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TWIGA project activities for the enhancement of heavy rainfall predictions in Africa: low-cost GNSS network deployment and NWP model parameterization.

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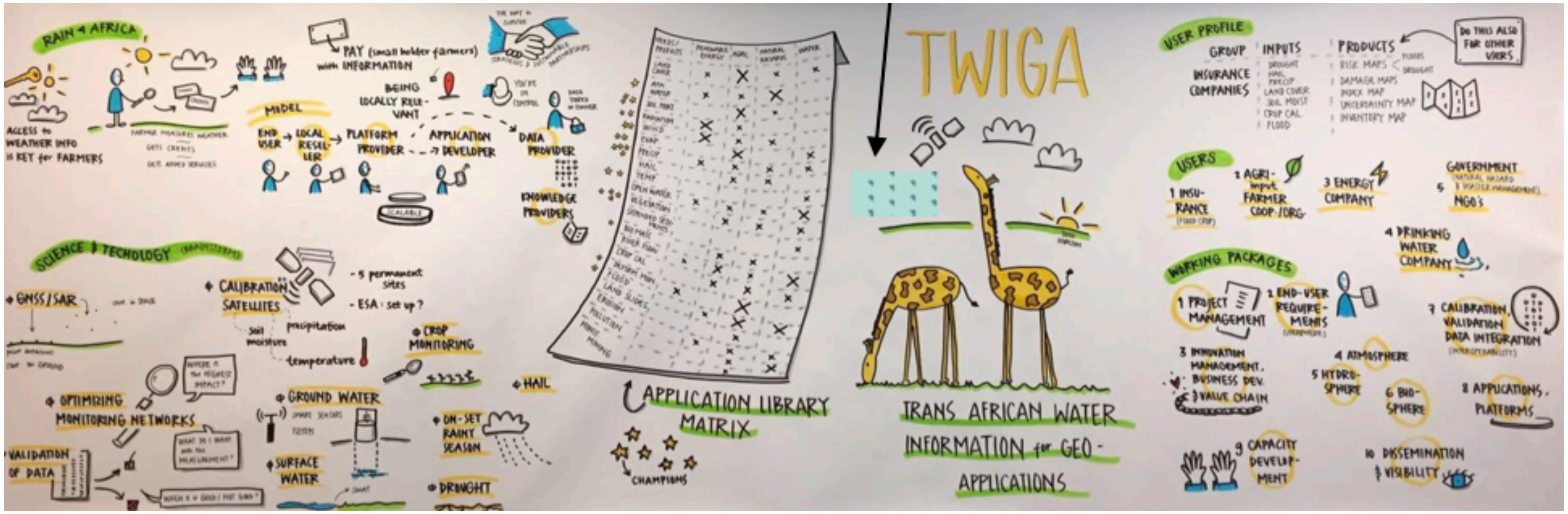
TWIGA - Transforming **W**eather Water data into value-added **I**nformation services for sustainable **G**rowth in **A**frica

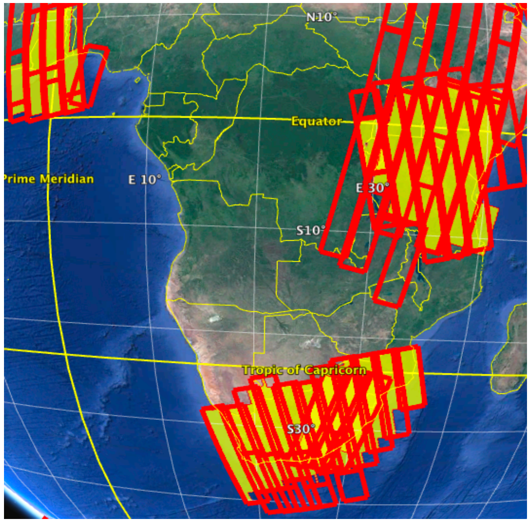


TWIGA aims at providing **currently unavailable** geo-information on weather, water and climate for sub-Saharan Africa.

The project will enhance **satellite-based geo-data** with **innovative in situ sensors** and will develop related information services that answer needs of African stakeholders and the GEOSS community.

Geo-information on tropospheric water vapour

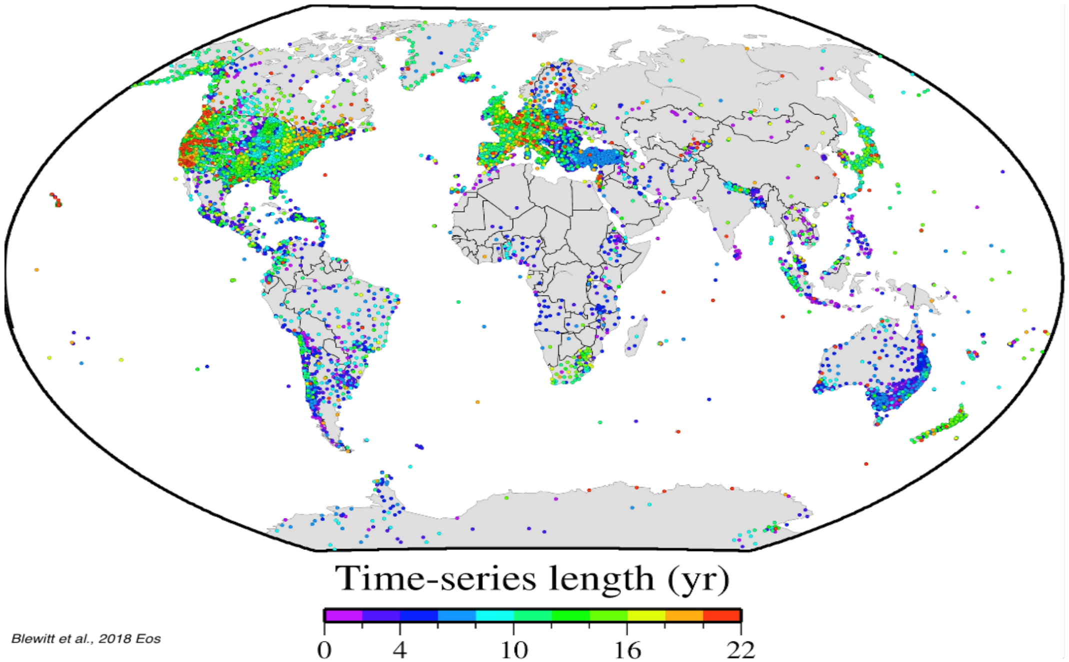
In order to enhance the prediction of heavy rains, in situ low-cost GNSS sensors are synergistically used with satellite based Sentinel SAR images and NWP models to monitor the tropospheric water vapor spatial and temporal distribution.



GNSS data are collected from low-cost single/dual frequency receivers: low-cost sensors can be profitably exploited in Africa where geodetic GNSS networks are missing. SAR data are collected from the Copernicus – Sentinel 1A/B mission.

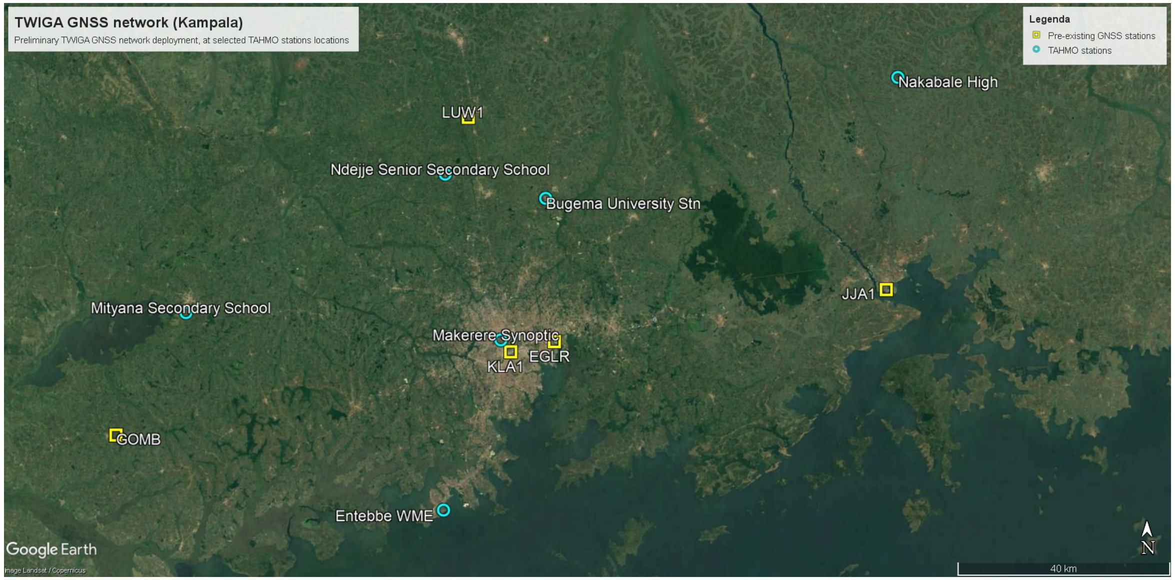
TWIGA GNSS low cost sensors

The high cost of geodetic GNSS sensors has prevented an evenly distributed deployment around the globe.
This figure (source) shows the current distribution of GNSS stations (dots) and the length of their datasets (colors from blue for “younger” stations, to red for “older” ones). The disparity between the U.S., Europe, Japan and the rest of the world is striking.



TWIGA GNSS low cost sensors – Uganda network

Six low-cost GNSS receivers have been deployed in Uganda, in and around Kampala by Makerere University, with the support of GReD, PoliMi and TU Delft.
Nine low-cost**, dual frequency**, GNSS receivers will be installed in Kenya.
The selection of suitable sites is done in cooperation with the Kenya Meteorological Department (KMD). KMD will be involved in the network deployment and maintenance activities.



The data collected by the two networks will fill the gap of water vapor observations in the two sub-Saharan countries.

TWIGA GNSS data processing

The data collected by the Uganda network are processed by using the open-source software goGPS currently developed by GReD.

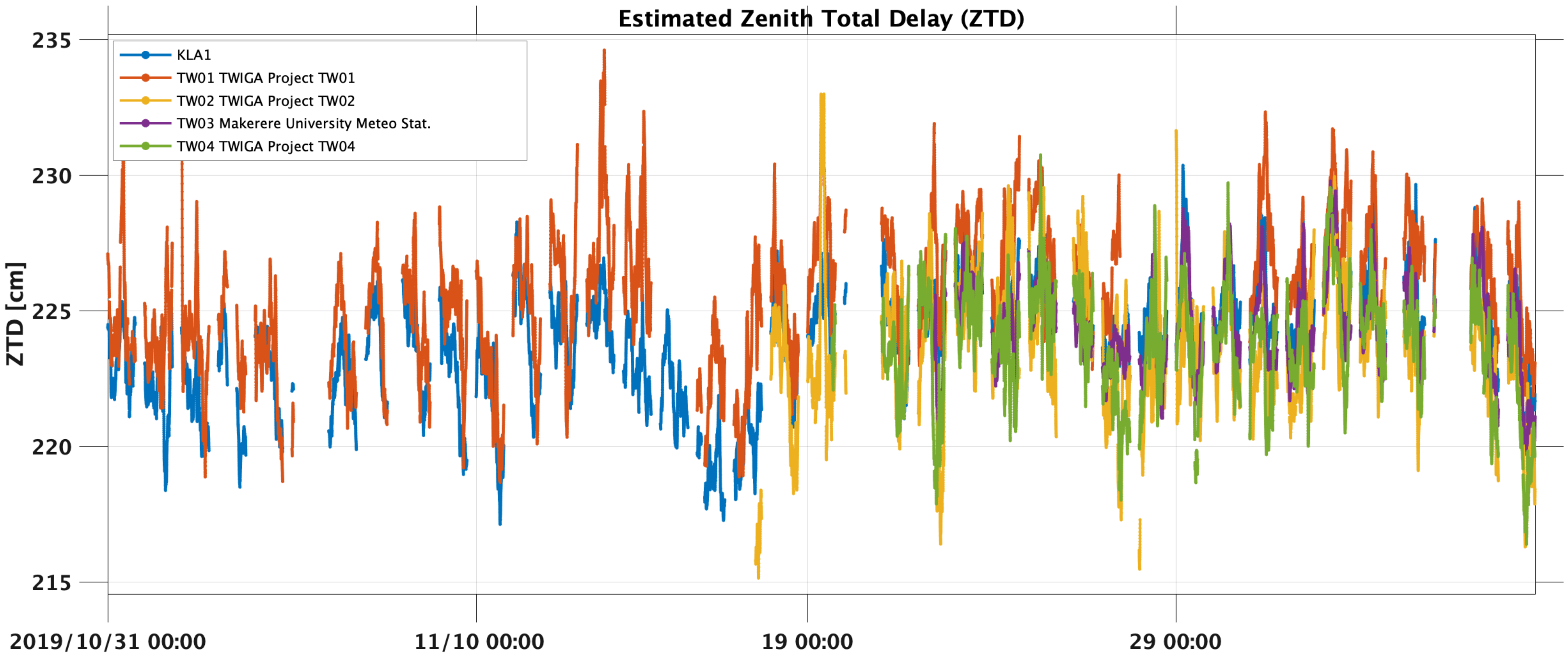
Its latest beta version (gogps-project.github.io) is loosely based on older releases [1] (Herrera et al. 2016) and implements a PPP positioning strategy by a batch least-squares solution.

The ionospheric component of the atmospheric delay is locally estimated by exploiting the available dual frequency geodetic stations and a modified implementation of the SEID Approach [2] (Deng et al. 2009).

The Kenya GNSS stations will allow for iono-free combinations of the dual frequency observations thus avoiding this correction.

TWIGA GNSS data processing

The following picture shows an example of GNSS ZTD time series derived from the observations collected by 4 low-cost receivers of Uganda network and by the geodetic receiver used for ionospheric correction.
The estimated ZTDs refers to last November 2019.

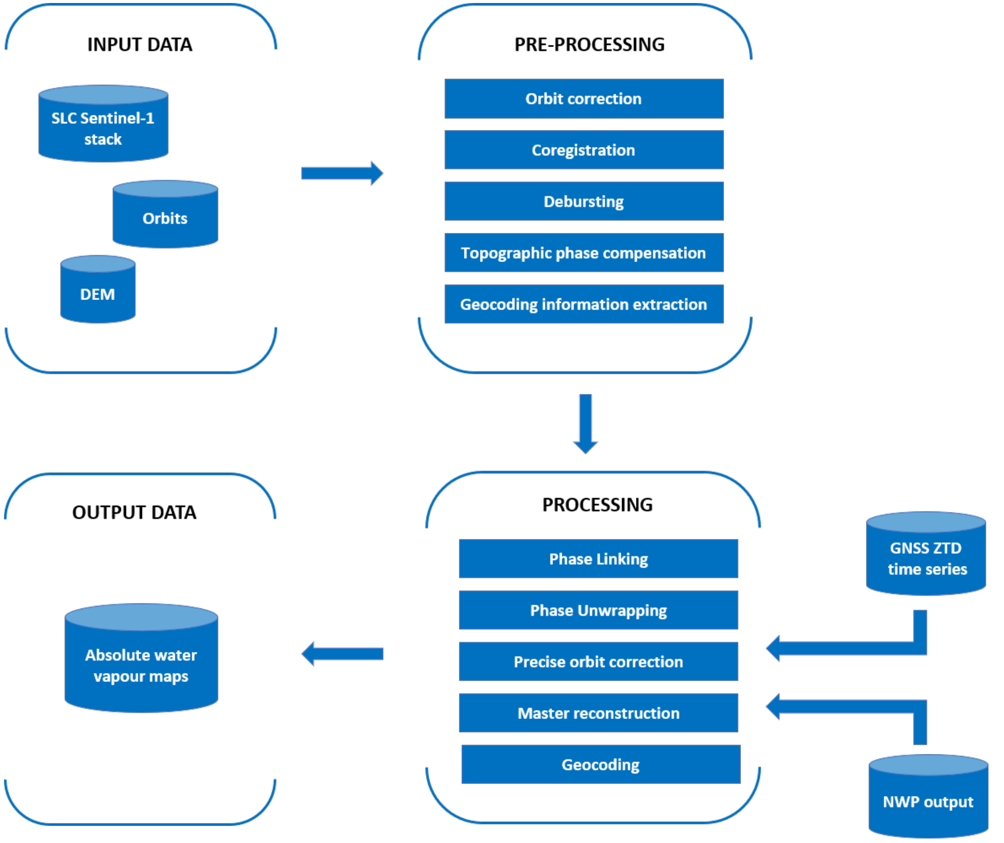


TWIGA GNSS water vapor products for the use of meteorological partners

The GNSS water vapor time series are shared within the TWIGA partners through the HydroNET Platform.
A service delivering such data to meteorological agencies is under development to cope with TWIGA objectives.

TWIGA Sentinel SAR images for water vapor monitoring

The radar sensors on board of the ESA twin satellites Sentinel 1 A/B are able to scan the entire planet with a frequency of 3 days.
An effective and robust method to extract water vapour maps from those images by exploiting the GNSS and NWP model products was designed and implemented within TWIGA.

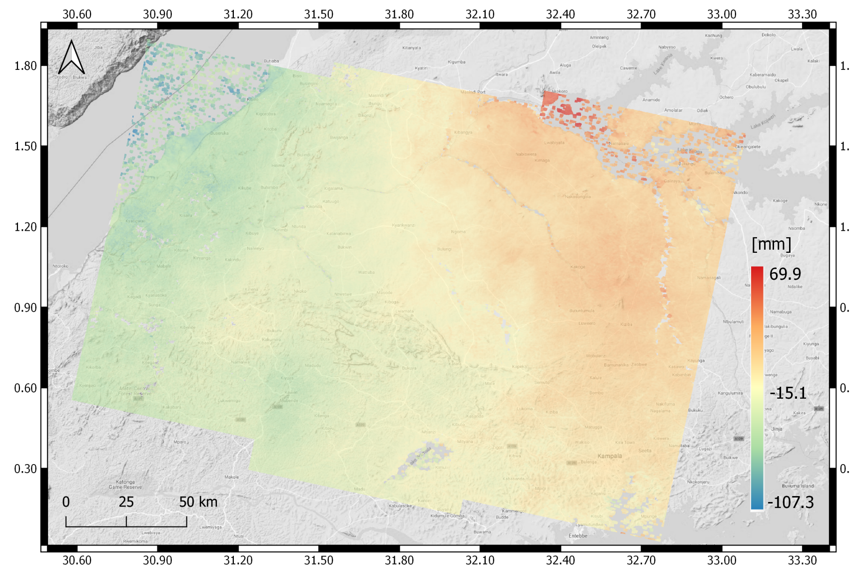


TWIGA Sentinel SAR images for water vapor monitoring

Given a set of Single Look Complex (SLC) images, the pre-processing tool outputs a stack of coregistered images without topographic phase contribution.

After that, the processing performs five steps:

- The phase linking method [3,4] efficiently extracts the differential (referred to an unknown master) water vapour maps by jointly processing the stack of pre-processed images.
- The phase unwrapping restores the physical spatial continuity of the maps.
- The precise orbital correction exploits the GNSS ZTD time series to remove the residual orbital errors affecting the maps.
- The master reconstruction exploits the outputs of NWP models to compute the (previously unknown) master, thus it produces the final absolute water vapour maps.



Differential water vapour map (11/17/2019 - 17/11/2019) in Uganda test site.

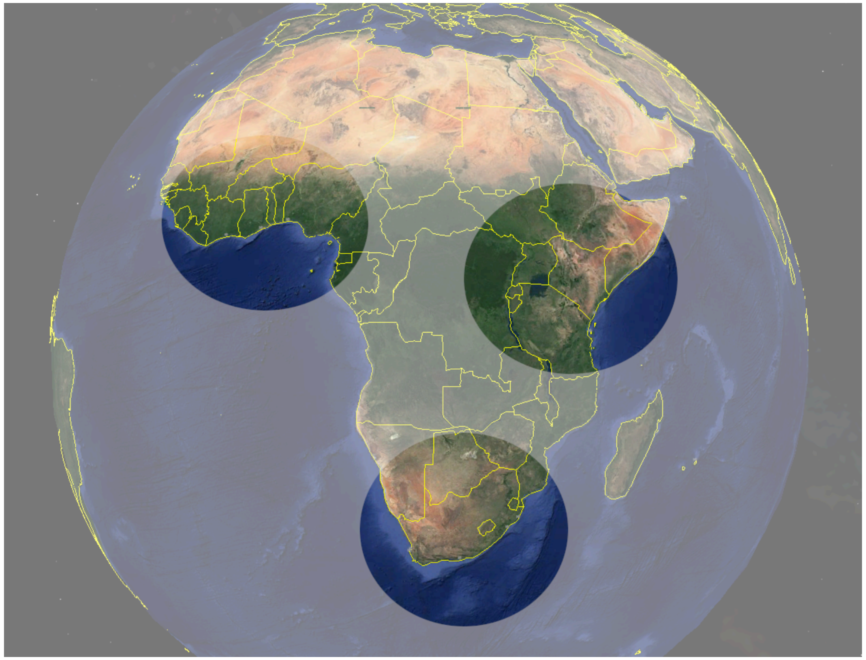
- The geocoding converts the maps from the SAR geometry into a map coordinate system.

NWP sensitivity tests in view of data assimilation experiments

The Weather Research and Forecasting ,WRFv4.0 model [5] has been selected to perform the assimilation experiments. Sensitivity tests on the setup of the model for the prediction of heavy rain events in tropical regions are needed to account for the specific weather dynamics of those areas.

Three case studies of 2018 have been simulated:

Ghana:
27-30 June



Kenya-Uganda:
19-23 May

South Africa:
21-24 March

Sensitivity to physical parameterizations

Each event has been simulated six times using three **planetary boundary layer schemes**:

- Yonsei University (PBL1)
- Mellor-Yamada-Janjic (PBL2)
- Asymmetric Convection Model 2 (PBL7)

and two **microphysical schemes**:

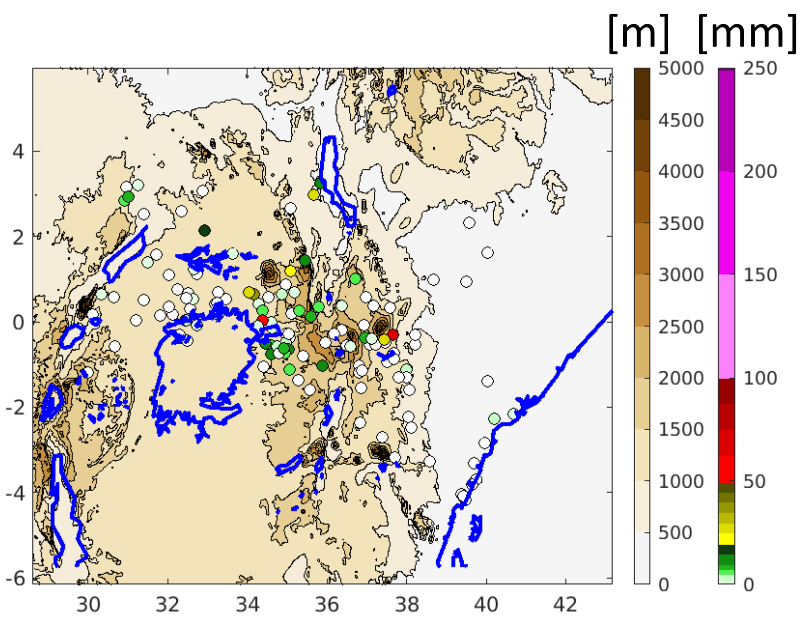
- WRF Single Moment 6 (MP6)
- Thompson (MP8)

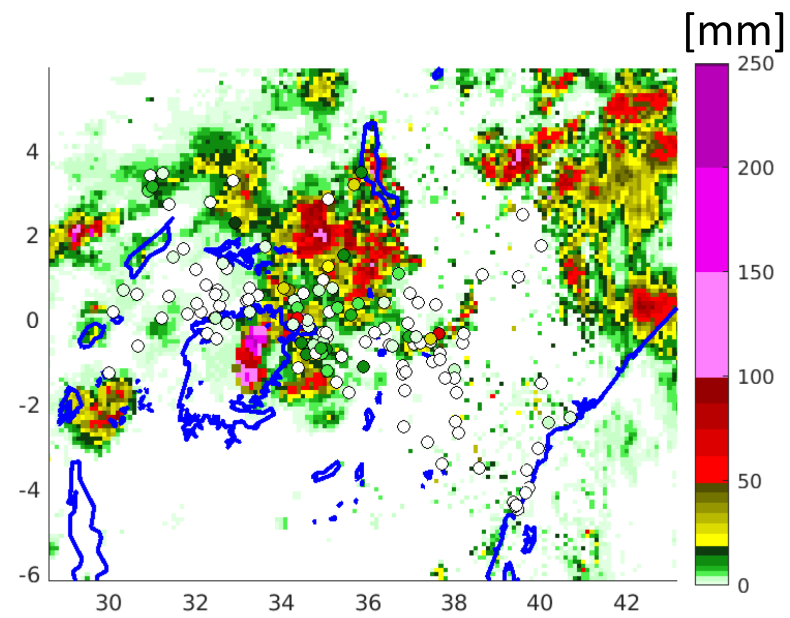
Results have been compared to the IMERG final product satellite rainfall estimate. This because, despite the recent increase of rain gauges coverage provided by the TAHMO network, the ground-based sensors density is still too low to capture convective events, that are typical of the tropical regions.

Example: a convective event

The Kenya-Uganda case under consideration (21 May 2018) has been a convective case, very likely triggered by the presence of orographic features along the border between the two countries (brown shading, left panel).

The circles denote the cumulated rainfall between 18-24 UTC of the 21 May 2018 measured by the TAHMO rain gauges, and the color shading on the right is the IMERG estimate. IMERG overestimates the TAHMO observations, but there is a qualitative agreement between the two.

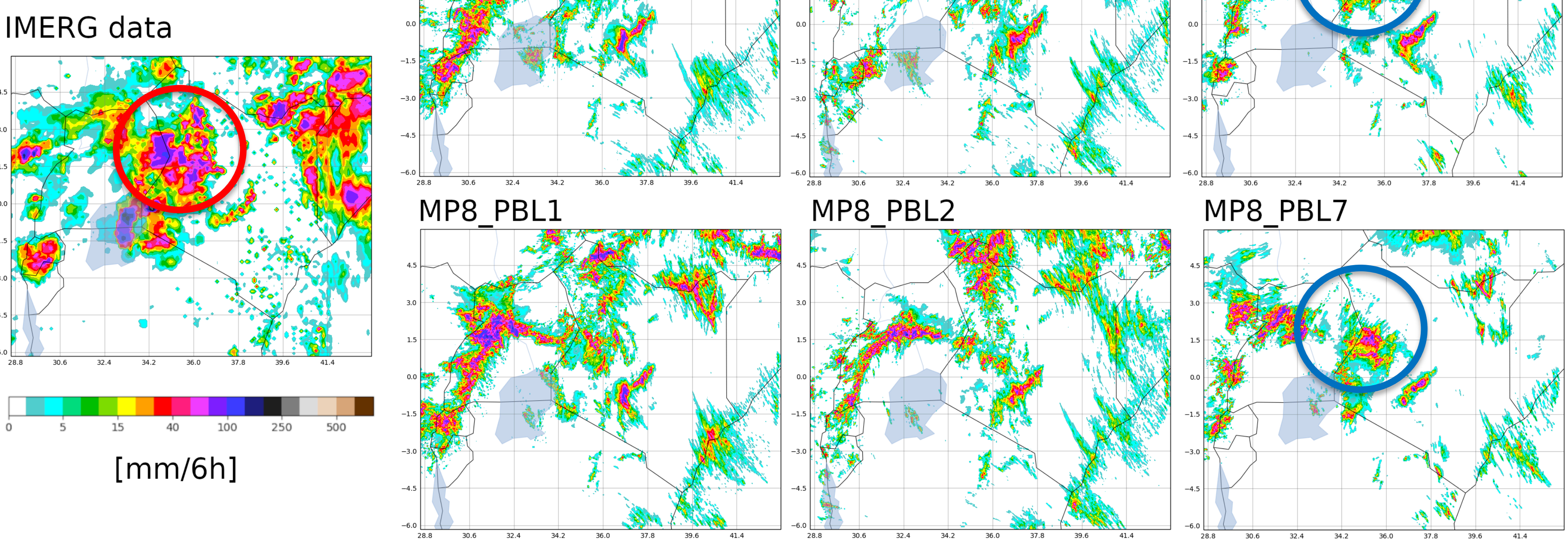




Kenya-Uganda case study

The convective rainfall under study (red circle in the left panel) can only be simulated when using the PBL7 (Asymmetric Convective Model 2, blue circles in the right-most panels). The simulations underestimate the IMERG rainfall estimate, but the satellite overestimate the rain gauges.

Cumulated rainfall between 18-24UTC 21 May 2018



Best performing setup

Comparing the model performances to the IMERG data, the configuration with PBL7 (Asymmetric Convective Model 2) and MP8 (Thompson) appears to be the most accurate. This does not mean that the model always describes the rainfall field in details.

However, since satellite estimates are known to have limitations due to their retrieval algorithm, before performing data assimilation experiments, which are very computationally expensive, a validation with respect to another satellite estimate such as GSMaP, is envisaged.

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