Monitoring Groundwater Storage Changes From Gravity Recovery and Climate Experiment (GRACE) satellites

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Tuesday 15th May 2018

Training School on Ground Penetrating Radar
Rome, Italy

Brief Biography of M. Shamsudduha

Dr. Mohammad Shamsudduha ("Shams") is a ***Research Fellow*** *at UCL Institute for Risk and Disaster Reduction (IRDR) and the* ***Project Manager*** *of a UK Government-funded international consortium project, GroFutures (Groundwater Futures in Sub-Saharan Africa).*

Shams has a Ph.D. in Hydrogeology from UCL Department of Geography and joined IRDR in March 2012 where he has been working on a number of research projects largely on issues around 'water risks' across the world. Over an extended academic career, Shams has received training and degrees from various universities around the world (Australia, Bangladesh, UK and USA). Shams has more than 12 years of experience in conducting research, largely collaborative and interdisciplinary in nature, with universities, research institutes, government departments, and non-governmental organisations. Shams has co-developed a decade long, successful research partnership with organisations in Bangladesh. Under GroFutures, Shams is expanding his research arena within the Sub-Saharan Africa that includes Ethiopia, Tanzania, Niger and Nigeria. Additionally, Shams has published over 28 research articles in peer-reviewed, international journals, and is currently serving as an Associate Editor for the journal of Climate Risk Management.

Research Interests of M. Shamsudduha

Shams research interests revolve around 'water risks' at local to global scales. Shams' specific research interests include:

- *Risks of water and food insecurity: resilience of terrestrial water resources to sustain irrigated agriculture and fresh drinking-water supplies in South Asia and Sub-Saharan Africa*
- *Risk to public health and food-grain production associated with chronic exposure to toxic metals (e.g. Arsenic) in untreated groundwater-fed water supplies in Asian Mega-Deltas*
- *Impacts of changes in global climate and land-use on groundwater replenishment and risks of rising sea levels, and more frequent and extensive flooding on livelihoods of dwellers in low-lying deltas in South and Southeast Asia.*

TU1208 GPR Association

International non-profit network on Ground Penetrating Radar

Cooperation - Sharing - Open science - Excellence - Embracing diversity - Inclusiveness - Innovation - Bottom up

Founded in September 2017 as a follow up of COST Action TU1208

Training School on Ground Penetrating Radar for civil engineering and cultural heritage management

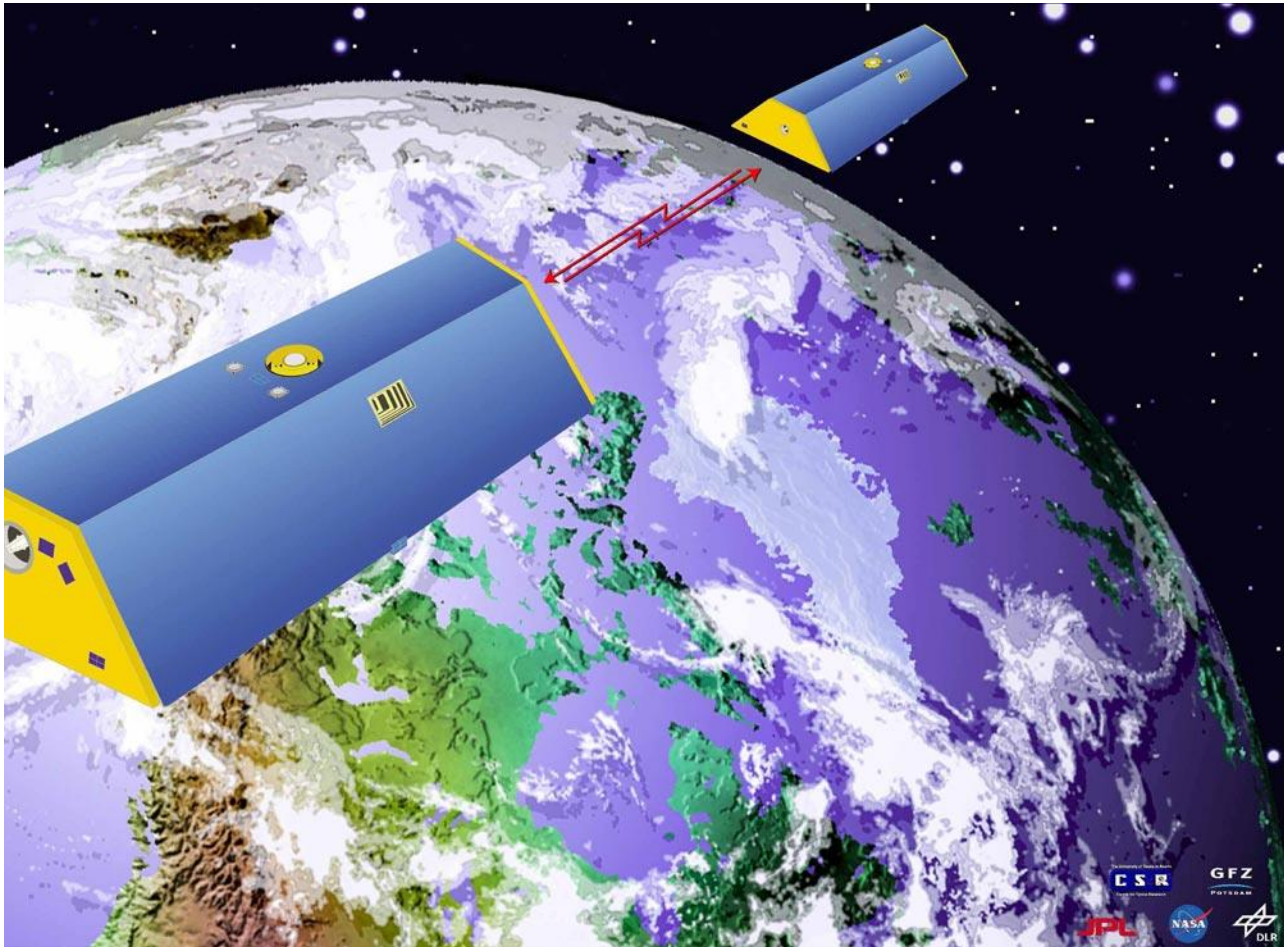
Roma, Italy, May 14-18, 2018

Tuesday, 15 May 2018

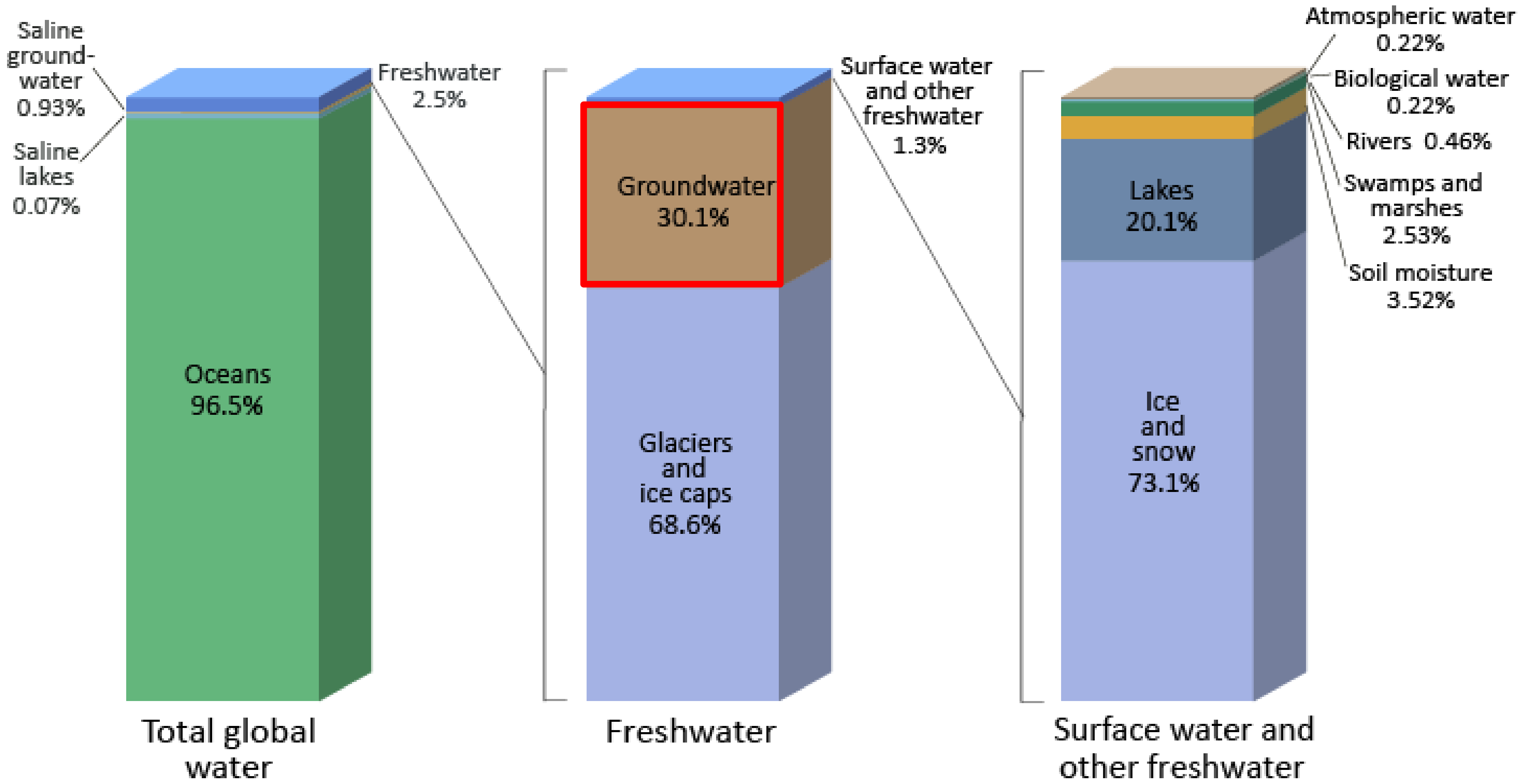
- **Use of GPR and complementary geophysical techniques in civil engineering (with a main focus on roads, bridges and groundwater resource monitoring)**

14:00 - 15:30	M. Shamsudduha	Groundwater resource monitoring using complementary geophysical techniques. Examples of data analysis and interpretation.

Monitoring Groundwater Storage Changes From Gravity Recovery and Climate Experiment (GRACE) satellites



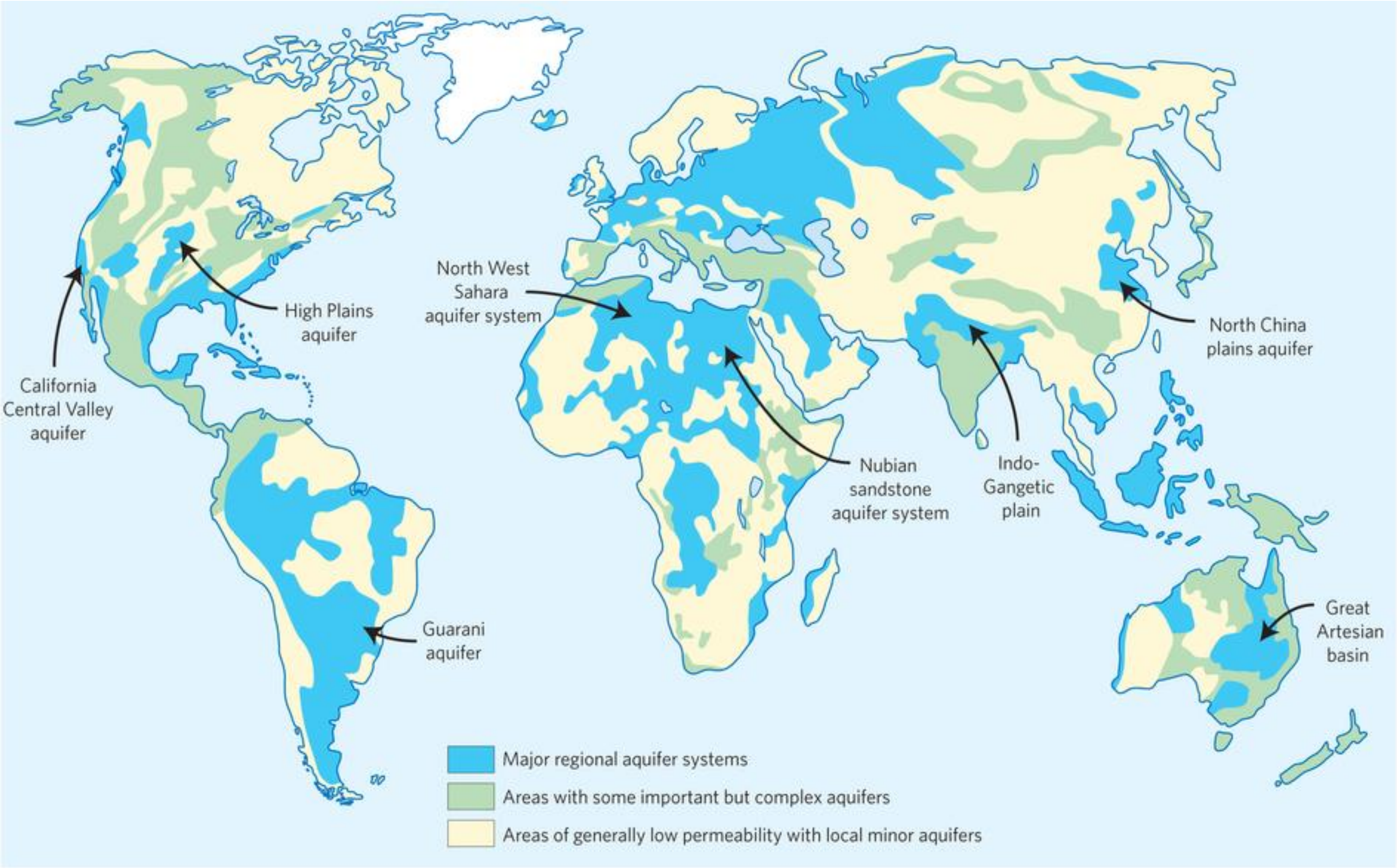
Background: Distribution of water on Earth



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

Background: Distribution of water on Earth

Distribution of aquifers on Earth



Taylor et al. (2013), Nature Climate Change, vol. 3, 322–329

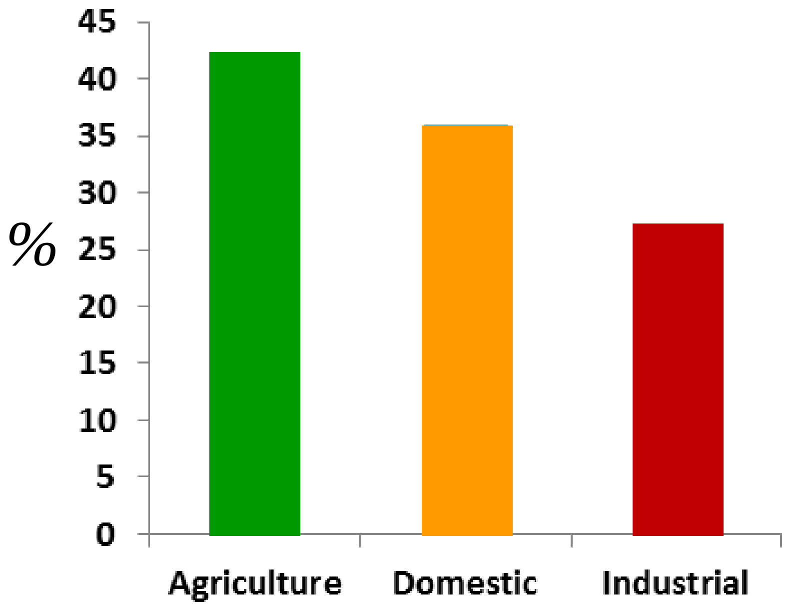
Background: Global Use of Groundwater

***Agricultural* water supply**

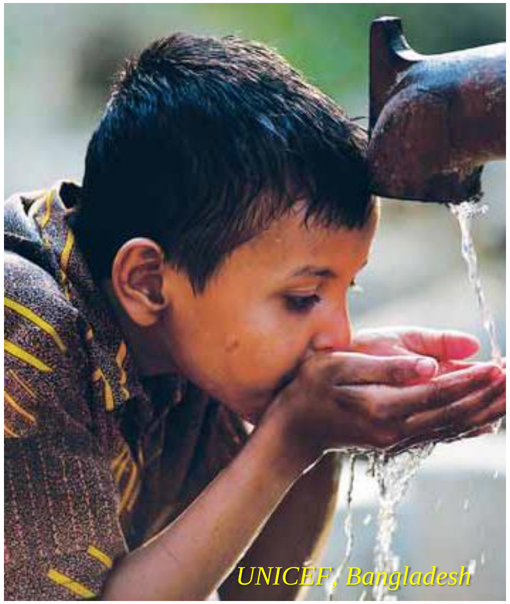
***Domestic* water supply**

***Industrial* water supply**

Groundwater: *1/3rd of all global freshwater withdrawal*



Taylor et al. (2013), Nature Climate Change, vol. 3, 322–329



Background: Groundwater Use in Bangladesh

Groundwater provides 98% of Bangladesh's drinking water supplies

There are 10-12 million tubewells in Bangladesh

A typical hand-operated tubewell (No.6) in Bangladesh

Groundwater provides 80% of the irrigation water supplies in Bangladesh

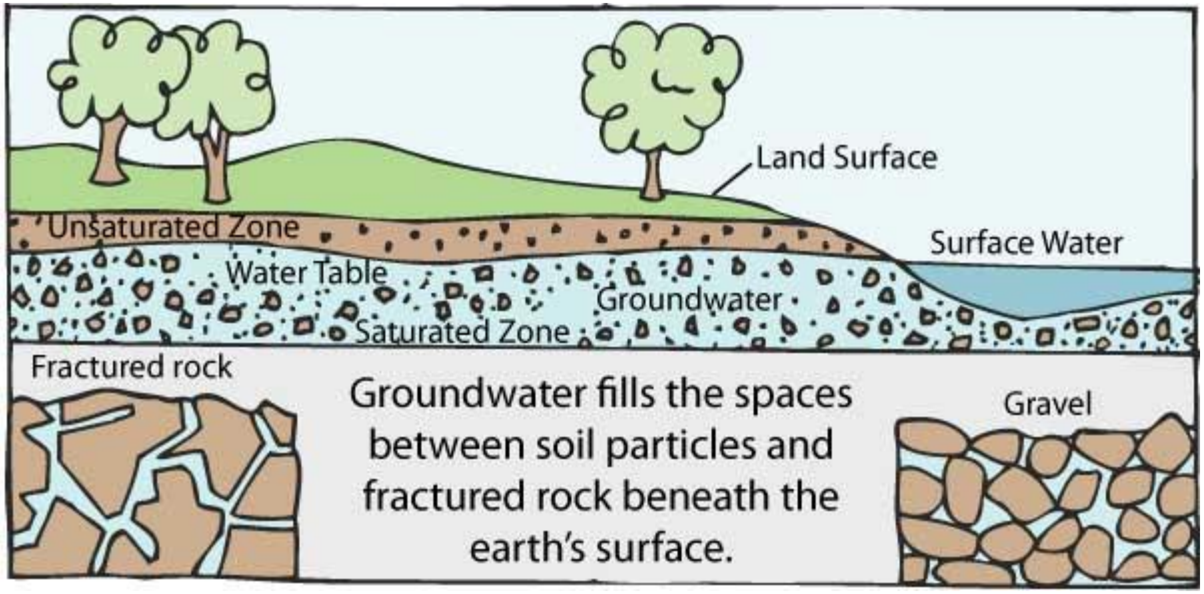
How secure is the groundwater storage?

Is groundwater abstraction in balance with recharge?

Total no of shallow irrigation wells: 1.2 million (2006-07)

Boro rice field in northwest Bangladesh is being irrigated with groundwater

Groundwater Monitoring: What, Why & How?



Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers.

http://www.groundwater.org/

Groundwater has an important role in the environment: *it replenishes streams, rivers, and wetlands and helps to support wildlife habitat; it is used as primary source of drinking water and also in agricultural and industrial activities.*

www.fao.org/gtos/doc/ecvs/t03/t03-groundwater-report-v05.doc

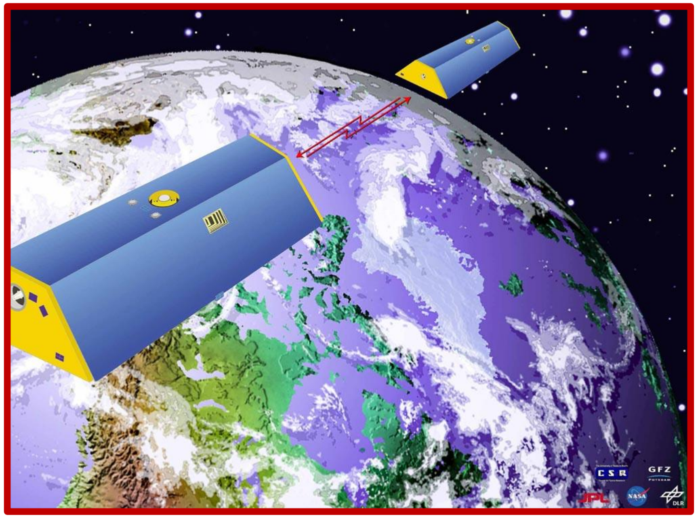
Groundwater Monitoring: What, Why & How?

Groundwater monitoring involves in situ, satellite and airborne observations and laboratory analysis of quality variables. A groundwater monitoring programme includes both groundwater quantity (e.g. groundwater level) and quality monitoring networks.

www.fao.org/gtos/doc/ecvs/t03/t03-groundwater-report-v05.doc

Groundwater-level recording in Tanzania

Groundwater-level monitoring by UCL's Groundwater Penetrating Radar technology (Source: Lai Bun Lok)



Groundwater storage changes by GRACE

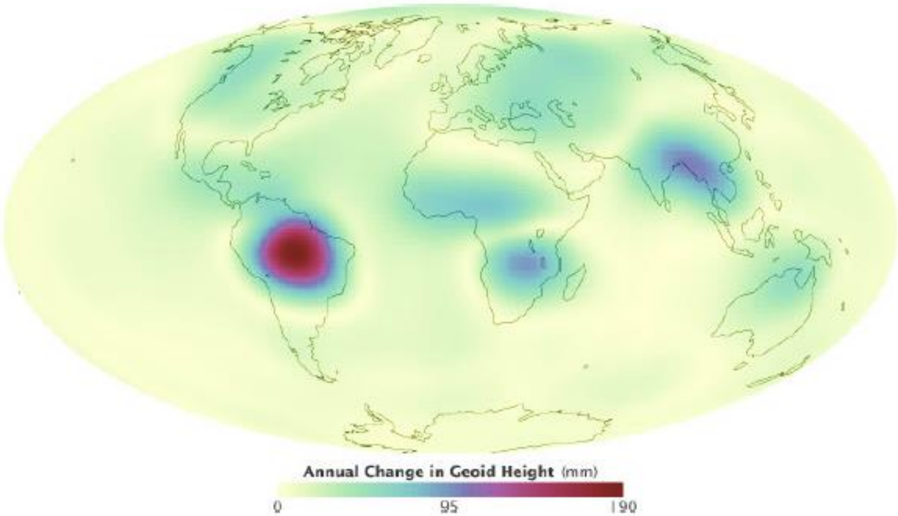
GRACE Satellite Mission: the central concept

"The first thing I tackled in the 1970s was the task of computing the orbits of satellites very accurately to support satellite altimetry missions. We reached the point that we could compute orbits that had an accuracy of a few centimeters" – **Byron Tapley**

Tapley's computations hit a glitch that he couldn't fix. He observed that the satellite orbits varied seasonally!

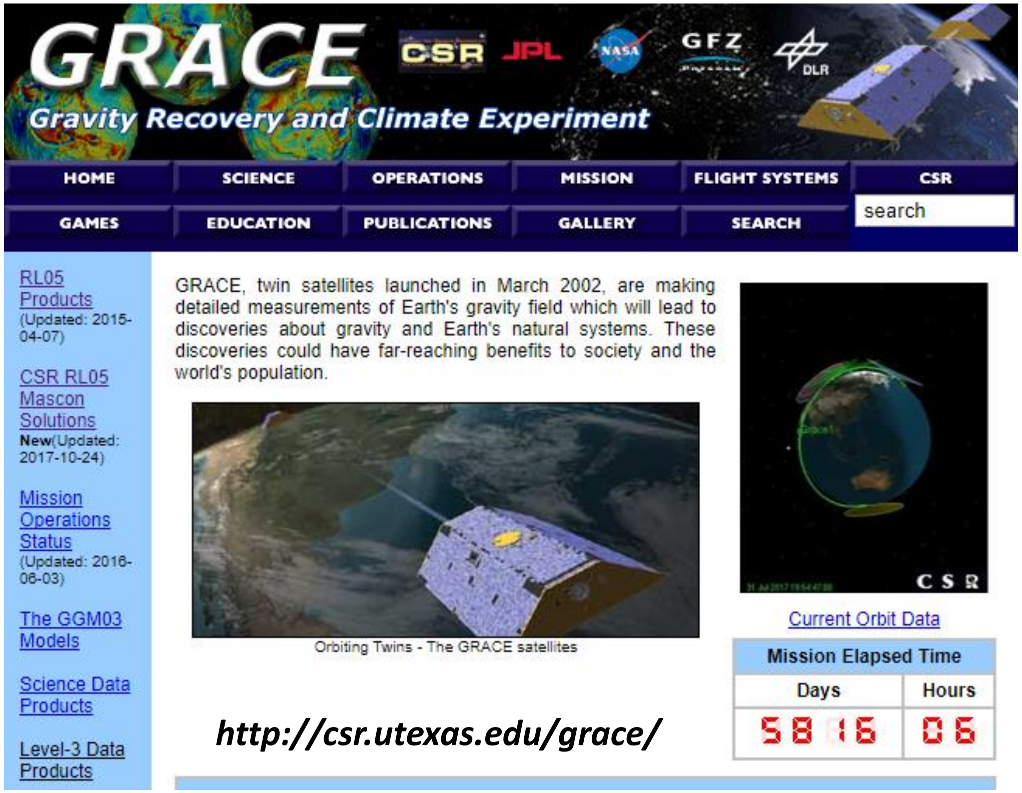
- these subtle shifts in Earth's gravity occur primarily due to movement of **water mass** from one place to another on and under land, in the ocean, and in the atmosphere

- only satellite could measure these subtle, tiny shifts accurately enough to map Earth's gravity in fine detail



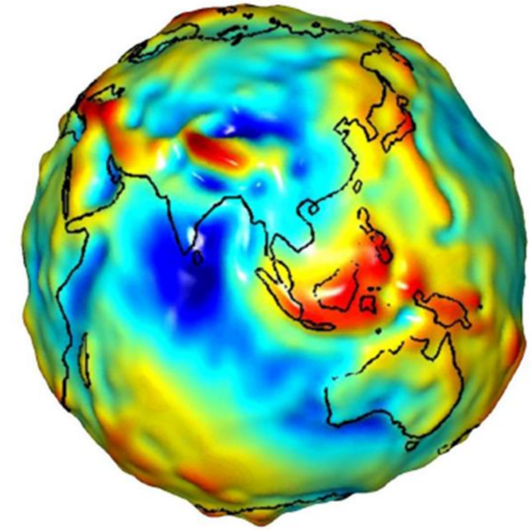
The GRACE mission was led by B. Tapley (PI) of the University of Texas at Austin (USA) and Frank Flechtner (Co-PI) of the German Research Centre for Geosciences (GFZ)

GRACE: 16-Year Mission and Earth's Gravity



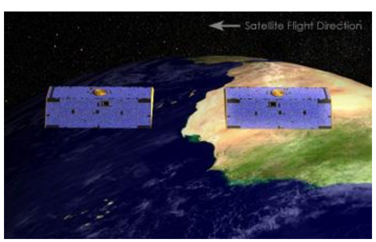
http://csr.utexas.edu/grace/

~16 Years

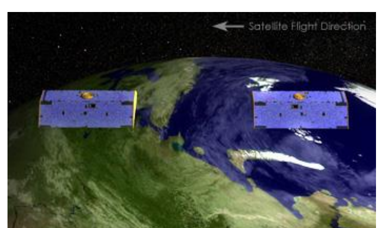


- *Monthly gravity anomaly maps generated by GRACE are 1000 times more accurate than previous gravity maps*

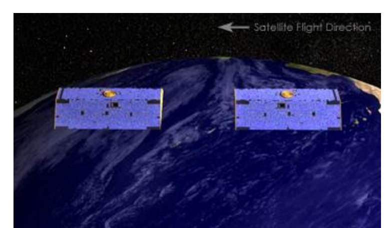
leaving land



approaching land



Over ocean



http://earthobservatory.nasa.gov/

GRACE Satellites Map Monthly Changes in TWS

Global TWS Monthly Anomaly over land from GRACE

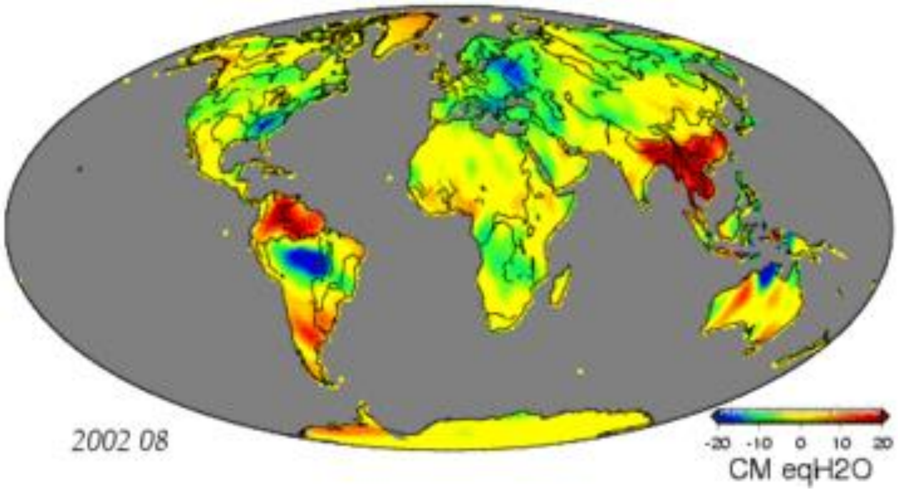
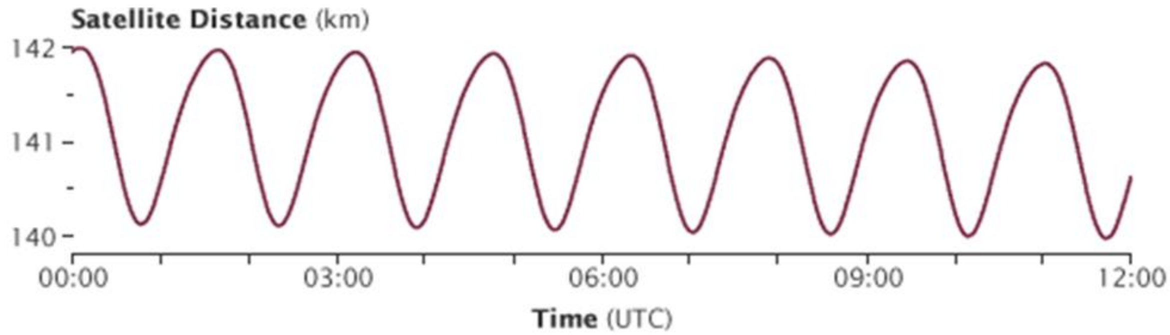


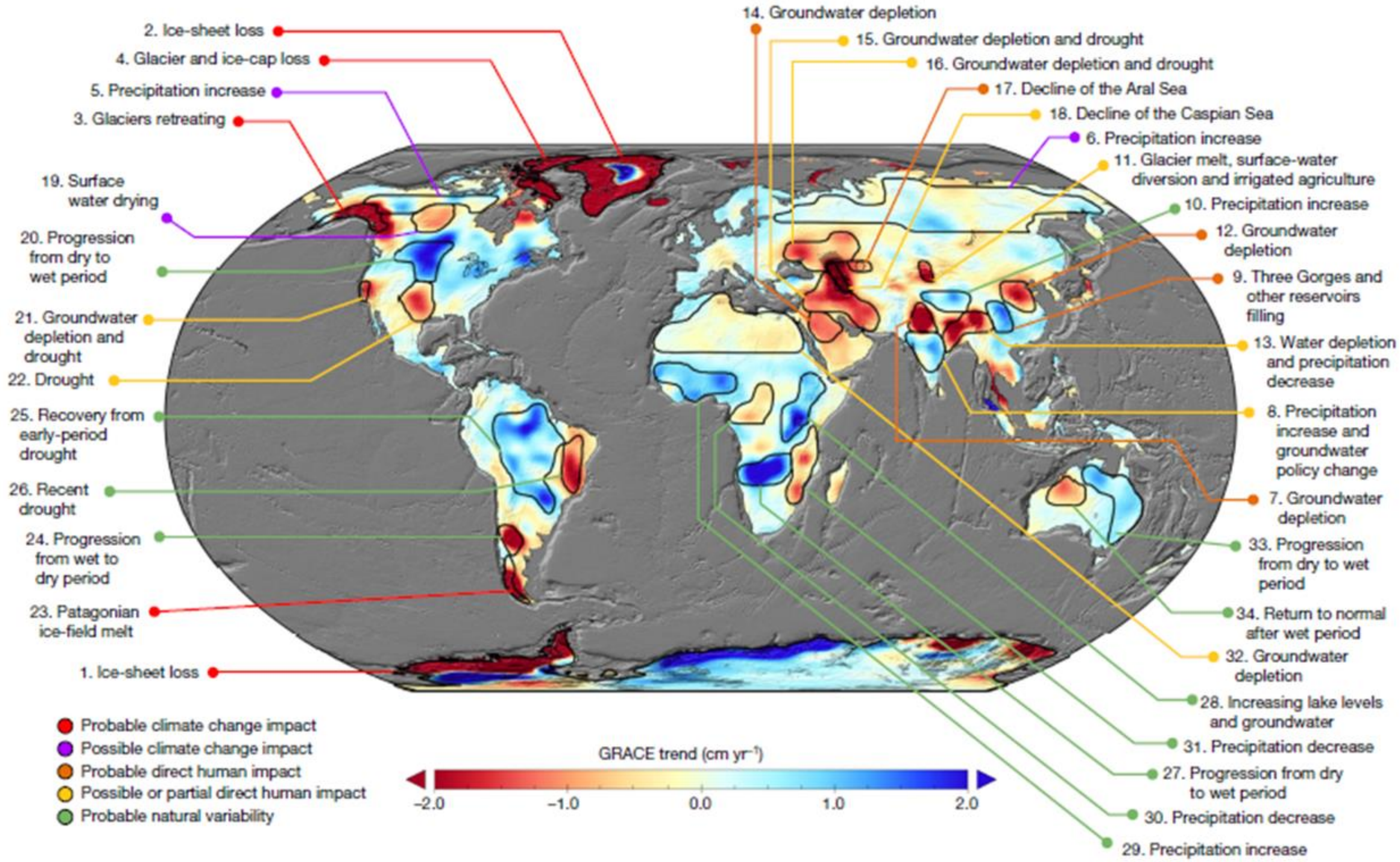
Image source: Wikipedia



During each 90-minute orbit, the distance between the GRACE satellites varies by about 2 kilometers (1.2 miles). Instruments aboard the satellites measure the separation to a precision of one micrometer (NASA graph by Robert Simmon and Kevin Ward, using GRACE data from the JPL Physical Oceanography DAAC).

Trends in Global Terrestrial Water Storage

Trends in terrestrial water storage (cm/yr), including groundwater, soil water, lakes, snow, and ice, as observed by GRACE from April 2002 to March 2016



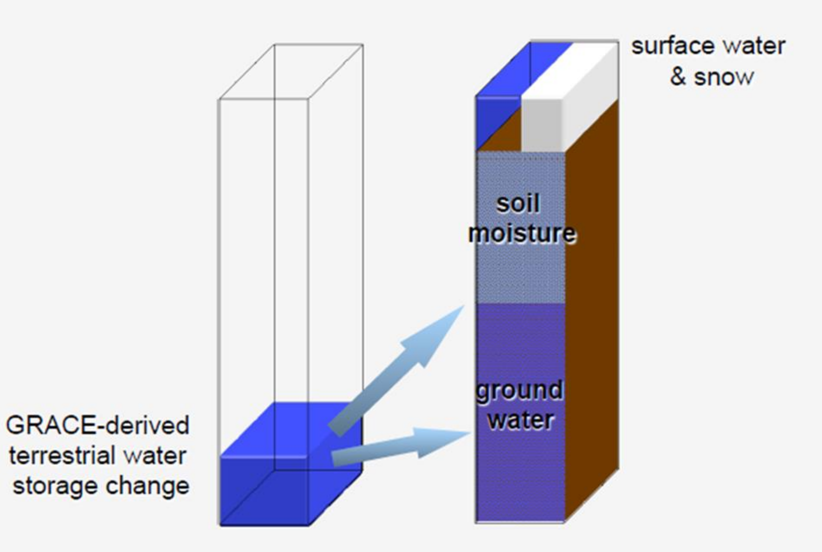
GRACE observes changes in water storage caused by natural variability, climate change and human activities such as groundwater pumping

Rodell et al. (2018)

GRACE for Mapping Groundwater Storage Changes

$$\Delta TWS = \Delta ISS + \Delta SWS + \Delta SMS + \Delta GWS$$

- Fluid mass changes represent total terrestrial water storage changes (ΔTWS) after removing atmospheric mass variations and ocean tides



$$\Delta GWS = \Delta TWS - [\Delta ISS + \Delta SWS + \Delta SMS]$$

- **How good is the estimation of GRACE-derived ΔGWS?**

Monitoring groundwater storage changes in the highly seasonal humid tropics: Validation of GRACE measurements in the Bengal Basin

M. Shamsudduha,[1] R. G. Taylor,[1] and L. Longuevergne[2]

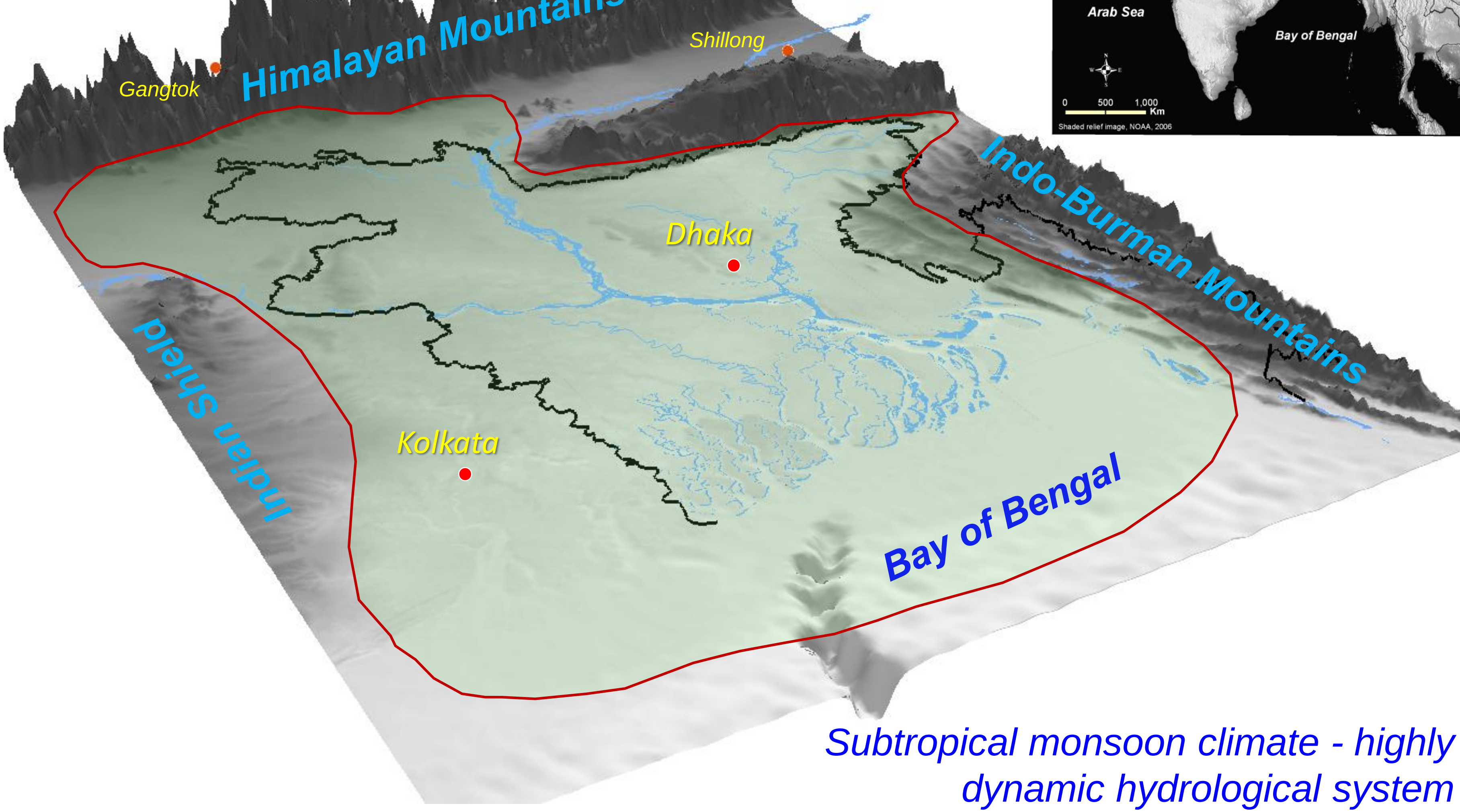
Water Res. Resour.

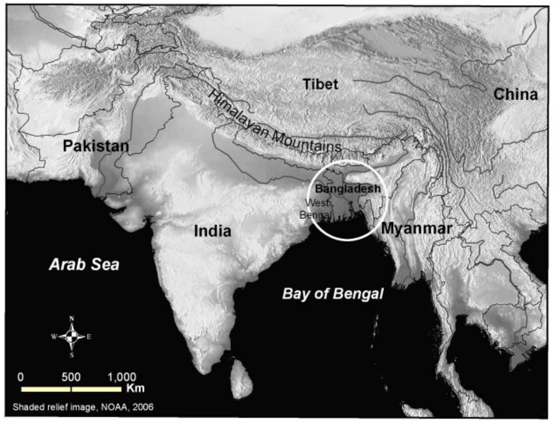
Received 1 June 2011; revised 20 October 2011; accepted 5 January 2012; published 10 February 2012.

Bengal Basin: Location and Topography

One of the largest sedimentary basins in the world

Area: ~300,000 km²

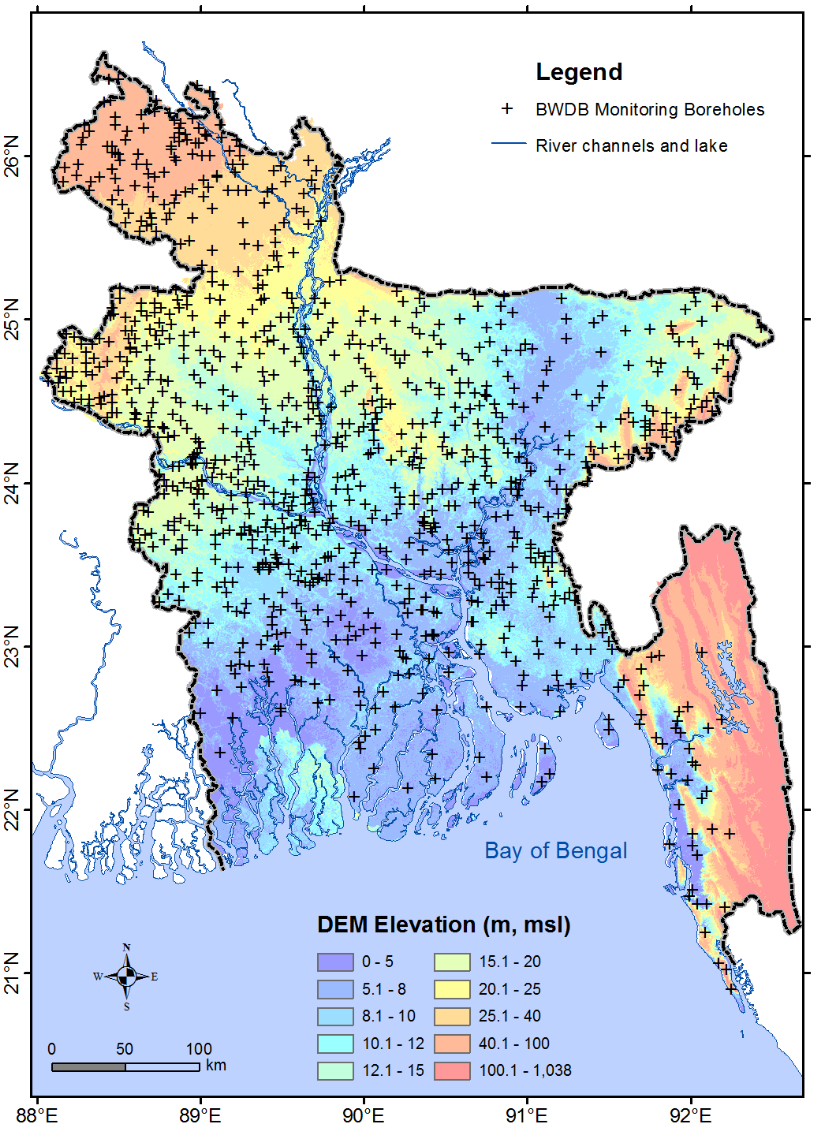


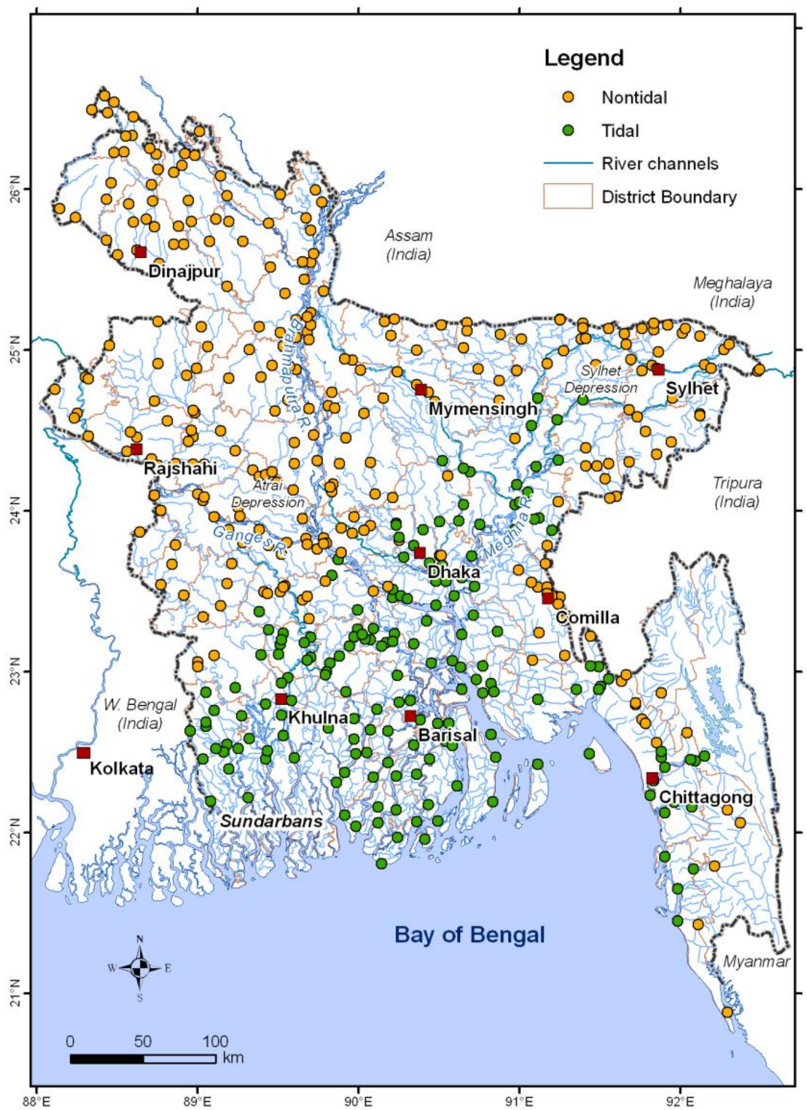


Subtropical monsoon climate - highly dynamic hydrological system

Bengal Basin: A Natural Laboratory

Dense network of surface water and groundwater monitoring stations



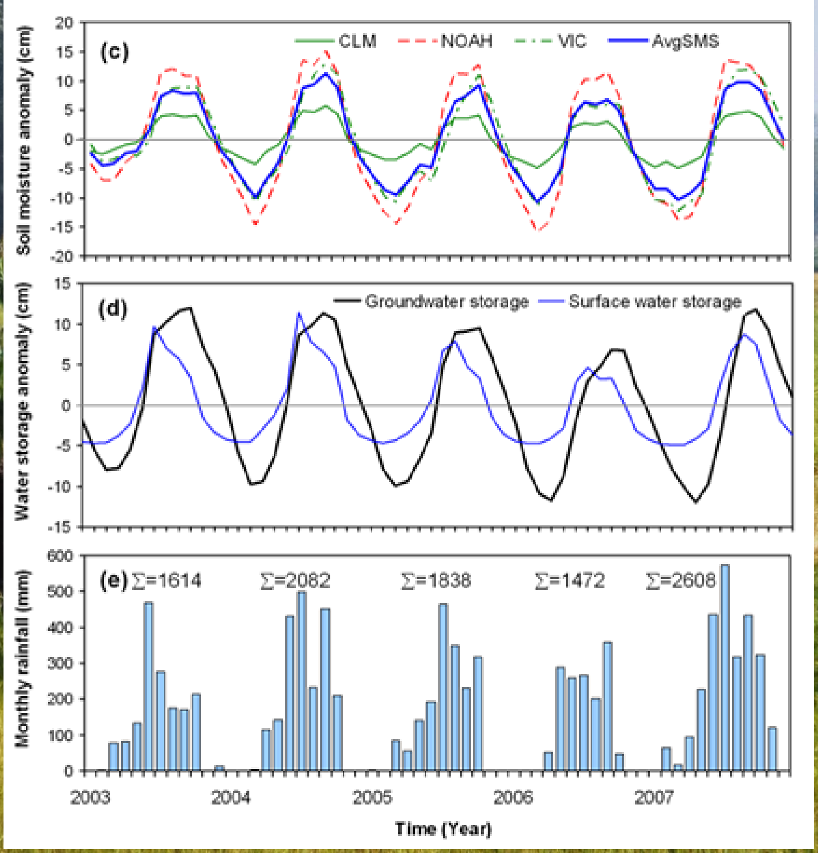


GRACE-derived GWS in the Bengal Basin

Datasets used in the study of ΔGWS in the Bengal Basin:

- ΔGWS & ΔSWS constrained by observations at 236 & 298 monitoring stations

- ΔSMS constrained by *simulated* soil moisture from LSMs: CLM, NOAH, VIC



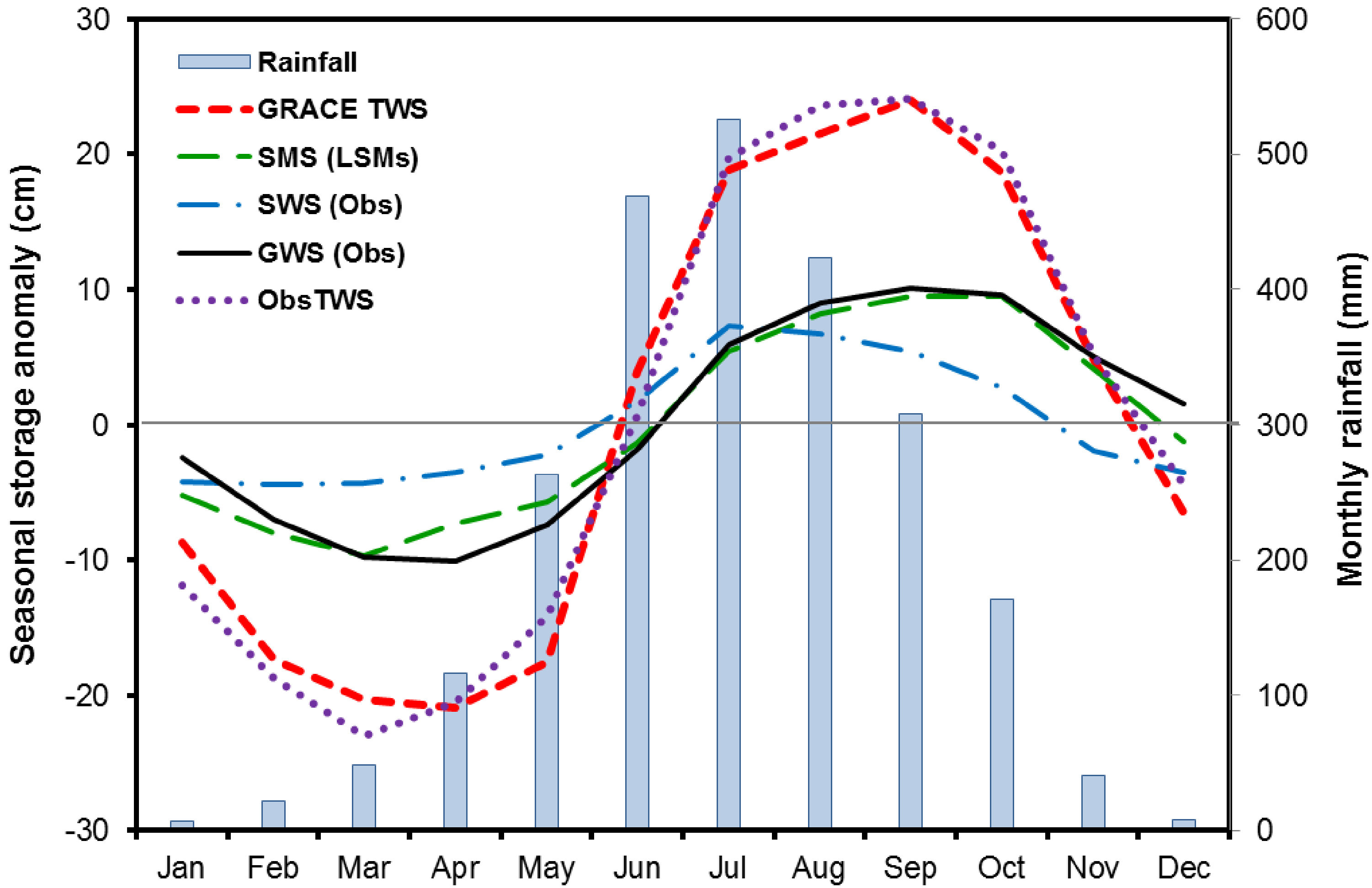
Shamsudduha et al. (2012)

Background picture shows irrigation of Boro rice in Bangladesh

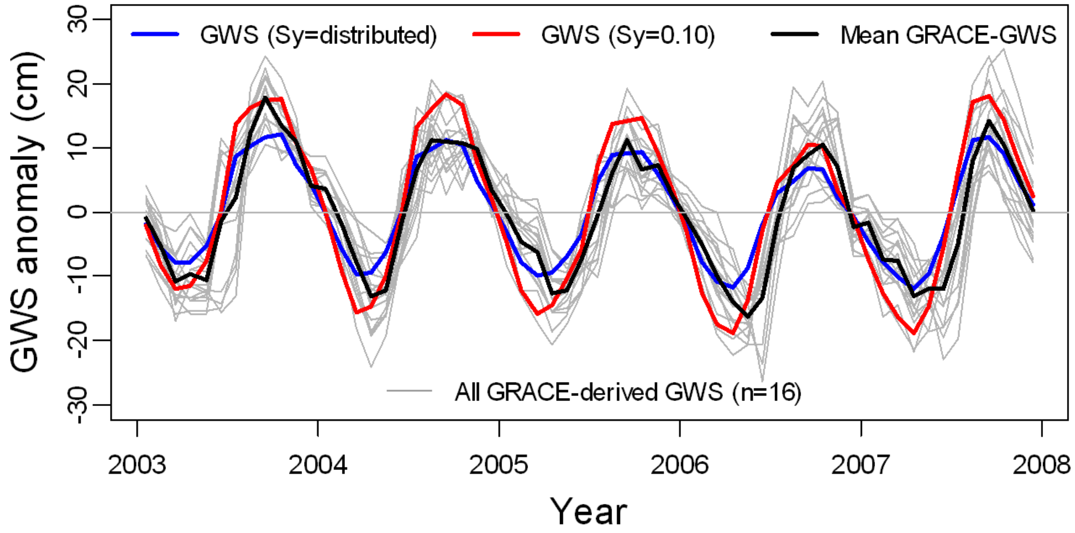
Groundwater Storage in the Bengal Basin

$$\Delta GWS = \Delta TWS - (\Delta SWS + \Delta SMS + \Delta ISS)$$

Observed *GRACE* *Observed* *LSMs (GLDAS)* *Nil*



Validation of GRACE-derived ΔGWS



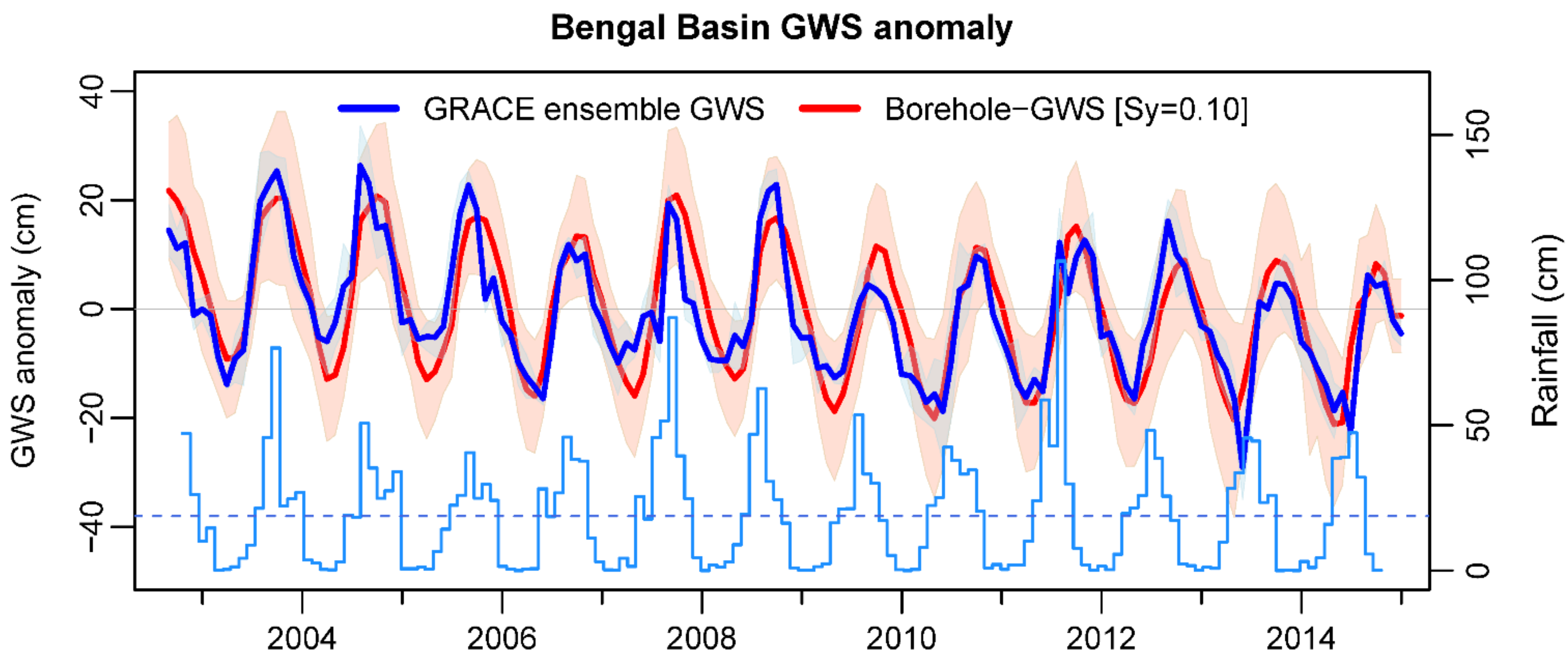
GRACE data: CSR and GRGS

SMS data: NOAH, VIC, CLM

SWS data: observational

GWS data: observational

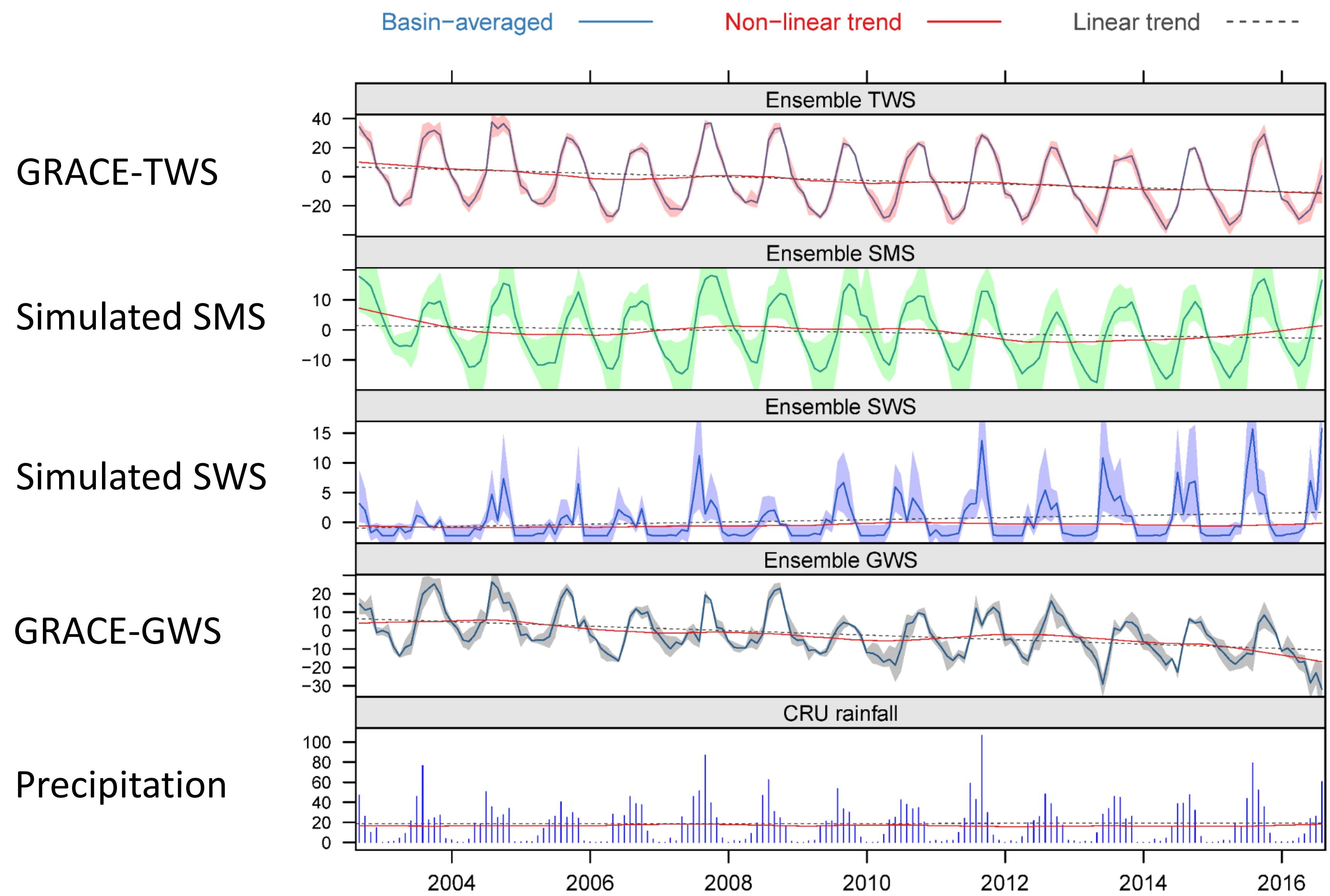
An updated analysis:



Groundwater Storage in the Bengal Basin

An updated analysis:

Bengal Basin (Bangladesh)



Summary

- Groundwater is the largest store of freshwater (~30%) on Earth; surface water storage represents ~1%
- Groundwater sustains drinking, irrigation and industrial water supplies in many countries around the world
- Monitoring of groundwater storage and quality is critical to sustainable resource development (i.e. water & food security)
- Groundwater-level or storage change can be measured by various techniques including spaceborne GRACE satellites (basin scale) and GRP techniques (local scale)
- Without monitoring impacts of human use and climate change on groundwater would be challenging to assess

Presentation citation

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