Overview of the Gravity Recovery and Climate Experiment (GRACE) Data and Applications

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Outline

• About GRACE
• GRACE Data and Access
• GRACE Data Applications
About GRACE

Courtesy: Materials provided for this presentation are courtesy of Brian Thomas, Jay Famiglietti (JPL), JT Reager (JPL), Matt Rodell (Goddard), John Bolten (Goddard)
GRACE


- GRACE is a twin satellite system
- Launched in May 2002
- Polar, sun-synchronous orbit
- Global Coverage
- Sensors
  - Microwave K-band Ranging Instrument
  - Accelerometers
  - Global Positioning System Receivers
GRACE


- GRACE is a joint satellite mission between NASA and the German Aerospace Center (DLR)
- Measures changes in total, column-integrated Terrestrial Water Storage (TWS) from space
- Measurement of spacecraft to spacecraft distance within a few millionths of an inch requiring extremely sensitive instruments
- Provides a time-series of monthly, time-variable gravity field estimates
GRACE Satellite

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

- Measures 250 gravity profiles per day that can be related to water storage within the Earth’s surface
- Unique in its ability to monitor water at all levels, down to the deepest aquifer
- Weighs monthly increase/decrease of water storage with an accuracy of 1.5cm
How can gravity monitor water?

- Long-term average distribution of the mass within the Earth system determines its mean or static gravity field
- Variations of Earth’s gravity field largely determined from
  - motion of water and air on time scales ranging from hours to decades

*Reference: [http://www.csr.utexas.edu/grace/asdp.html](http://www.csr.utexas.edu/grace/asdp.html)
From Gravity to Equivalent Terrestrial Water Thickness

- Observed monthly changes in gravity are caused by monthly changes in mass.
- Mass changes can be thought of as concentrated in a very thin layer of water at the surface, whose thickness changes.
- Vertical extent is measured in centimeters, much smaller than the radius of the Earth or the horizontal scales of the changes, which are measured in kilometers.

Ground Water from Terrestrial Water Storage

- GRACE has no vertical resolution
  - cannot distinguish between water stored as snow, soil moisture, and ground water
- Differences between Terrestrial Water Storage (TWS) anomalies and changes in water storage determined by land surface models allows for vertical disaggregation of the signal in order to constrain model states
Ground Water from Terrestrial Water Storage

\[ P - ET - Q = \Delta TWS \text{ [terrestrial water balance]} \]
\[ \Delta TWS = \Delta GW + \Delta SM + \Delta SWE + \Delta SW \]
\[ \Delta GW = \Delta TWS - \Delta SM - \Delta SWE - \Delta SW \]

- \( P \) = precipitation
- \( ET \) = evapotranspiration
- \( Q \) = river discharge
- \( \Delta TWS \) = change in terrestrial water storage [from GRACE]
- \( \Delta GW \) = change in groundwater storage [unknown]
- \( \Delta SM \) = change in soil moisture \( \Delta SWE \) = change in snow water equivalent
- \( \Delta SW \) = change in surface water storage

[\( \Delta GW, \Delta SM, \Delta SW \) from Global Land Data Assimilation System (GLDAS) models]
GRACE Data and Access
GRACE Terrestrial Water Storage Data

- Provides monthly anomalies (deviations from the mean) in total column water
  - groundwater, soil moisture, snow
- Spatial Resolution: 150,000km² (~380km)
- Given the extremely high precision of GRACE, the resulting errors are ~1.5cm for monthly storage anomalies at the 150,000km² scale

*Reference: Jay Famiglietti, JPL, 2015
GRACE Level-2 Data Access

There are three centers for GRACE data access:

1. JPL data portal:
   – ftp://podaac.jpl.nasa.gov/allData/grace

2. GFZ data portal:
   – http://isdc.gfz-potsdam.de

3. GRACE Website at University of Texas at Austin Center for Space Research (CSR):
   – http://www.csr.utexas.edu/grace
   – Latest data format release: http://www.csr.utexas.edu/grace/RL05.html
Grace Level-3 Data Access

Several GRACE users have put together resources to create & distribute value-added (or Level 3) products from GRACE project data products

  – Provides time-series of surface mass anomalies in map form, after suitable treatment for smoothing and corrections

• CU, Boulder: [http://geoid.colorado.edu/grace/](http://geoid.colorado.edu/grace/)
  – Provides an interactive tool for calculation error-corrected mass anomalies in regional or global time series

• ICGEM: [http://icgem.gfz-potsdam.de/ICGEM/ICGEM.html](http://icgem.gfz-potsdam.de/ICGEM/ICGEM.html)
  – Distributes a full range of current and historical static Earth gravity field models
  – Also includes tutorials and software resources for physical geodetic calculations, and contains links to related gravity field services
JPL Grace Data Portal

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.

Data News & Updates
Please check Data News and Updates for announcements and important information.

Featured Resources
- GRACE global gravity animation
- GRACE data over the United States, 2003-2012
- Scale in the Sky

+ more resources
GRACE Data Formats

http://grace.jpl.nasa.gov/data/get-data/

- Mass Concentration Blocks (mascons)
- Avoids spherical harmonics calculations
- Available at 0.5-degree grid, but recognizes original 3-degree resolution
- Gain factors are used for hydrology-based analysis

- Terrestrial Water Storage Anomaly and Scaling Factors
- netCDF or ASCII format
- 1-degree global grid
GRACE Interactive Data Analysis and Download Portal
http://geoid.colorado.edu/grace/

WELCOME TO THE CU GRACE MISSION
REAL-TIME DATA ANALYSIS PORTAL

This website allows visitors to perform basic data analysis on publicly available Level-2 GRACE data. Computations are performed in real-time, producing downloadable maps or time series.

Analyze Data »
GRACE Interactive Data Analysis and Download Portal

http://geoid.colorado.edu/grace/dataportal.html

Map and Time Series Plotting Options

Zoom-in and Time Series Region Selection Options
GRACE Interactive Data Analysis and Download Portal

http://geoid.colorado.edu/grace/dataportal.html

GRACE Data Selection Options
Monthly Terrestrial Water Storage Data: Time Selection

http://geoid.colorado.edu/grace/dataportal.html

Time Selection

• YYYY:DY
• DY=Decimal Year
  – Day of Year/365
• DY=0.79
  – Represents 0.79*365=288th Day of the Year = 15 October
  – 2010.79 selects data for October 2010
Monthly Terrestrial Water Storage Anomaly Visualization

http://geoid.colorado.edu/grace/dataportal.html

Terrestrial Water Anomaly for September 2015 showing deficit over Brazil
Time Series of Monthly Terrestrial Water Storage Anomaly

http://geoid.colorado.edu/grace/dataportal.html

Click on the location and choose the time series option.

Data & Image Download
GRACE Applications
GRACE Provides Emerging Trends in Freshwater Resources

Rate of Change of Terrestrial Water Storage (TWS) as an Equivalent Height of Water (cm/yr) from GRACE, 2002 - 2015

*Source: Matt Rodell (NASA-GSFC)
GRACE Observes the Seasonal Hydrologic Cycle in the Amazon Basin

- GRACE data has relatively low spatial resolution
- Useful in monitoring large-scale terrestrial water changes
- Image on the right shows monthly change (2003) compared to 14-month average

*Courtesy of: Paul Thompson, GRACE Science Team*
GRACE Ground Water Data Used for Drought Monitoring

http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx
Potential for Flood Prediction

GRACE-Based Flood Index
Maxima, May 2007

Recorded Floods, Dartmouth Flood Observatory, May 2007

*Reference: J.T. Reager (JPL) and J. Famiglietti (JPL), 2009
Regional Groundwater Studies
California Central Valley

*Reference: Thomas et al., in prep
Assimilation of GRACE Terrestrial Water Storage (TWS) Data Results in Higher Resolution & Better Accuracy Than Models Alone

From scales useful for water cycle and climate studies…

*Reference: Matt Rodell (NASA-GSFC)

…to scales needed for water resources and agricultural applications
GRACE - Monitoring Groundwater Depletion in India

Courtesy: NASA Goddard Visualization Lab
Monitoring Terrestrial Water Change in Brazil

Courtesy: NASA Goddard Visualization Lab
Explore the GRACE Data Portal
http://geoid.colorado.edu/grace