Tropospheric products as a signal of interest – overview of troposphere sensing techniques

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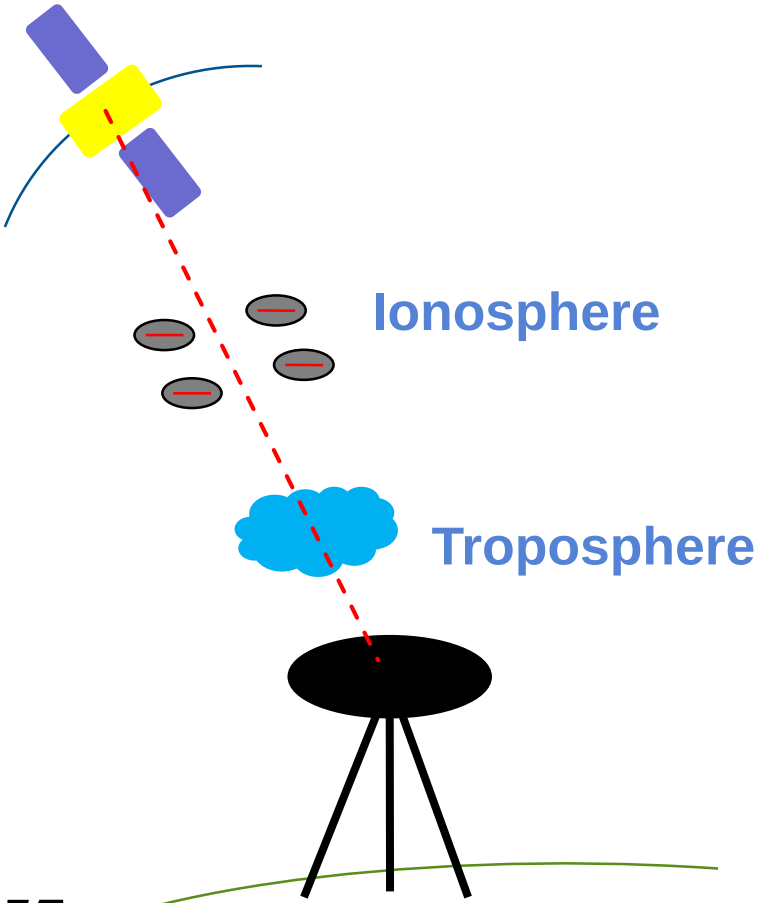
Motivation



The microwave signal propagating through the atmosphere is delayed.

The **ionospheric delay** is caused by the free electron content.

The **tropospheric delay** is caused by the air molecules and the water vapor.

The **tropospheric delay** was initially considered just as a **source of error**, but it can provide **valuable information** on the state of the troposphere.

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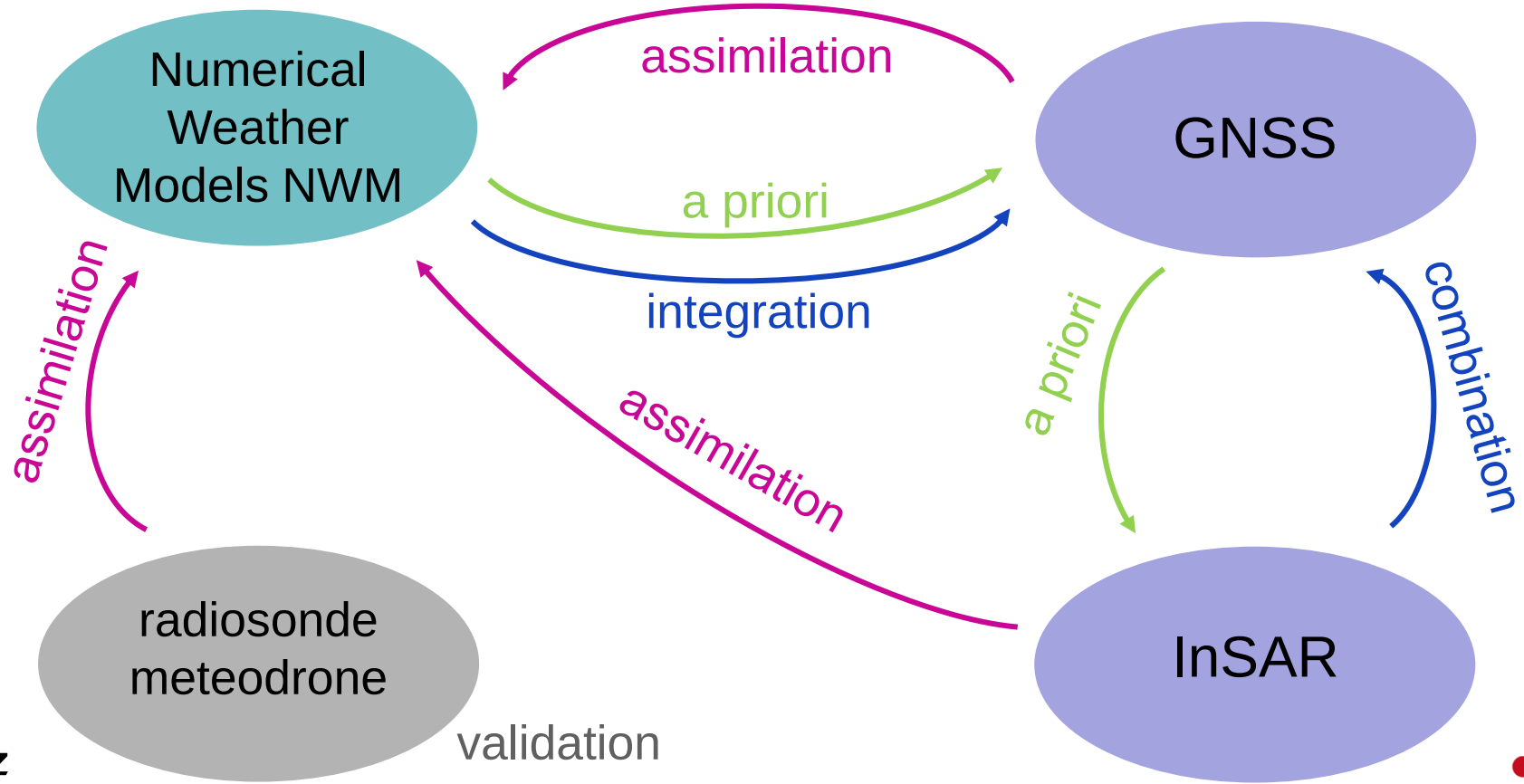
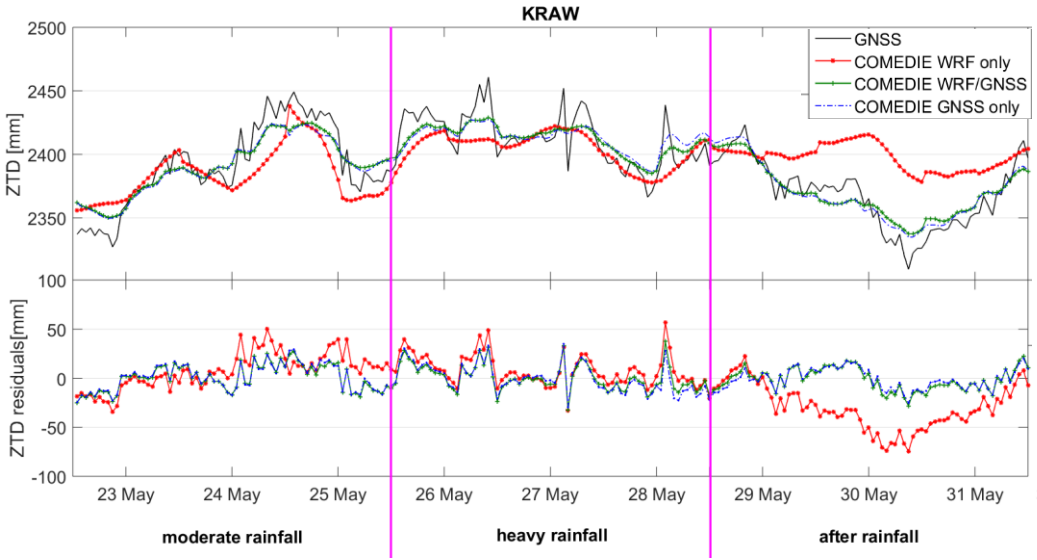
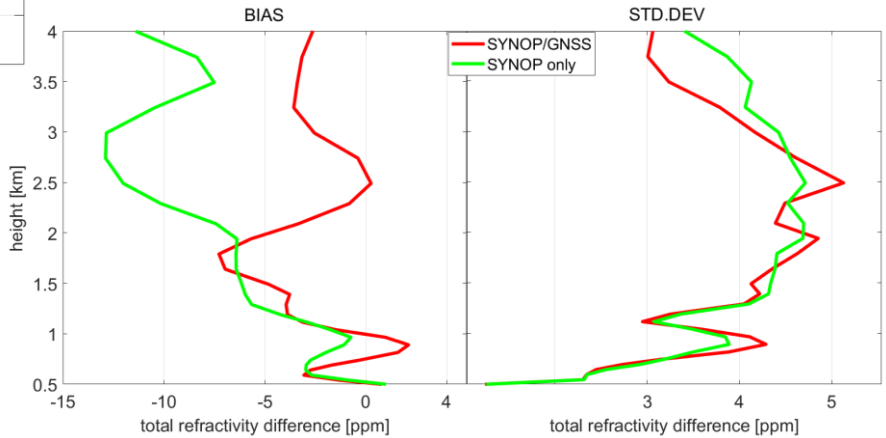
Tropospheric delay as a signal of interest



Integration of data sources



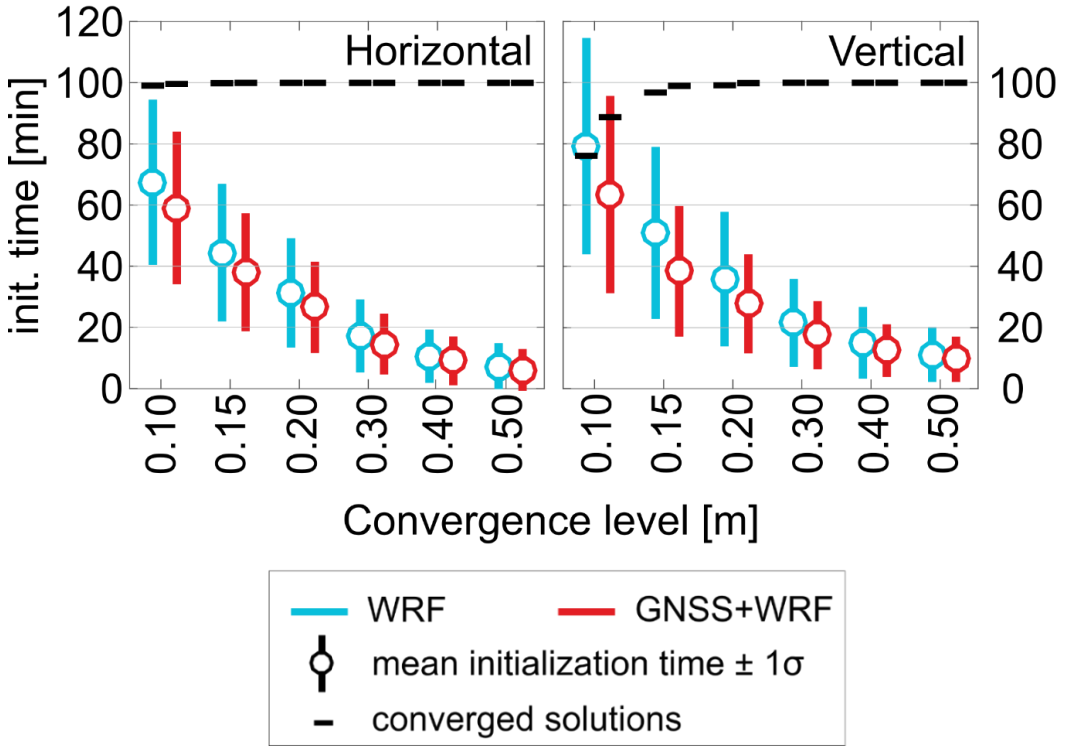
GNSS and NWM WRF ← or GNSS and SYNOP ↓ using the least-squares collocation software COMEDIE.



Integration leads to **improvement of the agreement** with reference data sources (e.g. GNSS↑, RS →).

Wilgan et al, 2017a, JOGE

GNSS+NWM for PPP

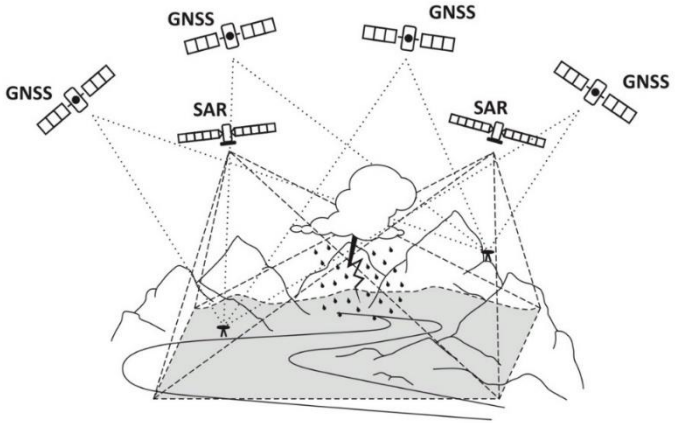


Wilgan et al, 2017b, GPSS

Using the integrated GNSS+NWM (WRF) model as a priori for PPP leads to:

- **Reduction of 3D bias** by 20 mm (57%) in static and 10 mm (40%) in kinematic mode.
- **Shortening the convergence time** by 13% for horizontal coordinates and 20% for vertical coordinates (for 10 cm convergence level).
- **More converged solutions**.

Combining GNSS and InSAR



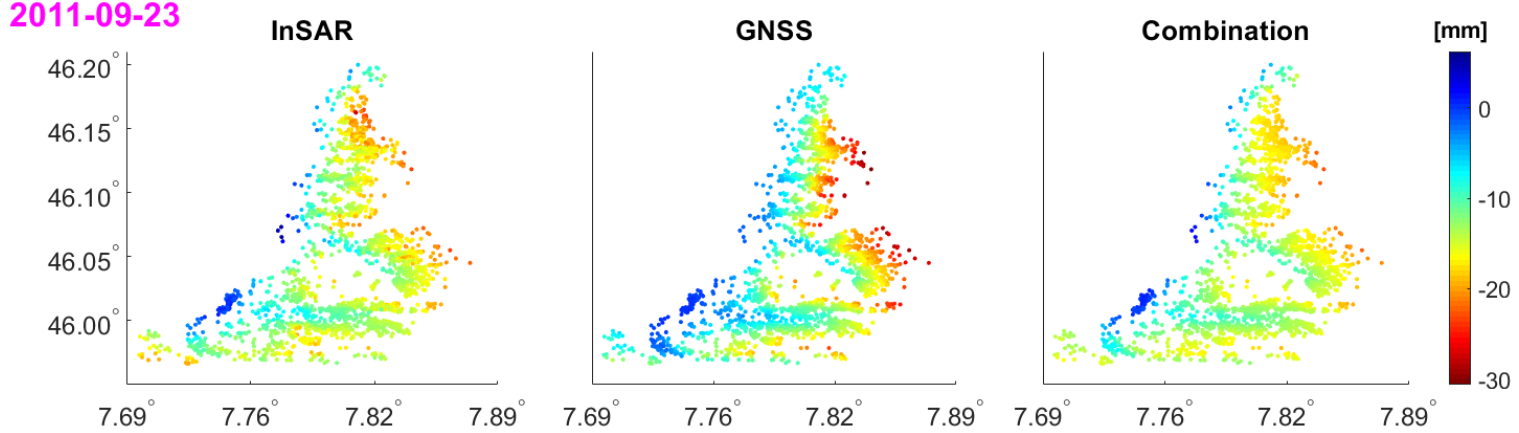
Taking advantage of the **complementary characteristics**:

GNSS

- high temporal resolution
- low spatial density

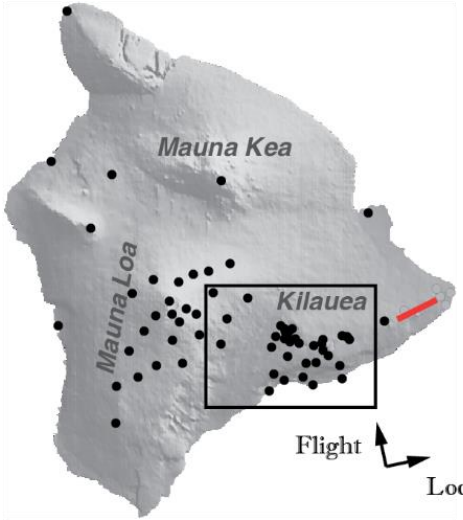
InSAR

- low temporal resolution
- high spatial density

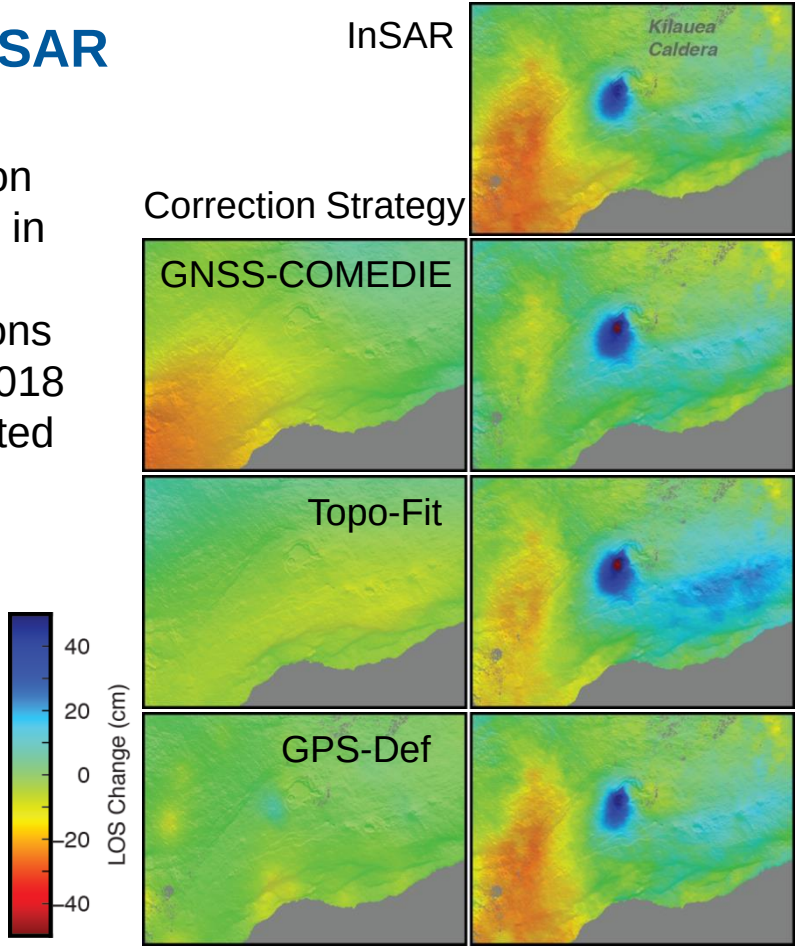


Shehaj et al, 2020, Navigation

GNSS for InSAR



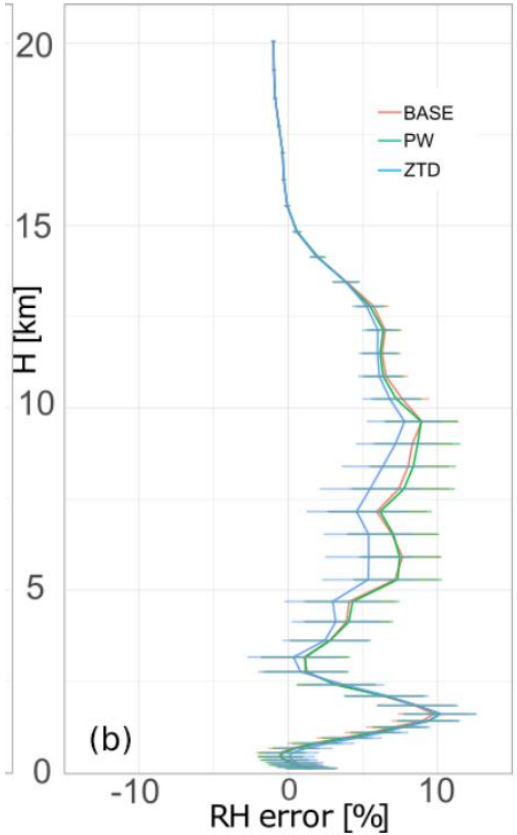
- Kilauea volcano eruption and Mw6.9 earthquake in May 2018
- 57 Sentinel-1 acquisitions from April to October 2018
- 77 GNSS stations located in Big Island, Hawaii



Sentinel-1 May 14 − 20, 2018 (ascending)

With large number of GPS sites, GNSS-COMEDIE correction provides the **best RMS reduction** for 21 ascending and 23 descending Sentinel-1 scenes.

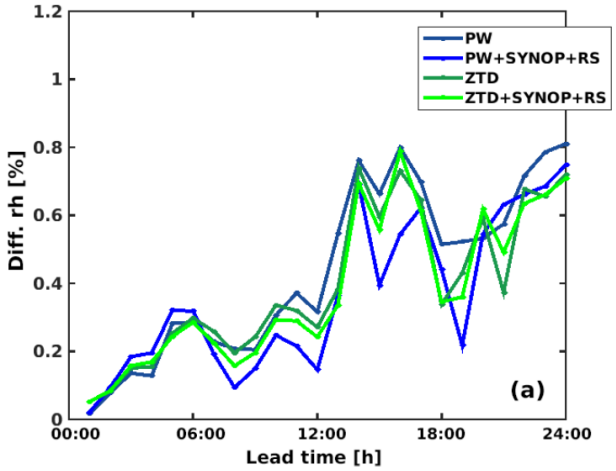
GNSS for NWM



Rohm et al, 2019, AMT

←Humidity profile
GPS ZTD: above 2.5 km decreases bias by 20%

2m relative humidity →
GPS ZTD: bias reduction by 2%



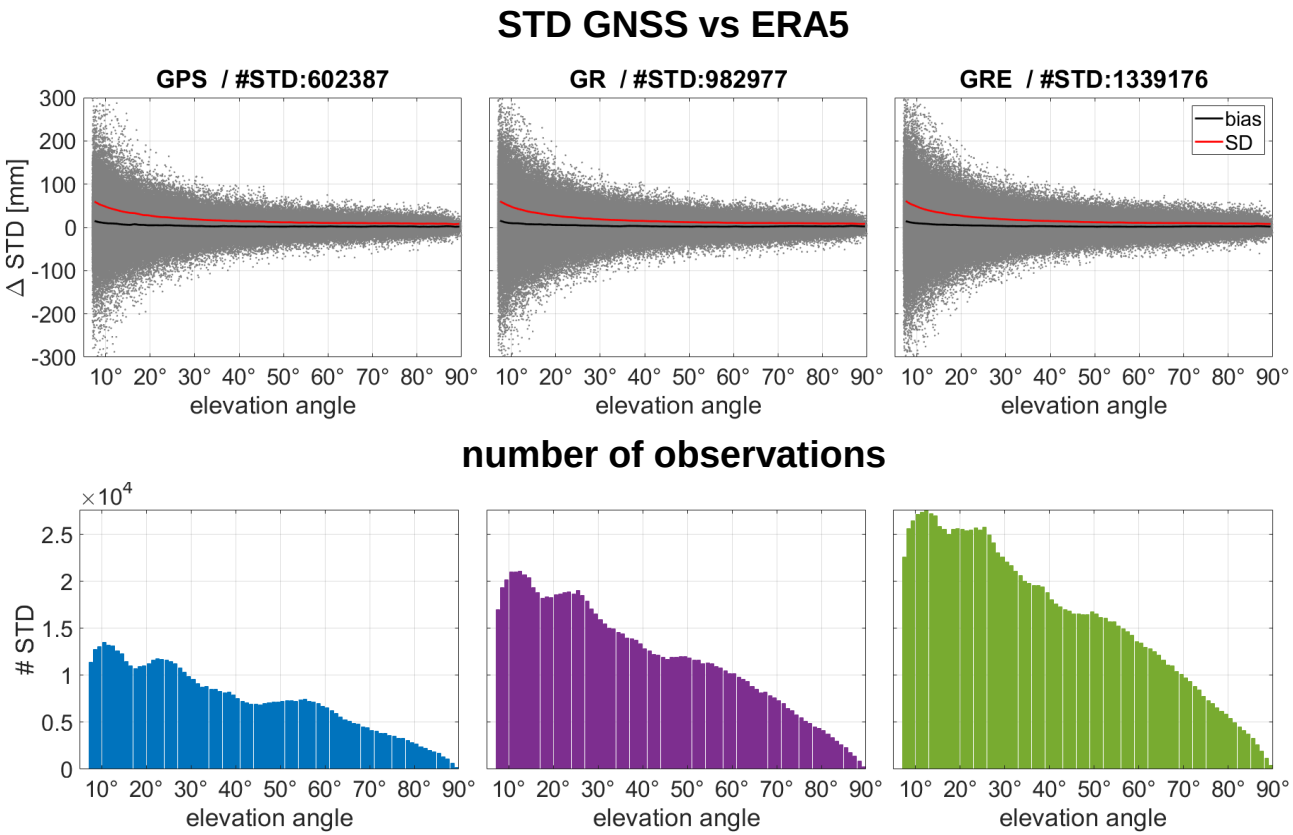
Assimilation of GPS PW/ZTD often leads to positive or neutral effect on the forecasted meteorological parameters.

This study: **positive impact on moisture field and precipitation forecasts (WRF)**

Multi-GNSS for NWM

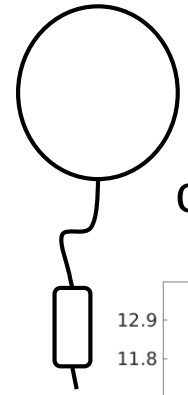
Current operational assimilation:
GPS-only ZTD/PWV
Current challenge:
multi-GNSS STD

GRE, GR and GPS-only have similar agreement with ERA5, but GRE provides more low-elevation angle observations

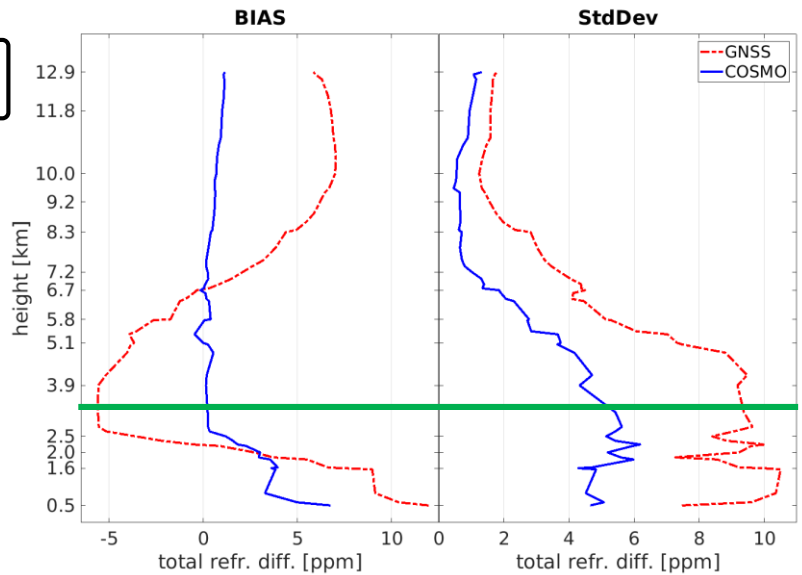


Wilgan et al, 2021, in prep.

GNSS vs alternative data sources



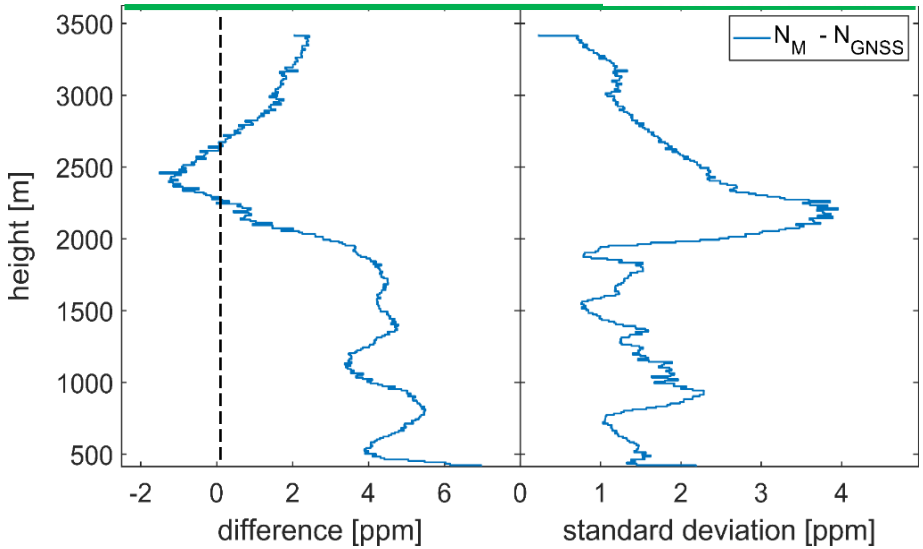
classical - radiosondes



Wilgan et al, 2017a, JOGE

new - meteodrone

Source: Meteomatics



Wilgan et al, 2020, ASR

Meteodrones (SD=1.7 ppm) are in **higher agreement with GNSS** data than radiosondes (SD=5.1 ppm).

Summary

Tropospheric products as signal of interest:

- **Integration** of data sources (e.g. NWM+GNSS) **leads to the accuracy enhancement**.
- Using the integrated model **shortens the convergence time** for PPP.
- Using one microwave technique **can mitigate the atmospheric errors** in another (e.g. GNSS for InSAR).
- **Combining** different space techniques (e.g. InSAR + GNSS) **utilizes their complementary characteristics**.
- Using the **GNSS** data for **assimilation** into NWM leads to **positive** effect on meteorological forecasts.
- Future **challenge** in GNSS assimilation: **slant tropospheric delays**.
- Using **alternative methods of data acquisition** – e.g. meteodrones instead of radiosondes.

Thank you for your attention!
Questions?

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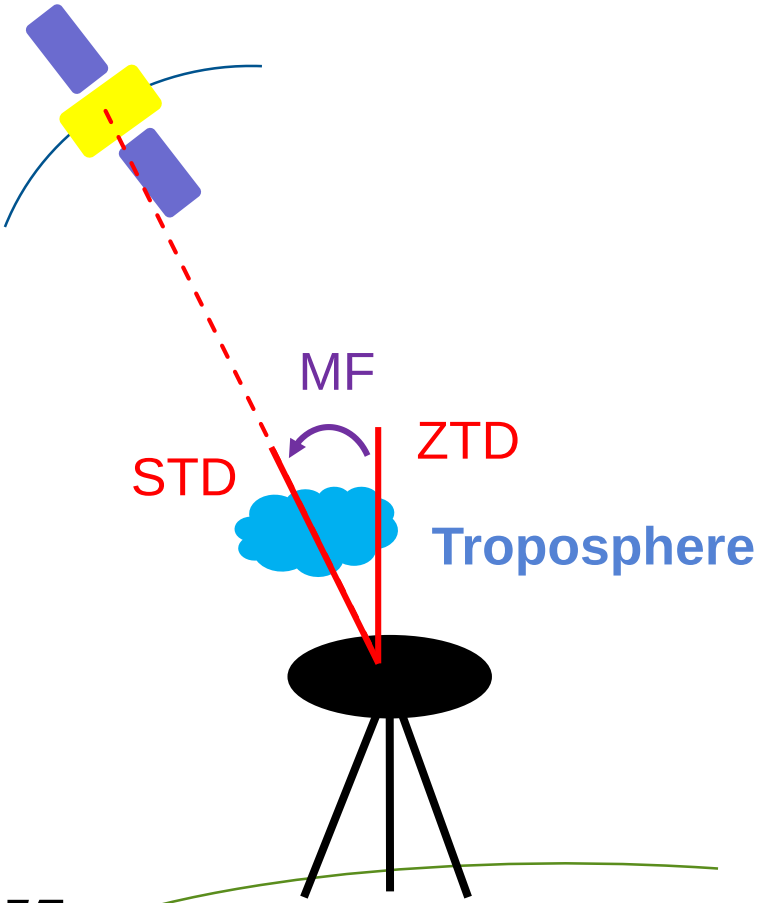

Extra

Total refractivity *N*

$$N_{tot} = k_1 \frac{p-e}{T} + k_2 \frac{e}{T} + k_3 \frac{e}{T^2}$$

Zenith total delay *ZTD*

$$ZTD = 10^{-6} \int N_{tot} ds$$

Slant total delay *STD*

$$STD = MF_h(el)ZHD + MF_w(el)ZWD + MF_g(A)\left(G_N \cos(A) + G_E \sin(A)\right)$$