Mass Balance Methods for Estimating Regional to Global Freshwater Discharge Using GRACE and Altimetry

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Methods discussed today

- Land-based
  - -Discharge from the continents into the ocean
  - $-dS_L/dt = P - E - Q$
  - -Use GRACE for dS/st

- Ocean-based
  - -Discharge into the ocean from the continents
  - $-dS_O/dt = P - E + Q$
  - -Use altimetry for sea level rise, remove thermal expansion

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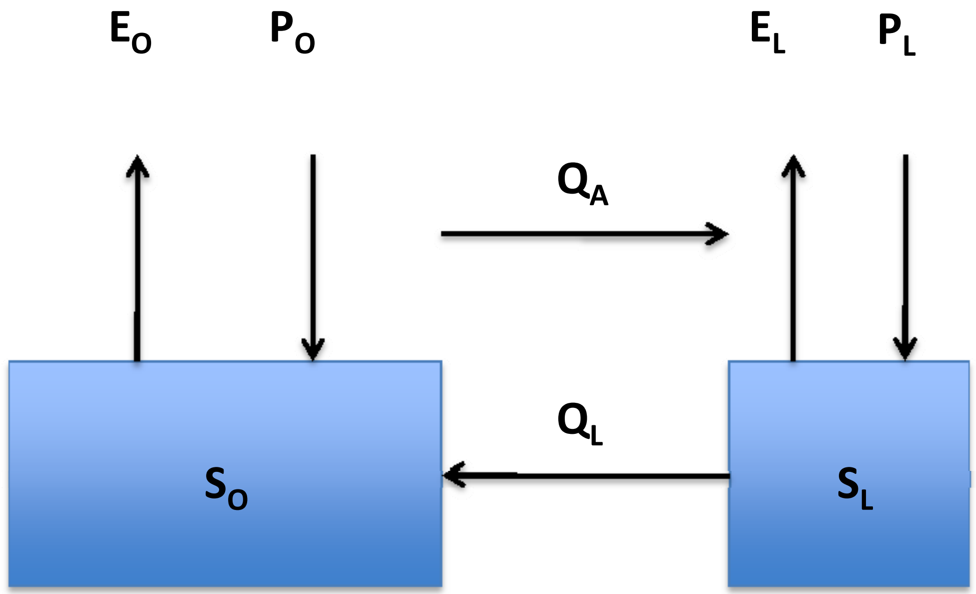


$$\Delta S_O = P_O - E_O + Q_L$$

$$\boxed{\Delta S_L = P_L - E_L - Q_L}$$

Regional and global discharge estimation using GRACE on land

Terrestrial water balance

$$\Delta S_{LAND} = P - E - R$$

Atmospheric water balance

$$\Delta W = E - P - divQ$$

Coupled land-atmosphere water balance

$$R = \Delta S_{LAND} - \Delta W - divQ$$

ΔS_{LAND}: storage change (dS/dt)

P: precipitation

E: evaporation

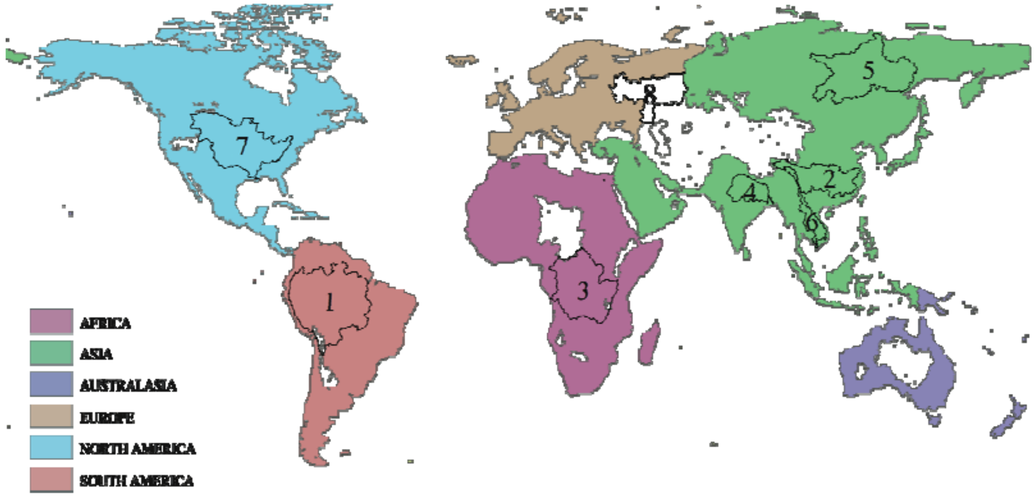
R: discharge

ΔW: precipitable water storage change (dW/dt)

divQ: horizontal water vapor divergence

- ***Previously had to assume that $\Delta S_{LAND} = 0$ and apply at annual time scales***
- ***Now we have ΔS_{LAND} so we can compute monthly time series***

Regional and global discharge estimation using GRACE on land



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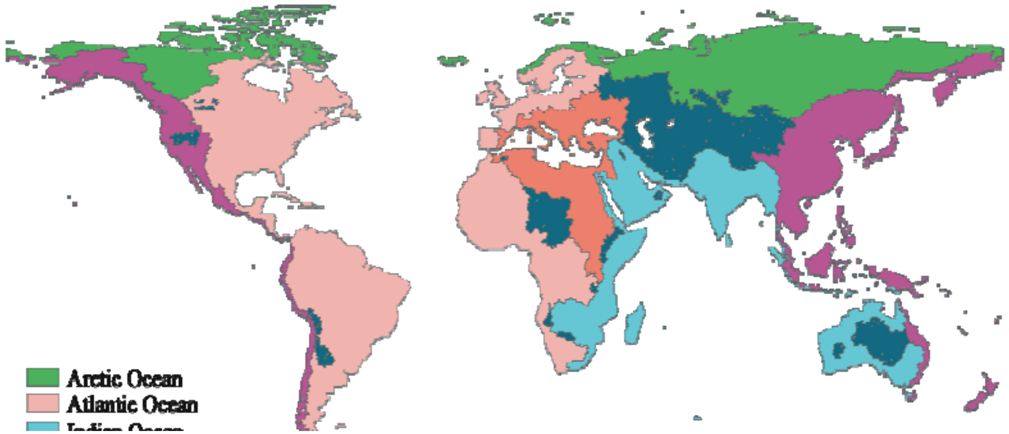
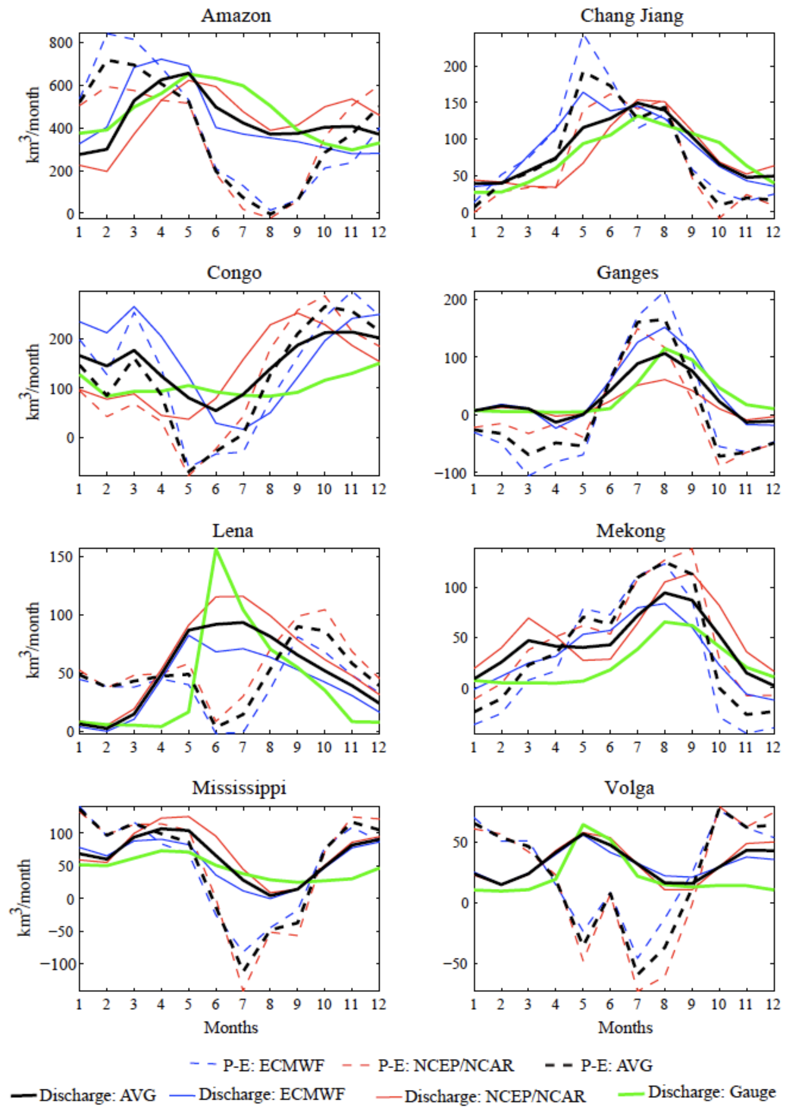


Syed et al., 2009

Regional and global discharge estimation using GRACE on land



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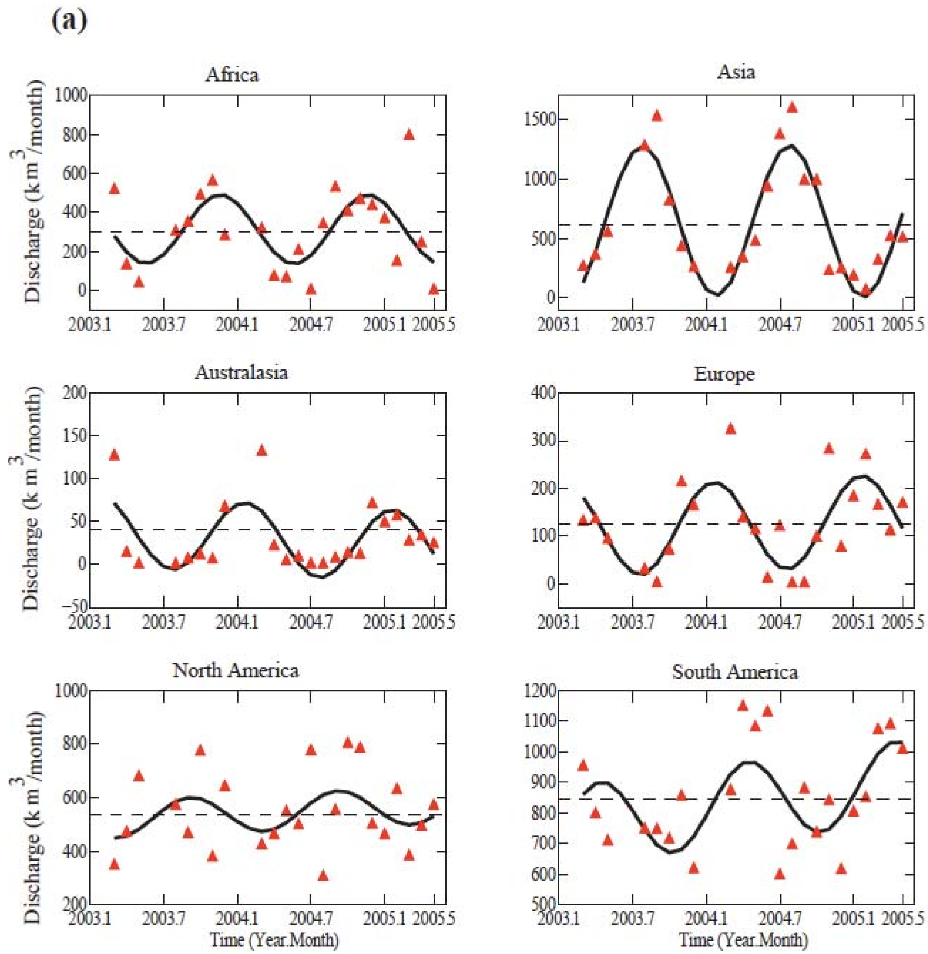
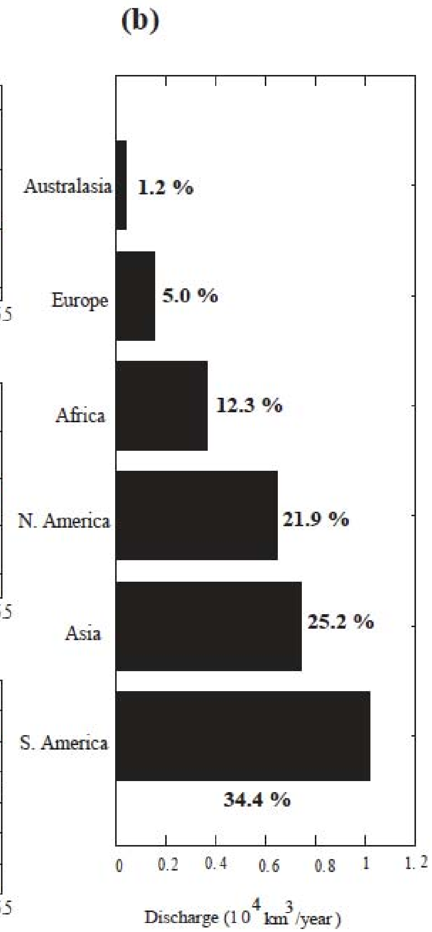
Regional and global discharge estimation using GRACE on land





Syed et al., 2009

Regional and global discharge estimation using GRACE on land

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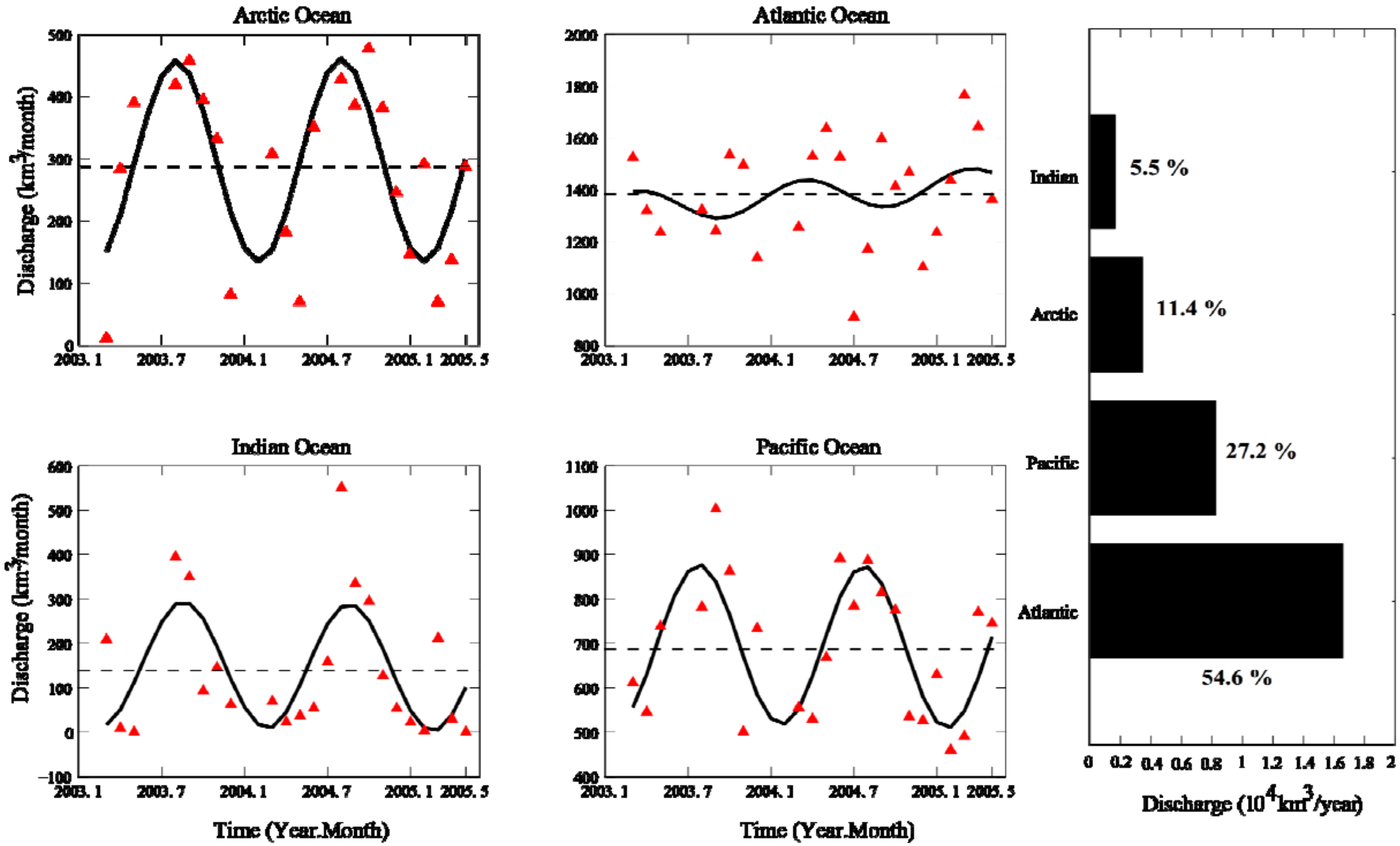

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Regional and global discharge estimation using GRACE on land

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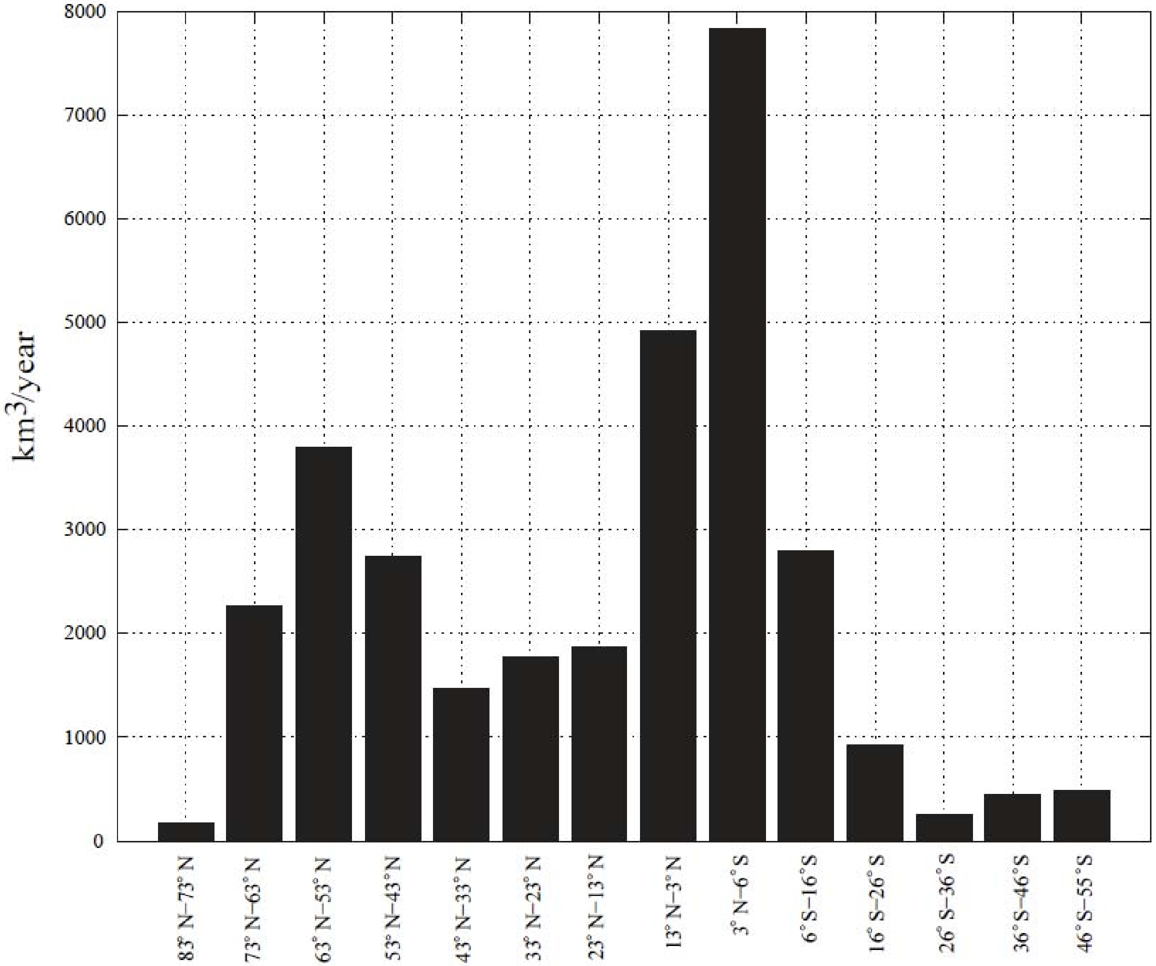

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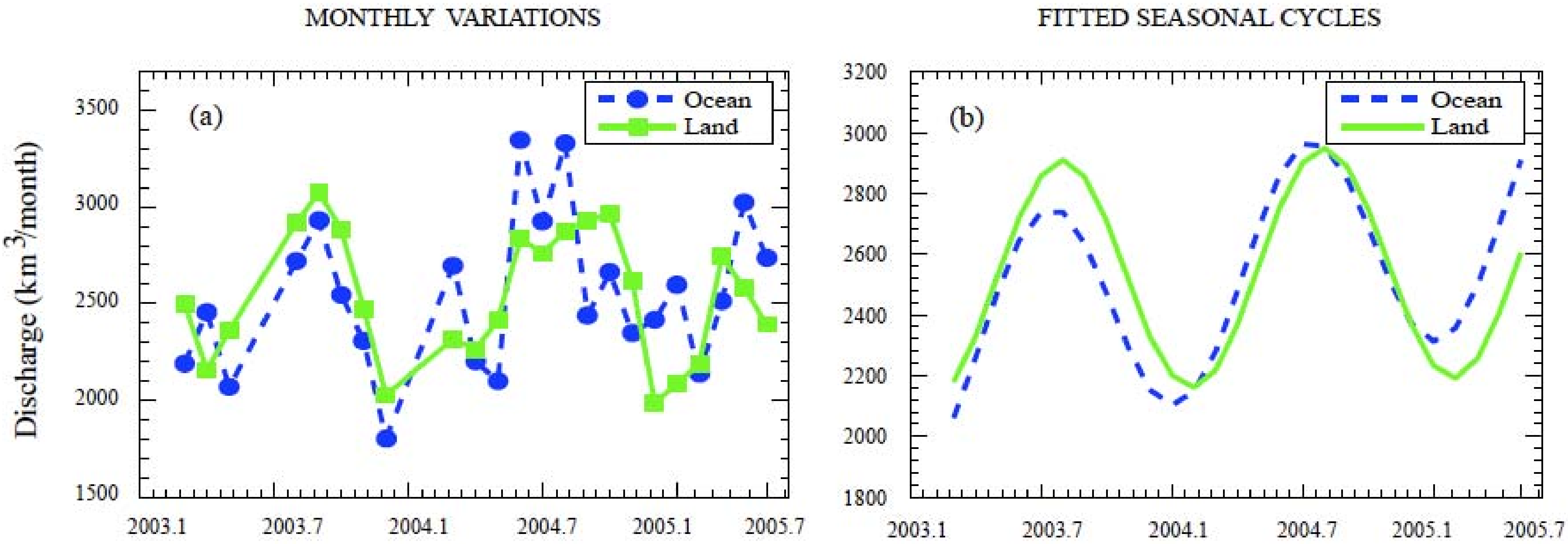
Regional and global discharge estimation using GRACE on land



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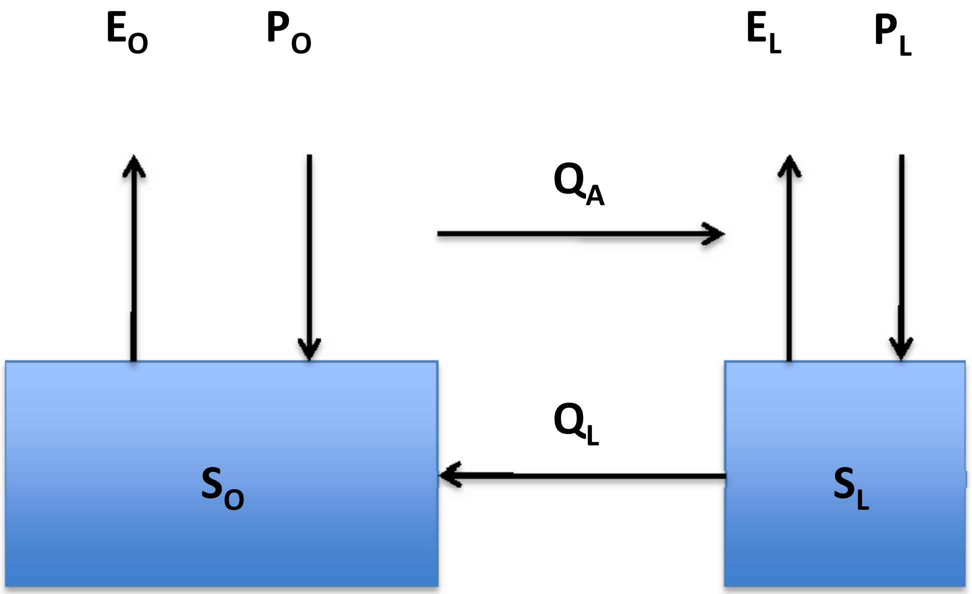
Global discharge estimation using an ocean mass balance



$$\Delta S_O = P_O - E_O + Q_L$$

$$\Delta S_L = P_L - E_L - Q_L$$

Global discharge estimation using an ocean mass balance

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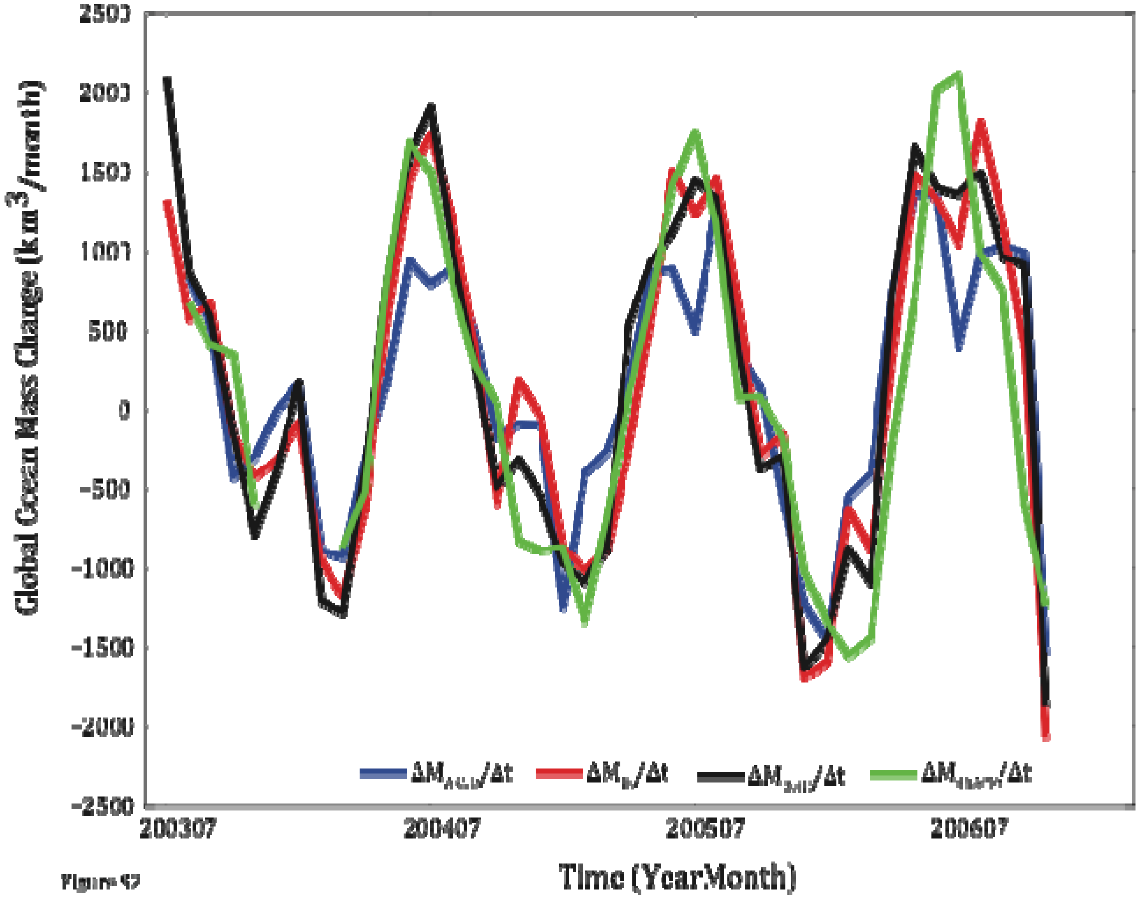
Global ocean mass change



Global ocean mass change from T/P & Jason-1 mean sea level variations minus thermal expansion

Temperature data from ARGO floats, Ishii (2006) and Ingleby and Huddleston (2007).

Comparisons were favorable during GRACE era, so we used both Ishii and IH to compute global discharge from 1994-2006

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Global discharge estimation using an ocean mass balance

Global ocean precipitation from GPCP and CMAP

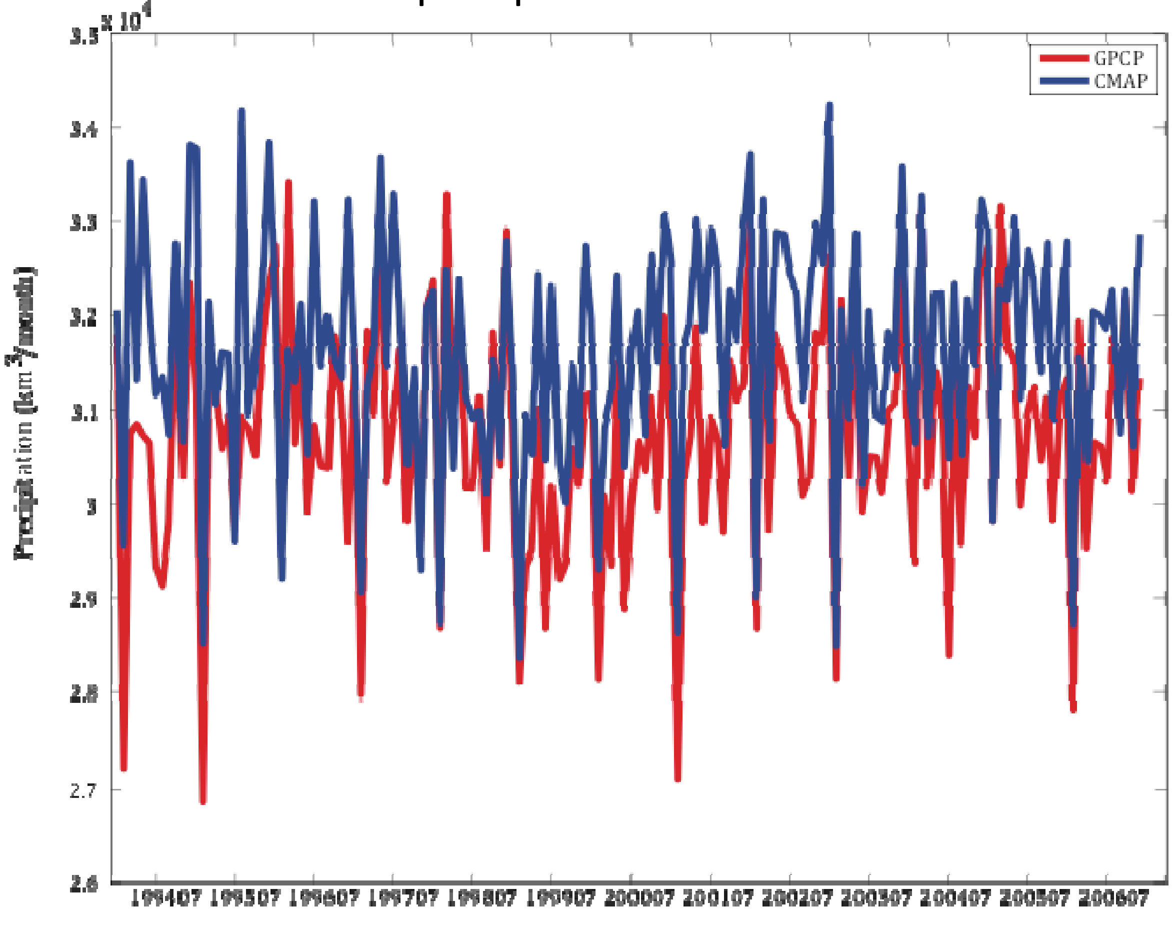

Figure S4

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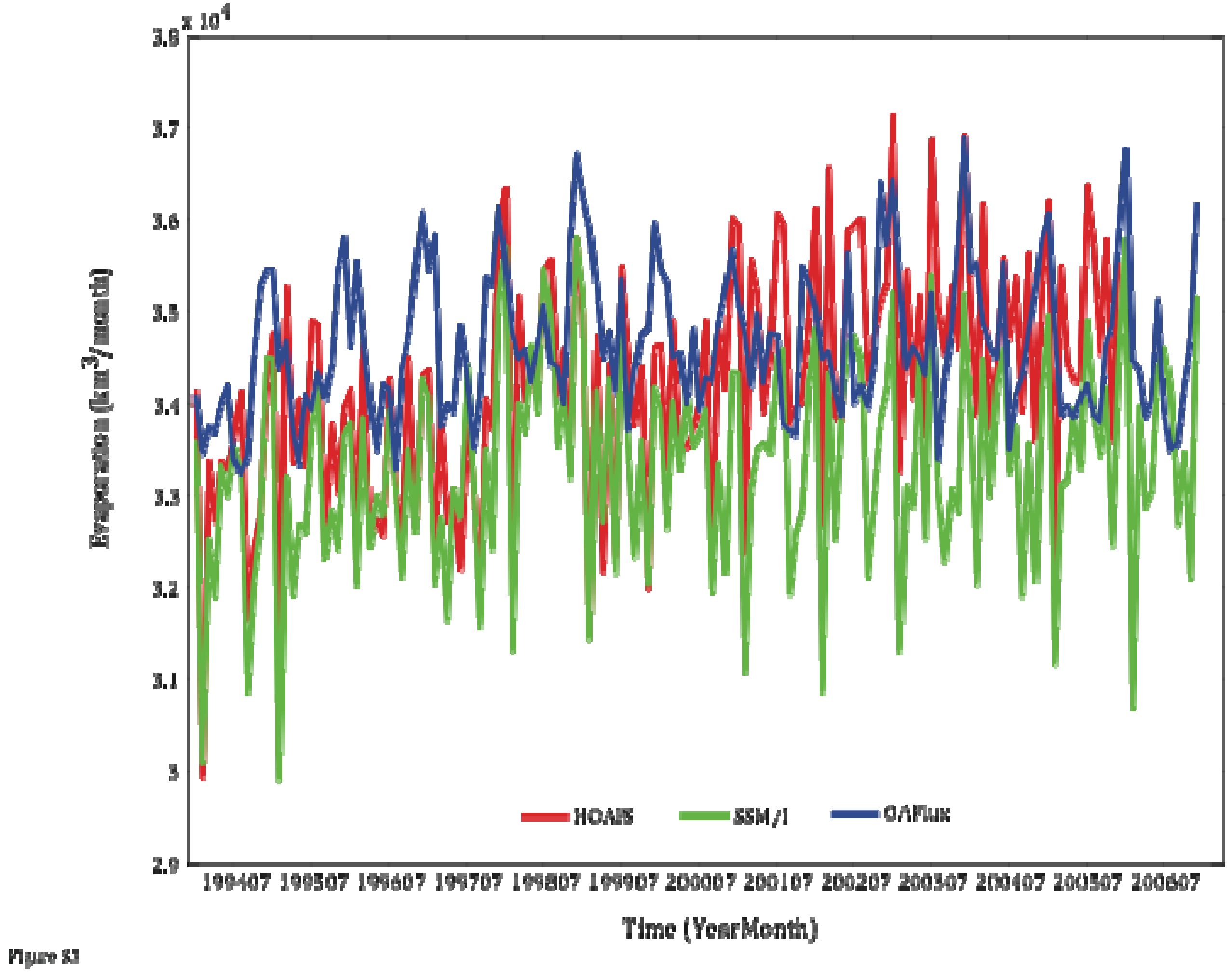
Global discharge estimation using an ocean mass balance

Global ocean evaporation from OAFlux, HOAPS, SSM/I



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Global discharge estimation using an ocean mass balance

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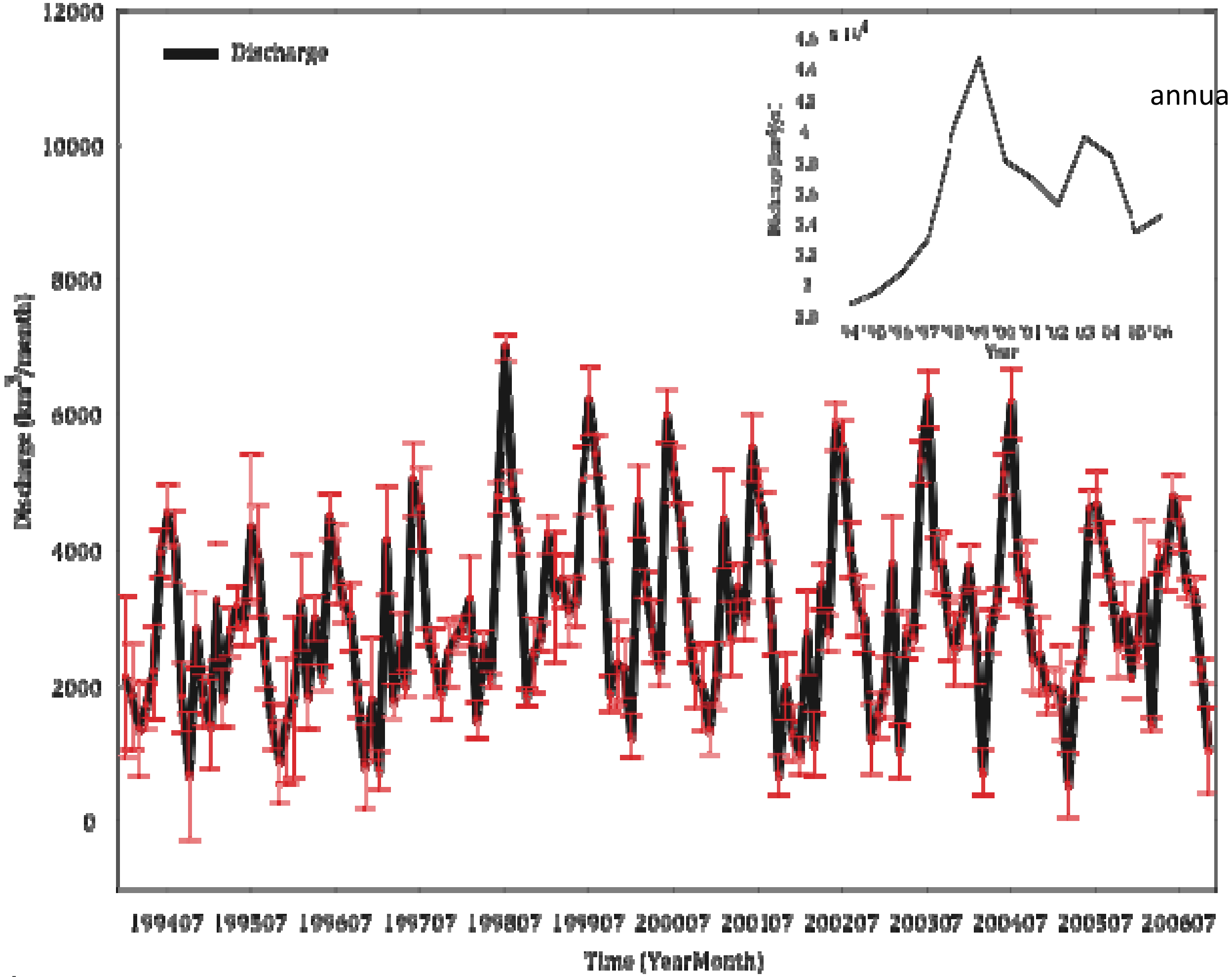
Global discharge time series, 1994-2006



annual discharge

Monthly discharge

Figure 1

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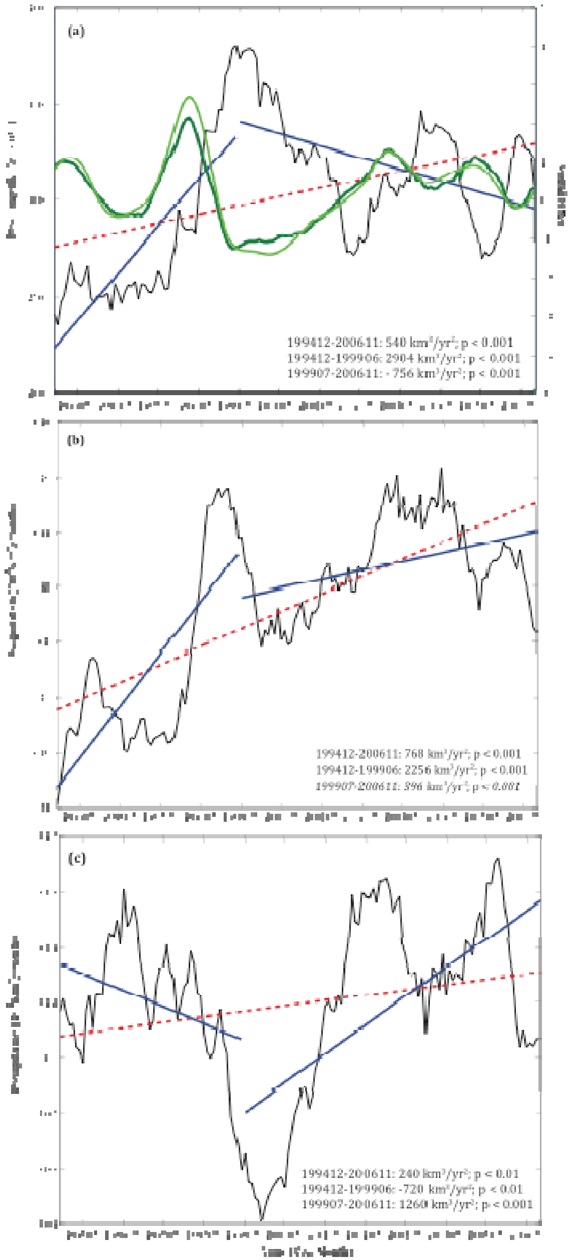
Discharge, annual cycle removed

Evaporation, annual cycle removed

Precipitation, annual cycle removed



Lots of interannual variability

Emerging trends show increase in discharge of 540 km^3/yr^2 or 1.5%/yr for the 13-year time period

Apparently driven by increasing evaporation over the oceans which results in increasing precipitation on land

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Table 1. Mean, standard deviation, and the emerging trend in the global-ocean mass balance components

Component (data source)	Mean	Standard deviation	Trend
Discharge (R) [illegible]	[illegible] km^3/y	[illegible] km^3/y	540 km^3/y^2
Evaporation (E) (SSM/I, [illegible] & HOAPS)	[illegible] km^3/y	[illegible] km^3/y	[illegible] km^3/y^2
Precipitation (P) (GPCP & CMAP)	[illegible] km^3/y	[illegible] km^3/y	[illegible] km^3/y^2
Global ocean mass change [illegible] sea surface heights)	[illegible] km^3/y	[illegible] km^3/y	[illegible] km^3/y^2

[illegible]

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Some food for thought

- The discharge rate includes the ice sheets which are on the order of ~400 km^3/yr
- The discharge trend includes the ice sheet acceleration, which is on the order of ~40 km^3/yr
- Implications for water cycle acceleration if these short-term trends continue for the longer term

Summary

- Mass balance methods using GRACE, altimetry and supporting datasets can deliver coarse-scale global discharge now. However, they do not have the spatial-temporal resolution required to observe the behavior of surface water dynamics, flood inundation, etc. that SWOT will have. It is a nice, low-resolution complement that is powerful at climatological timescales.

- Role of discharge in land contributions to global mean sea level rise probably deserves more attention. While the ice sheets are a major long-term driver, the water cycle and the balance of P, E, and Q have a huge impact on short-term variations in sea level rise.