Towards the integration of GNSS, SAR and NWP for heavy rainfall forecast in sub-Saharan Africa within the TWIGA project

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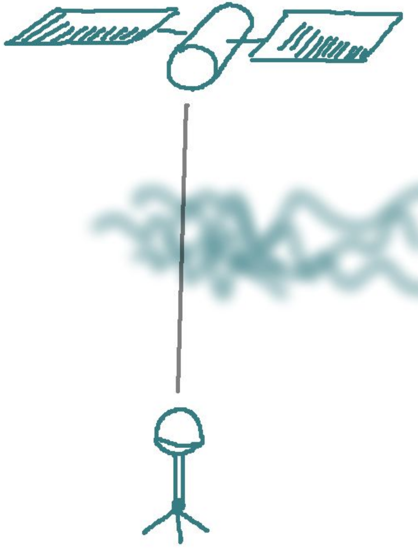
TWIGA wants to integrate GNSS, SAR and NWP

GNSS (Global Navigation Satellite System) and **SAR** (Synthetic Aperture Radar) measurements can be used to derive information on the columnar water vapor content, with the estimation of ZTD [Bevis et al., 1992; Hanssen et al., 1999].

$$L = \int ds \left[\frac{c}{v(s)} - 1 \right]$$

ZTD (Zenith Total Delay) is a measure of the electromagnetic signal delay L composed of a hydrostatic contribution due to the mass of the air column, and a wet component, due to the amount of water vapor.



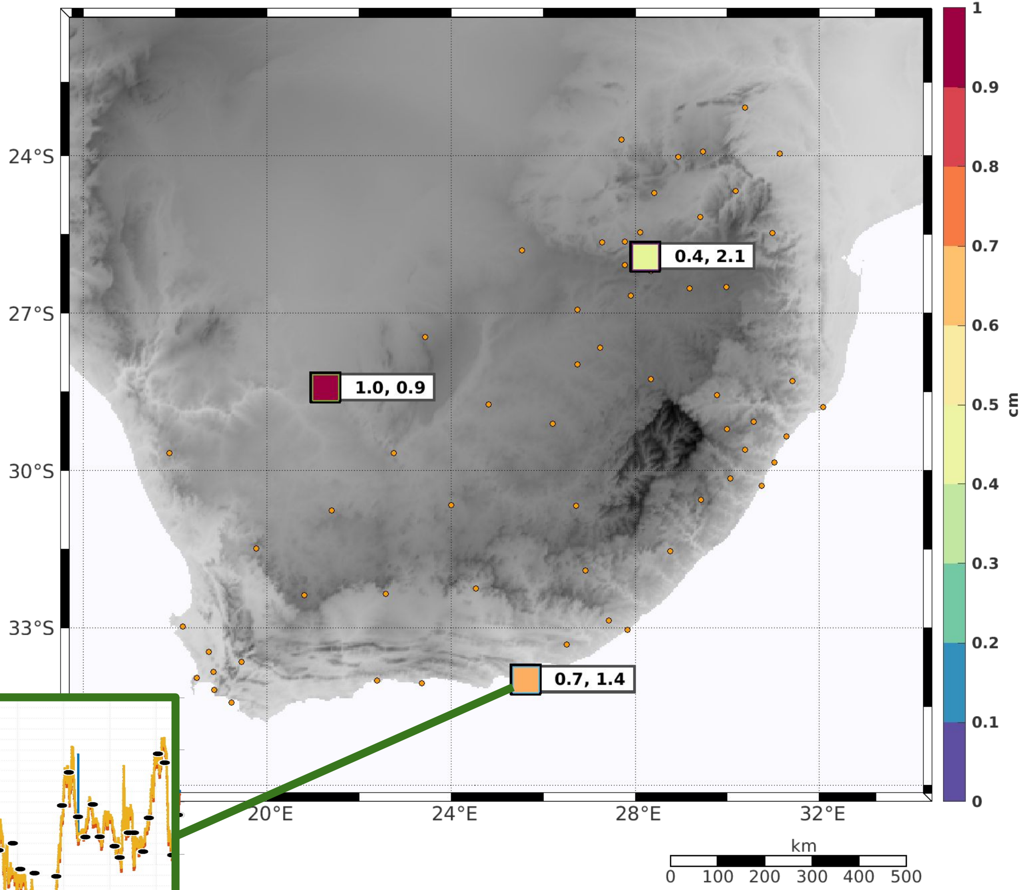
Both GNSS and SAR ZTD products can be assimilated in numerical weather prediction (**NWP**) models to improve their forecasting skills during heavy rainfall events.

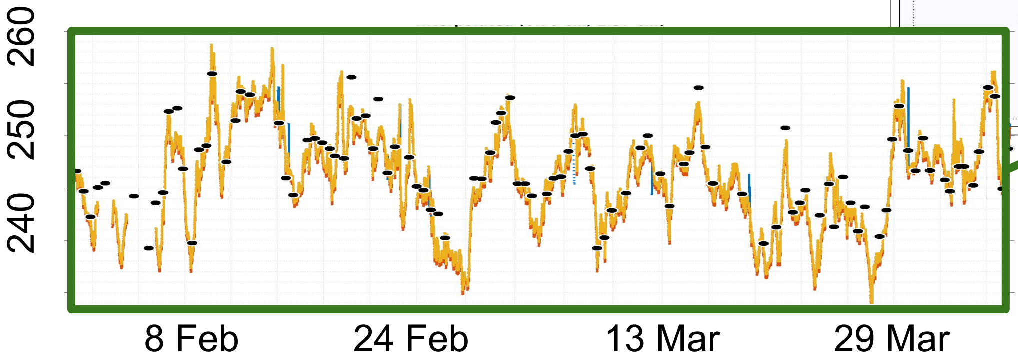
TWIGA H2020 (https://twiga-h2020.eu/) wants to synergically use them to better predict heavy rainfall in sub-Saharan Africa with reliable low-cost sensors.

GNSS validation in South Africa

GNSS ZTD time series are validated with the available radiosonde stations (RS) in the period February-March 2018.

Orange dots: GNSS receivers,
Squares: mean [cm] and
standard deviation [cm] of the GNSS-RS.



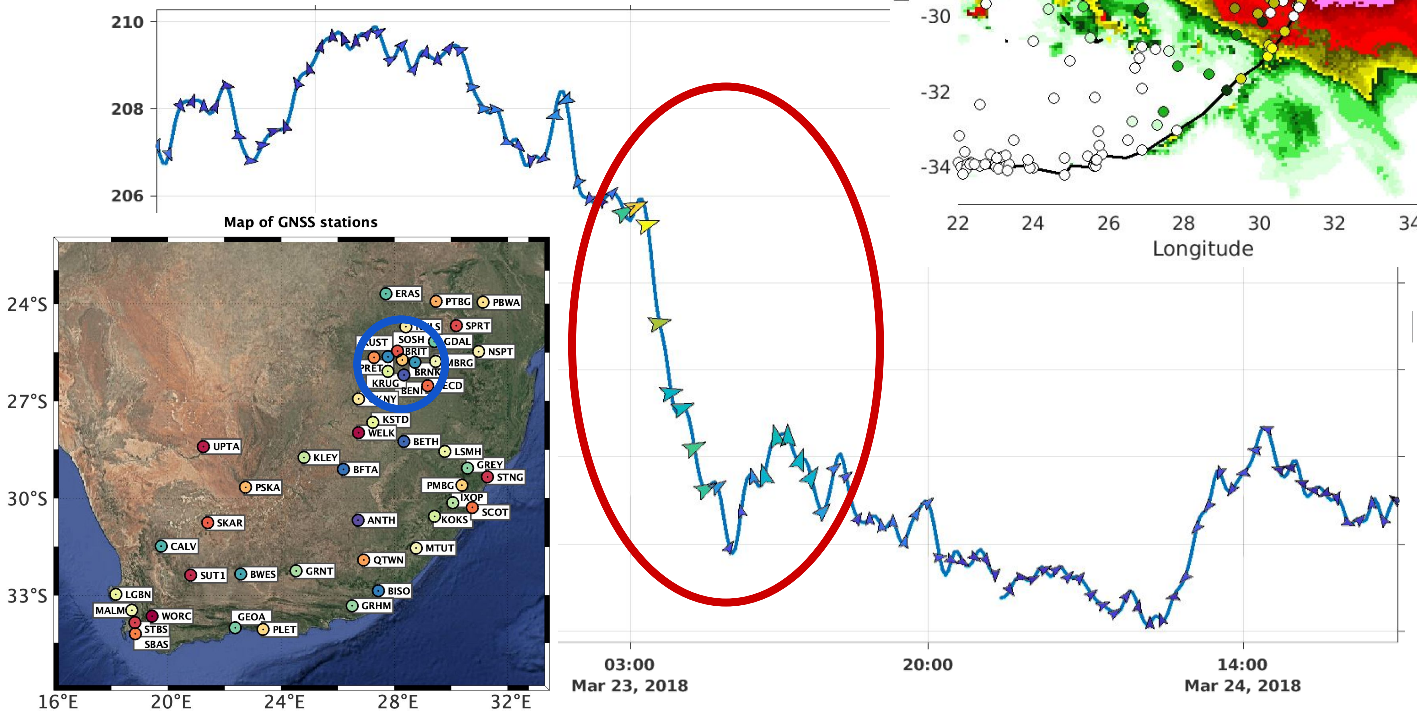


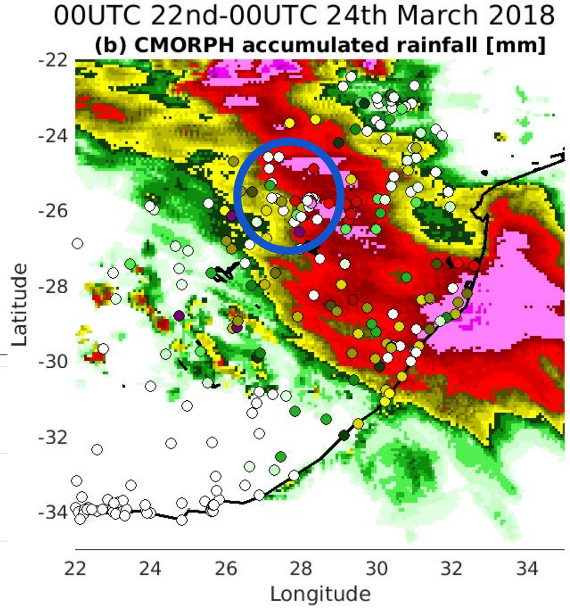
Black dots: RS ZTD at Port Elizabeth
Yellow: GNSS ZTD interpolated (z,p)

GNSS tropospheric gradient signal

Between the 22nd and the 24th of March 2018 a heavy rainfall event stroke the area of Pretoria (blue circles in the maps).

GNSS time series detected large variations of ZTD with strong tropospheric ZTD gradients.



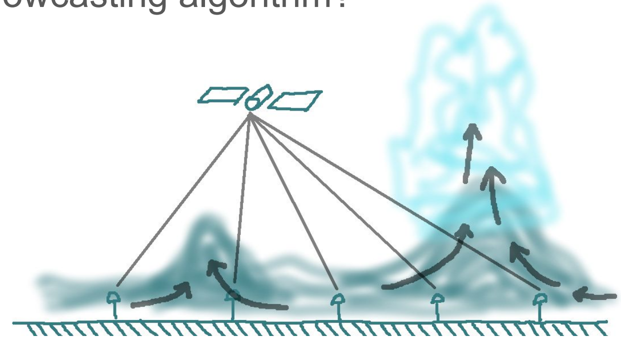


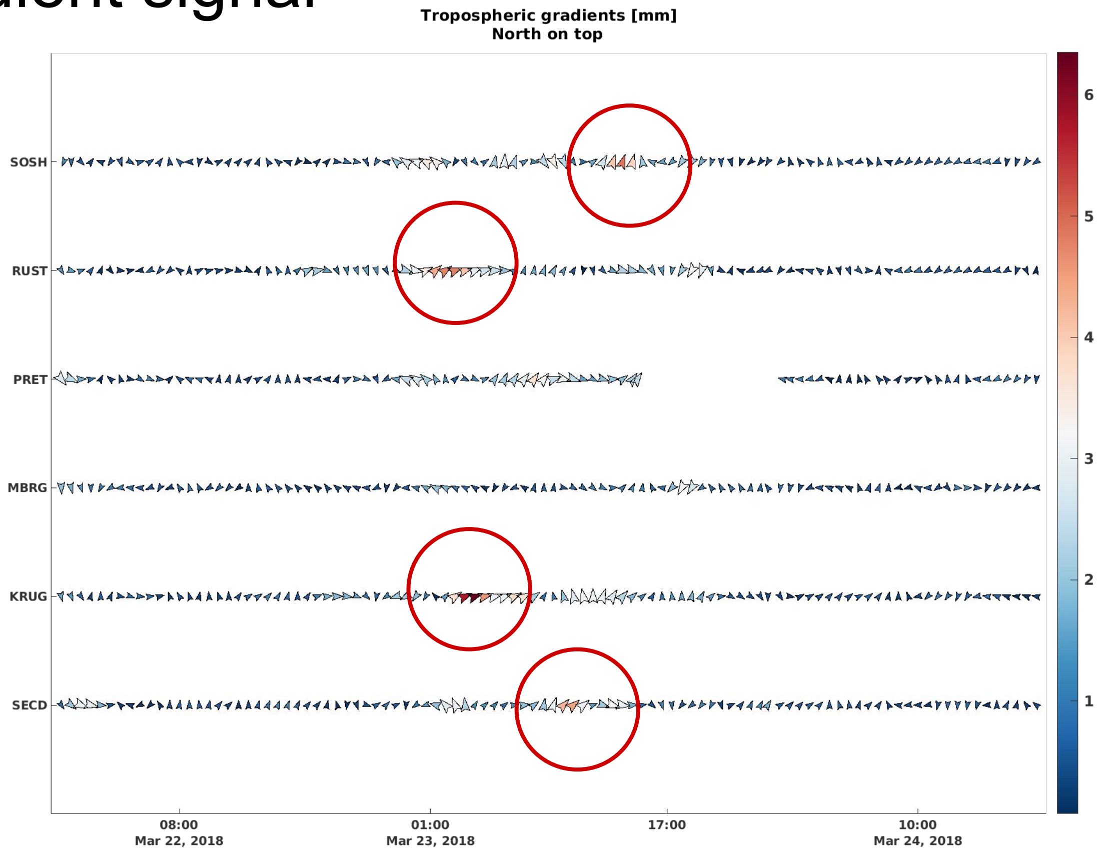
GNSS tropospheric gradient signal

There is evidence that strong rainfall events are associated with intense ZTD gradients and abrupt ZTD time variations [Shoji 2013; Radhakrishna et al. 2015].

Analysis are ongoing to characterize this relationship in this area.

How can we use this information in a skilful nowcasting algorithm?



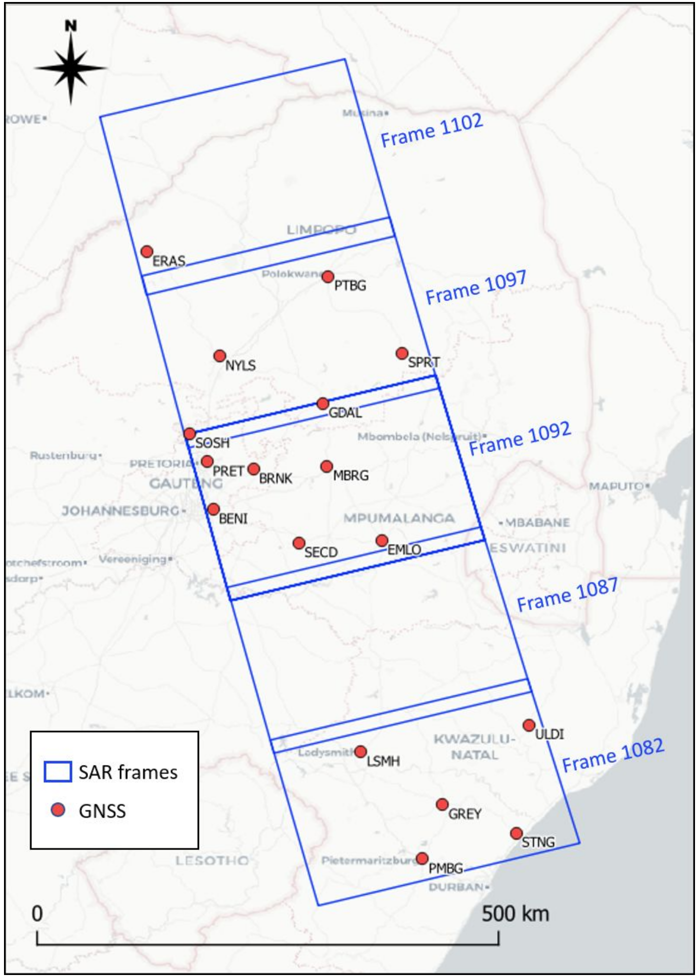


InSAR ZTD maps generation

One of the goals of the TWIGA project is the joint exploitation of GNSS and SAR-derived atmospheric products.

In the figure one the right, five Sentinel-1 frames are depicted with a set of GNSS stations.

Such stations are used to correct for any orbital error in SAR interferograms and to fix the (missing) interferometric constant [Manzoni et al., 2020; Meroni et al., 2020].



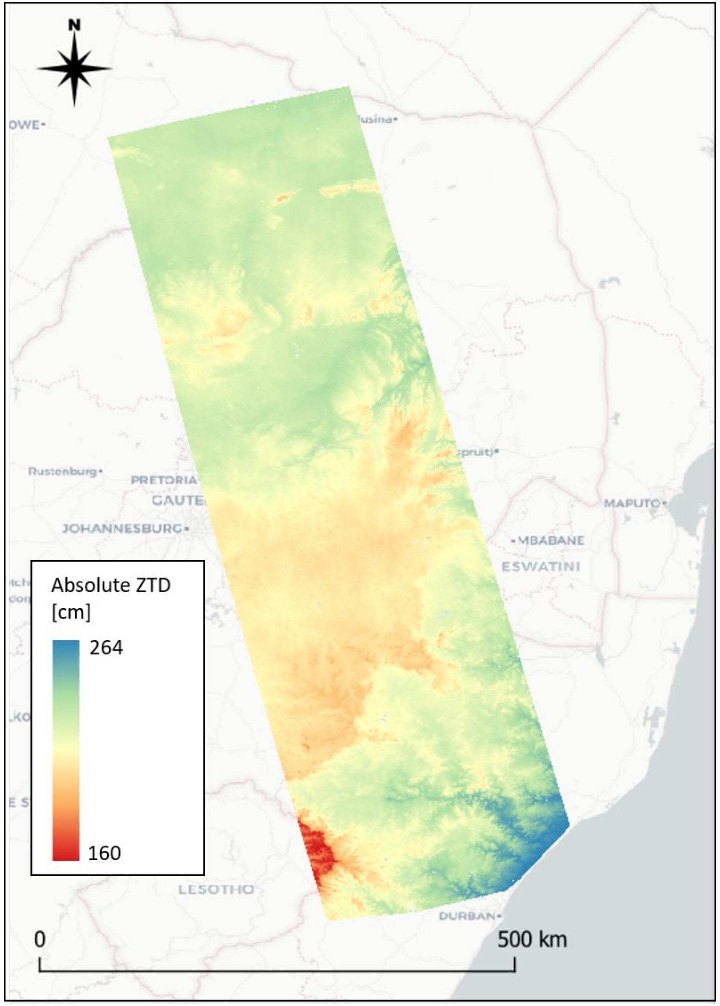
InSAR ZTD maps generation

Once the orbits are fixed using the existing GNSS network, we can estimate the absolute ZTD from the differential interferogram.

To do so, an unknown master should be estimated. In this case, we used a master image generated using a product based on a NWP model (GACOS) [Meroni et al., 2020].

The final product is a 850km by 250km ZTD map.

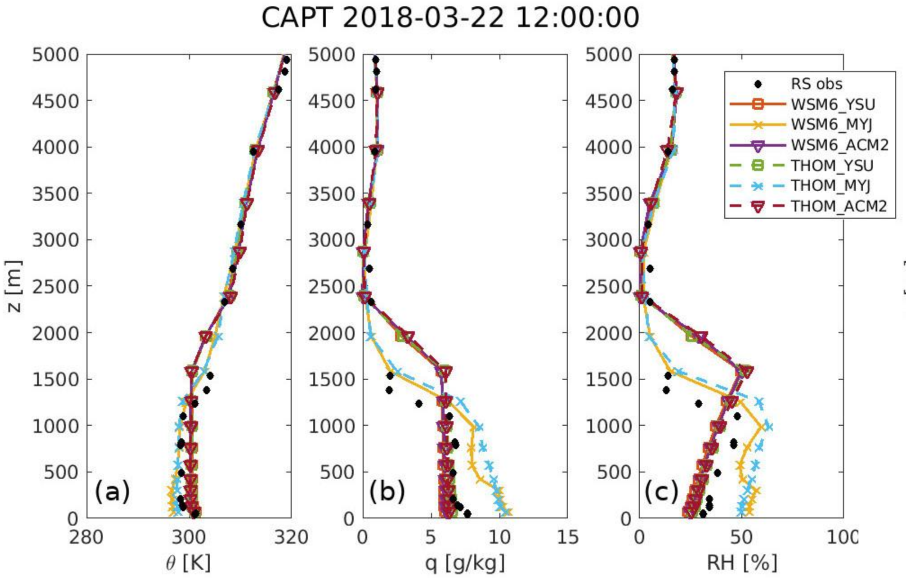
In order for this map to be easily manageable and browsed, a compression is performed. This step is able to reduce the size of the map of several order of magnitude.



NWP: WRF sensitivity to PBL and MP schemes

A set of sensitivity experiments were performed for a heavy rainfall event in Kenya-Uganda and two events in South Africa.

Nonlocal PBL schemes (YSU and ACM2) outperform local ones (MYJ) in terms of heavy rainfall forecast. This happens because local schemes overestimate the low-level moisture, generating unrealistic atmospheric instability and spurious rainfall.



Potential temperature, mixing ratio and RH comparisons with RS data in Cape Town.

Meroni et al. (2021)

Data assimilation experiments of GNSS and SAR ZTD

We will perform some DA experiments to understand the sensitivity of the models to the **spatio-temporal resolution** of the ZTD observational products:

- GNSS every 6 hours, CV5
- GNSS every 12 hours, CV5
- SAR at 4.5 km resolution, CV5
- SAR at 13.5 km resolution, CV5
- SAR at 4.5 km resolution, CV7+LSAC
- SAR at 13.5 km resolution, CV7+LSAC

Different background covariance matrices will be used to fully exploit the high resolution information contained in the ZTD SAR maps.