Recent changes in the water balance components of the Nile basin

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Overview

One of the most critical components of the water cycle is terrestrial water storage (TWS), which is considered an essential climate Variable (ECV). Understanding trends and seasonal shifts in TWS provides valuable insights into understanding changes in water cycle fluxes, including river discharge, precipitation, and evapotranspiration. This study focuses on analyzing water balance equation components within the Nile basin to unravel the hydrological variabilities in this region using data from GLOFAS, GRACE and GRACE-FO.

Nile region

The goal of the study is to analyze TWS within the Nile basin to unravel the hydrological variabilities, such as floods and droughts.

This region experiences severe droughts, and human actions have threatened water resources due to the increased population.

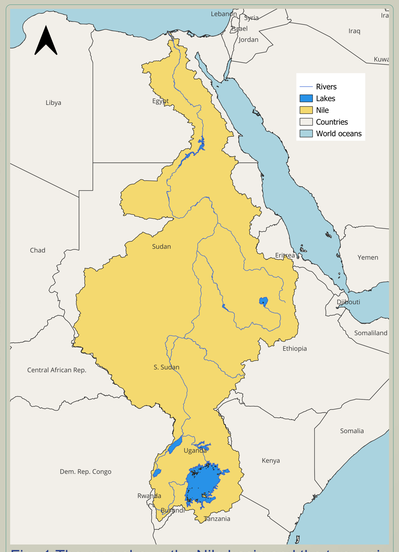

Fig. 1 The map shows the Nile basin and the two main tributaries of the Nile: the Blue Nile and the White Nile. In this research, the water balance components in the Nile basin have been investigated.

Methodology

By obtaning the terrestrial watershed mass change rate, $\frac{dS}{dt}$ from GRACE and GRACE-FO (Fig .2), river discharge, R from GLOFAS, the net water flux, P - ET is calculated based on water balance equation:

$$\frac{dS}{dt} = P - ET - R$$

where P is precipitation and ET is evapotranspiration.

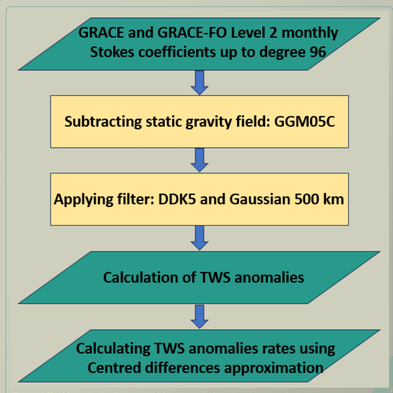

Fig. 2 Calculation of terrestrial water storage anomalies from GRACE and GRACE-FO.

Terrestrial water storage anomalies in the Nile basin

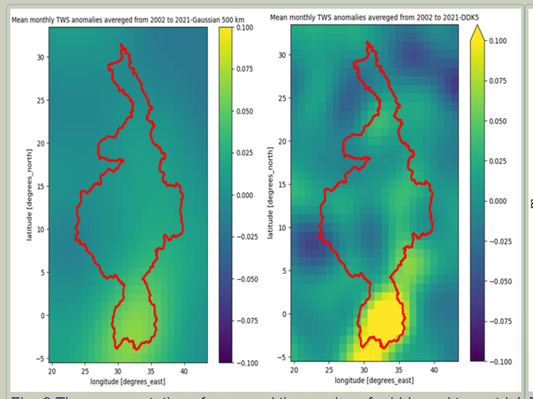

Fig. 3 The representation of averaged time series of grid-based terrestrial water storage anomalies from 2002 to 2021, showing a significant anomaly in the south of the basin (Lake Victoria).

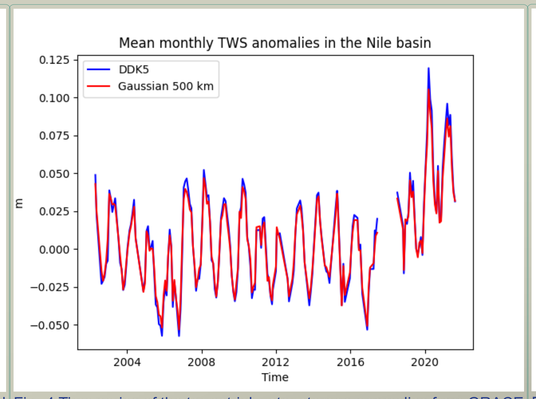

Fig. 4 Time series of the terrestrial water storage anomalies from GRACE and GRACE-FO during the period 2002–2020. A significant increase in water storage anomalies can be observed during the years 2019-2021.

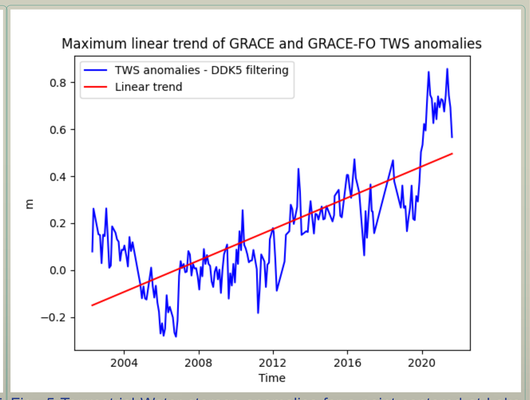

Fig. 5 Terrrestrial Water storage anomalies for a point centered at Lake Victoria. The water storage increased with a trend of 0.004 m per month and a total of 0.64 m from 2002 to 2021. Also, a remarkable positive trend can be seen in the GRACE-FO data during 2019-2021.

Based on the figures, the highest values of changes in obtained grided TWSA were centered on Lake Victoria. The TWSA trends were positive for approximately 66 percent of the area of the basin during 2002-2021, and the TWSA trend was the most at the [-1,33] location in Lake Victoria.

Water balance in the Nile basin

Fig .6 depicts the time derivatives of monthly TWSA estimates, dS/dt from Level-2 GRACE and GRACE-FO observations applying the DDK5 filter at the monthly scale for the Nile basin.

Using the water balance equation, R from GLOFAS river discharge data, and TWSA rates from GRACE and GRACE-FO (a DDK5 filter was applied), the P - ET was calculated at the basin scale, as shown in Fig . 7.

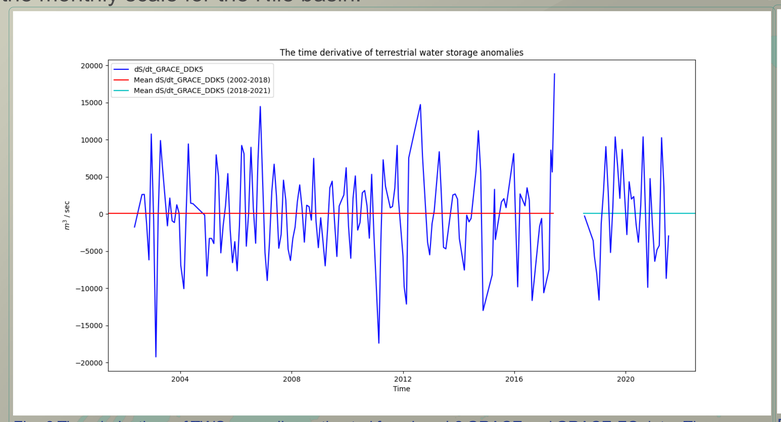

Fig. 6 Time derivatives of TWS anomalies estimated from Level-2 GRACE and GRACE-FO data. The average of the time series is 75.72 m^3/sec over 2002-2018 and is 124.17 m^3/sec over 2018-2021, respectively.

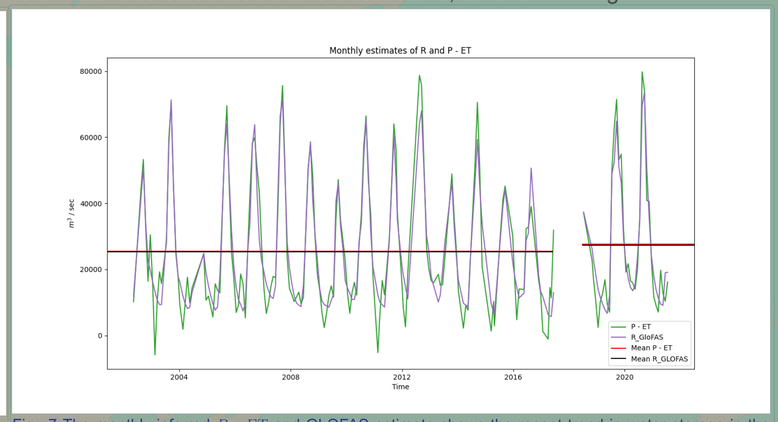

Fig. 7 The monthly inferred P - ET and GLOFAS estimate shows the recent trend in water storage in the Nile basin. The averages of the P - ET and R time series are 25376.12 m^3/sec and 25300.40 m^3/sec over 2002-2018 and 27390.15 m^3/sec and 27265.98 m^3/sec over 2018-2021, respectively.

Conclusion

The mean TWS anomaly rate from 2018-2021 is larger than the mean TWS anomaly rate from 2002-2018, about 48.47 m3/sec. This increase does not indicate the effect of the significant increase in storage changes from 2018 to 2021. It rather suggests that the GRACE and GRACE-FO derived Ds/dt is still quite noisy and needs smoothing operations, where the seasonal signal is removed.

The change in the recent mean P - ET and R are somewhat higher, which could hint at a higher water cycle throughput (i.e., with more P - ET, more R exiting is expected) in that time period and more water sticking in, e.g., Lake Victoria.

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