Analysis of three satellite-based precipitation products over Eastern Africa and Southern Africa

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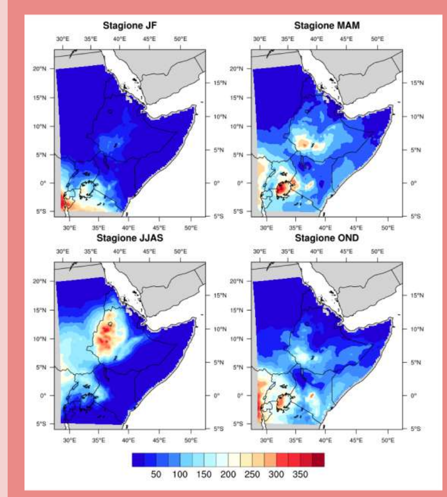
Introduction

During the last decades, East Africa (EA) and Southern Africa (SA) have experienced an intensification of hydrological hazards, such as floods and droughts which have affected drammatically the population. Keeping historic data records and constantly updating the datasets have become fundamental in precipitation and hazard monitoring. The development of satellite-based precipitation products can counterbalance the scarcity of rain-gauge networks in these areas. In this work, a new method of investigation is developed: satellite-based datasets are used in direct inter-product comparisons, avoiding the traditional rain-gauge validation. Principal aim of this study is to provide a method to analyze similarities and differences based on time and location constraints of a specific dataset.

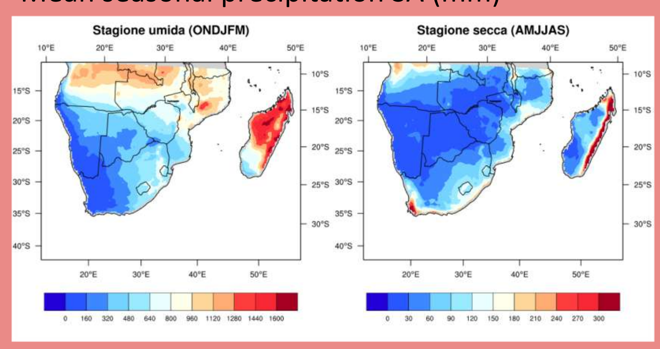
Study area



Mean seasonal precipitation EA (mm)

EA. Complex topography affects the climate of the region. Precipitation seasonality varies in space: mono or bimodal precipitation seasonality.

Mean seasonal precipitation SA (mm)



SA. Southwesterly gradient in rainfall. Monomodal precipitation seasonality.

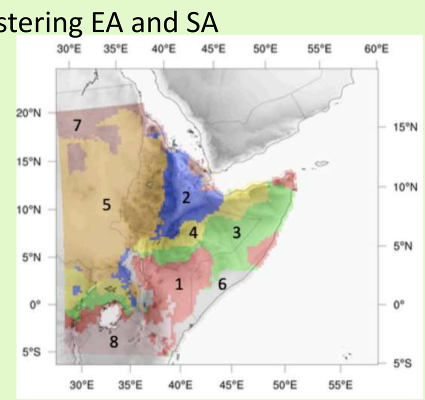
Satellite-based precipitation products

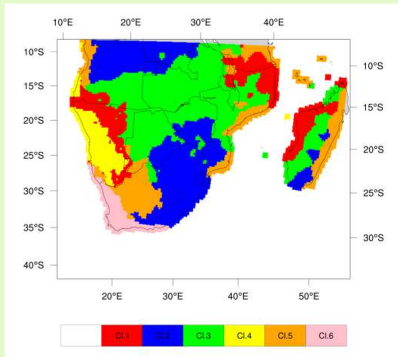
TAMSAT v3 is a cloud-indexing daily rainfall dataset based on high-resolution thermal infrared (TIR) observations calibrated using historical rain-gauge estimates.
CHIRPS is a daily cloud-indexing TIR-based and high spatial resolved product. It is calibrated with passive microwave (PMW) observations and bias-corrected with rain-gauge data.
MSWEP v2 is a relatively new global rainfall-product that merges PMW observations, rain-gauge and re-analysis data.

Method

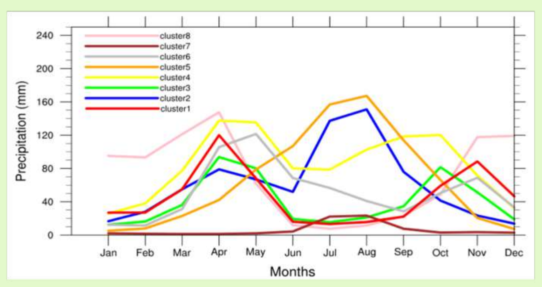
Cluster analysis. This method is used to divide the territory depending on its rainfall annual cycle. A k-means clustering algorithm has been applied firstly to the Global Precipitation Climatology Centre (GPCC) station-based gridded dataset then to the satellite-based products.

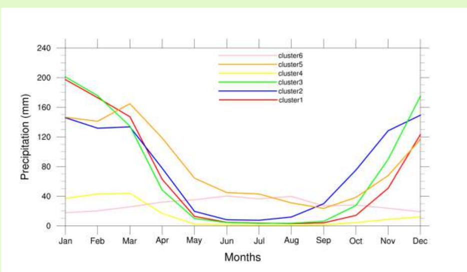
Clustering EA and SA



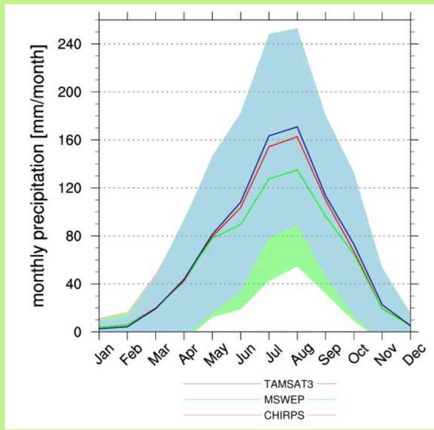


GPCC_Clim mean annual precipitation cycle for EA and SA clusters



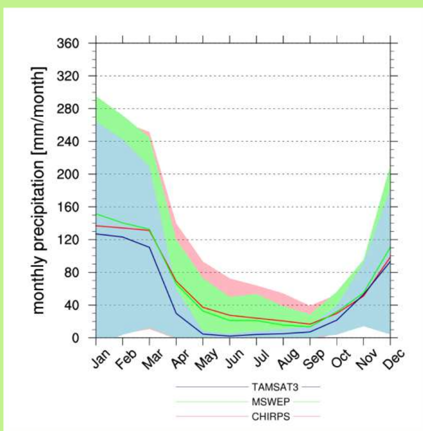


First evidence: the different products behave differently in the two regions.



EA: CHIRPS (red) and TAMSAT3 (blue) show similar performances; MSWEP (green) tends to underestimate the amount of precipitation.
(e.g. cluster 5)

Annual precipitation cycle (±σ)



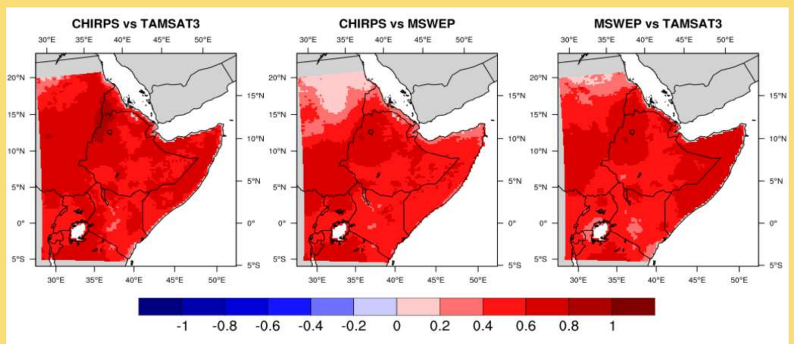
SA: MSWEP and CHIRPS are the most comparable datasets; TAMSAT3 underestimates both the amount of precipitation and the number of rainfall events.
(e.g. cluster 5)

Categorical statistics. The aim of this method is to assess the capabilities of a dataset to discriminate rain from no-rain events compared to another satellite product chosen as reference. A contingency table is built with a rainfall threshold of 1 mm and used to calculate categorical indices: Probability Of Detection (POD), False Alarm Ratio (FAR), Hanssen-Kuipers discriminant (HK) and Bias Score (BIAS).

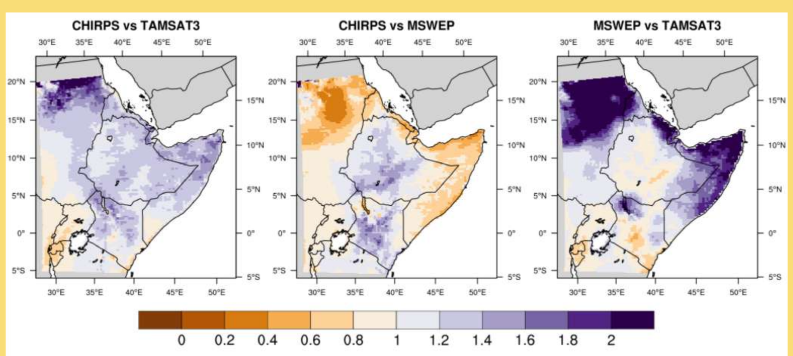
Pairwise comparison statistics. It is used to evaluate the performance of a satellite-based product in estimating the amount of rainfall compared to the others. The comparison is done at different temporal scales (daily, monthly and seasonally) calculating different parameters: Mean Error (ME), Mean Absolute Error (MAE) and Pearson correlation coefficient (CC).

Results

Desert regions. E.g. Sudan desert

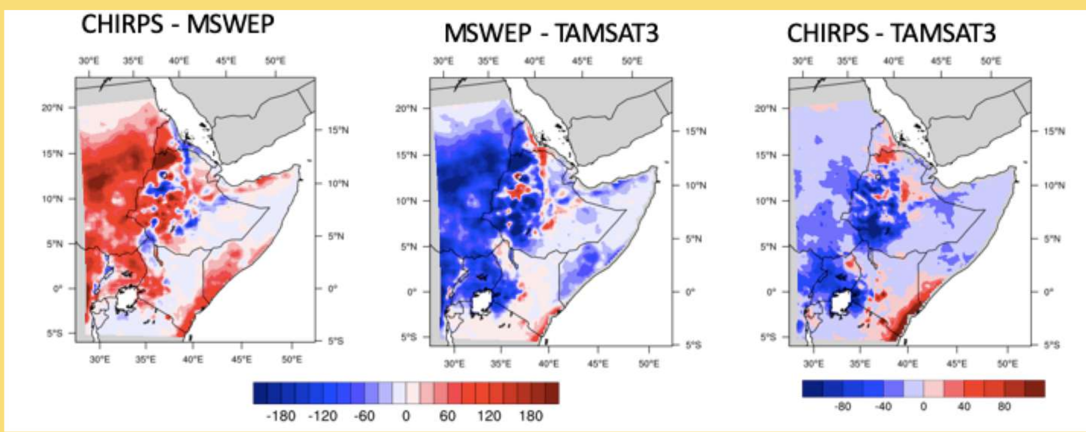


HK index (high) and POD index (low) over EA



- MSWEP understimates rain events;
- CHIRPS, TAMSAT3 show better agreement even if they could overestimate rainfall amount owing to sub-cloud evaporation.

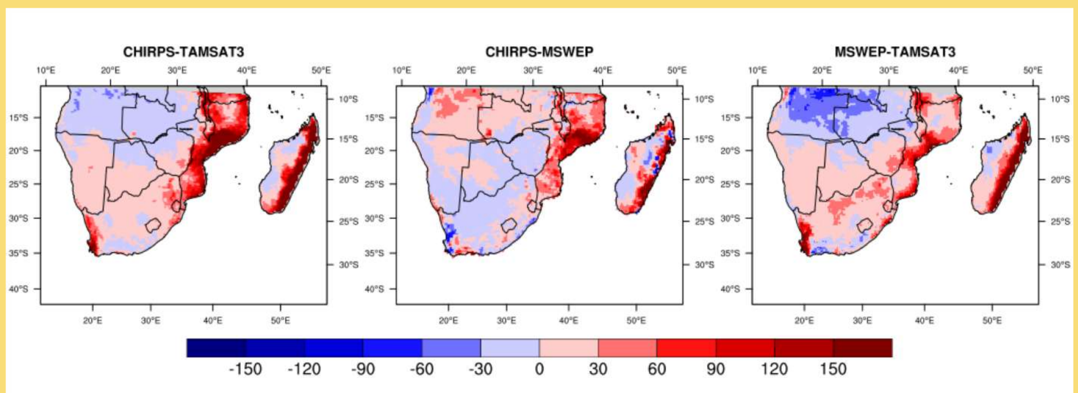
Mountain regions. Ethiopian Highlands



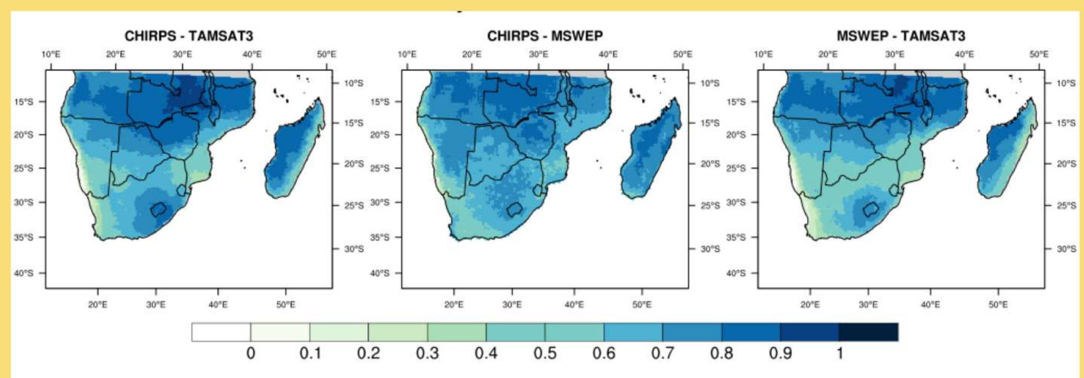
ME [mm/season] for season JJAS over EA

TIR-based satellite products (CHIRPS and TAMSAT3) underestimate rainfall over mountainous regions → frequently they can't identify warm orographic rain

Costal regions. Madagascar and Mozambique

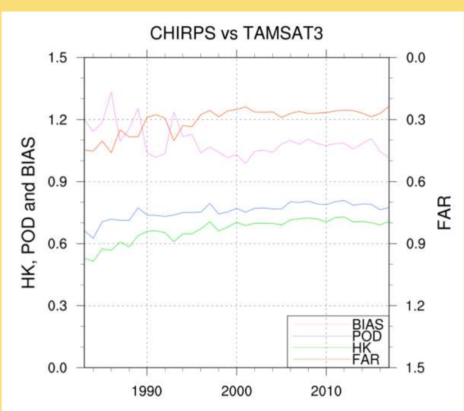


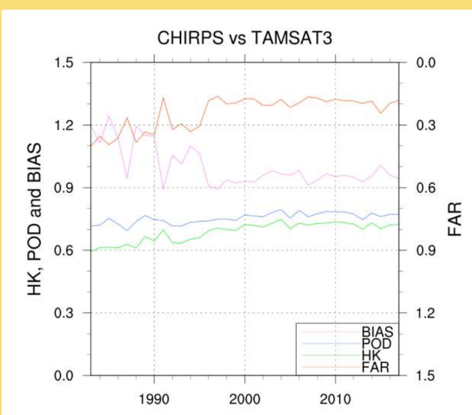
ME [mm/season] for dry season (above) and POD index (below) over SA



Where precipitation is influenced by frontal systems or extra-tropical cyclones, TIR- based products (CHIRPS and TAMSAT3) perform worse due to their reliance upon the observation of CCD.

Categorical index stability





Categorical index stability for EA (left) and SA (right)

TAMSAT3 shows the tendency to "improve" since the mid-1990 → decrease in missing data in the TIR from METEOSAT satellites.

Conclusions

- **EA:** TAMSAT3 and CHIRPS datasets show better agreement;
  SA: CHIRPS and MSWEP show greater similarities;
- The most **complex regions** for satellite products are mountainous, desert and coastal regions;
- The precipitation detection characteristics essentially depend on the **precipitation formation mechanisms**: orographic clouds and frontal systems represent a major challenge for TIR or PMW-based products.