Decrease in total water storage in the Magdalena River basin in recent years inferred from GRACE data

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1. Introduction

Groundwater is becoming increasingly important as a strategic water resource in many regions of the world, and particularly in Colombia where some regions are already facing surface water scarcity and drought-related problems. Global change-related decreases of terrestrial water storages can have strong effects on the sustainability of groundwater resources over continental regions. Identifying long-term trends in terrestrial water storages can have important implications for water management. Here we use remote sensing data from the Gravity Recovery and Climate Experiment (GRACE), to investigate the existence of long-term trends in the total water storage in the Magdalena river basin, the most important basin for water resources in Colombia.

2. Methods

We use data of rainfall, evaporation and river flow from gauging stations (from Hydrology, Meteorology and Environmental Studies Institute - IDEAM) and products such as TRMM, GPCC, MODIS and GLEAM, to evaluate the consistency of different GRACE data products through water balance computations (Famiglietti et al., 2011).

Table 1. Database used in the analysis

Source	Variable	Resolution	Time	Units
GRACE (CSR, JPL ,GFZ)	lwe_thickness	1° x 1°	Apr 2002 – Jan 2017	cm/month
GRACE JPL and CSR Global Mascons	lwe_thickness	0.5° x 0.5°	Apr 2002 – Jun 2017	cm/month
TRMM	Precipitation	0.25° x 0.25°	Jan 2000 – Dec 2016	mm/hr
GPCC	Precipitation	0.5° x 0.5°	Jan 2000 – Oct 2016	mm/month
CRU	Precipitation	0.5° x 0.5°	Jan 2000 – Dec 2015	mm/month
MODIS	Evapotranspiration	0.5° x 0.5°	Jan 2000 – Dec 2014	mm/month
ERA Interim	Precipitation Evaporation	0.75° x 0.75°	Jan 2000 – Dec 2016	m/month
GLEAM v3A	Evapotranspiration	0.25° x 0.25°	Jan 2000 – Dec 2014	mm/day
GLEAM v3B	Evapotranspiration	0.25° x 0.25°	Jan 2003 – Dec 2015	mm/day
IDEAM	Precipitation Evaporation Average flow	886 stations 162 stations 1 station	Jan 2000 – Nov 2016 Jan 2000 – Nov 2016 Jan 2000 – Dec 2015	mm/month mm/month m^3/s

$$dS/dt = P(t) - E(t) - Q(t)$$

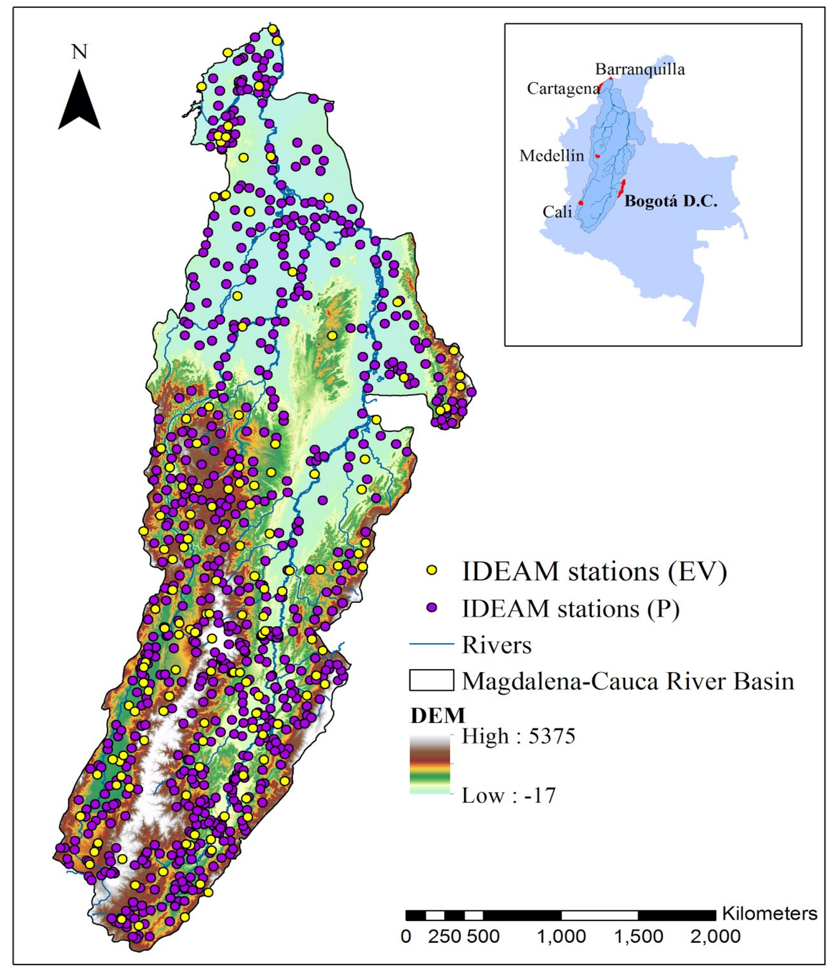

Fig 1. The Magdalena-Cauca river basin with the stations of evaporation (EV) and precipitation (P) from IDEAM

Correlation analysis between water balances and the different GRACE data products were performed. Then, a trend analysis was carried out with the best correlation GRACE data, through *Mann-Kendall test*. For this analysis, we identify before the period with less and constant uncertainty in GRACE measurements, and in the cases where one or two monthly values were missing, these were approximated by averaging the months before and after the data gap.

With the purpose to analyze surface water and groundwater components, we use data of soil moisture from the GLDAS output, and we isolate the groundwater component (GWS) of total water storage from GRACE (TWS) (Rodell et al., 2007; Hachborn et al., 2017)

$$\Delta GWS = \Delta TWS - \Delta GLDAS$$

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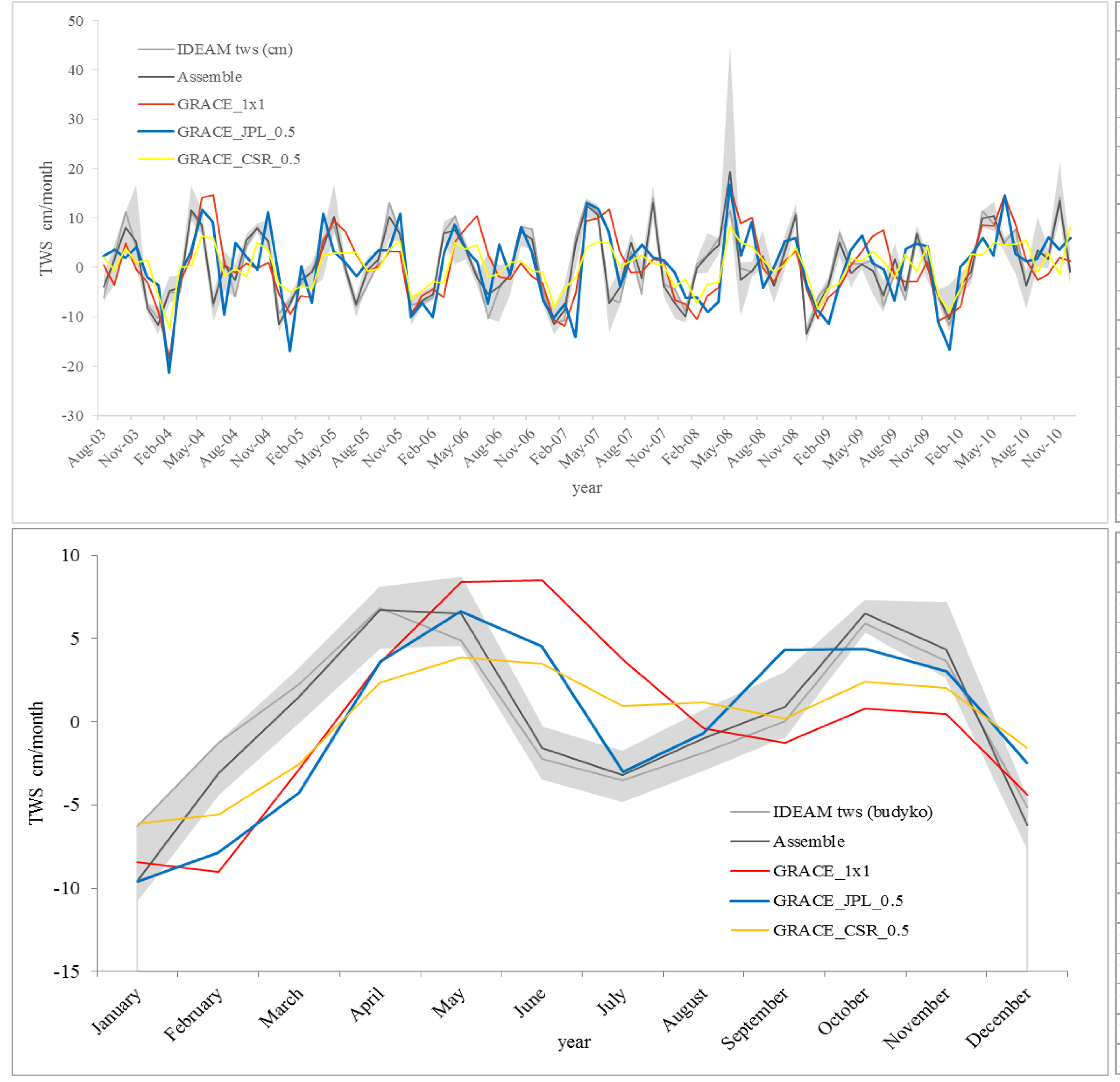
3. Results:

We found that the observed water balance agrees well with the storage changes observed from GRACE, specially the JPL Global mascon, thus giving confidence that the GRACE data captures storage changes in the basin and can be used to estimate trends.



Correlations			
	GRACE_1x1	JPL_0.5	CSR_0.5
IDEAM	0.4803	0.5428	0.4489
IDEAM-GLEAMv3A	0.4498	0.5284	0.4154
IDEAM-GLEAMv3B	0.4361	0.5135	0.4032
CRU-ERA	0.4254	0.4830	0.3657
CRU-MODIS	0.4008	0.4654	0.3454
CRU-GLEAMv3A	0.4025	0.4641	0.3427
CRU-GLEAMv3B	0.3992	0.4631	0.3445
GPCC-ERA	0.5838	0.6057	0.5358
GPCC-MODIS	0.5639	0.5876	0.5214
GPCC-GLEAMv3A	0.5640	0.5904	0.5162
GPCC-GLEAMv3B	0.5638	0.5778	0.5149
TRMM-ERA	0.5809	0.6066	0.5194
TRMM-MODIS	0.5541	0.5855	0.5001
TRMM-GLEAMv3A	0.5414	0.5791	0.4832
TRMM-GLEAMv3B	0.5405	0.5739	0.4832
Assemble	0.5080	0.5663	0.4595

Correlations			
	GRACE_1x1	JPL_0.5	CSR_0.5
IDEAM	0.4911	0.7433	0.6339
IDEAM-GLEAMv3A	0.4429	0.7027	0.5850
IDEAM-GLEAMv3B	0.3953	0.6310	0.5382
CRU-ERA	0.5758	0.8212	0.7192
CRU-MODIS	0.5610	0.8157	0.7013
CRU-GLEAMv3A	0.5621	0.8057	0.6962
CRU-GLEAMv3B	0.4799	0.7342	0.6311
GPCC-ERA	0.6422	0.8402	0.7738
GPCC-MODIS	0.6168	0.8160	0.7412
GPCC-GLEAMv3A	0.6266	0.8160	0.7459
GPCC-GLEAMv3B	0.5767	0.7576	0.7027
TRMM-ERA	0.6401	0.8393	0.7727
TRMM-MODIS	0.6137	0.8136	0.7391
TRMM-GLEAMv3A	0.6225	0.8113	0.7412
TRMM-GLEAMv3B	0.5782	0.7559	0.7028
Assemble	0.5650	0.7885	0.7003

Fig 2. Comparison between observed total water storage change (dS/dt) from IDEAM and the assemble, and that from GRACE products. Grey shading shows the range in the observed water balance estimate of dS/dt from differents sources for the assemble. In a) time series of TWS and in b) annual cycle.

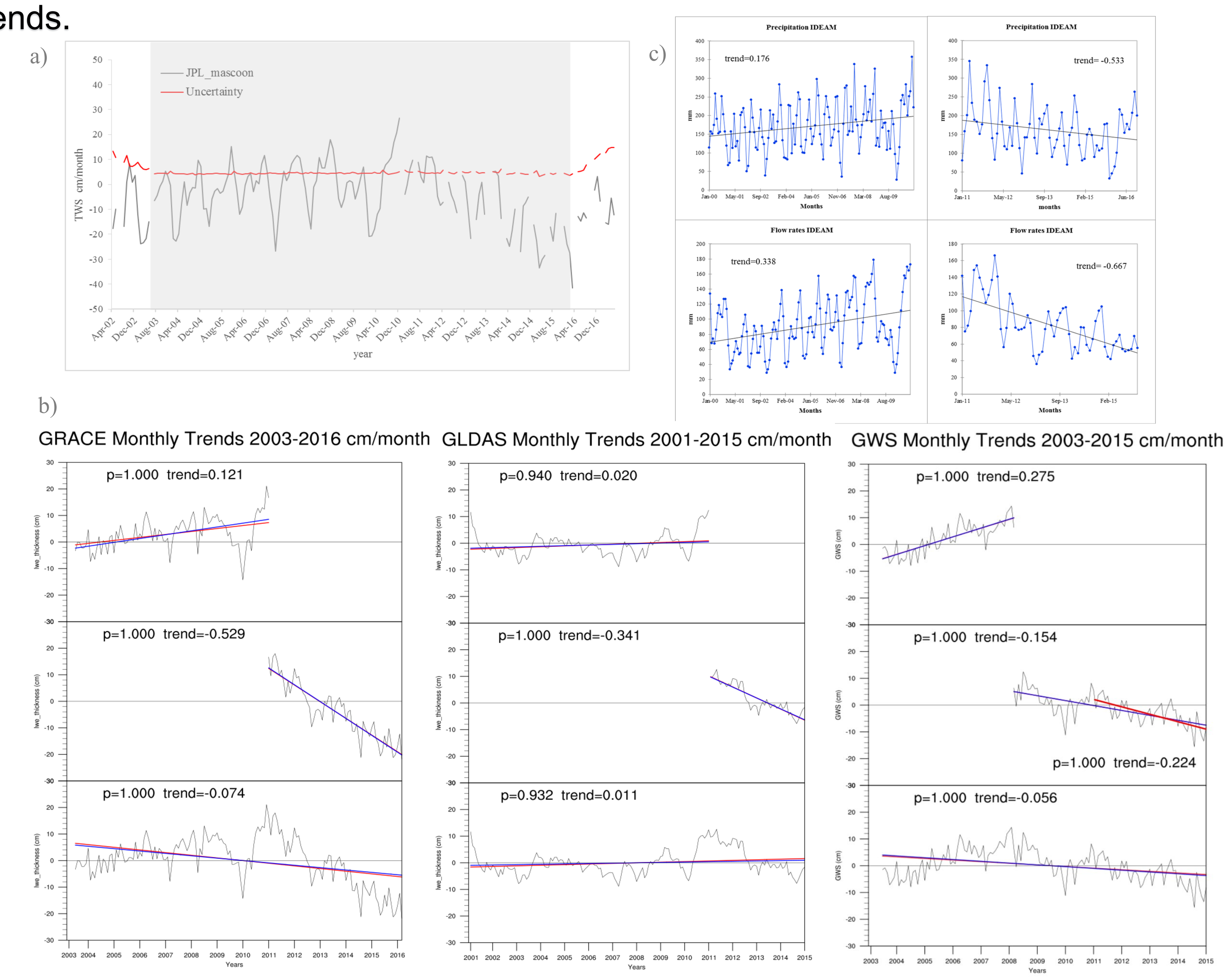


Fig 3. a) Uncertainty associated with GRACE measurement. b) GRACE TWS, GLDAS and GWS monthly trends. c) Precipitation and flow rate trends from IDEAM.

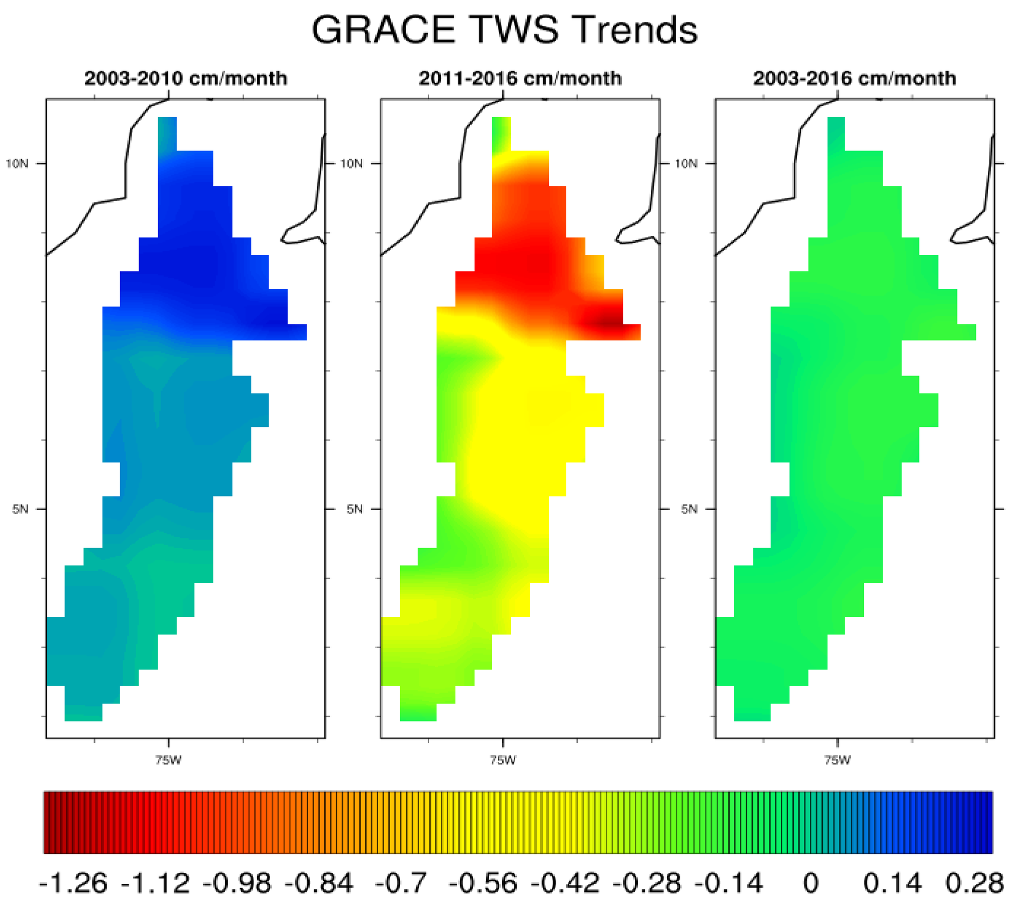


Fig 4. Trend maps of TWS in Magdalena-Cauca basin.

Using the Mann Kendal test, we found a decreasing trend in the total water storage starting around 2011, especially in the lower part of the basin, which is consistent with trends in river flow and precipitation over the whole basin. Isolating the groundwater component from TWS using GLDAS data, we can note preliminarily a decreasing trend starting even years before, since around 2008. Nevertheless, there are a big uncertainty and It is necessary to evaluate these results with in situ well data.

4. Conclusions

Our results provide an example of using GRACE data to investigate variations in continental water resources that affect their sustainability and, therefore, can have important implications for decision making and water management, in both surface water and groundwater. More generally, our results provide insight into the use of GRACE data for inferring water balance variations and trends that may exacerbate droughts and water insecurity.

5. References

Famiglietti, J. S., Lo, M., Ho, S. L., Bethune, J., Anderson, K. J., Syed, T. H., … Rodell, M. (2011). Satellites measure recent rates of groundwater depletion in California's Central Valley. Geophysical Research Letters, 38(3), L03403. http://doi.org/10.1029/2010GL046442

Hachborn, E., Berg, A., Levison, J., & Ambadan, J. T. (2017). Sensitivity of GRACE-derived estimates of groundwater-level changes in southern Ontario, Canada. Hydrogeology Journal, 2391–2402. https://doi.org/10.1007/s10040-017-1612-2

Rodell, M., Chen, J., Kato, H., Famiglietti, J. S., Nigro, J., & Wilson, C. R. (2006). Estimating groundwater storage changes in the Mississippi River basin (USA) using GRACE. Hydrogeology Journal, 15(1), 159–166. https://doi.org/10.1007/s10040-006-0103-7