Reconstruction of the interannual terrestrial water storage of the Amazon Basin over the past decades from GRACE, altimetry data and in situ observations

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Introduction

Terrestrial water storage (TWS) composed of surface waters, soil moisture, groundwater and snow where appropriate, is a key element of global and continental water cycle. However, estimating TWS change is difficult because of scarce or even inexistent data on water storage. Since 2002, the Gravity Recovery and Climate Experiment (GRACE) space gravimetry mission provides a new tool to retrieve large-scale TWS variations. But the GRACE life time is still very short. Here we propose a novel approach that combines GRACE-based TWS spatial patterns with multi-decadal-long in situ river level records, to reconstruct past 2-dimensional TWS over a river basin. This method is based on the reduced space optimal interpolation described by Kaplan et al (2000). Results are presented for the Amazon Basin for the period 1980-2008. They are validated through a comparison with TWS from a global hydrological model and the correlation with known climate forcing modes over the region. This method offers great potential to improve knowledge of past TWS in many basins over the world where climate variability and change are the main drivers of TWS changes.

Scaling of in-situ EWH data and GRACE EWH field

Amazon river watershed with its main sub-basins

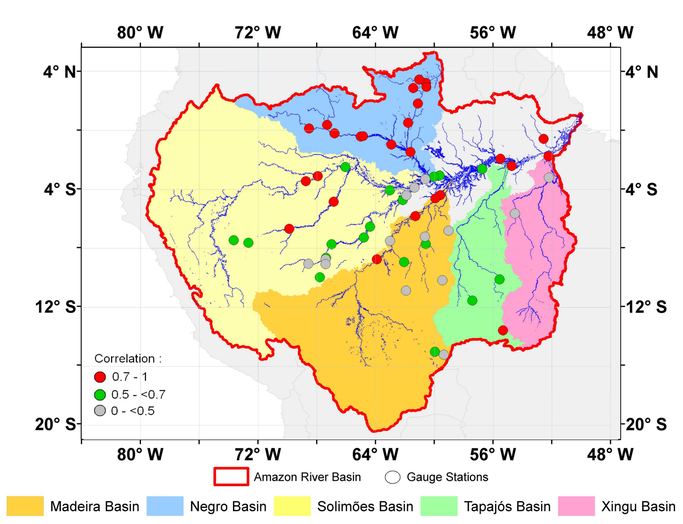


Figure. 1 : Amazon river watershed with its main sub-basins. The location of the 23 in situ river stages used in the reconstruction over 1980-2008 is indicated by red dots. The color of the dots corresponds to the correlation coefficient between TWS from GRACE data and in-situ level data over 2003-2008. In situ level data are from the Brazilian water agency ANA network.

Trend of TWS from GRACE data 2002-2008

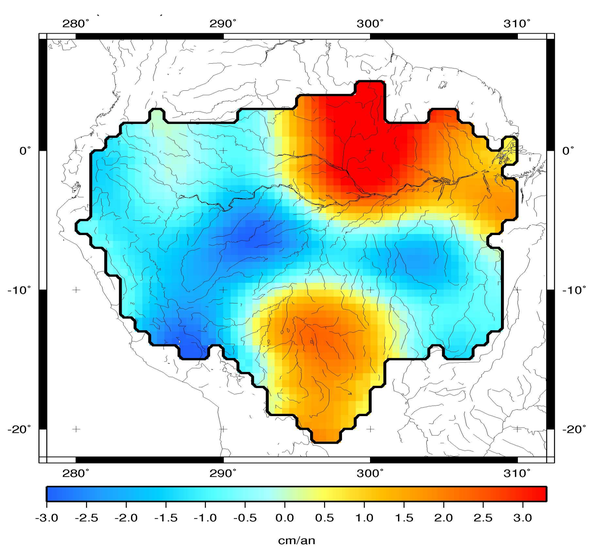


Figure. 2 : GRACE data used is 1°x1° equivalent water height (EWH) monthly grids (release 2) computed by the GRGS from 2002-2008.

Scaling EWH for in situ level stations

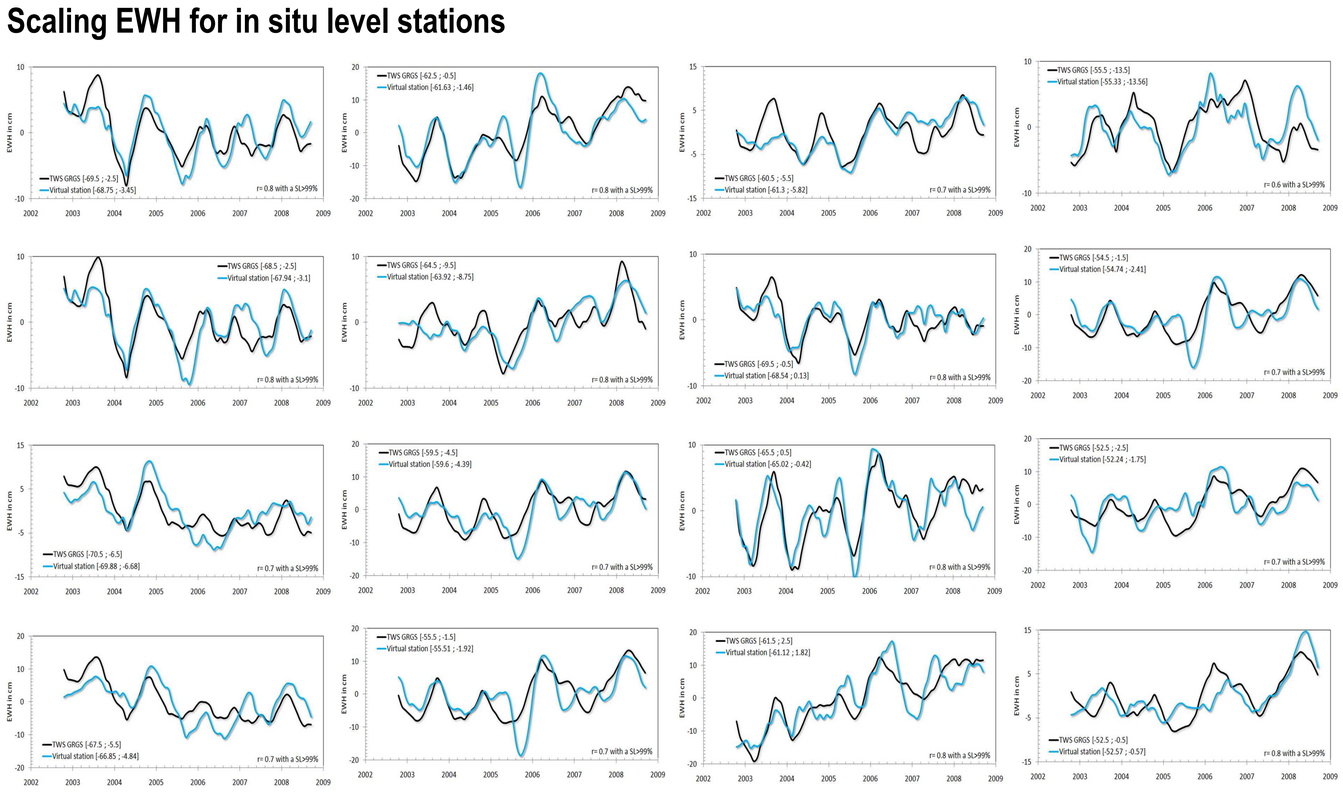


Figure. 3 : The figure shows the scaling result for some in situ station (see red dots on fig. 1 for locations). The TWS from GRACE over 2003-2008 period is plotted in black lines and the in situ river levels scaled in EWH over the same period are in blue lines. r is the correlation coefficient and SL its significance level.

Next step : TWSR of Congo Basin

from altimetry EWH data and GRACE TWS field

In a next step of our work, we will adapted this method to reconstruct the TWS over the Congo basin, where in situ data are lacking, over 1993-2010 from altimetry EWH from Topex/Poseidon and ENVISAT data and GRACE TWS filed.

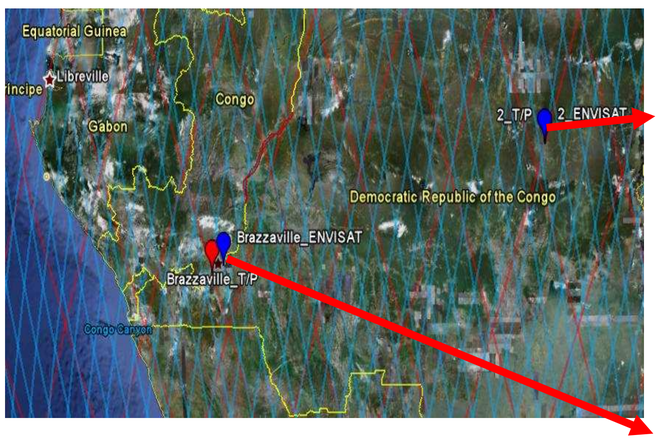
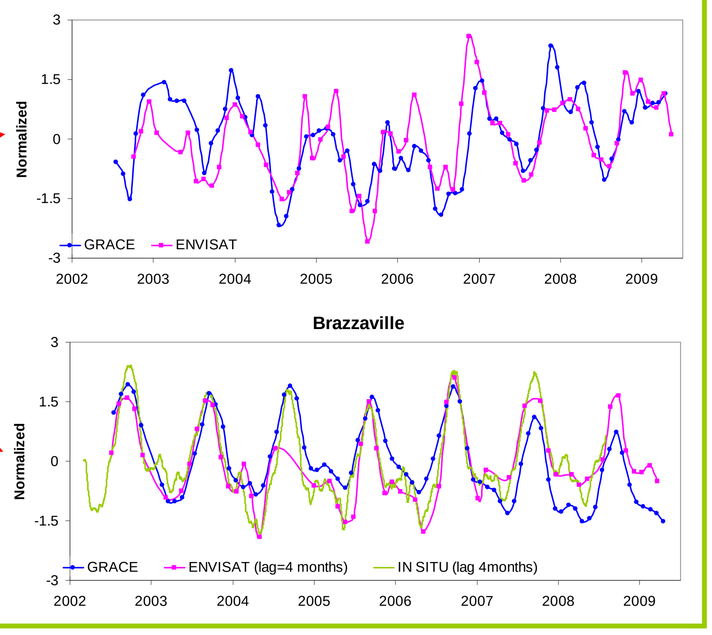


Figure. 3 : Congo basin
Topex/Poseidon tracks in blue, ENVISAT tracks in red.



TWS Reconstruction (TWSR) results

Basin-averaged of the TWSR from 1990-2008 and 1980-2008

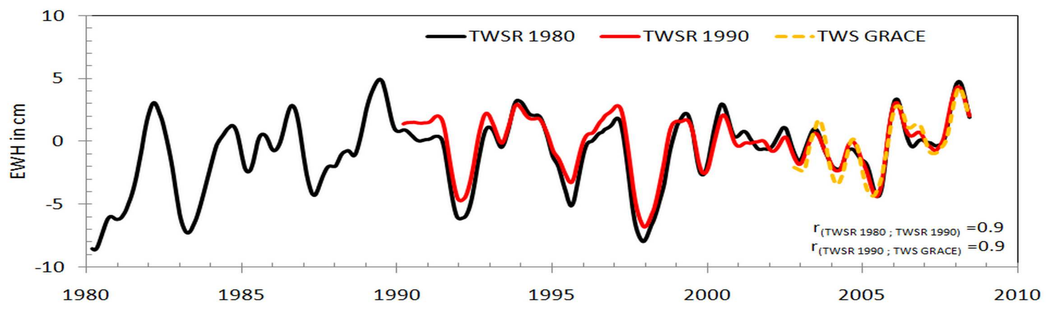


Figure. 4: The basin-averaged of the TWSR over 1980-2008 is the black line and in red line over 1990-2008 (from respectively 23 and 36 in situ gauges). In dot line the GRACE TWS over 2003-2008 (5-month running mean).

Basin-averaged of the TWSR comparison with ISBA-TRIP

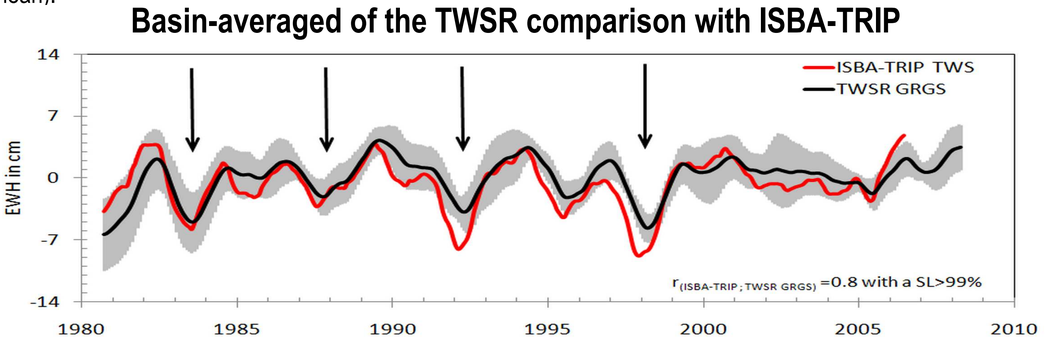


Figure. 5: The basin-averaged of the TWSR is in black line and its error bars are in grey. The error in TWSR computed here is the sum of the error due to the least square method and the error of the in situ records. ISBA-TRIP hydrological model is in red line. The El Niño events are represented by arrows.(12-month running mean)

EOF decomposition of TWSR

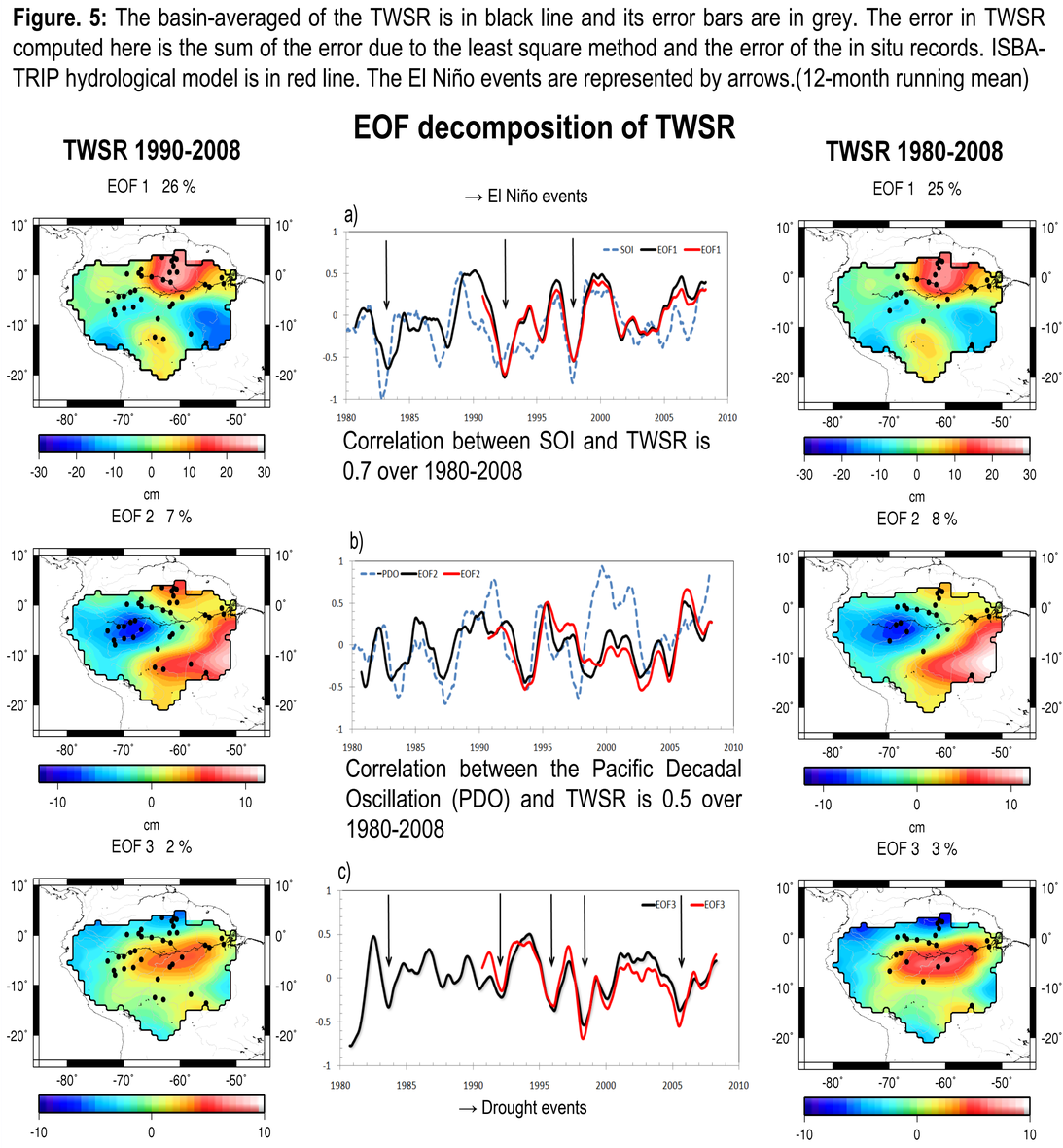


Figure. 6: The left panel shows the EOF analysis for the TWSR over 1990-2008. The locations of the 36 in situ stations used for the reconstruction are indicated by black dots. The right panel shows the EOF analysis for the TWSR over 1980-2008. The locations of the 23 in situ stations used for the reconstruction are indicated by black dots. The middle panel shows the EOFs' time series computed on the TWSR over 1990-2008 in red line and in black line over 1980-2008 (12-month running mean).

Conclusion

The present study has established for the first time direct, observation-based, estimate of TWS spatiotemporal variability over the Amazon basin. It is only based on TWS observations from GRACE and in situ water levels. The observed timing and regional distribution of the TWSR over the Amazonian basin during ~30 years shows no long-term trend and confirms the dominant influence of ENSO and PDO. In addition, recurrent drought events affecting the centre of the basin are also well reproduced. The approach developed in this study offers interesting perspective for improving our knowledge of past TWS in many river basins over the world where climate variability is the main driver of TWS change. However, it will be less easily applicable in river basins which have been strongly affected by anthropogenic forcing.

References

Kaplan, A., Kushnir, Y., Cane, M.A., 2000. Reduced space optimal interpolation of historical marine sea level pressure. *Journal of Climate* 13,2987-3002.

Llovel, W., Cazenave, A., Rogel, P., Lombard, A., Nguyen, M.B., 2009. Two dimensional reconstruction of past sea level (1950-2003) from tide gauge data and an ocean global circulation model, *Climate of the Past* 5,217-227.