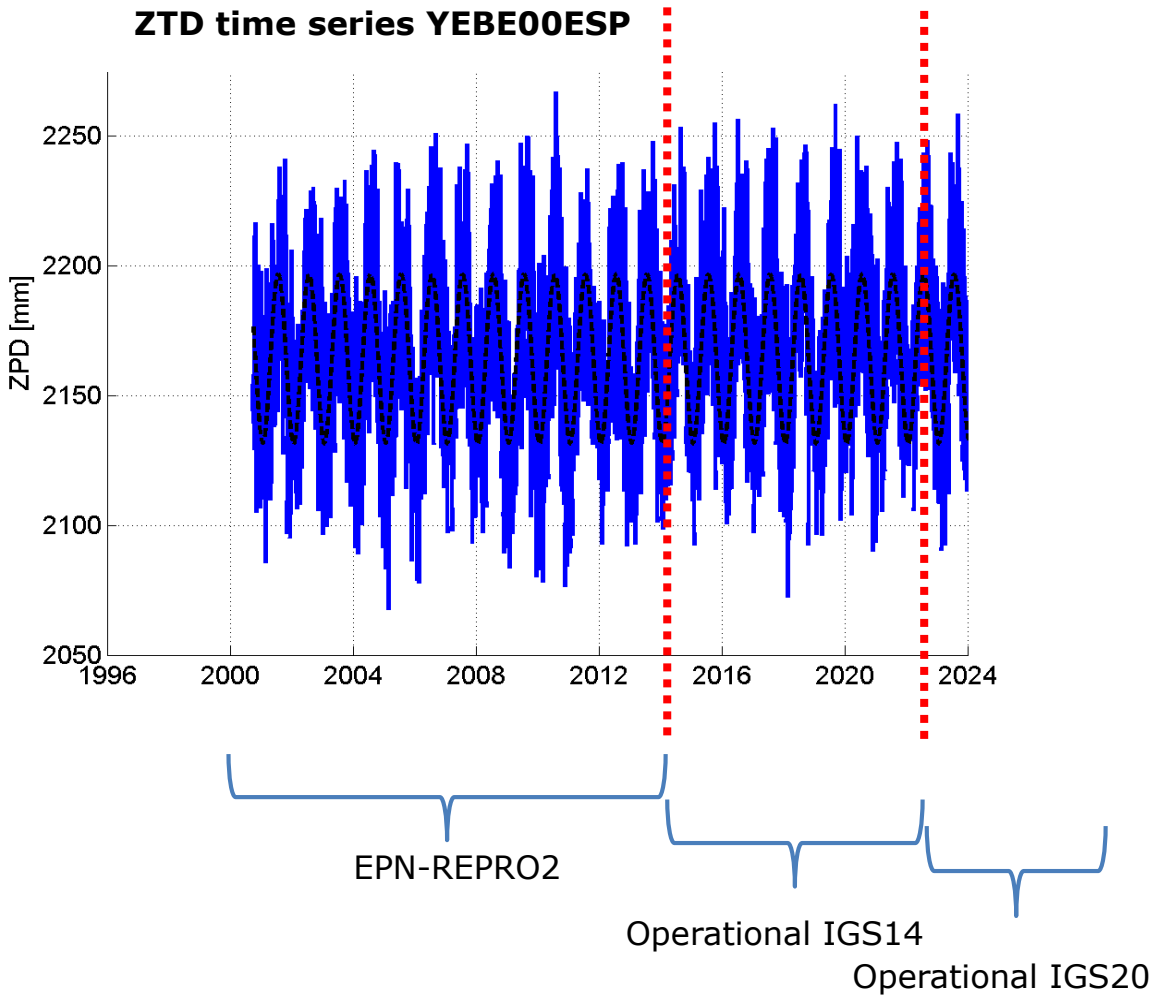
BKG, GFZ, IGE, IGN, NKG

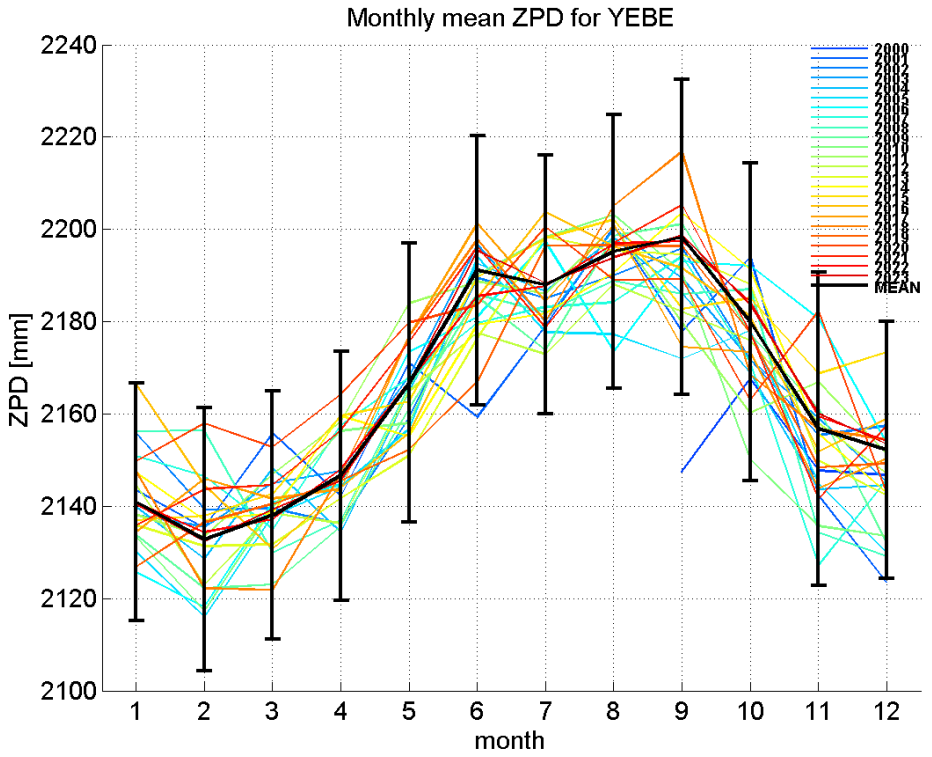


http://www.epncb.oma.be/_productsservices/troposphere/zpd_biases_station.php?station=YEBE00ESP

EPN multi-year tropo solution T2295 (1996-2023)

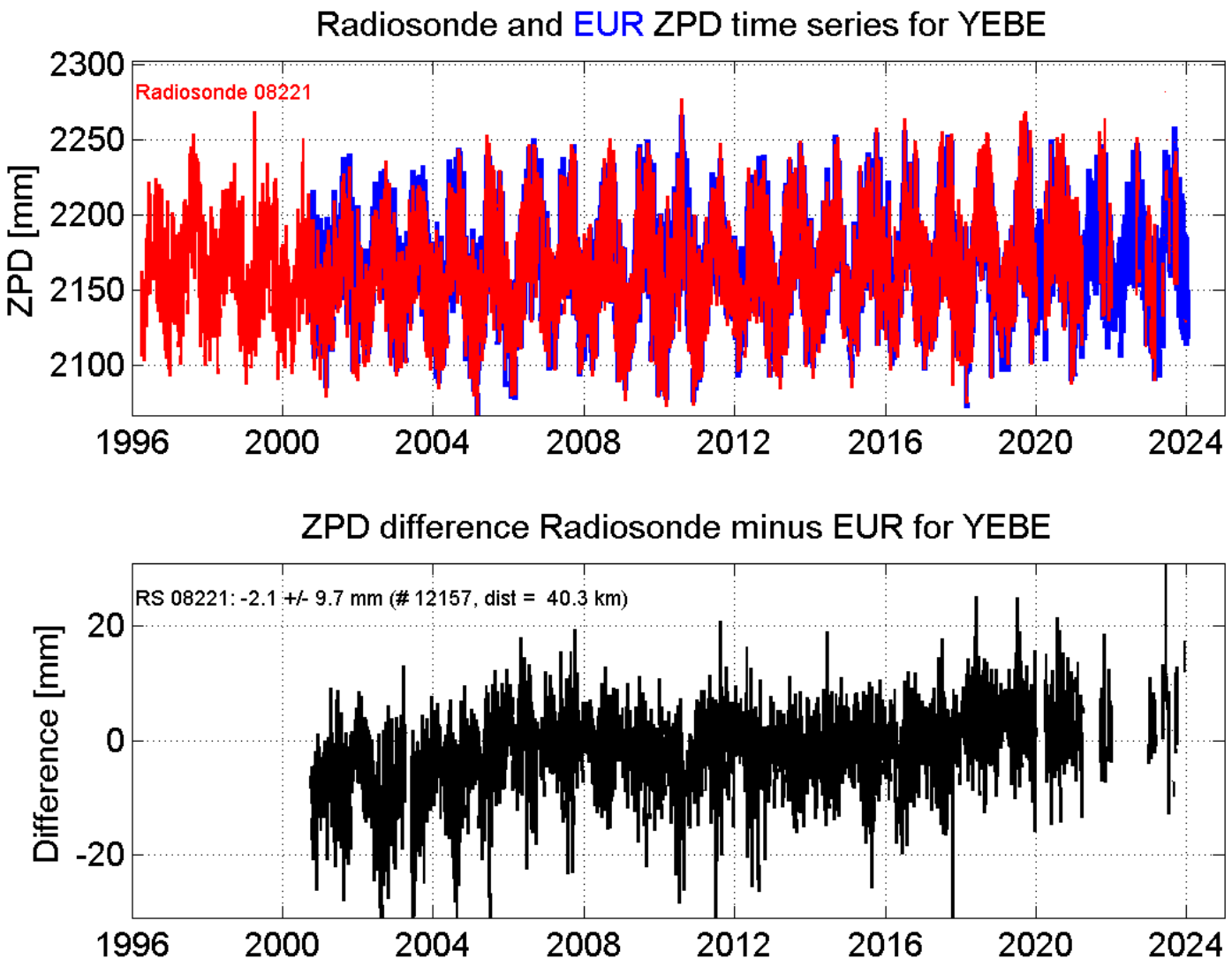
Released on May, 2024 (Ref. EUREF Message Number 11801)





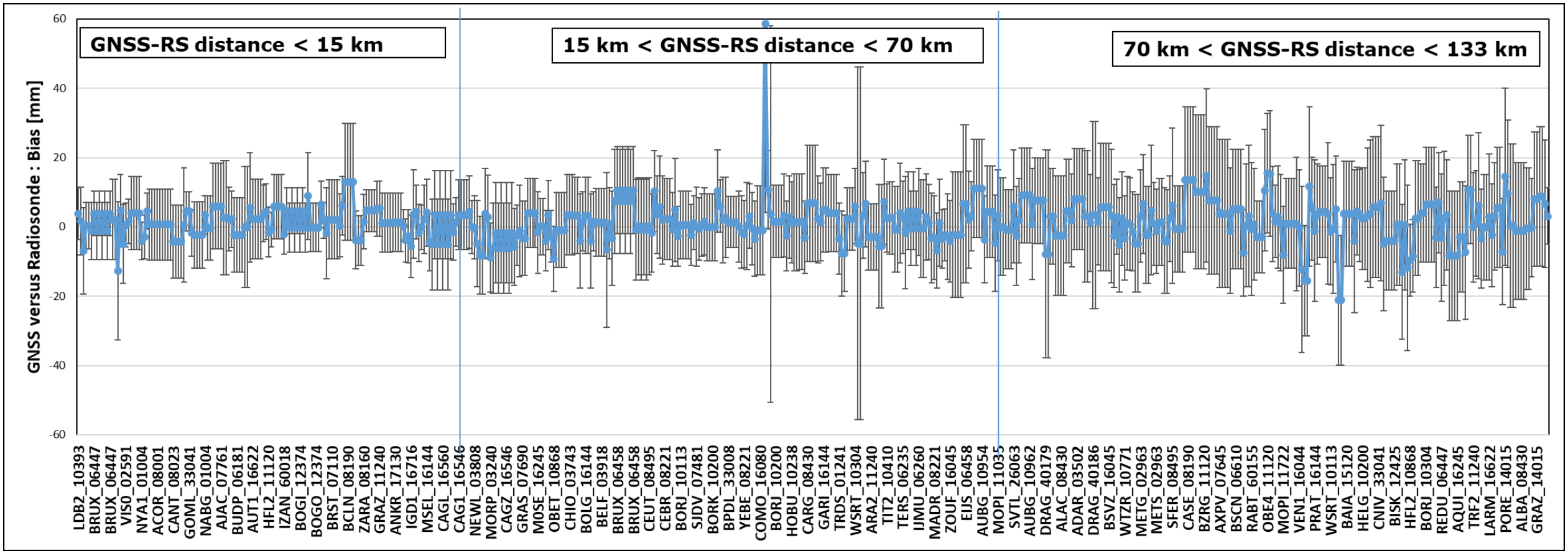
http://www.epncb.oma.be/_productsservices/troposphere/zpd_timeseries_station.php?station=YEBE00ESP

GNSS and RS EPN multi-year tropo solution T2295 (1996-2023)



https://epncb.oma.be/_productsservices/troposphere/zpd_radiosondes_station.php?station=YEBE00ESP

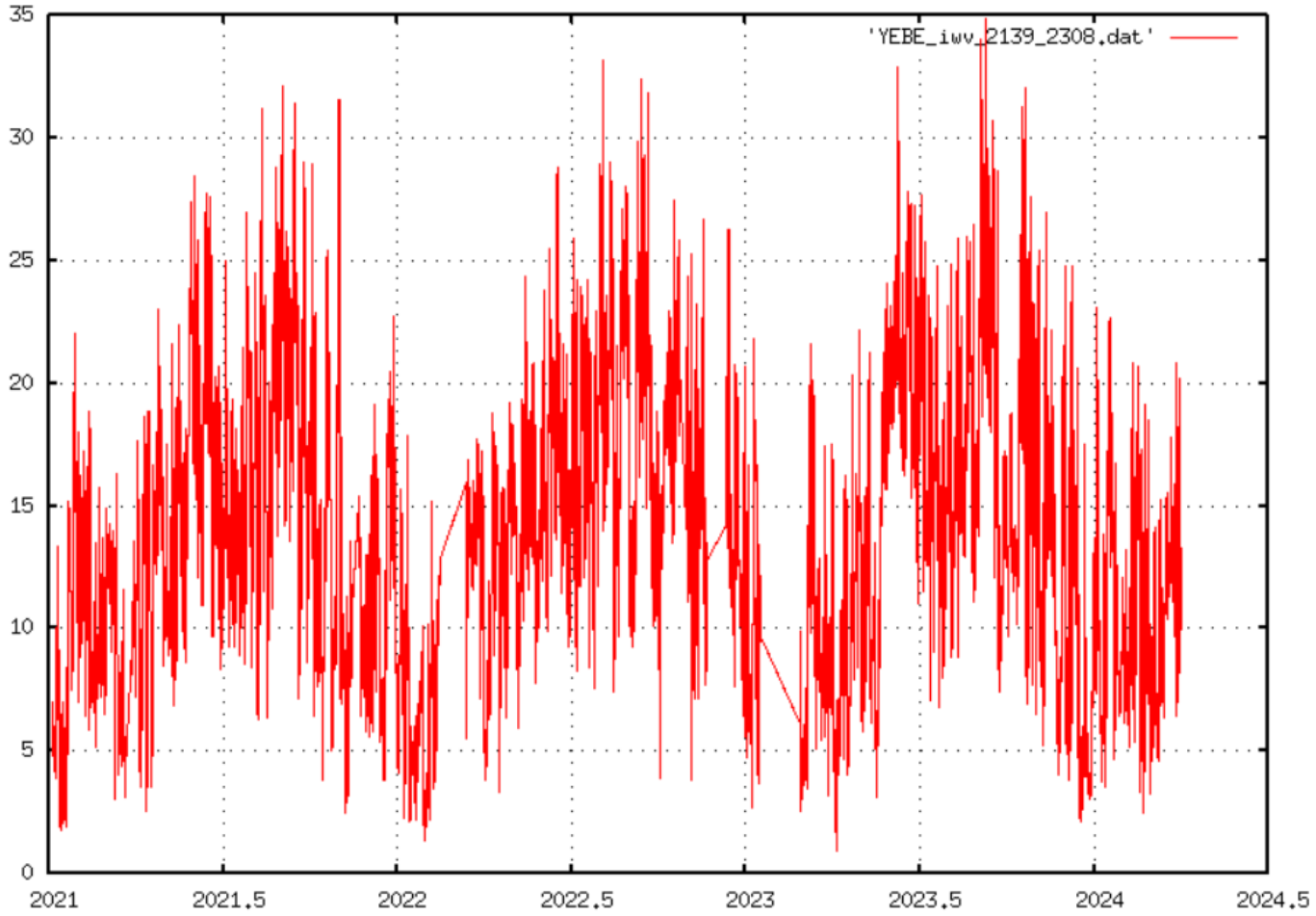
GNSS and RS EPN multi-year tropo solution T2295 (1996-2023)



557 couples ordered according to the increasing distance between the GNSS station and the RS launch site

EPN IWV time series

IWV time series at YEBE00ESP

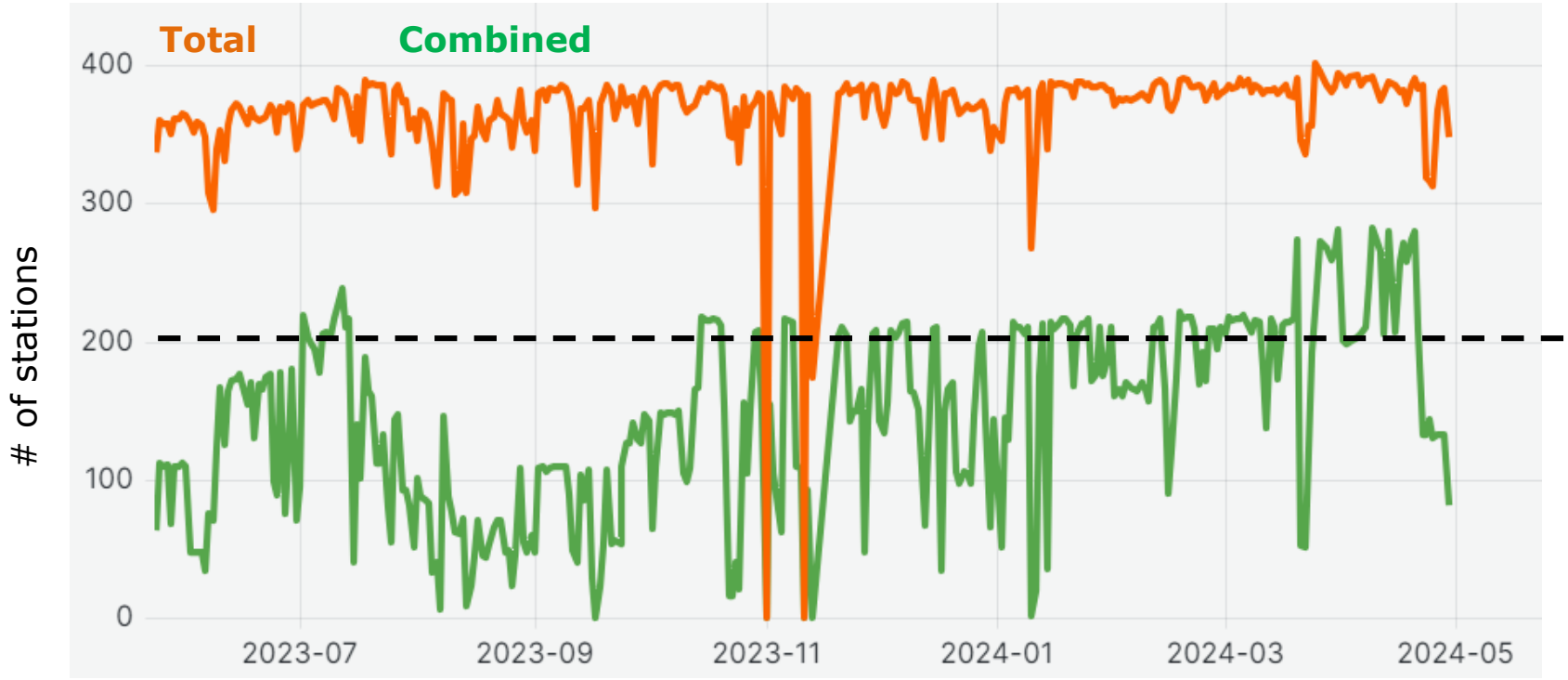


- **Input:** EPN ZTD combined values
- **Auxiliary Data:** ECMWF operational products available at TU WIEN:
  - Linear interpolation in time
  - Bilinear interpolation in space
- **Output:** EPN ZTD and IWV in SINEX_TRO_v2.0 from GPS week 2139 (21JAN03)

Rapid tropo combination - Status

- 10 EPN ACs are delivering rapid tropo estimates as a by-product of the rapid site coordinate processing
- Filename for daily troposphere solution and summary:

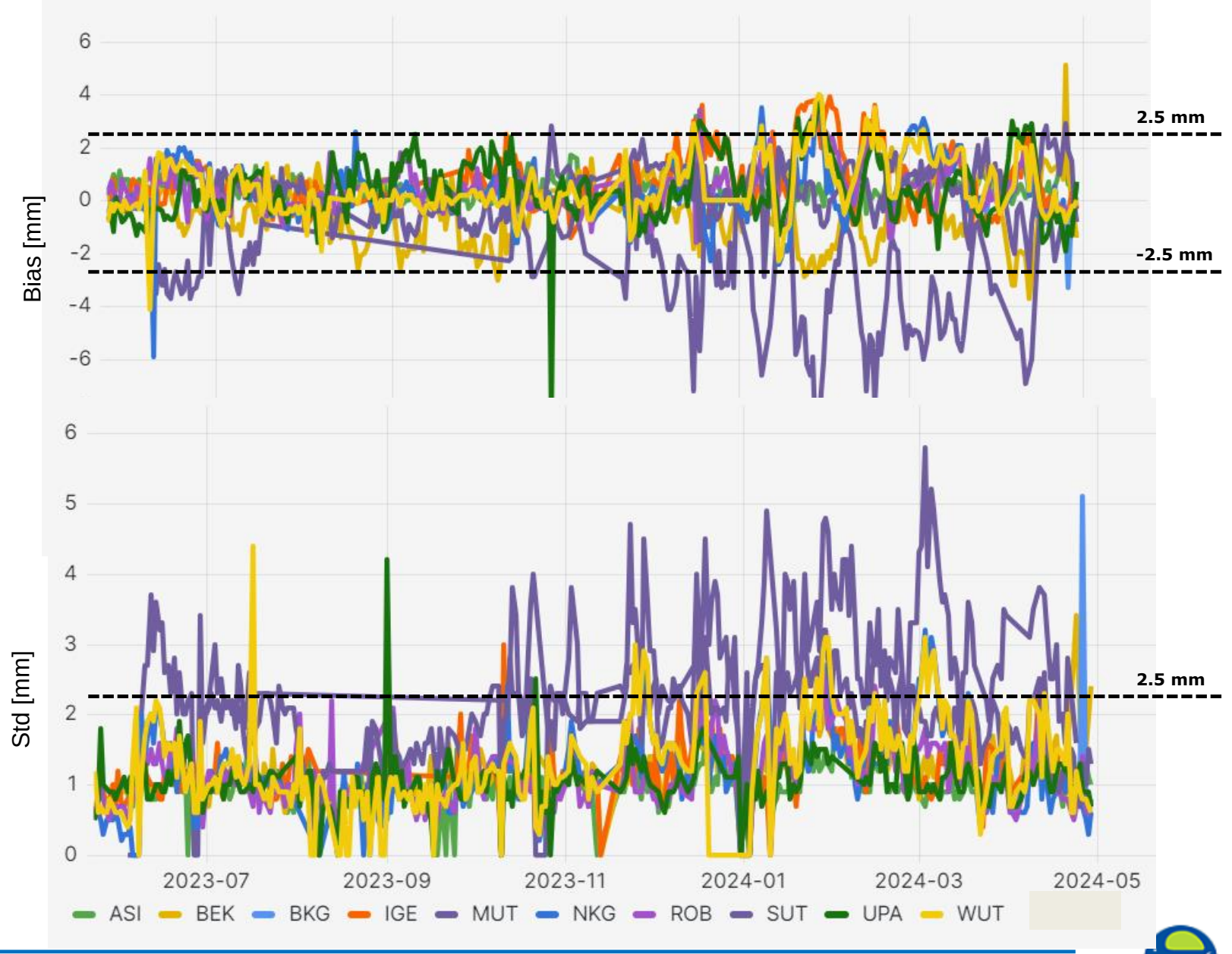
  EUR0OPSRAP_YYYYDOY0000_01D_01H_TRO.TRO.gz/SUM.gz
- Latency: 22 hours after the end of observations of the analyzed day



Operational Monitoring at AC level - Rapid

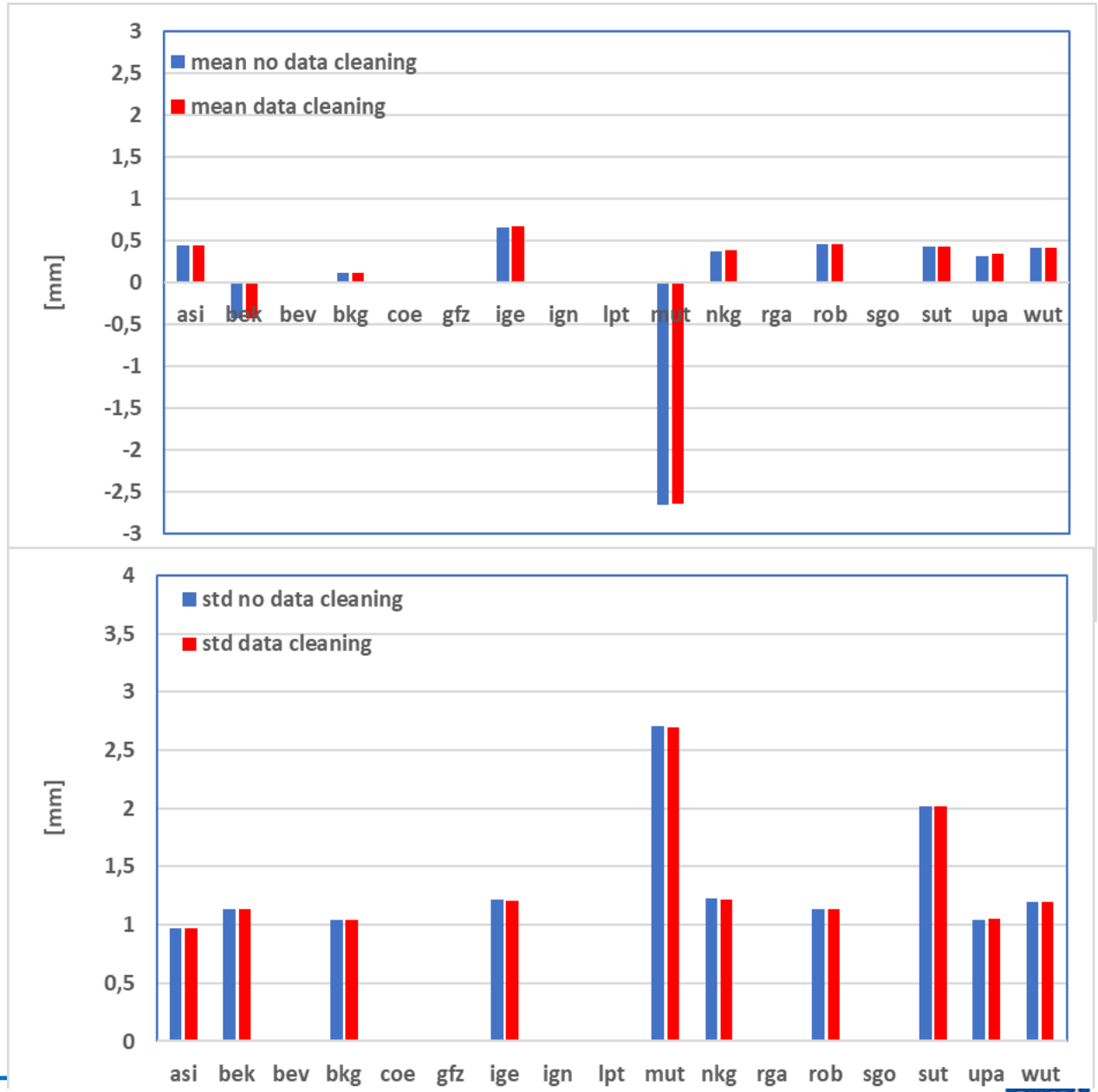
W.r.t. to final combination:

- Monitoring done on daily basis
- Less stations
- Less data cleaning done at AC level
- Some data cleaning done at combi level



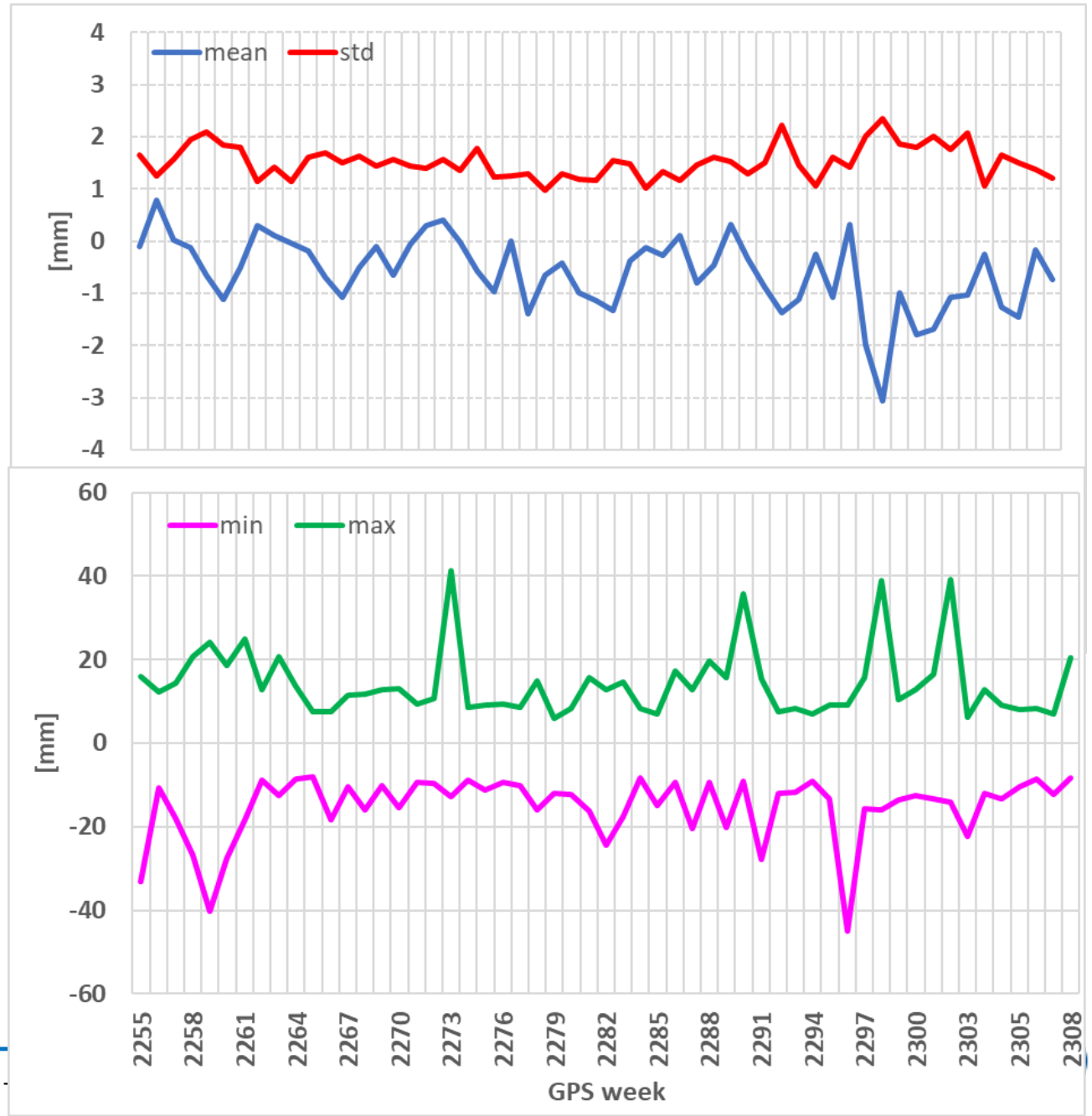
Operational Monitoring at AC level - Rapid

- Period: GPS week 2255-2306
  (23MAR26-24MAR23)
- Overall AC mean/std w.r.t. the combined solution
- Data cleaning done at combination level



Final vs Rapid tropo combination

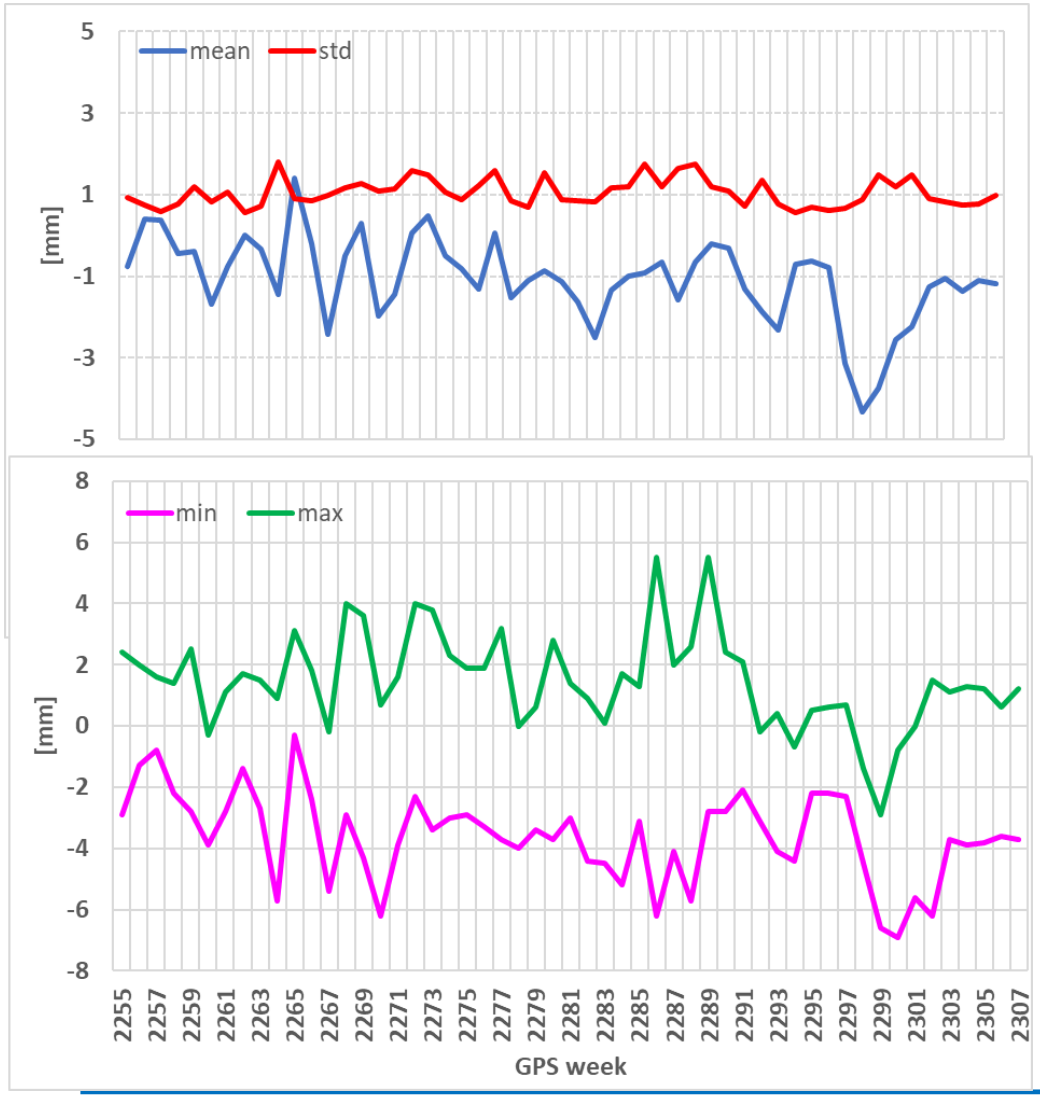
- Period: GPS weeks 2255-2308
  (23MAR26-24APR06)
- Weekly basis
- ALL common stations



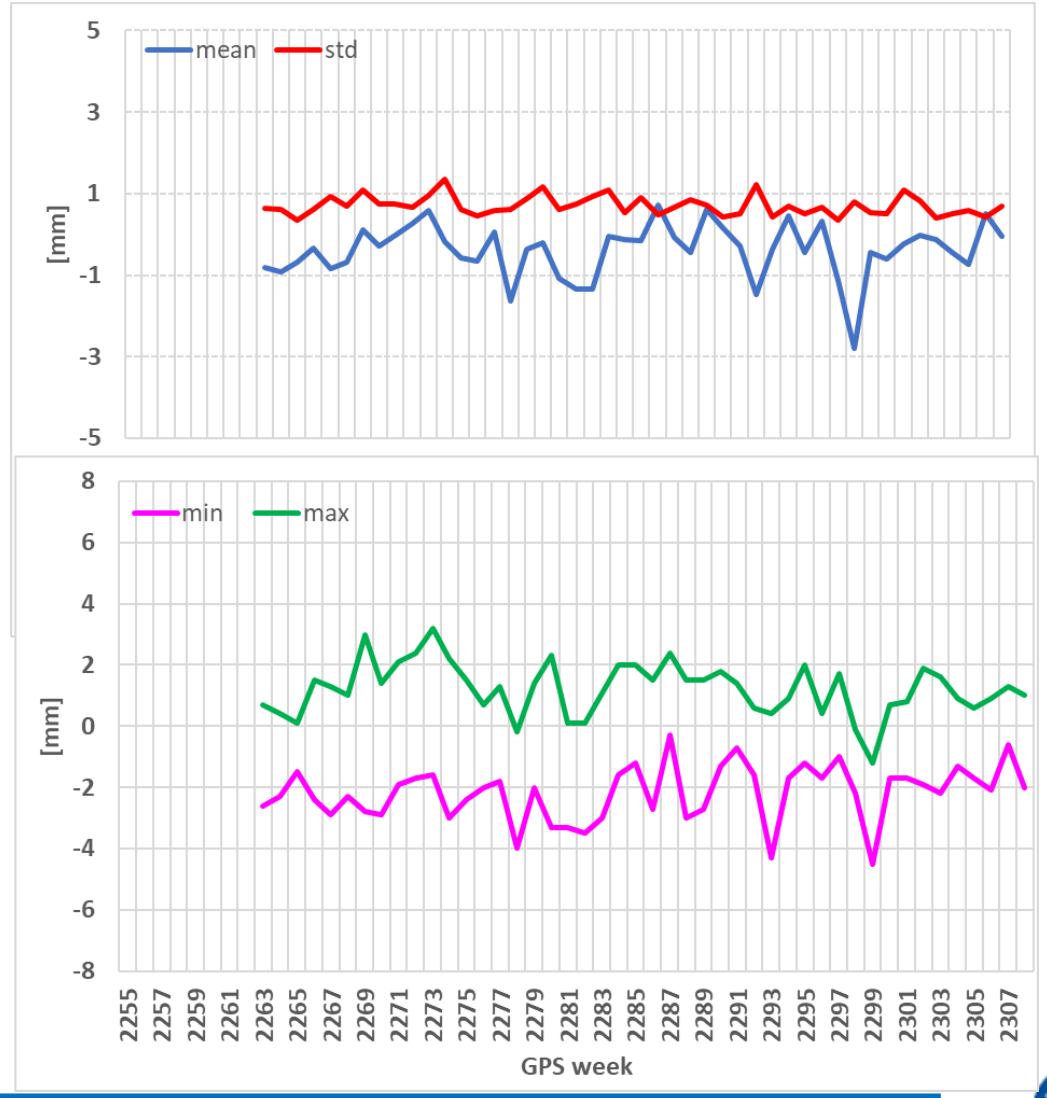
Final vs Rapid tropo combination @ MATE00ITA and BRUX00BEL

- Period: GPS weeks 2255-2308 (23MAR26-24APR06)

MATE00ITA



BRUX00BEL



EPN ZTDs used for the assessment of GOP RT tropo products

GOP RT products using different services (Sept., 2023):

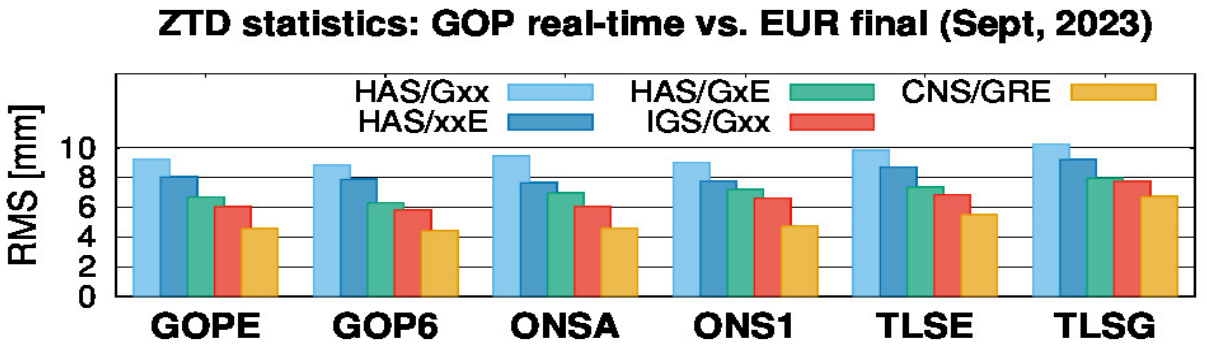
- Galileo High Accuracy Service (HAS): **GPS | GAL | GPS+GAL**
- IGS Real-time Service (IGS): **GPS**
- CNES RT corrections (CNS): **GPS+GLO+GAL**

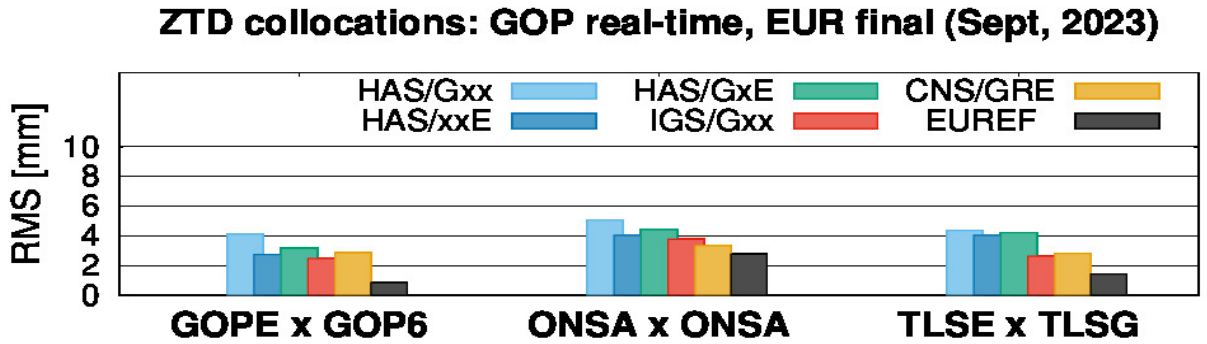
Strategy/software:

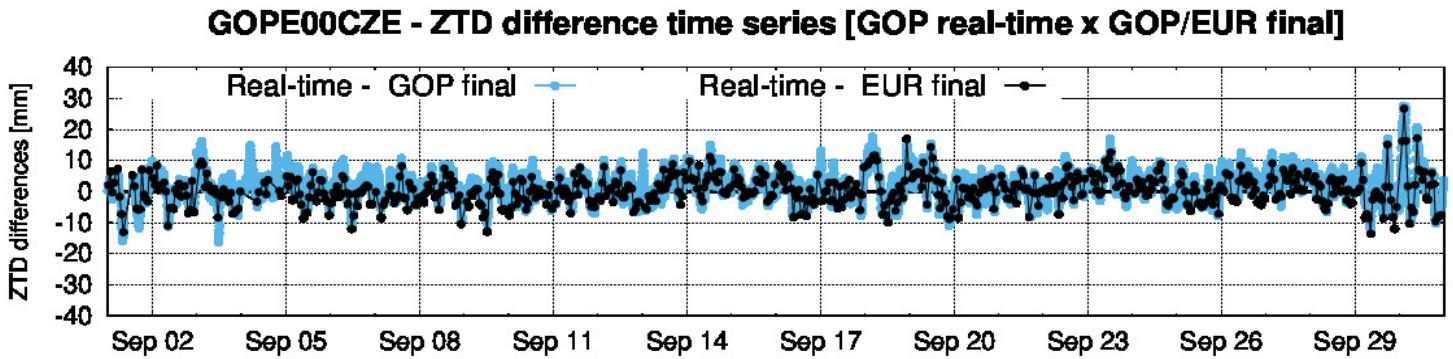
- PPP real-time ZTD + horizontal gradients (5-min sampling)
- G-Nut/Tefnut RT (https://www.gnutsoftware.com)

Comparisons (ZTD only):

- External validation (compared to FINAL product) ➔ **4-10 mm**
- Inner quality (compared at collocated stations) ➔ **2-5 mm**
- Inner quality of RT comparable to FINAL one (EUREF)
- IGS & CNES solutions comparable (impact of multi-GNSS)
- Galileo HAS solutions is fine (worse due to less global stations)







RMS statistics *(above)*:

1. Comparison of real-time products
2. Comparison of collocated stations

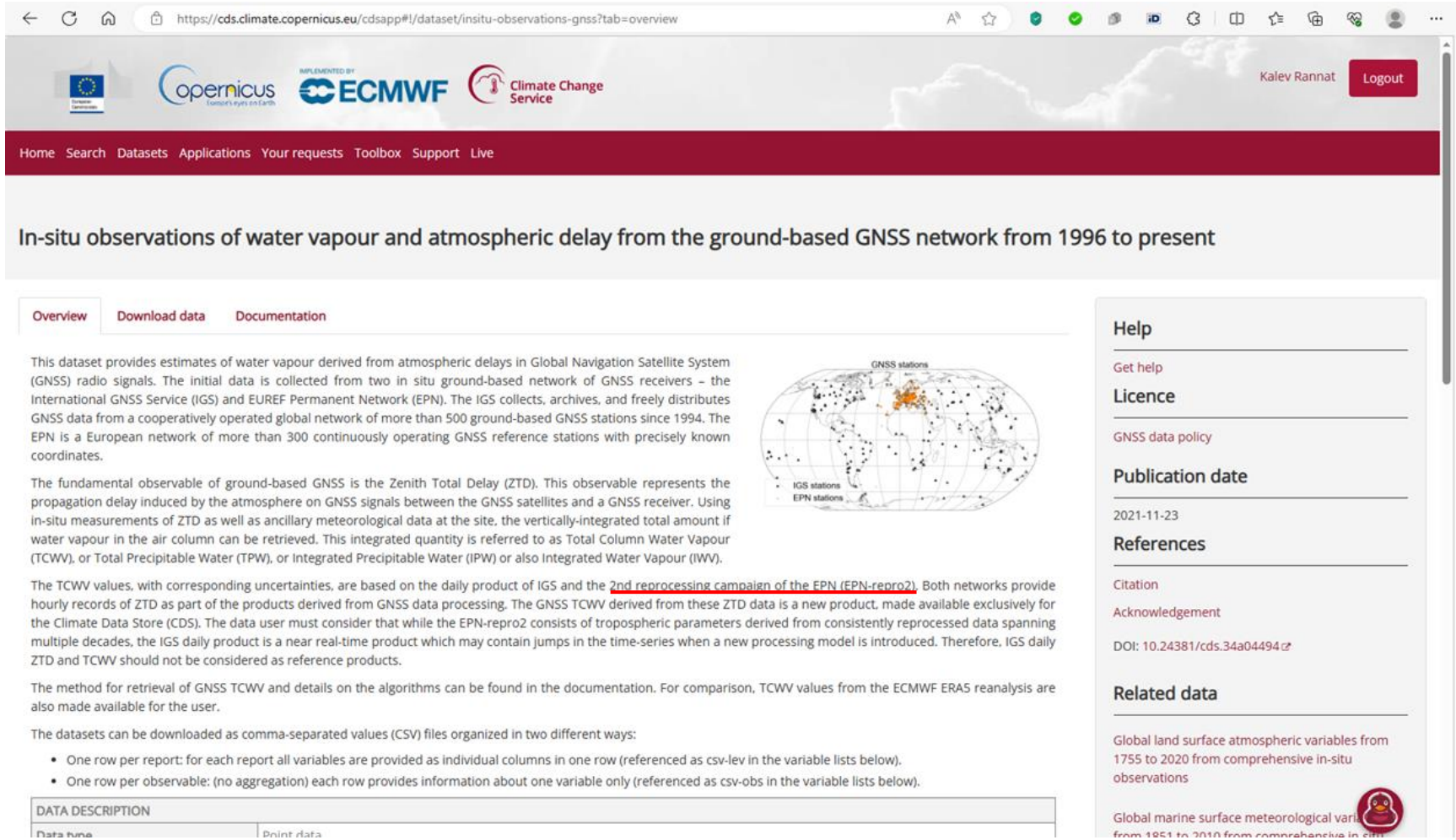
ZTD differences *(left)*:

1. GOP RT – GOP final (PPP)
2. GOP RT - EUR final (Combi)

Courtesy of Jan Dousa GOP

EPN-Repro2 ZTD in the Climate Data Store of Copernicus Climate Change Service

- CDS aims to provide high-quality GNSS-based IWV datasets for climate research and applications
- EPN-Repro2 ZTDs have been converted in IWV using ERA5 as Auxiliary Data



https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-observations-gnss?tab=overview

Rannat, K.; Keernik, H.; Madonna, F. The Novel Copernicus Global Dataset of Atmospheric Total Water Vapour Content with Related Uncertainties from GNSS Observations. Remote Sens. 2023, 15, 5150. https:// doi.org/10.3390/rs15215150

Summary and Next Steps

- Overview of the status of the EPN operational tropo products along with the monitoring activities
- Final tropo combination is provided regularly
- Rapid daily tropo combination has been set-up → overall std w.r.t. final 1-2 mm
- EPN ZTDs are operationally used as reference solution
- EPN-Repro2 dataset included in CDS of Copernicus Climate Change Service

Next step:

- EPN-Repro3 will provide an homogenously reprocess time series covering about the last 3 decades

Acknowledgment: *the EPN ACs for providing the solutions used for the combination, the EPNCB for making available some of the plots used in this presentation, the TU Vienna for the auxiliary data used in the ZTD2IVW conversion and the GNSS site owners for the collection and distribution of GNSS rinex data.*
e-GEOS work is carried out under ASI contract 2017-I.0-R.0


Mercé
ありがとう
Gracias
Rahmat
Matondo
Grazie
Misaotra
Efharisto
Köszönöm
Rahmat
Gracias
Terima Kasih
Dankjewel
Köszönöm
Takk
Efharisto
Mahalo
Mahalo
Terima Kasih
Kiitos
Tak
Sagolun
Merci
Mauruuru
Xièxie
Toda
Köszönöm
Danke
Takk
Grazie
Matondo
Takk
Takk
Tak
Mercé
Grazie
Dankie
Faleminderit
Obrigado
Dankie
Hvala
Kiitos
Misaotra
Faleminderit
Sagolun
Misaotra
Danke
Merci
Gracias
Sagolun
Obrigado
Obrigado
Спасибо
Kiitos
Obrigado
Mercé
Danke
Thank You
Mahalo
شكرا
Tak
Mercé
Toda
Kiitos
Xièxie
Thank You
Toda
Hvala
Grazie
Hvala
Merci
Спасибо
Faleminderit
Rahmat
Gracias
ありがとう
Rahmat
Xièxie
Danke
Matondo
Dankjewel
Thank You
Спасибо
Mauruuru
Efharisto
ありがとう
Gracias
Faleminderit
Sagolun
Merci
Tak
Sagolun
Merci
Dankie
Efharisto
Takk
Obrigado
Dankjewel
Dankjewel
Matondo
Kiitos
شكرا شكرا
Thank You
Xièxie
Grazie
Спасибо
Tak
Misaotra
ありがとう
Спасибо
شكرا
Toda
Hvala
Dankie
Danke
Köszönöm
Mahalo
Thank You
Terima Kasih
Terima Kasih
Mauruuru
Mauruuru

Extra Slide

Operational Monitoring at AC level – Final (left) Rapid (right)

- Different stations in the final and rapid