Terrestrial Water Storage Trends in Africa from Satellite Gravimetry

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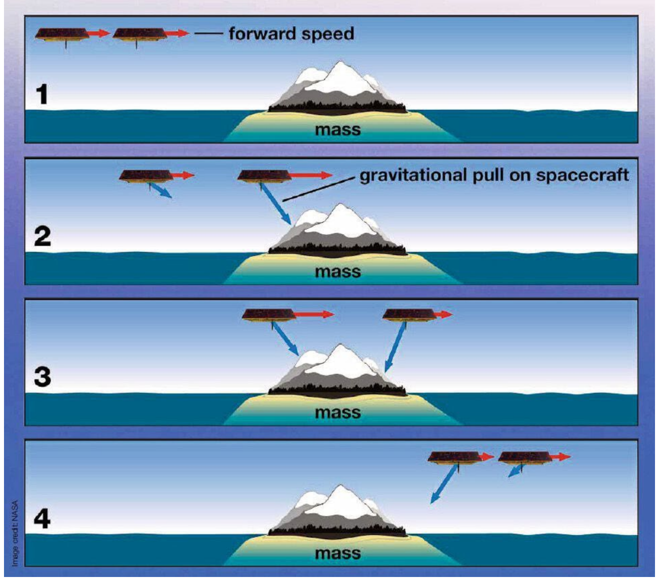
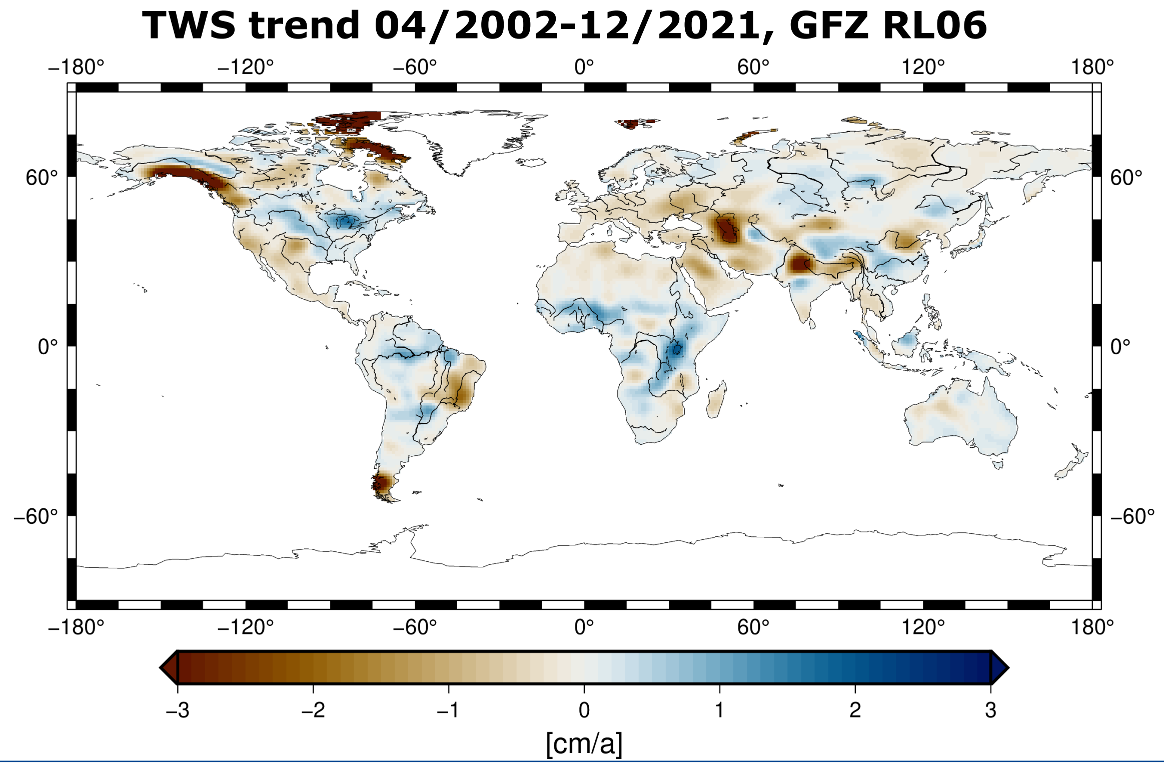
TWS with GRACE und GRACE-FO



- Gravity Recovery and Climate Experiment (GRACE, 2002-2017) and GRACE-Follow-On (GRACE-FO, since 2018) observe the temporal and spatial variations of the Earth's gravity field.
- From these variations we can deduce water mass variations on the continents.
- Terrestrial Water Storage (TWS) comprises all compartments of the hydrological cycle (ground water, surface water, soil moisture, snow, and ice)

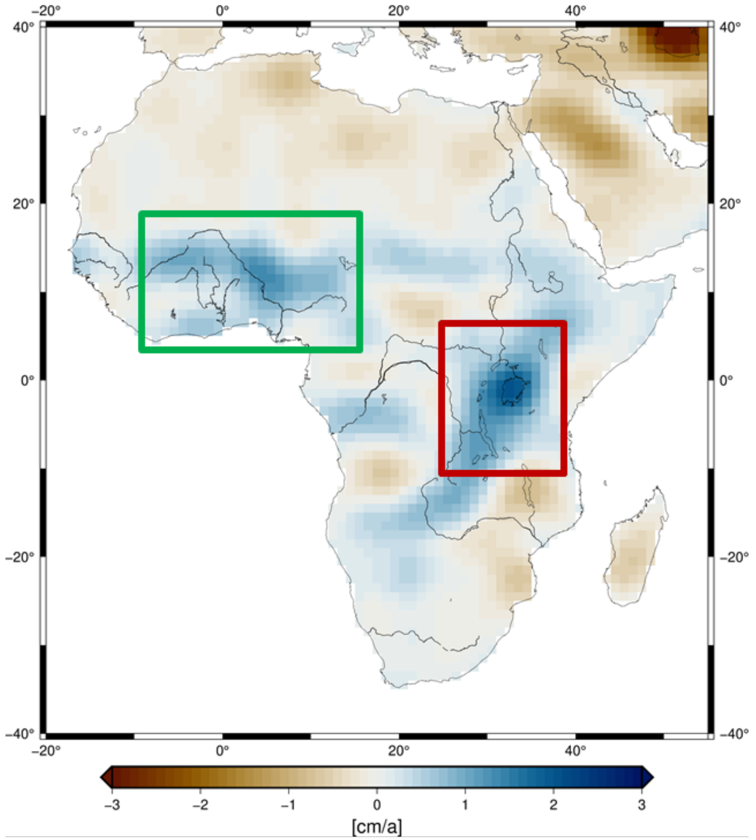
Global Terrestrial Water Storage Trends



- Only with the GRACE and GRACE-FO satellite mission, changes in terrestrial water storage (TWS) and emerging trends can be observed

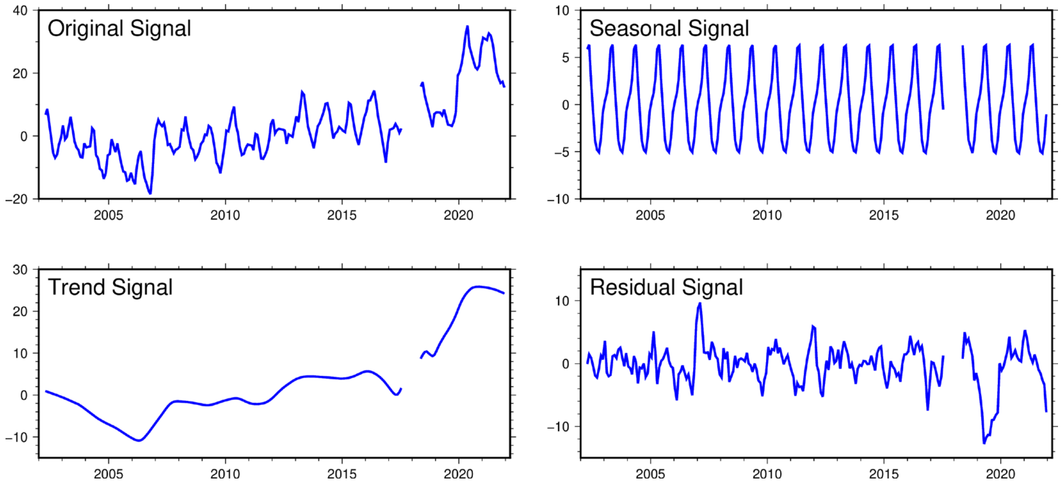
- Africa is the only continent with a net TWS increase over the GRACE/-FO period

TWS trend 04/2002-12/2021, GFZ RL06



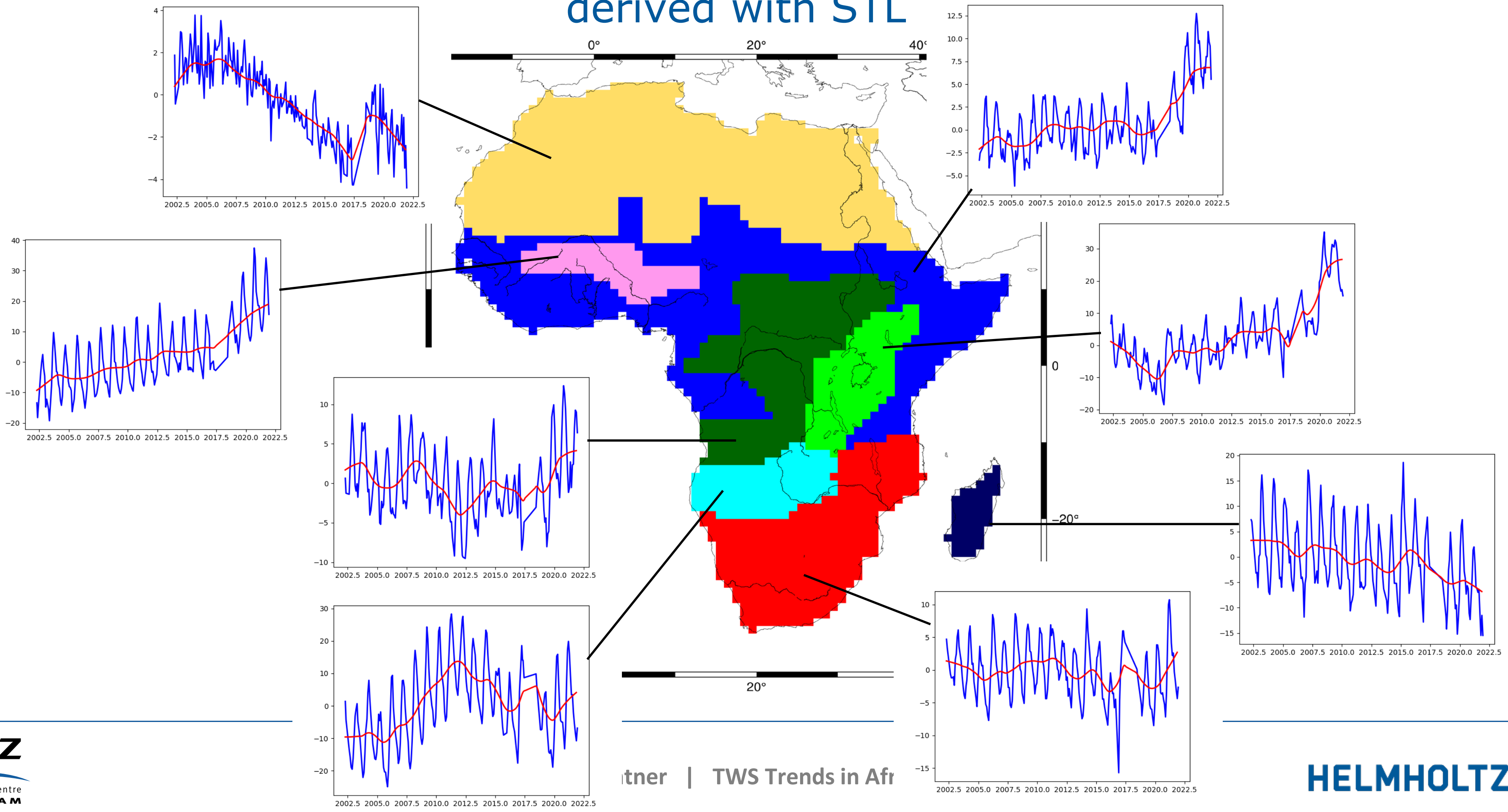
- TWS increase in the GRACE/-FO period in large parts of Africa
- Two hotspots:
  - Niger basin
  - East-African Rift region

TWS Time Series Analysis with STL

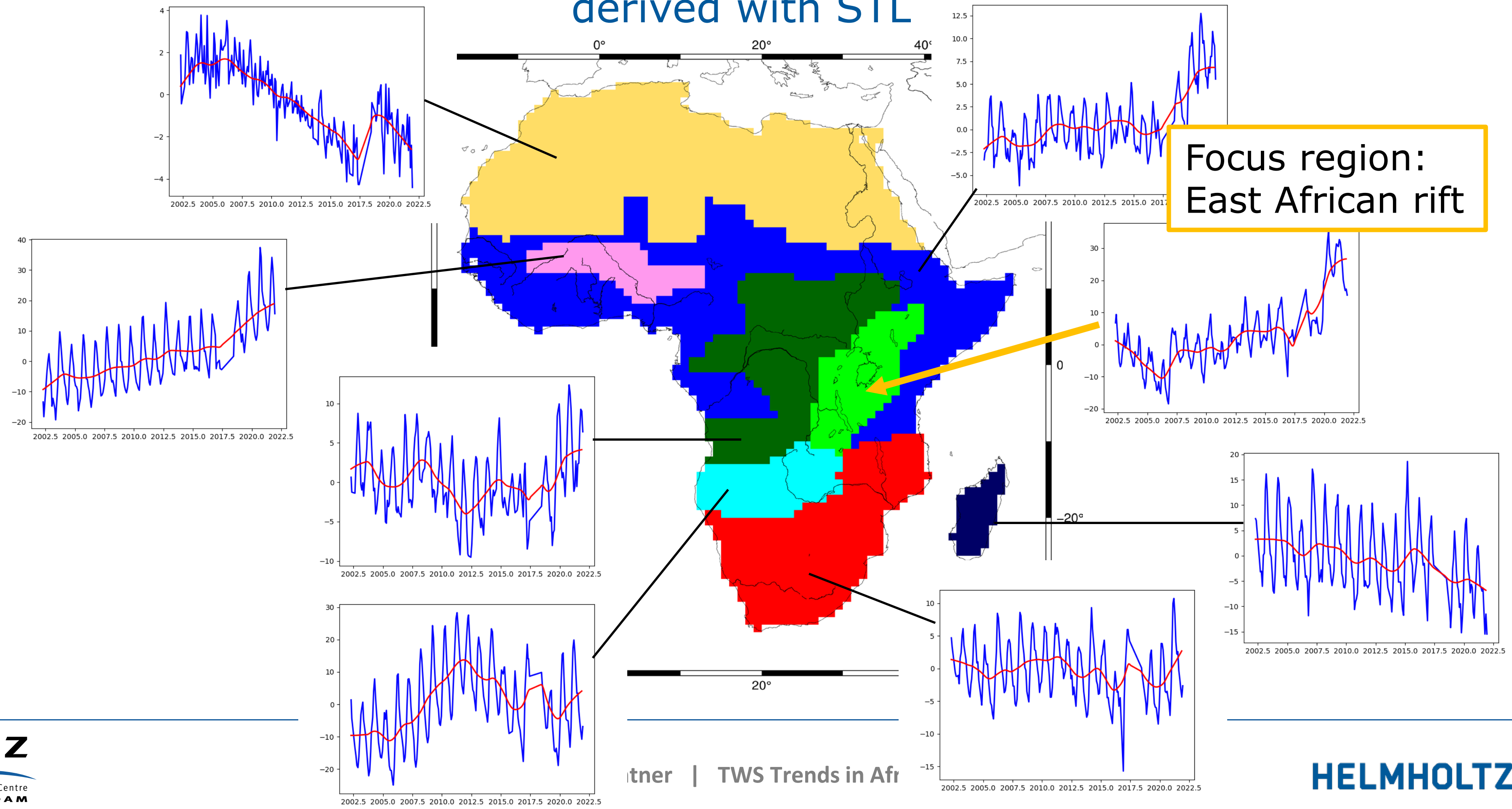


- Signal decomposition in annual/semi-annual periodic and linear trend is insufficient
- Seasonal-Trend Decomposition based on Loess (STL) is a non-deterministic method
- **Trend component also includes interannual signal variations**

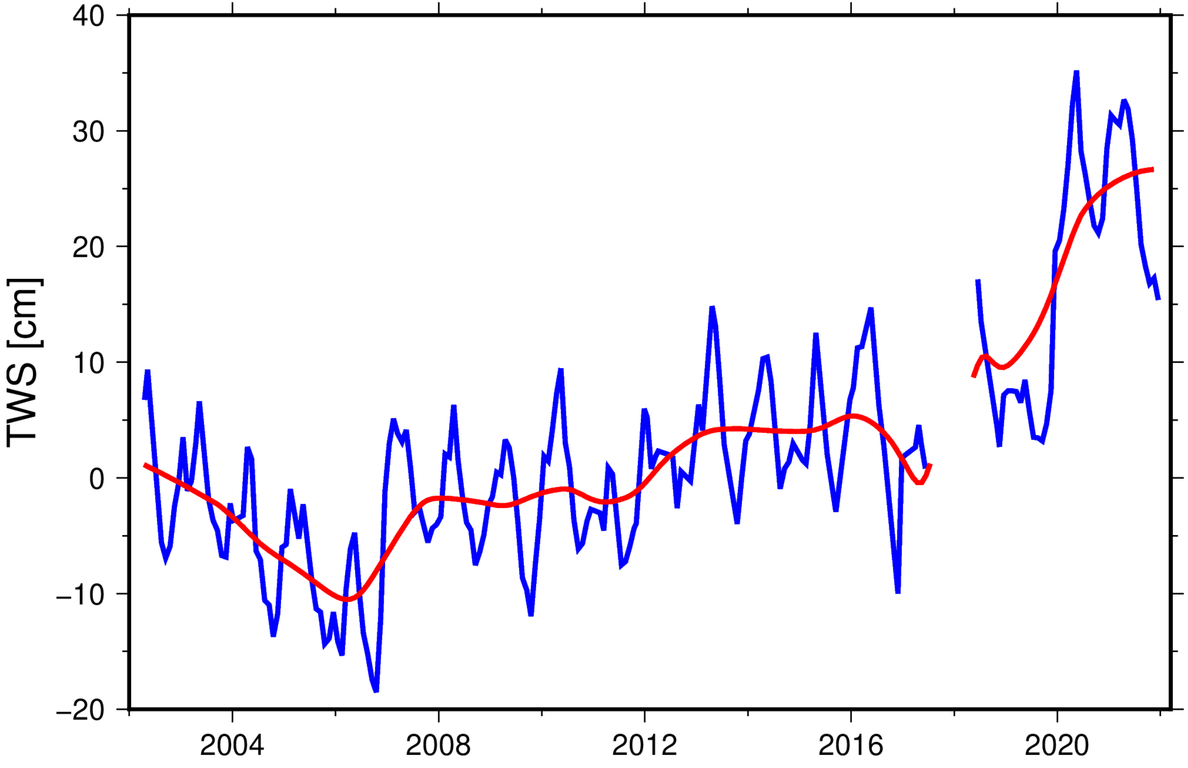
Clusters of interannual trend dynamics of TWS (2002-2021) derived with STL



Clusters of interannual trend dynamics of TWS (2002-2021) derived with STL



TWS in the East-African Rift Region

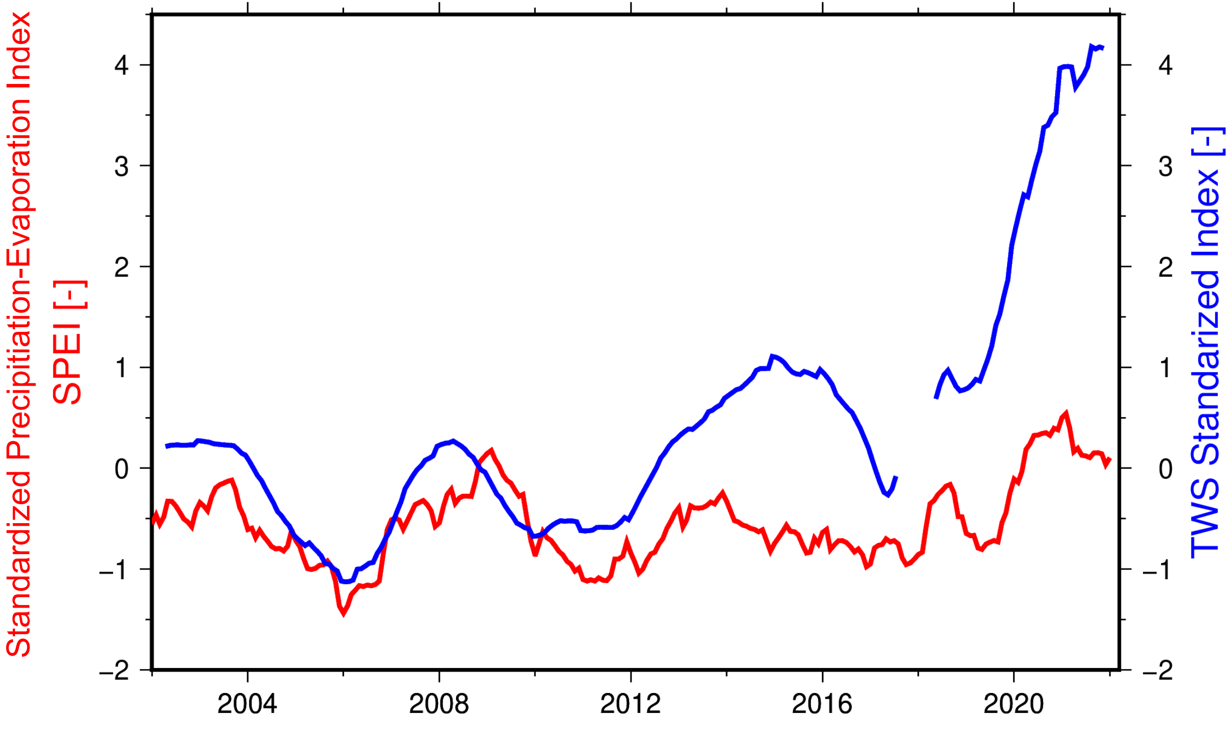


Origin of water storage variations

- Natural variability should be similarly seen in meteorological data

  → comparison between TWS and Standardized Precipitation Evaporation Index (SPEI)

SPEI versus TWS Standardized Index



TWS is transformed in Standarized Index with:

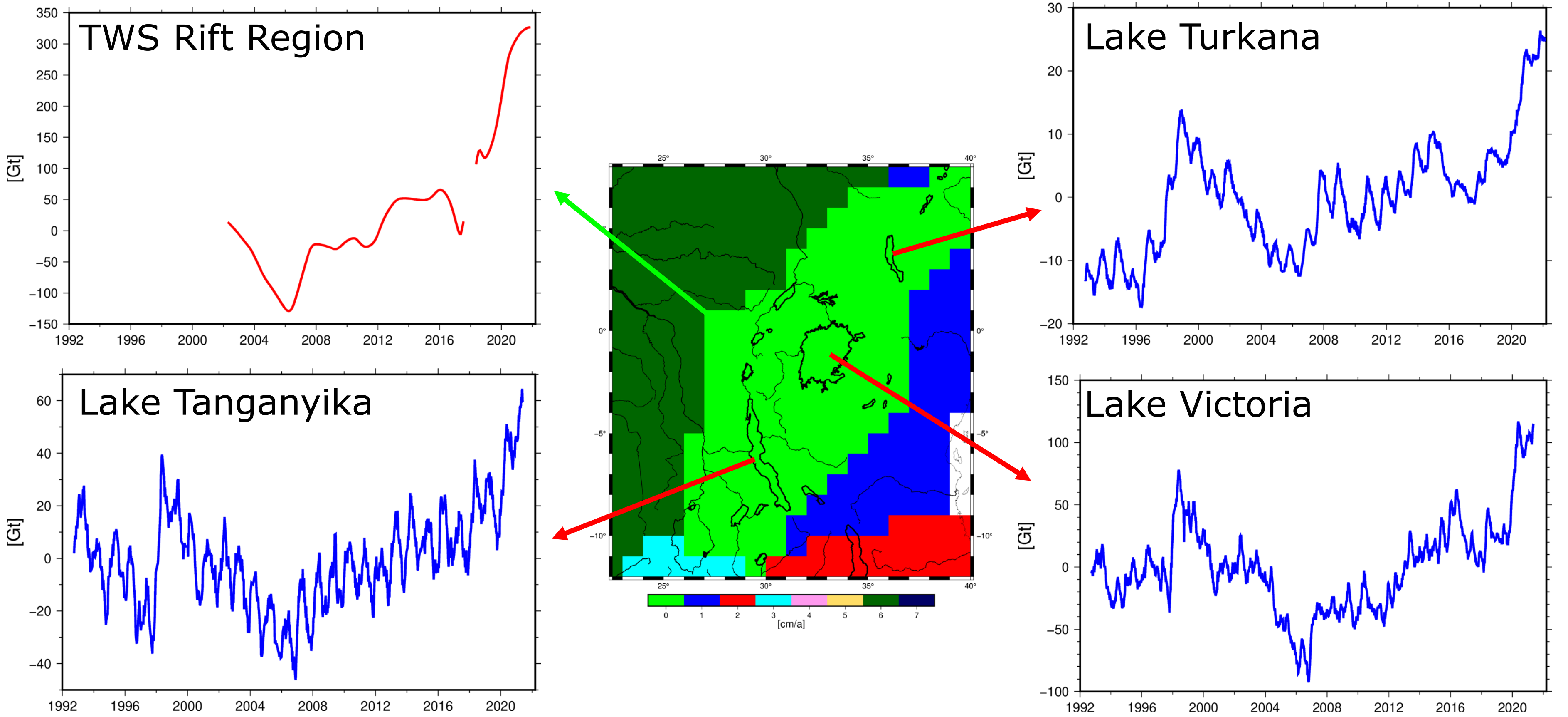
$$TWS_{i,j}\ SI = \frac{TWS_{i,j} - \mu_i}{\sigma_i} \quad ,$$

μ_i, σ_i, mean and standard deviation of month i

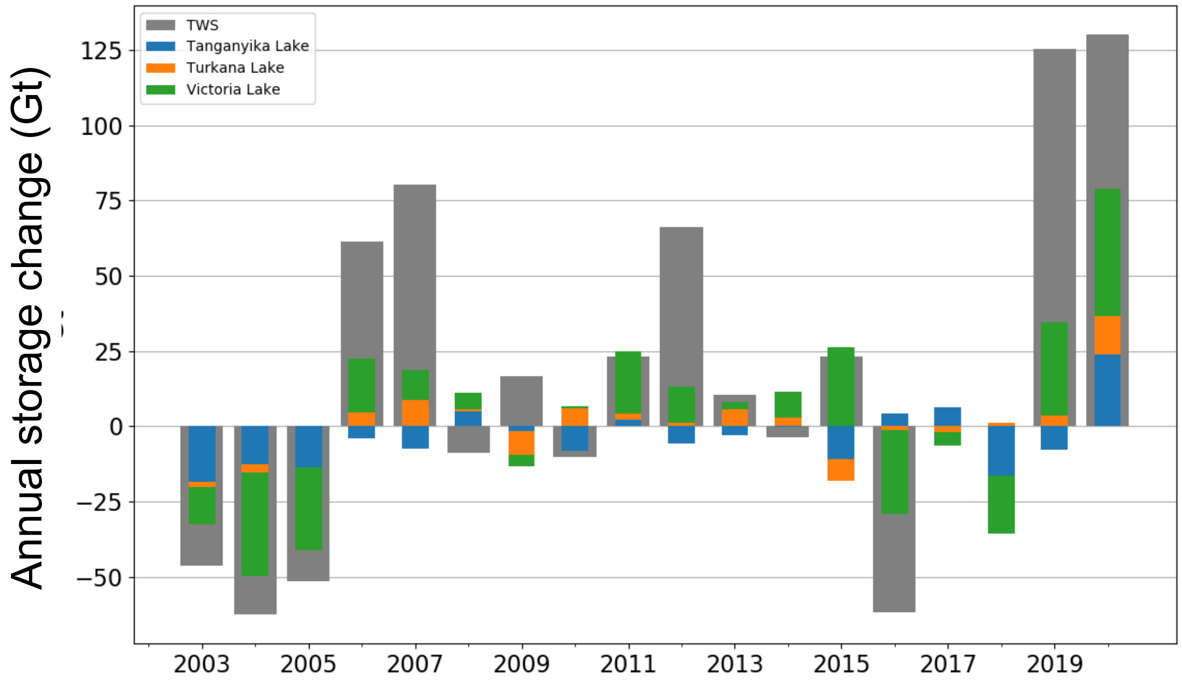
Origin of water storage variations

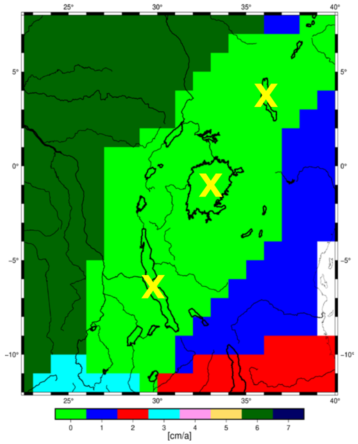
- Variation of precipitation and evaporation alone are not sufficient to explain the TWS variations
- The rift region is dominated by some of the largest lakes in the world
  → How do they vary in the study period?
- Water storage variations of the lakes can be inferred from water level variations based on satellite altimetry in combination with lake surface area (here taken as constant)

TWS and lake storage variations in the rift region



Contribution of Lake Storage to TWS change in the rift region





The three largest lakes in the region explain a large fraction of TWS changes in most years

(no GRACE/GRACE-FO TWS in 2017 and 2018)

Conclusions

- East African Rift region experienced a natural drying (until 2006) and wetting (since 2006) event in the GRACE/GRACE-FO period
- Variations in precipitation and evaporation alone are not sufficient to explain large TWS variations
- Storage in lakes largely contributes to the observed TWS variations
- Further research on the influence of the man-made regulation of Lake Victoria outflow and water level

Thank you for your attention

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