Groundwater Depletion

Observing changes in groundwater storage

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Outline of discussion

• GRACE satellites
• Global groundwater stress
• Site-specific examples
  – Central Valley, California, USA
  – East Africa
  – Colorado River Basin, USA
• Uncertainty in global groundwater storage
NASA Gravity Recovery and Climate Experiment (GRACE)

- Launched in 2002
- Functions like a ‘scale in the sky’ that can weigh the monthly increase or decrease in water storage in a large (>150,000 km²) region with an accuracy of 1.5 cm
Groundwater depletion: Colorado River Basin

\[ \Delta S_{\text{Total}} = \Delta S_{\text{Snow}} + \Delta S_{\text{Surface Water}} + \Delta S_{\text{Soil Moisture}} + \Delta S_{\text{Groundwater}} \]

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

Remove this \((\Delta S_{\text{Snow}} + \Delta S_{\text{Surface Water}} + \Delta S_{\text{Soil Moisture}})\) from \(\Delta S_{\text{Total}}\)…

To isolate this \((\Delta S_{\text{Groundwater}})\)
Global Groundwater Depletion
Limitations of GRACE

• Scale
  >150,000 km²

• Salt water intrusion/water quality

• 3-dimensional changes
  No information of groundwater flow

• Confined vs. Unconfined
Global Groundwater Stress

Definition of “Groundwater Use”

• Renewable Groundwater Stress (RGS)

\[ RGS = \frac{use}{availability} \]

use: withdrawal statistics or GRACE availability: simulated aquifer recharge

Global Groundwater Stress

Definition of “Groundwater Use”

Global Groundwater Stress
Definition of “Groundwater Use”

Regional Groundwater Studies
GRACE time series

Increase in storage

Decrease in storage

Date

TWS Anomalies (cu. km)
Regional Groundwater Studies
California Central Valley

Thomas et al., in prep
Regional Groundwater Studies
California Central Valley

Data Source
- USGS
- GRACE

Cumulative Groundwater Loss (cu. km)

Variable to Dry
Variable to Wet
Dry
Wet
Dry
Wet
Variable to Dry
Variable to Wet
Dry
Variable to Wet
Dry

62 64 66 68 1970 72 74 76 78 1980 82 84 86 88 1990 92 94 96 98 2000 02 04 06 08 2010 12 14 16 18 2020

Thomas et al., in prep
Regional Groundwater Studies
California Central Valley

Thomas et al., in prep
Regional Groundwater Studies
East Africa

- ~80% of population relies on groundwater
- Records impeded by limited funding and regional conflicts
Regional Groundwater Studies
East Africa

Estimated GW storage anomalies over Uganda

(a)

(b)

Nanteza et al., in prep
Regional Groundwater Studies
Colorado River Basin

Castle et al., 2014
Regional Groundwater Studies
Colorado River Basin

A) Volume Anomaly km³

-60  -40  -20   0   20   40   60

Groundwater
Reservoir Storage

Castle et al., 2014
Uncertainty in Global Groundwater Storage

Estimated groundwater storage (in cu. km)

Richey et al., 2015
Uncertainty in Global Groundwater Storage

Time to 90% depletion (in years)

Richey et al., 2015
GRACE Data
http://grace.jpl.nasa.gov/data/get-data/

Get Data

**GRACE Monthly Mass Grids - Land**
Land water storage from GRACE is updated monthly, and is provided on 1-degree global grids.

**GRACE Monthly Mass Grids - Ocean**
Ocean bottom pressure from GRACE is updated monthly, and is provided on 1-degree global grids.

**GRACE Monthly Mass Grids - JPL Global Mascons**
Global surface mass (land + ocean) from GRACE is updated monthly, and is provided on 0.5-degree global grids.

**Interactive GRACE Data Browsers**
These links to data browser allow the interactive retrieval of GRACE Land data over river basins, as well as the evaluation of long-term trends and mean seasonal amplitudes.
GRACE Data
Monthly GRACE Grids

- Terrestrial TWSA and Scaling Factors
- Time series error must be calculated
- netCDF or ascii format
- 1-degree global grid
GRACE Data
TWSA Mascons

• Mass Concentration Blocks (mascons)
• Avoids spherical harmonics calcs
• Available at 0.5-degree grid, but recognize original 3-degree resolution
• Gain factors are used for hydrology-based analysis
GRACE Data
CU GRACE Data Portal

GRACE TWS for pfafstetter basin: 1008 (300 km)

Download GRACE Data  Download Basin Map  Download Time Series Image
Questions?

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