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THE OVERVIEW OF

REAL-TIME GNSS METEOROLOGY @UPWr

- real-time ZTD/IWV accuracy
- horizontal gradients
- low-cost GNSS receivers

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IGS INTERNATIONAL GNSS SERVICE

IGS 2022 Virtual Workshop
„Science from Earth to Space"

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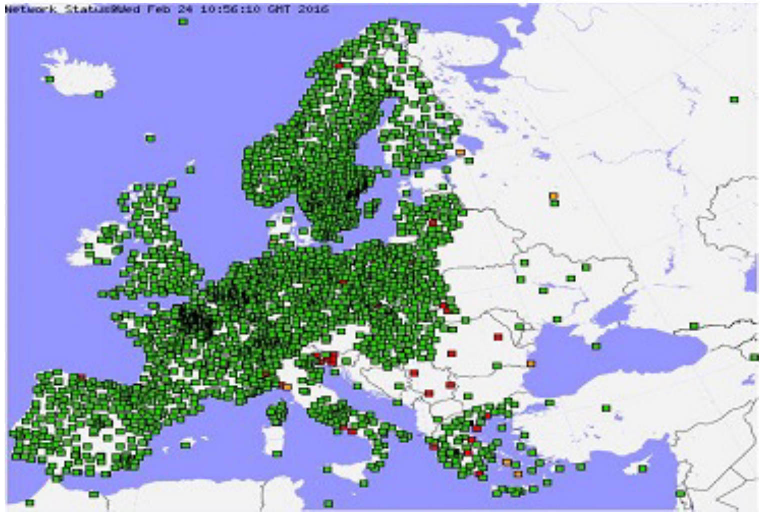
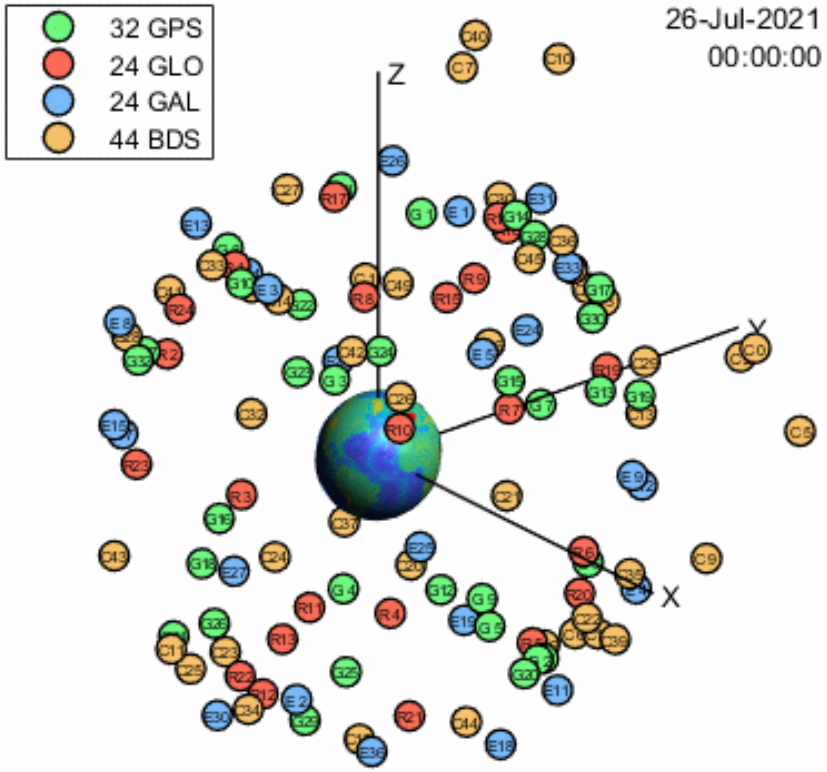
Motivation

Status of GNSS meteorology:

- well established tool
- provides Zenith Total Delays (ZTD)
- ZTD => Integrated Water Vapor (IWV)
- latency <1 hour

https://www.eumetnet.eu

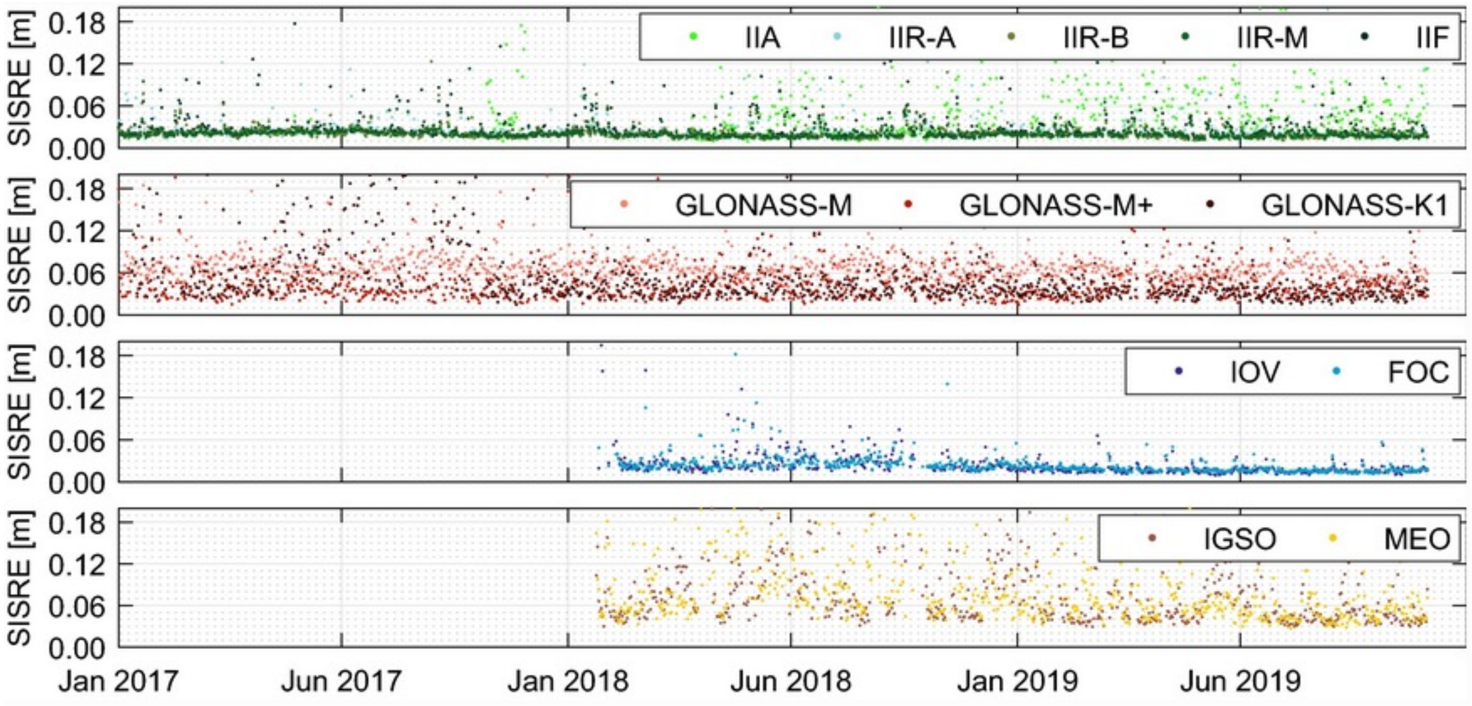


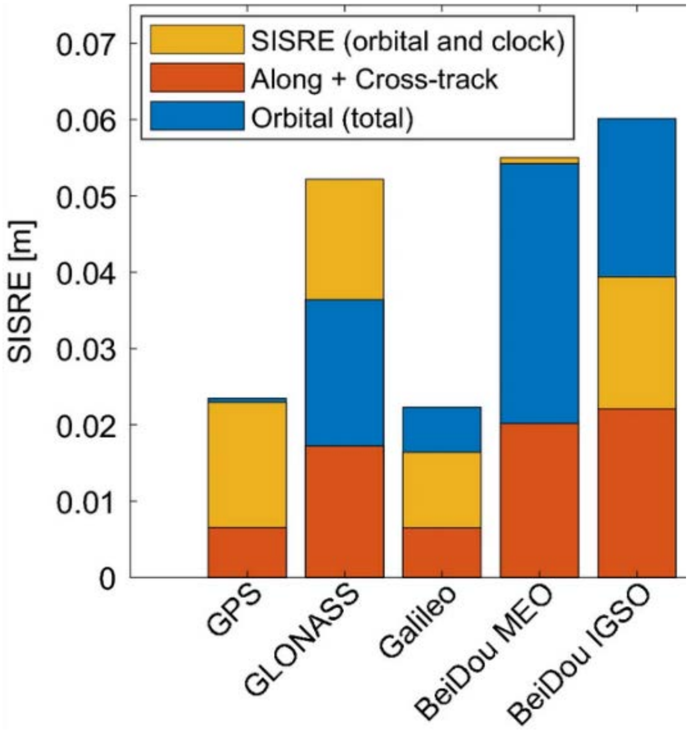


Challenges:

- multi-GNSS multi-frequency solutions
- transition to real-time
- estimation of (reliable) horizontal gradients
- monitoring severe weather conditions
- network densification (local scale phenomena)

Evolution of RT Orbits and Clocks



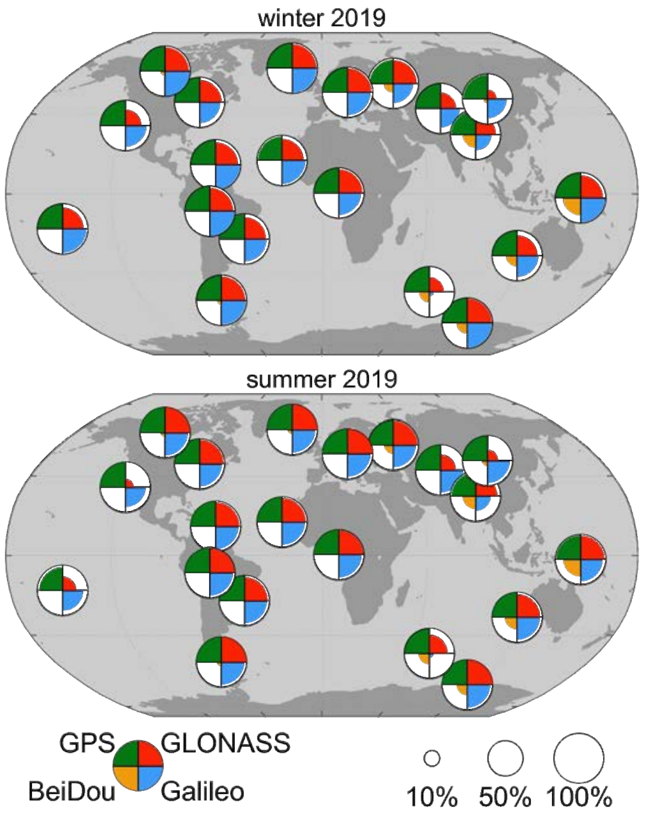


IGS RTS Status:

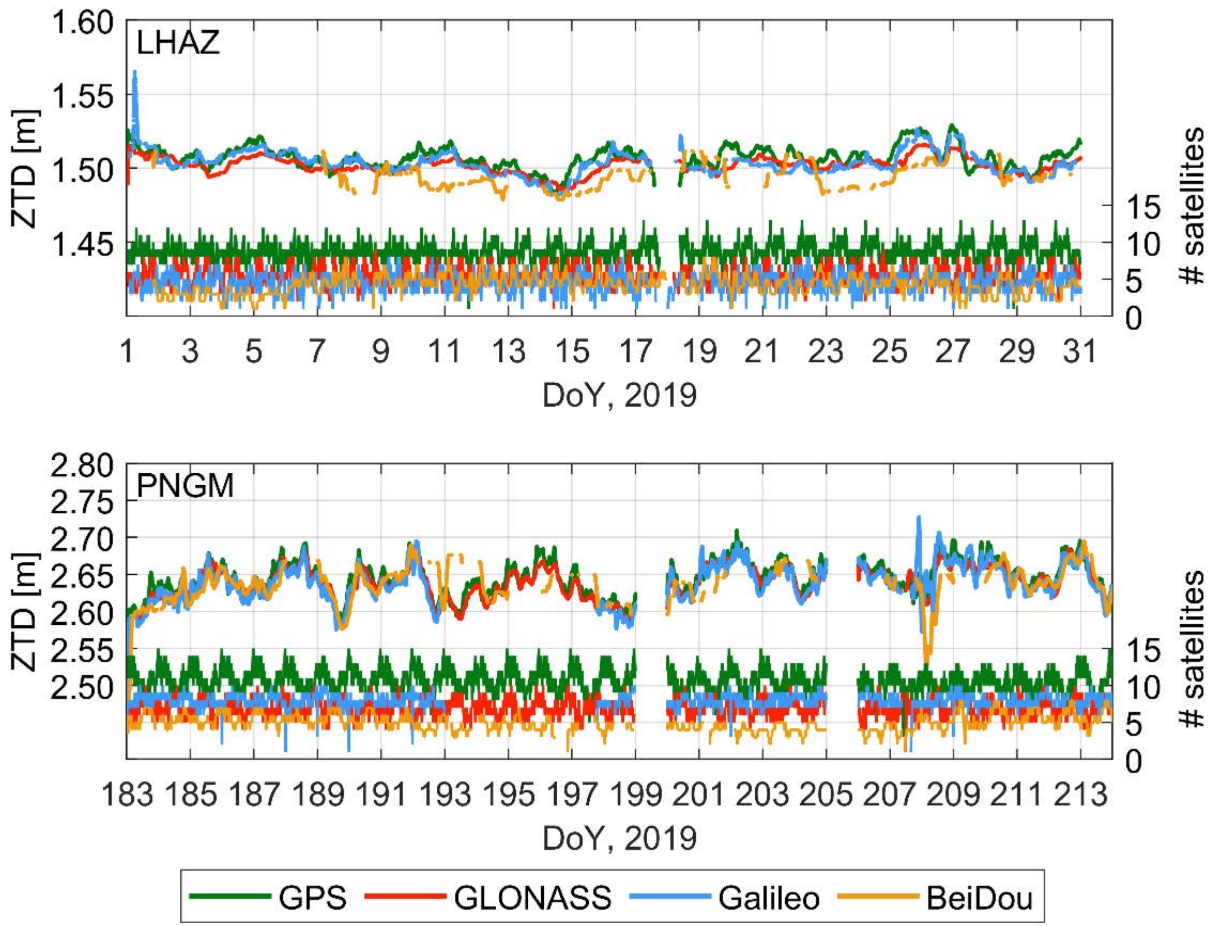
- 11 ACs , 79 mount points (in most cases G+R+E)
- constantly improving accuracy (SISRE)

Kazmierski, K., Zajdel, R. & Sośnica, K. *Evolution of orbit and clock quality for real-time multi-GNSS solutions*. GPS Solut 24, 111 (2020).

Single-GNSS ZTD



Availability of real-time ZTD from single GNSS processing

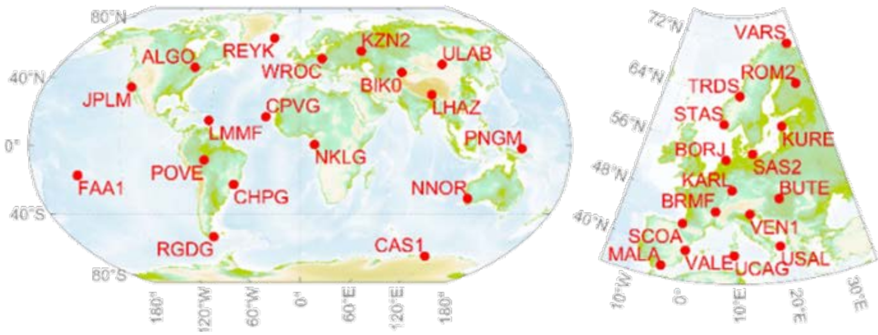


Time series of real-time ZTD from single GNSS processing

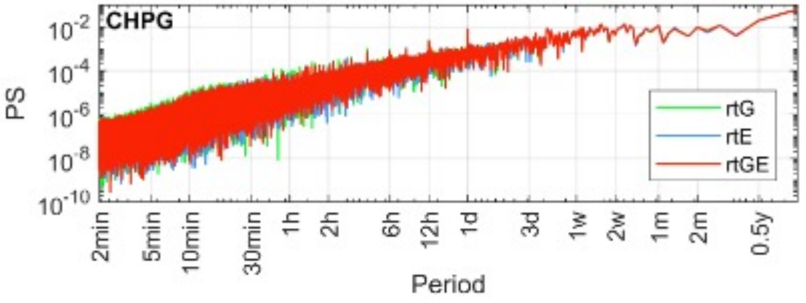
- GPS and Galileo result similar RT ZTD (r=0.97, RMSE=8.3mm)
- BeiDou (2) only in Asia (r=0.71, RMSE=25mm)

Hadaś T., Hobiger T., Hordyniec P. (2020) Considering different recent advancements in GNSS on real-time zenith troposphere estimates. GPS Solutions 24, 99

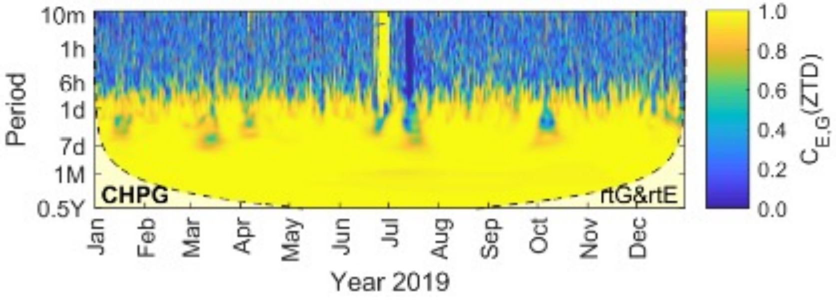
GPS + Galileo



Location of test stations from IGS and EPN networks.



PS density plot for real-time ZTD

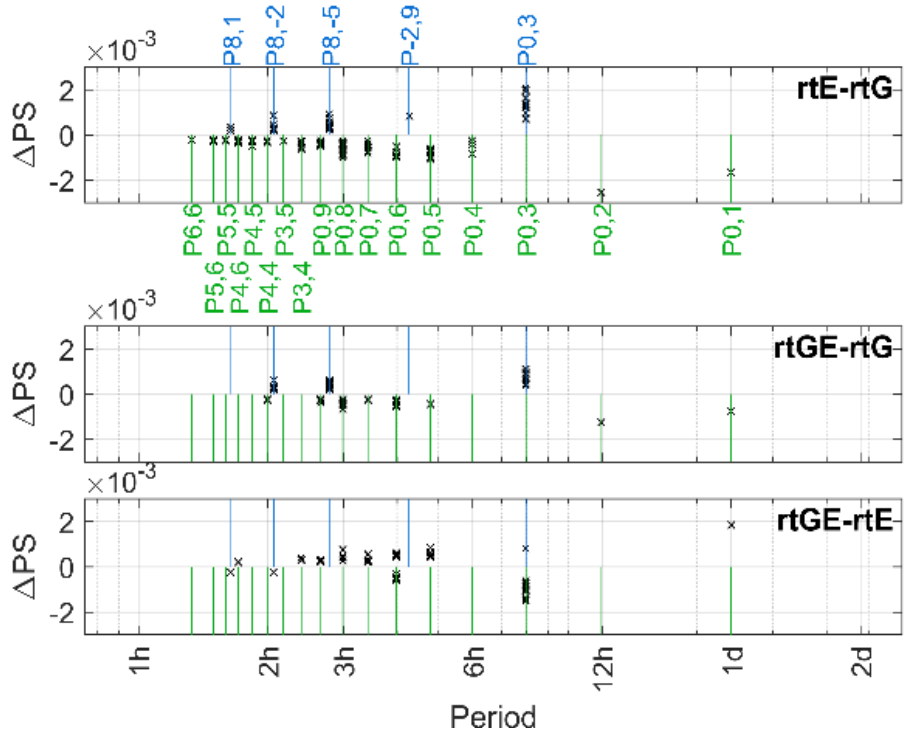


Magnitude squared wavelength coherence between ZTD from the GPS-only and Galileo-only solutions

Period P with expected orbit-related artificial signals:

$$P_{n,m}^{-1} = n \cdot f^S + m \cdot f_E$$

f^S – frequency of a satellite constellation period
f_E – frequency of the Earth revolution period
n,m – small integers

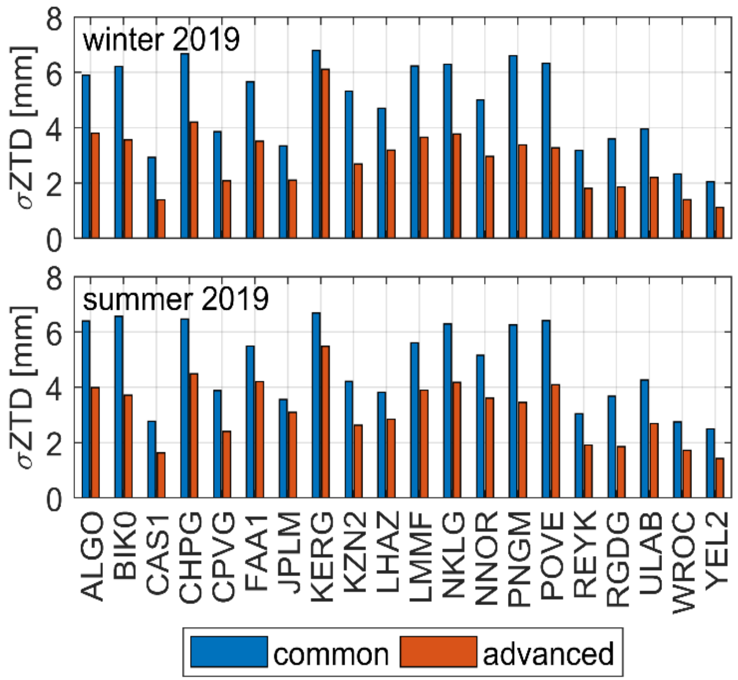


Peaks at differential PS (ΔPS) with selected periods of expected orbit-related artificial signals for GPS (green) and Galileo (blue).

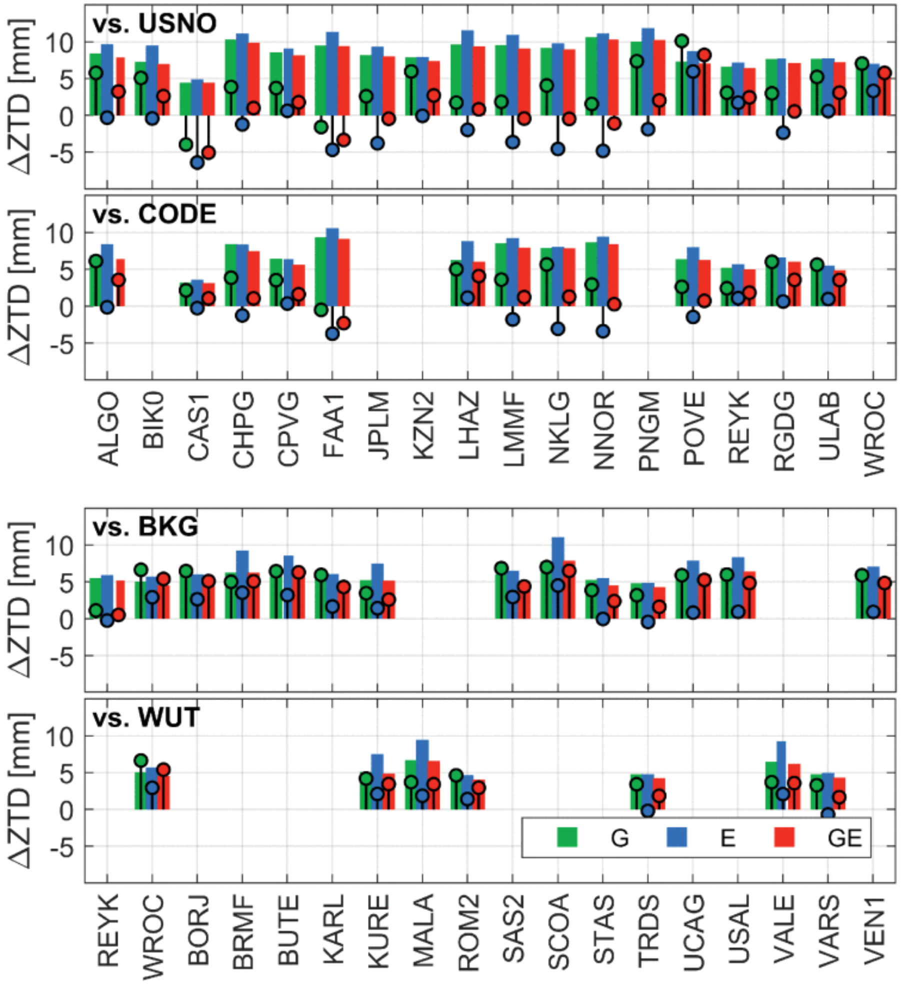
- single-system ZTD suffer from orbit-related artificial signals of high frequency;
- GPS + Galileo suppress such effects

Hadaś T., Hobiger T. (2021) Benefits of Using Galileo for Real-Time GNSS Meteorology. IEEE Geoscience and Remote Sensing Letters (18)10, pp. 1756-1760

Key findings



A posteriori standard deviations of estimated ZTD (σZTD) obtained with common and advanced strategies



Mean offset (circle) and standard deviation (bar) of ZTD differences between GPS-only, Galileo-only and GPS + Galileo real-time solution and final products from different analysis centers

- definition of superior strategy for RT ZTD: raw PPP, quad-GNSS, weighting, gradients
- RT GPS + Galileo: accuracy similar to quad-GNSS, suppress artificial signals
- RT ZTD accuracy: <10 mm vs GFS NWM; 7-8 mm vs IGS Final ZTD; 5-6 mm vs EPN

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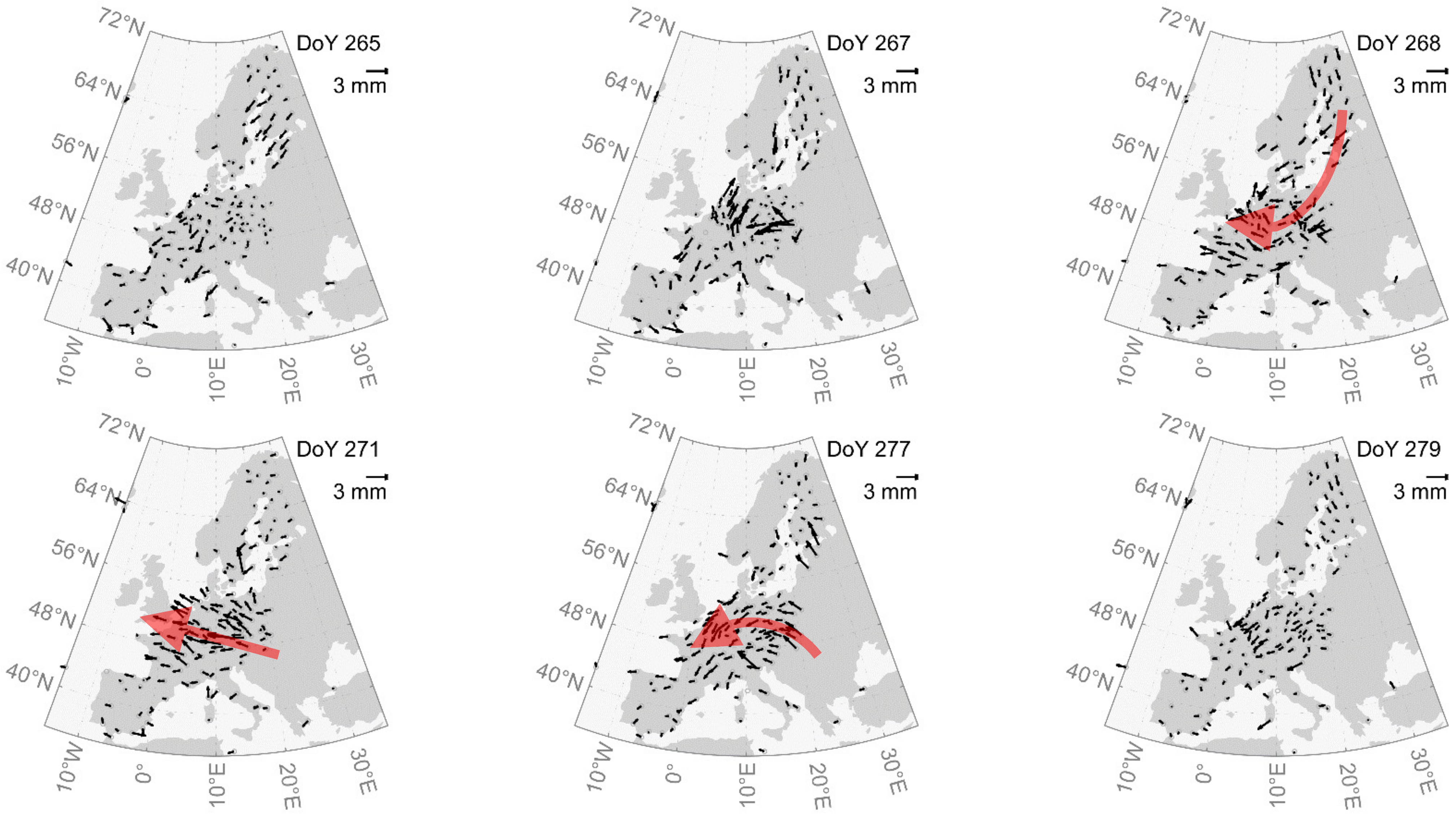
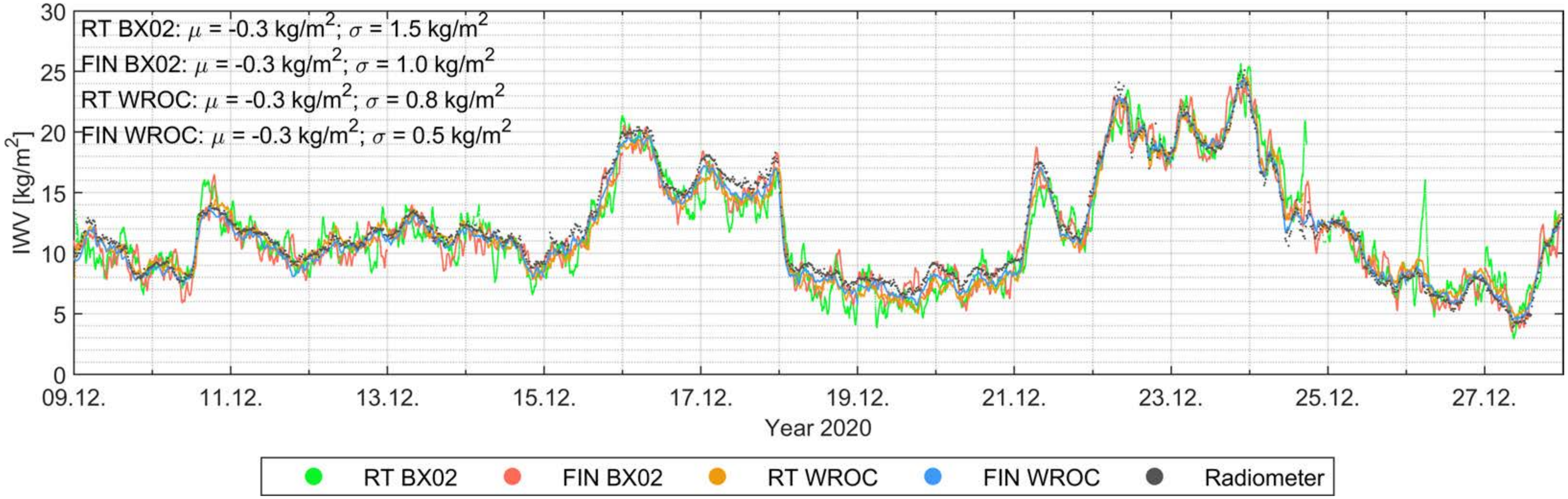
Troposphere asymmetry – Hurricane Lorenzo (2019)



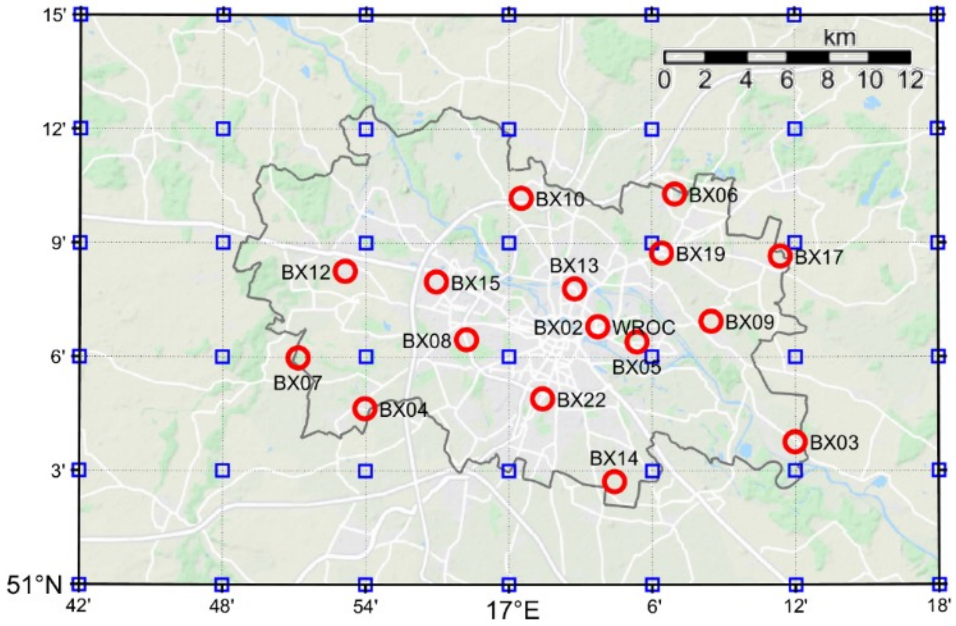
MONITORING RT ZTD/IWV WITH LOW-COST GNSS

Co-located instruments:

- IGS WROC
- low-cost GNSS (BX02)
- microwave radiometer



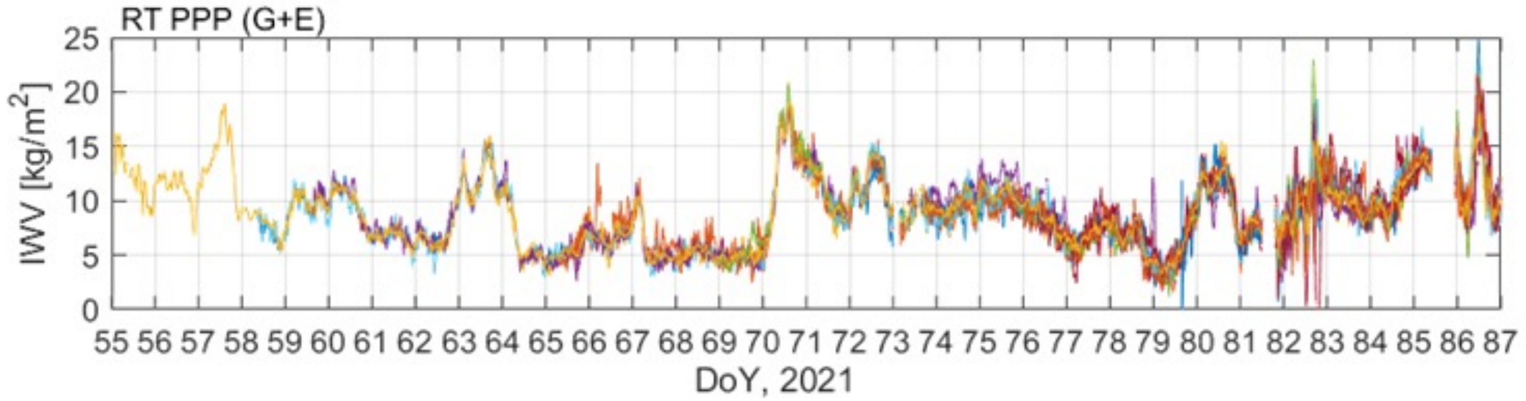
ZTD/IWV DYNAMICS AT A LOCAL SCALE



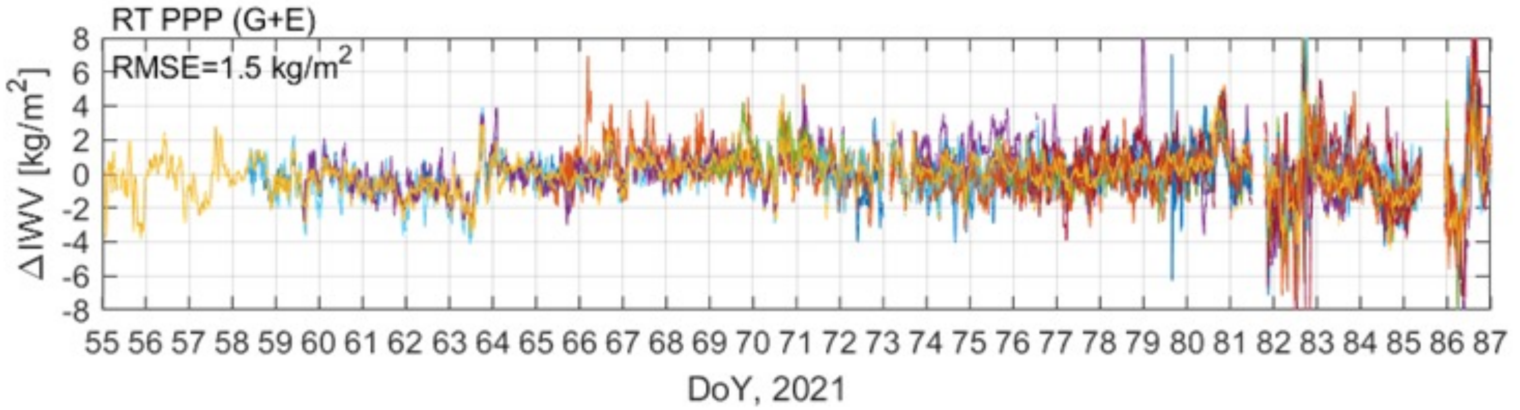
WRF grid point
low-cost station

- 17 low-cost stations
- c.a. 300 km² (3 – 8 km)
- ≥13 receivers for 15 days (March, 2021)

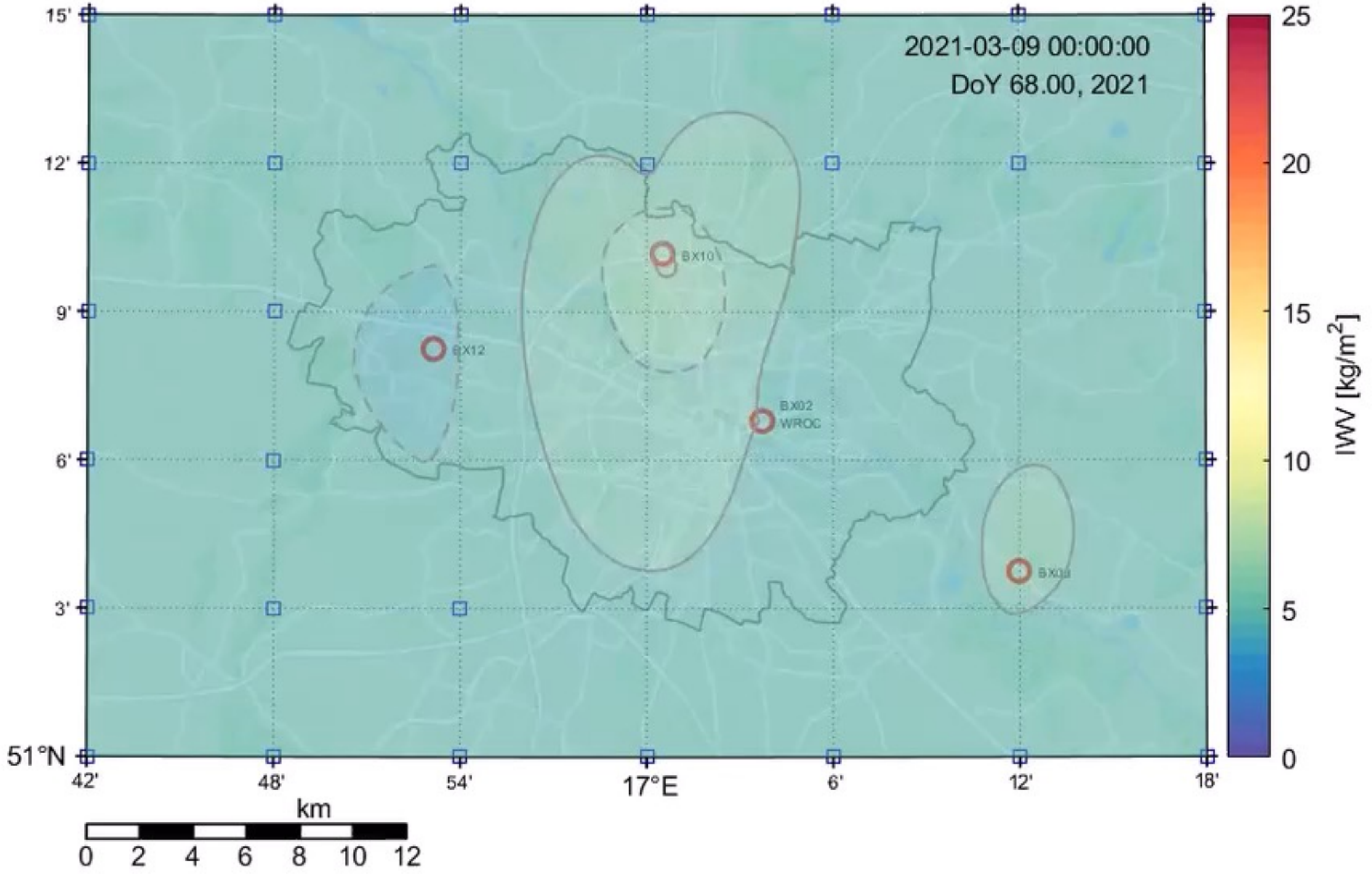
real-time IWV time series (42 days)



real-time IWV vs WRF



ZTD/IWV DYNAMICS AT A LOCAL SCALE



DIFFERENCES:

1) RT IWV vs WRF:

- 60% smaller than 1kg/m^2
- min: -10.7 kg/m^2
- max: +12.2 kg/m^2

2) inter-station IWV:

- max: 16.6 kg/m^2

Thank you!

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