Using GRACE for groundwater

J.T. Reager

Jet Propulsion Laboratory, California Institute of Technology

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Jet Propulsion Laboratory
California Institute of Technology

Basic Questions to ask before using GRACE for groundwater

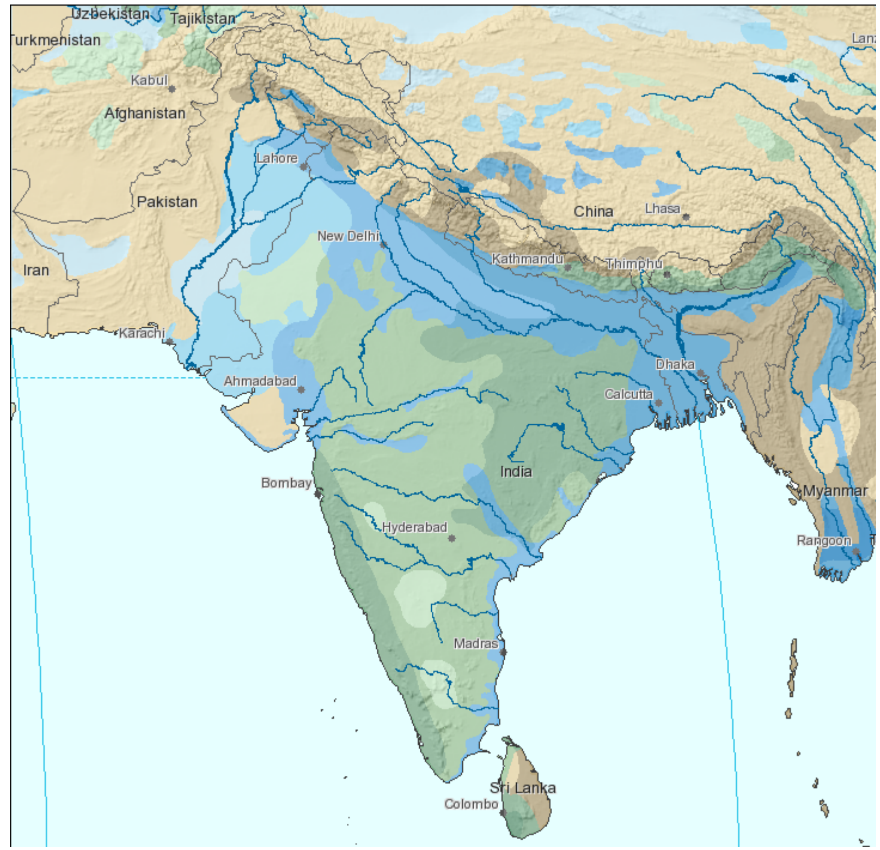
1. What is the size of the study region?

2. What are the components of water storage, and is that data available?

3. What will the results mean?

Groundwater in India

- 50-80% of domestic water use
- 40-50% of irrigation for agriculture
- Total irrigated area tripled from 1970 to 1999 (33 *10^6 ha)
- 1986: central groundwater authority established to manage resources and regulate development



UNESCO: WHYMAP

Groundwater in India

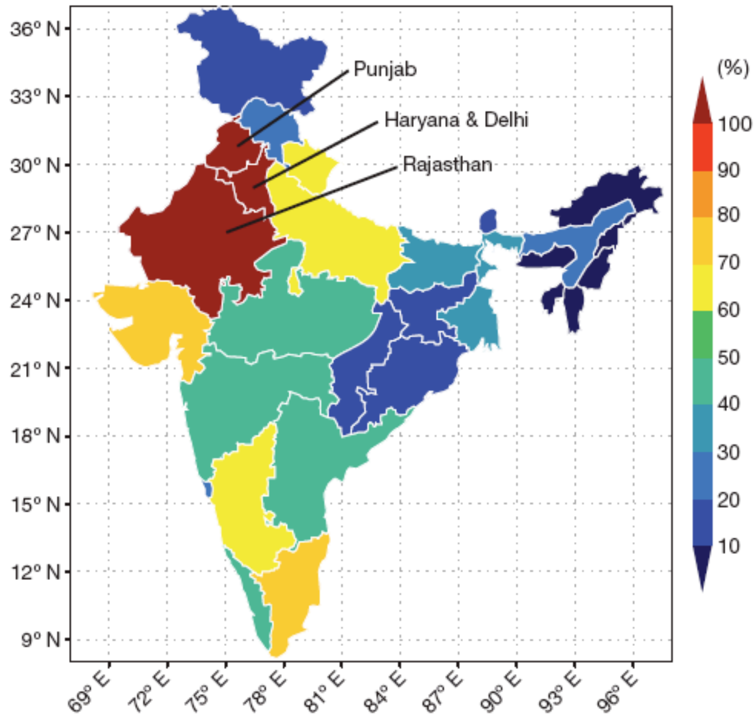


Figure 1 | Groundwater withdrawals as a percentage of recharge. The map is based on state-level estimates of annual withdrawals and recharge reported by the Indian Ministry of Water Resources[2]. The three states studied here are labelled.

- Ministry of water concerned about Rajastan, Punjab and Haryana
- Groundwater withdrawals in each state meet or exceed recharge
- Area = Rajasthan (342,239 km^2), Punjab (50,362 km^2) and Haryana (45,695 km^2)

Groundwater in India

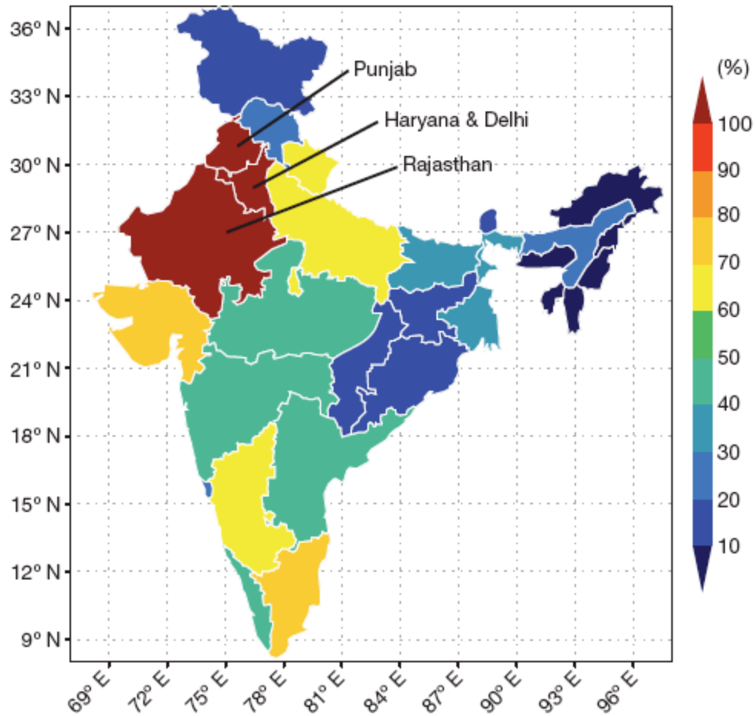


Figure 1 | Groundwater withdrawals as a percentage of recharge. The map is based on state-level estimates of annual withdrawals and recharge reported by the Indian Ministry of Water Resources[2]. The three states studied here are labelled.

Total water storage in this region comprised of:

- groundwater
- soil water
- surface water
  - Lakes and reservoirs (0.5 km^3/yr)
  - Rice paddies (annual signal only)
- Snow
- Glacial loss (2.8 km^3/yr)
- Biomass

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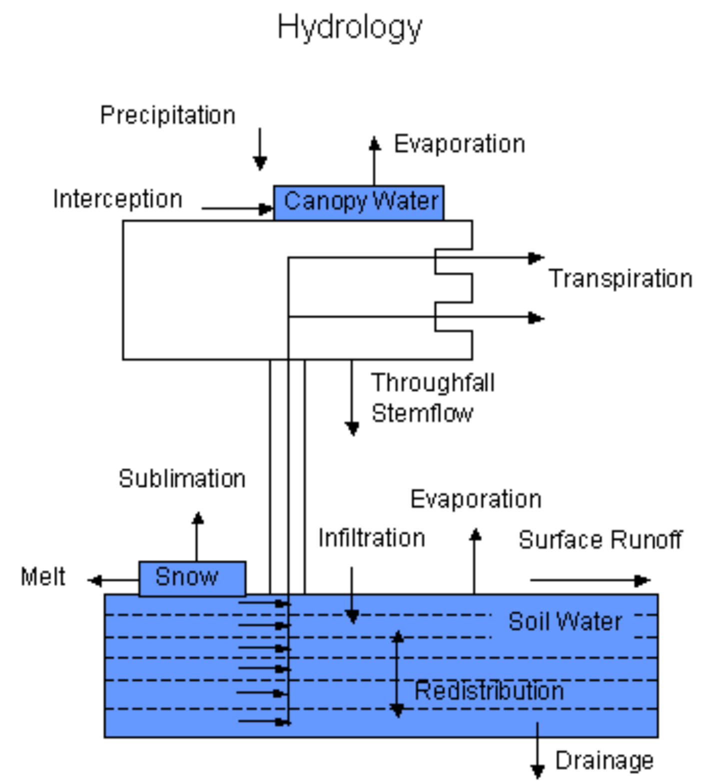
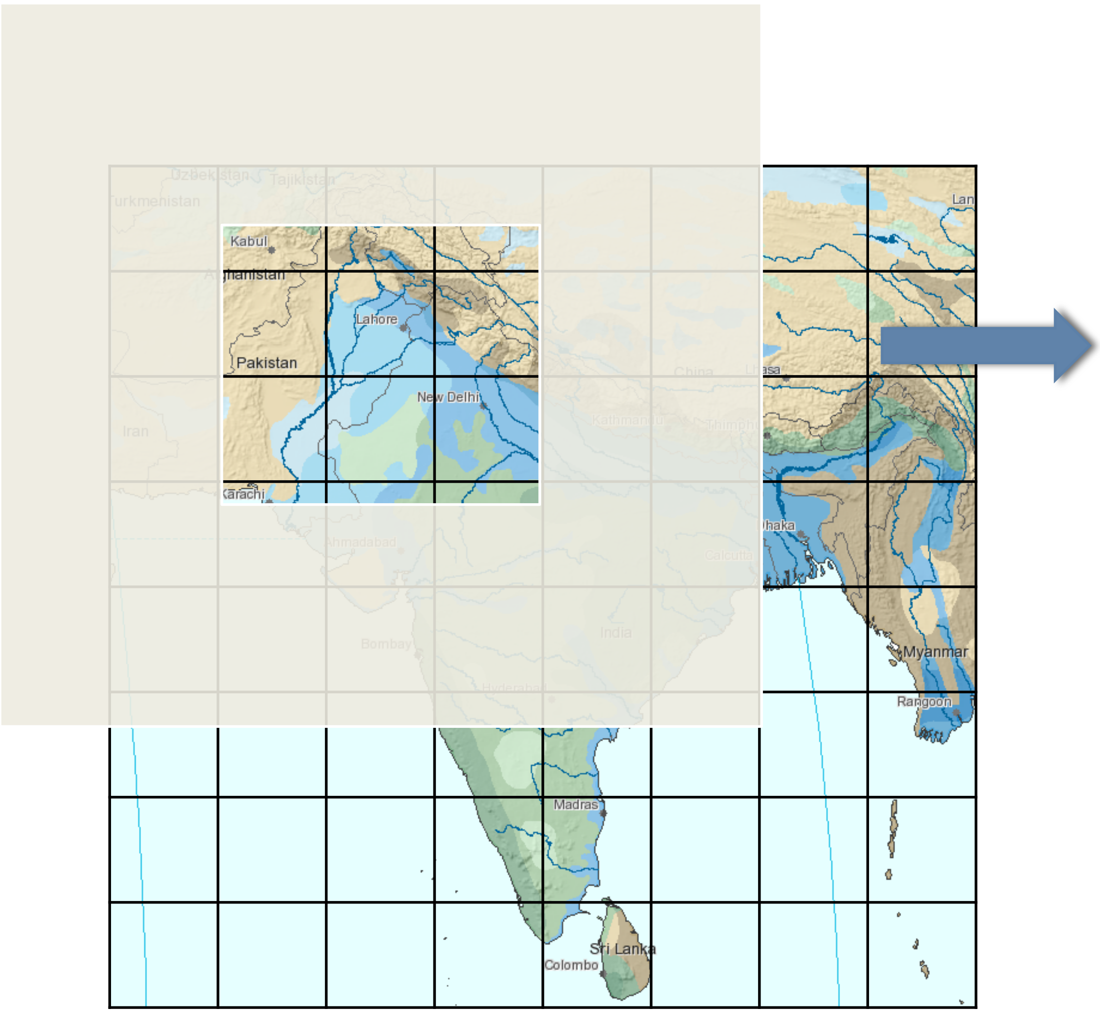
– Which data set do we need?

GLDAS soil moisture

- Global Land Data Assimilation System
- Inputs: precipitation, temperature and solar radiation
- Output from three land surface models: CLM, Noah, VIC
- Download as global grids

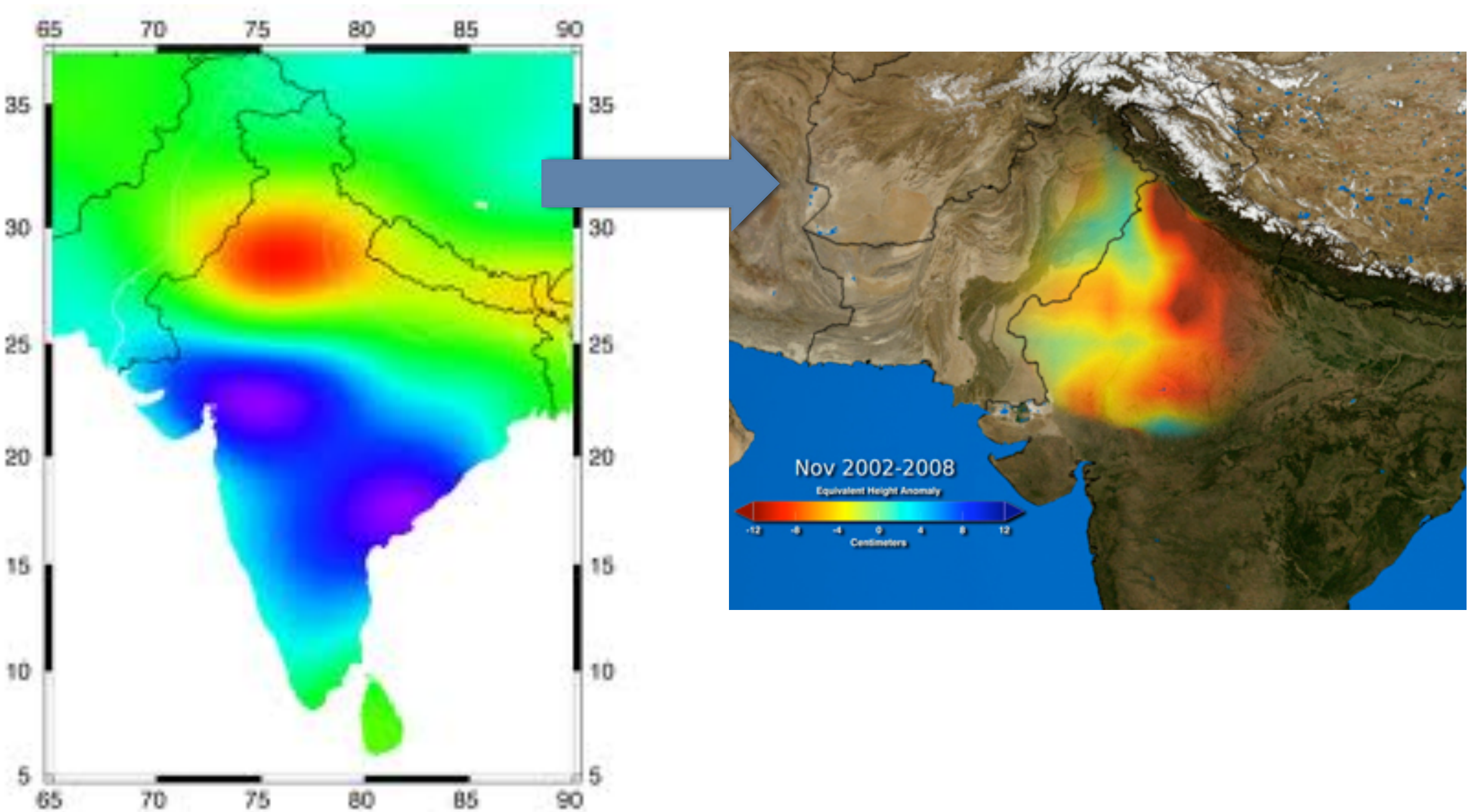


3. (2002) Ecological Climatology: Concepts and Applications. Cambridg

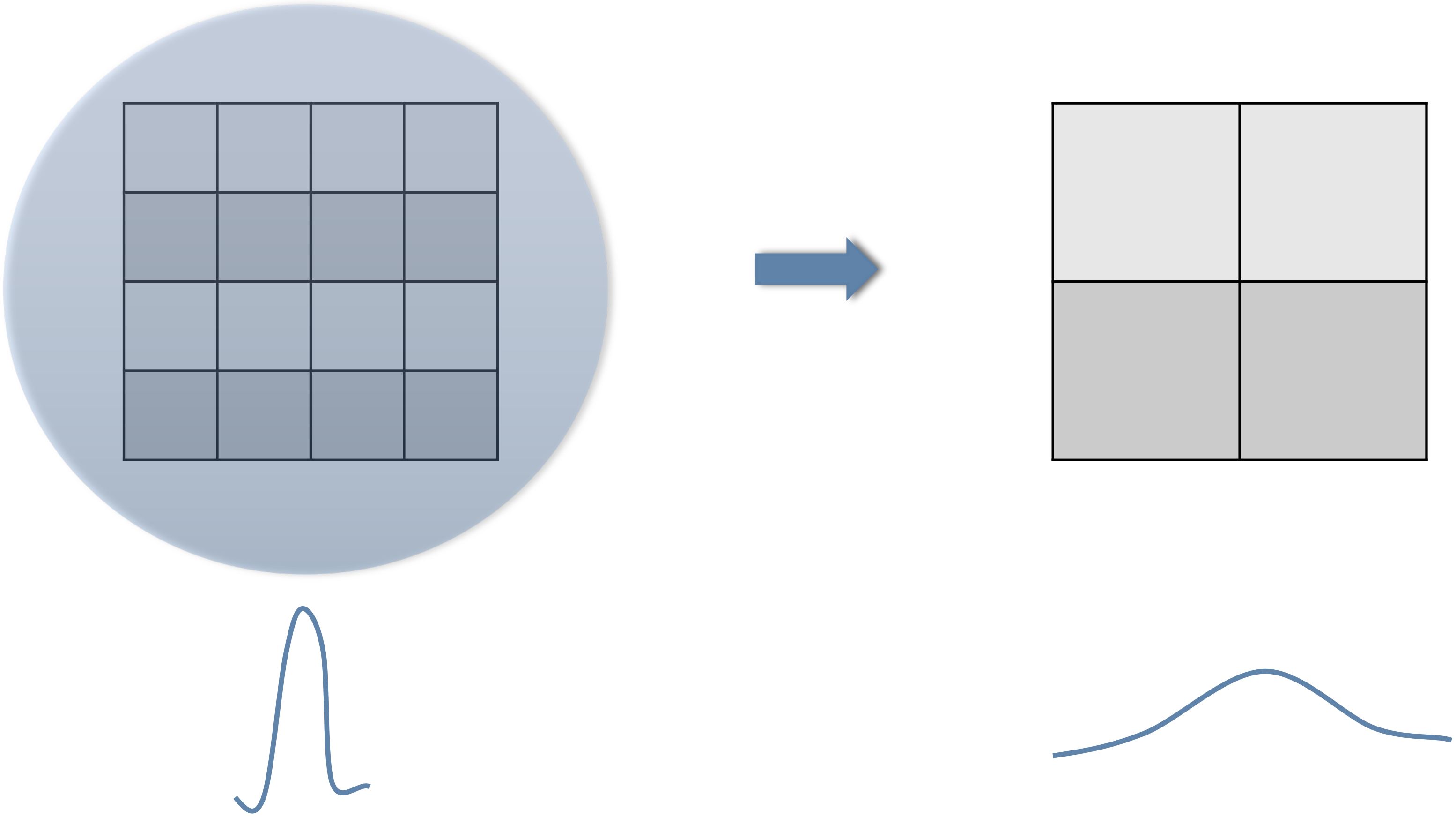


Uzbekistan
Tajikistan
Kabul
Lahore
Pakistan
New Delhi
Iran
China
Ahmadabad
Calcutta
India
Bombay
Myanmar
Rangoon
Madras
Sri Lanka
Colombo

GRACE signal loss and recovery



GRACE signal loss and recovery



GRACE signal loss and recovery

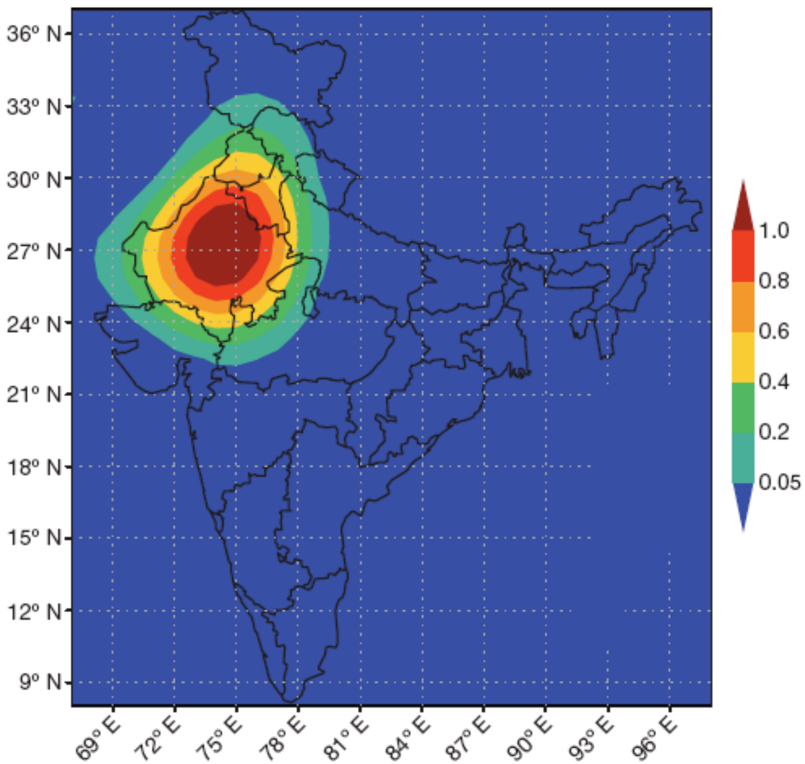
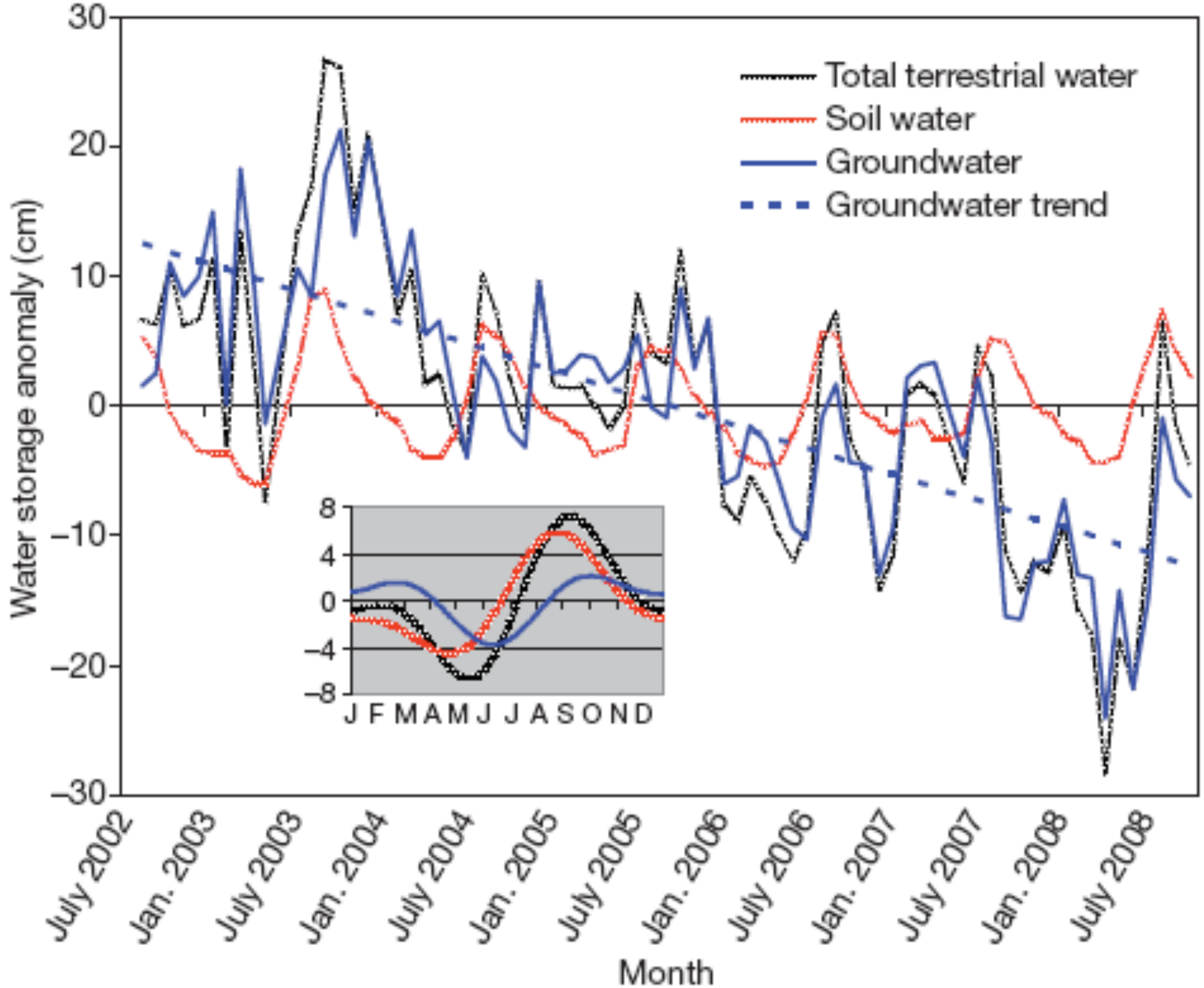


Figure 2 | GRACE averaging function. The unscaled, dimensionless averaging function used to estimate terrestrial water storage changes from GRACE data is mapped.

- Scale factor applied to region of interest
- Accounts for loss due to gaussian smoothing
- Recovers signal lost due to limited resolution of GRACE



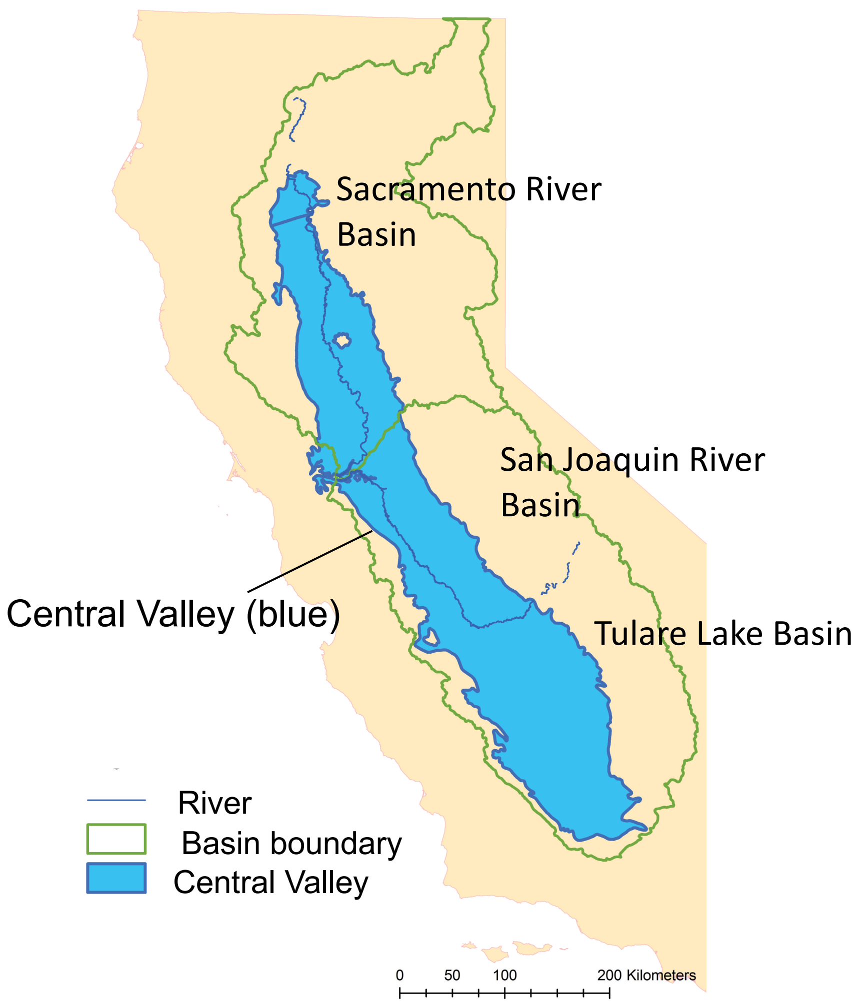
4 +/- 1 cm/yr height

17 +/- 4.5 $km^3 yr^{-1}$

109 km^3 total

13.2 km^3/yr – Indian Government reported balance

Water Storage Changes in California's Sacramento-San Joaquin River Basins, Including Central Valley Groundwater: October, 2003-March, 2009



The combined Sacramento and San Joaquin River Basins

- Cover an area of approximately 154,000 km^2
- Includes California's major mountain water source, the snowpack in the Sierra Nevada mountain range
- Includes its primary agricultural region, the Central Valley (~52,000 km^2)

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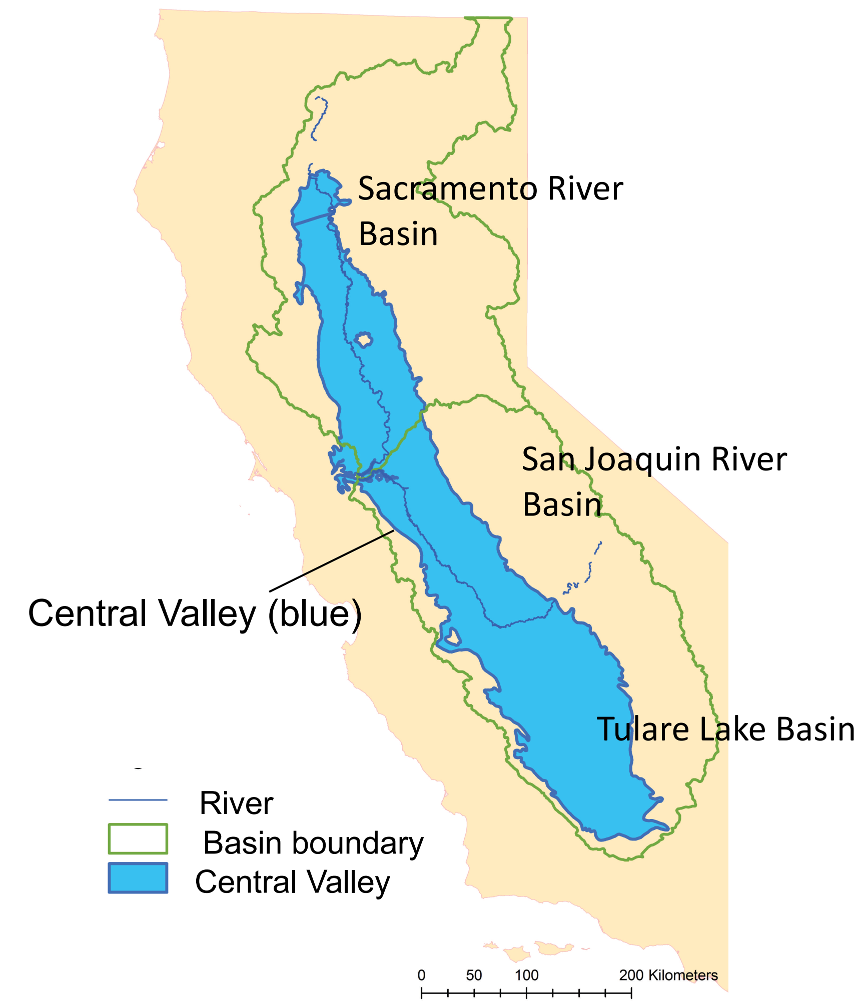

California's Central Valley

- Is one of the most productive agricultural regions in the world
- Produces more than 250 different crops worth $17 billion per year (2002), or 8% of the food produced in the U. S. by value
- Accounts for 1/6 of irrigated land in the U.S.
- Supplies 1/5 of the demand for groundwater in the U.S.
- Is the second most pumped aquifer in the U. S.

Monitoring groundwater availability in the Central Valley is critical to help manage California's water crisis, its impact on the state's economy and the Nation's food production

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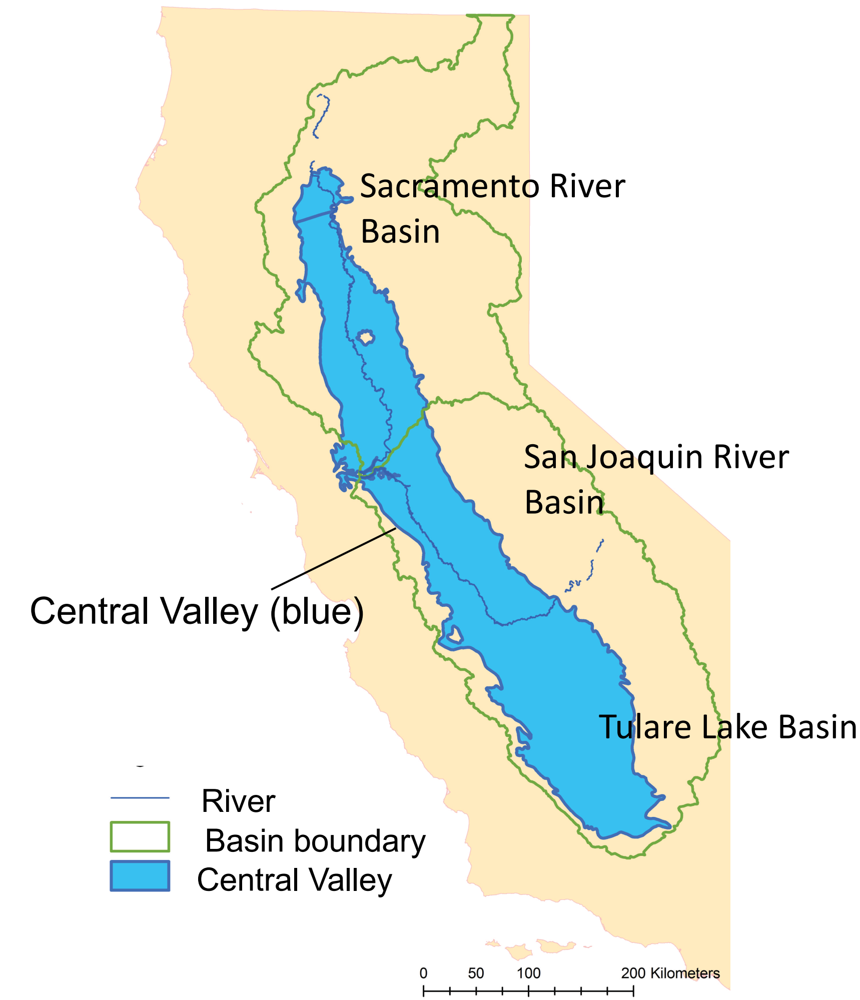

Total water storage in this region comprised of:

- groundwater
- soil water
- surface water
  - Lakes and reservoirs
- Snow (snotel SWE from DAg)

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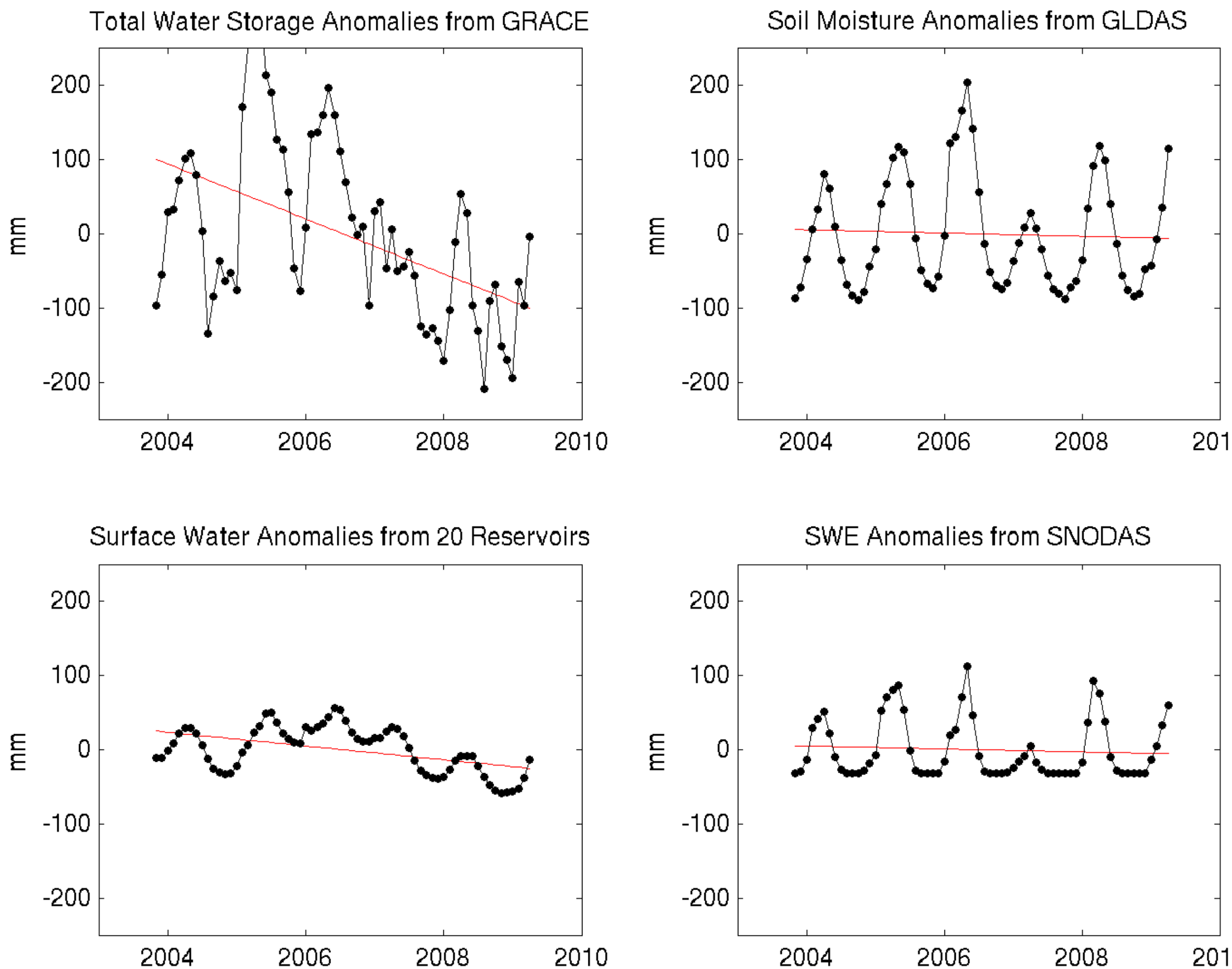
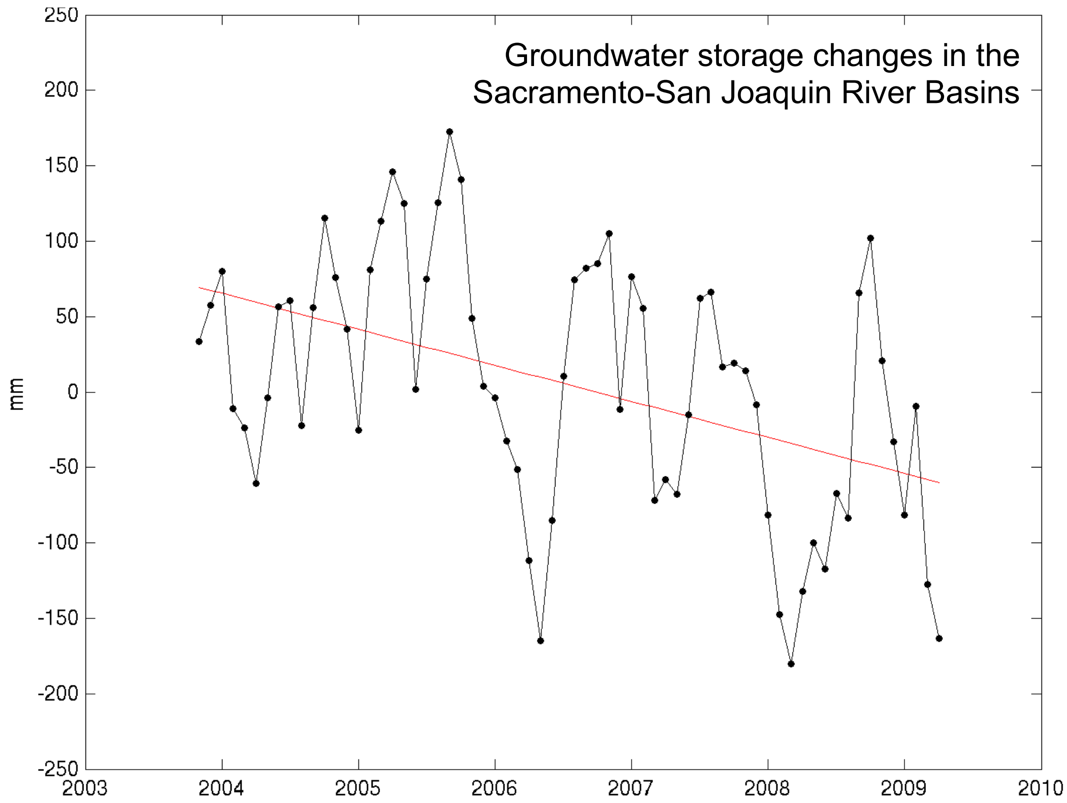


	Trend (mm/yr)
GRACE Total Water Storage	-37
Snow	-2
Surface Water	-9
Soil Moisture	-2

$$\Delta S_{\text{Groundwater}} = \Delta S_{\text{Total}} - \Delta S_{\text{Snow}} - \Delta S_{\text{Surface Water}} - \Delta S_{\text{Soil Moisture}}$$

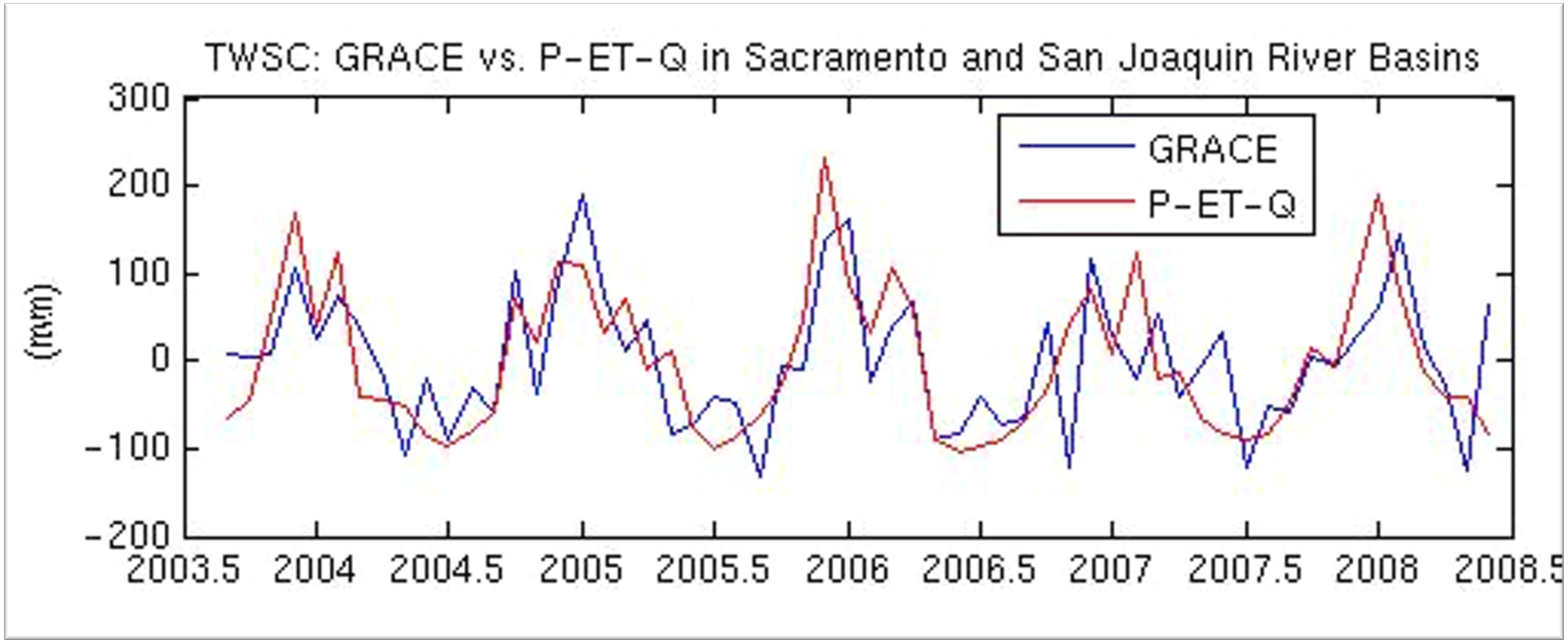


	Trend (mm/yr)	Volume lost (km^3)
GRACE Total Water Storage	-37	31.3
Snow	-2	1.7
Surface Water	-9	7.6
Soil Moisture	-2	1.7
Groundwater	-24	20.3

- In the 66 month period analyzed, the water stored in the combined Sacramento-San Joaquin River Basin decreased by over 31 km^3, or nearly the volume of Lake Mead
- Nearly two-thirds of this, or roughly 20 km^3, came from changes in groundwater storage, primarily from the Central Valley

Validation: Terrestrial water balance

- Precipitation: PRISM 0.25 degree grids for continental US
- Runoff: USGS stations for Sacramento and San Joaquin Rivers
- Evaporation from GLDAS
- $dS/dt = (S_2 - S_1)/dt$



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