

ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

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

Acknowledgements:

John Bolton (NASA-GSFC)

Brian Thomas (NASA-JPL)

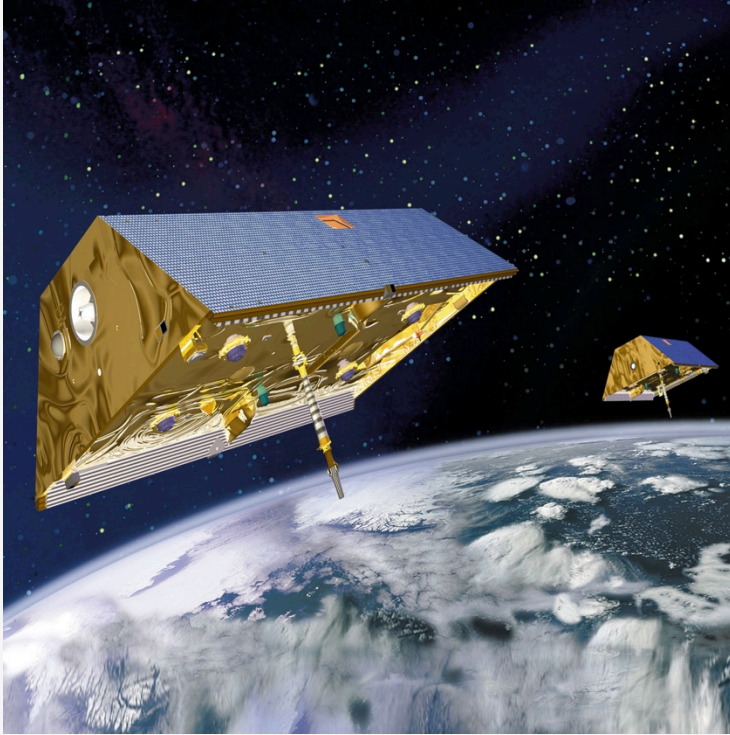
Outline

- About GRACE
- GRACE Data and Access
- GRACE Data Applications

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

GRACE

<http://www.jpl.nasa.gov/missions/details.php?id=5882>

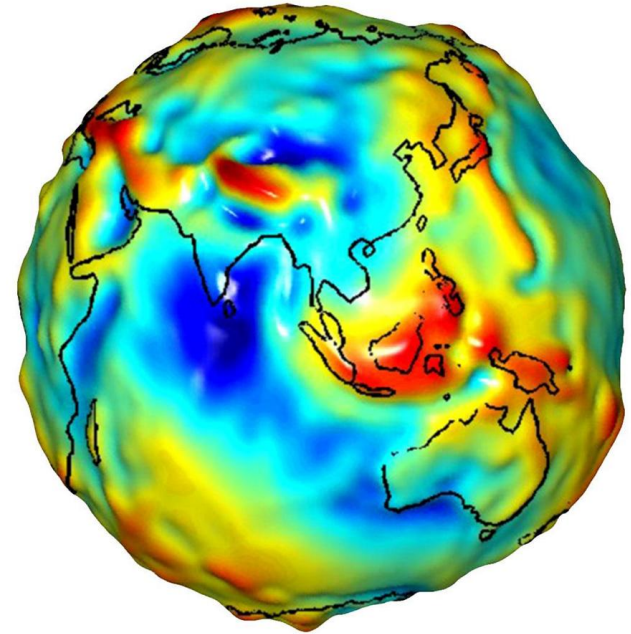


- GRACE is a twin satellite system
- Launched in May 2002
- Polar, sun-synchronous orbit
- Global Coverage
- Sensors
 - Microwave K-band Ranging Instrument
 - Accelerometers
 - Global Positioning System Receivers

GRACE

<http://www.jpl.nasa.gov/missions/details.php?id=5882>

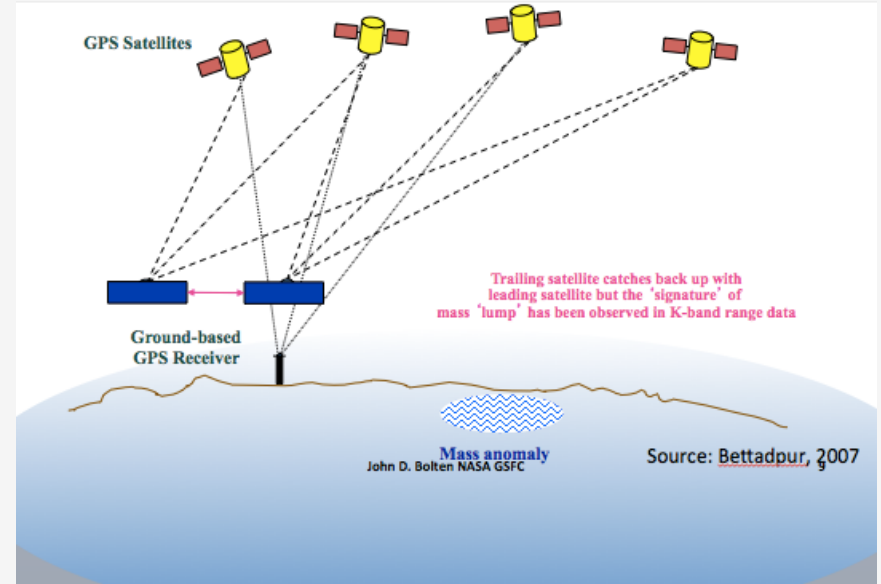
- GRACE is a joint satellite mission between NASA and the German Aerospace Center (DLR)
- Measures changes in total, column-integrated Terrestrial Water Storage (TWS) from space
- Measurement of spacecraft to spacecraft distance within a few millionths of an inch requiring extremely sensitive instruments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



GRACE Satellite

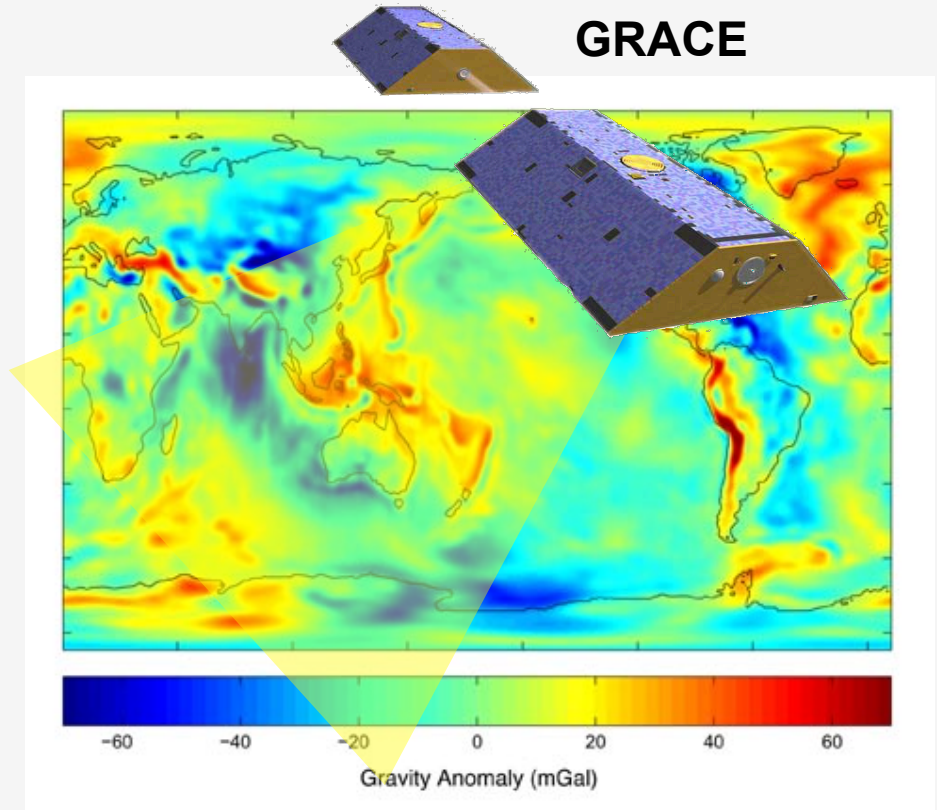
<http://www.csr.utexas.edu/grace/science/>

- 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?

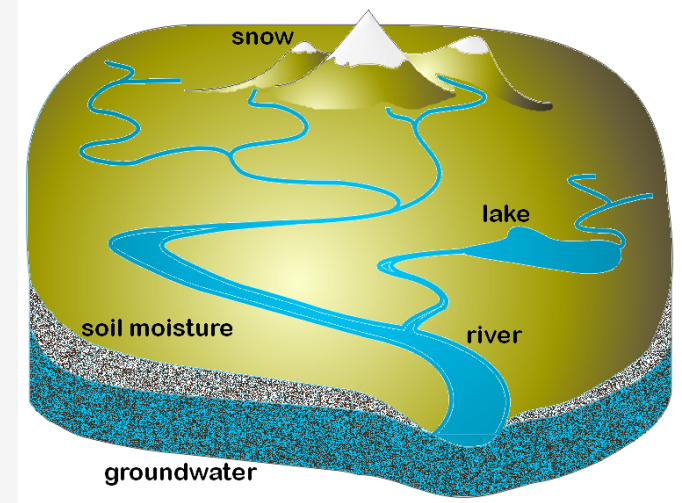
- Long-term average distribution of the mass within the Earth system determines its mean or static gravity field
- Variations of Earth's gravity field largely determined from
 - motion of water and air on time scales ranging from hours to decades



*Reference: <http://www.csr.utexas.edu/grace/asdp.html>

From Gravity to Equivalent Terrestrial Water Thickness

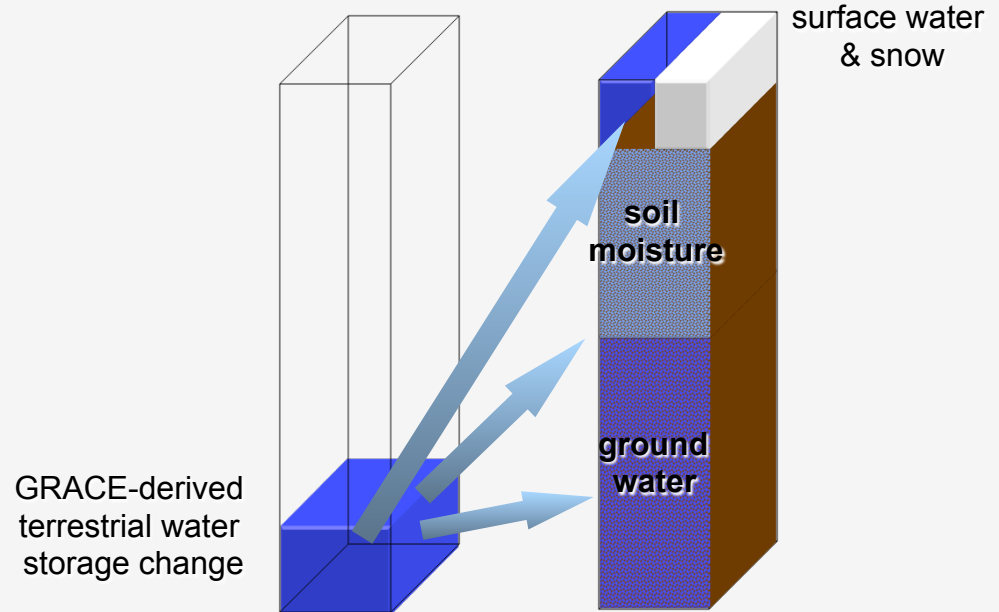
- Observed monthly changes in gravity are caused by monthly changes in mass
- Mass changes can be thought of as concentrated in a very thin layer of water at the surface, whose thickness changes
- Vertical extent is measured in centimeters, much smaller than the radius of the Earth or the horizontal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



*Reference: <http://grace.jpl.nasa.gov/data/monthly-mass-grids/>

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



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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

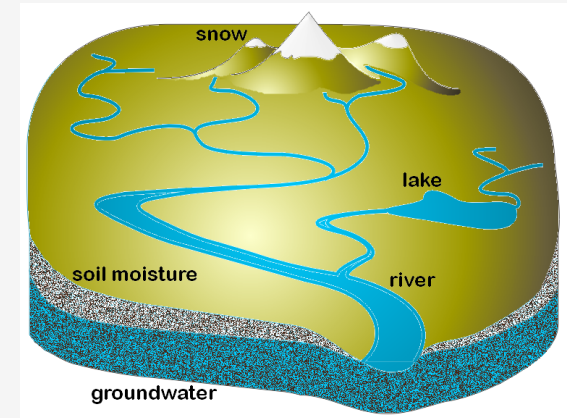
ΔTWS = change in terrestrial water storage [from GRACE]

ΔGW = change in groundwater storage [unknown]

ΔSM = change in soil moisture ΔSWE = change in snow water equivalent

ΔSW = change in surface water storage

[ΔGW , ΔSM , ΔSW from Global Land Data Assimilation System (GLDAS) models]



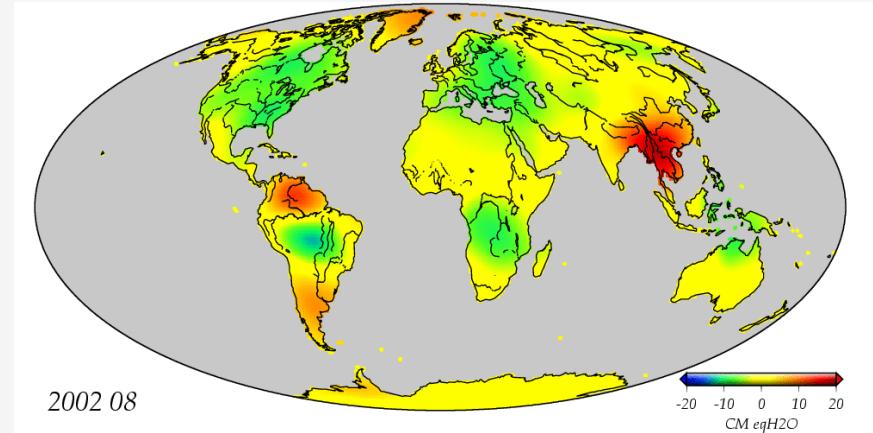
A satellite image of a lush, green forested landscape with a river winding through it. Overlaid on this is a semi-transparent map of the same area, showing roads, rivers, and various place names. The map overlay is centered and covers most of the image. The text 'GRACE Data and Access' is prominently displayed in the center of the map overlay, underlined.

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: $150,000\text{km}^2$ ($\sim 380\text{km}$)
- Given the extremely high precision of GRACE, the resulting errors are $\sim 1.5\text{cm}$ for monthly storage anomalies at the $150,000\text{km}^2$ scale

Terrestrial Water Storage Anomalies



*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

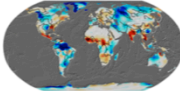
- GRACE Tellus: <http://grace.jpl.nasa.gov/data/get-data/>
 - Provides time-series of surface mass anomalies in map form, after suitable treatment for smoothing and corrections
- CU, Boulder: <http://geoid.colorado.edu/grace/>
 - Provides an interactive tool for calculation error-corrected mass anomalies in regional or global time series
- ICGEM: <http://icgem.gfz-potsdam.de/ICGEM/ICGEM.html>
 - 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

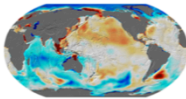
<http://grace.jpl.nasa.gov/data/get-data/>

[Mission](#) [Data](#) [Publications](#) [Multimedia](#) [Applications](#) [News & Events](#) [About](#)

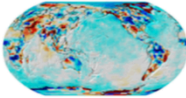
Get Data




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

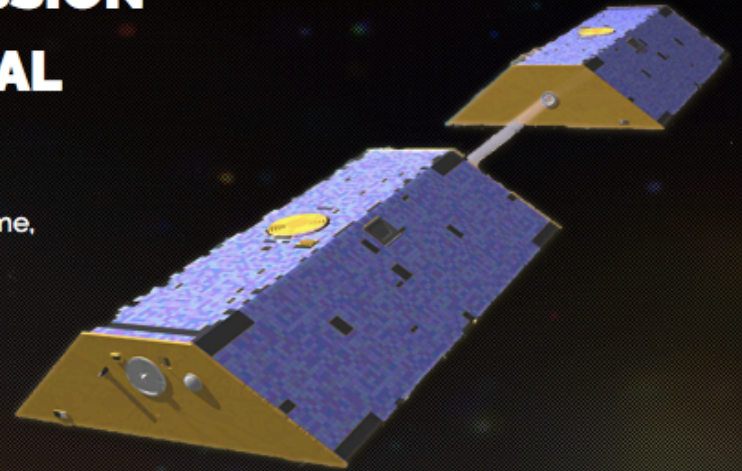
GRACE Interactive Data Analysis and Download Portal

<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 »

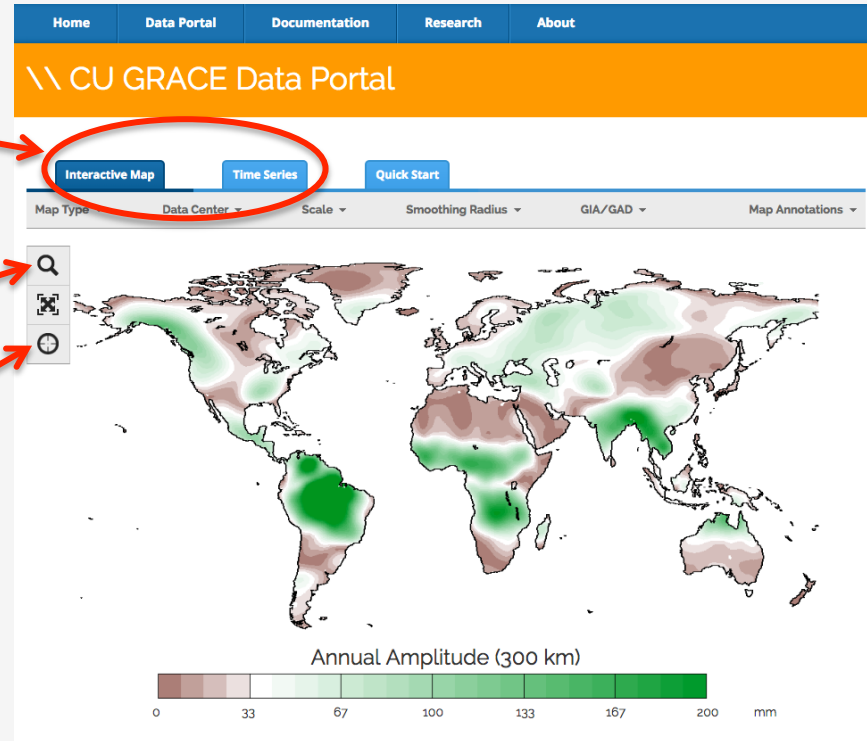


GRACE Interactive Data Analysis and Download Portal

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

Map and Time
Series Plotting
Options

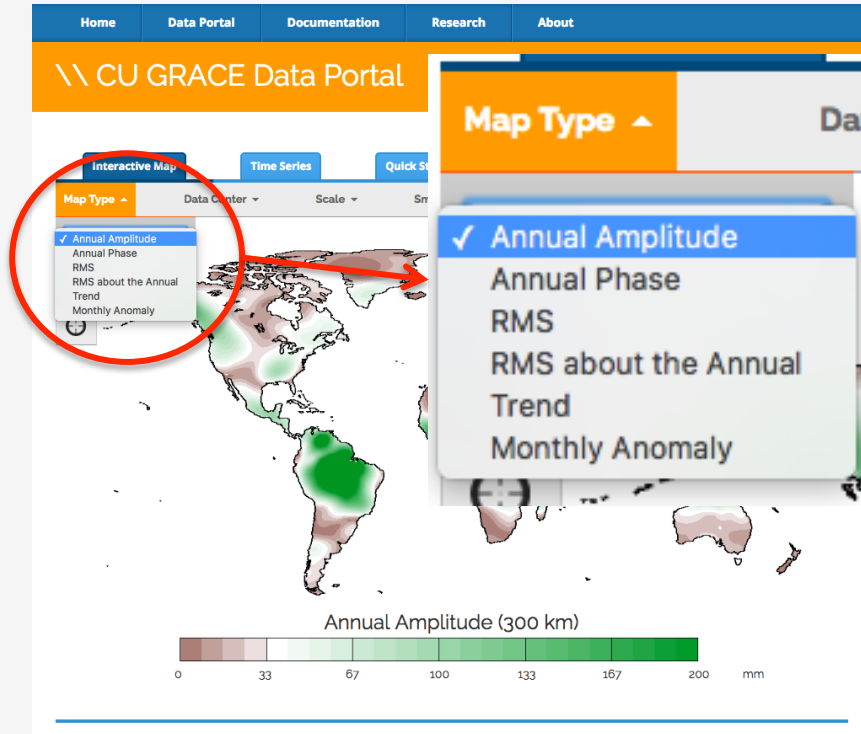
Zoom-in and Time
Series Region
Selection Options



GRACE Interactive Data Analysis and Download Portal

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

GRACE Data Selection Options

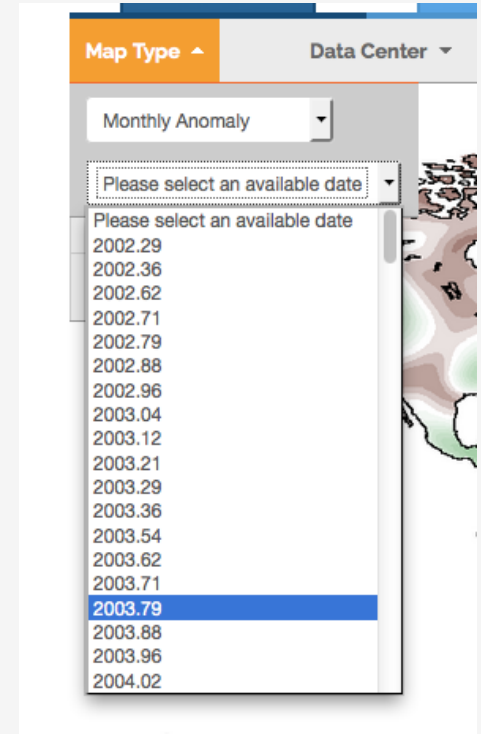


Monthly Terrestrial Water Storage Data: Time Selection

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

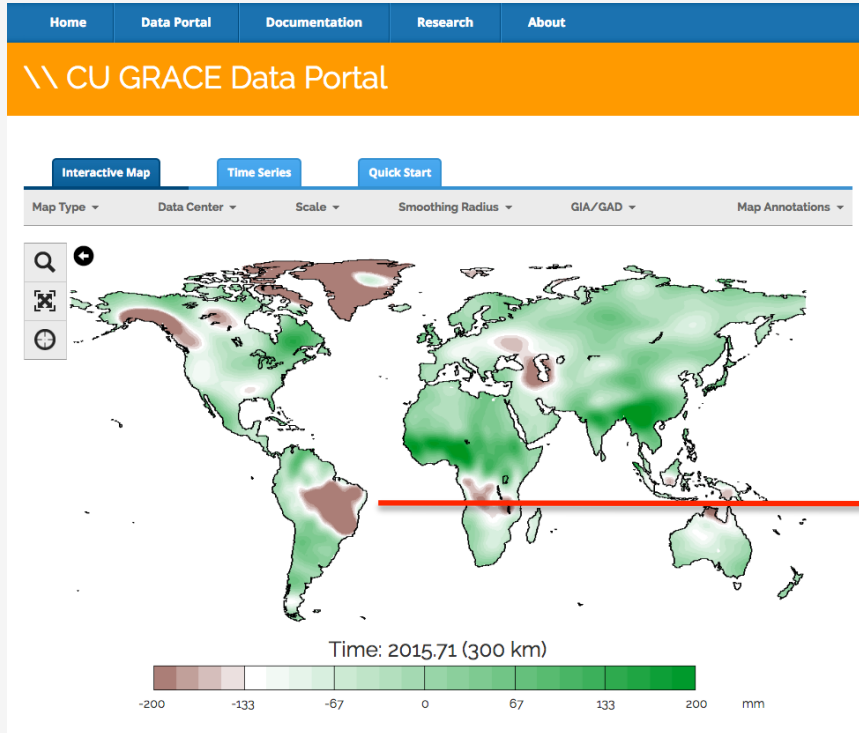
Time Selection

- YYYY:DY
- DY=Decimal Year
 - Day of Year/365
- DY=0.79
 - Represents $0.79 \times 365 = 288^{\text{th}}$ Day of the Year = 15 October
 - 2010.79 selects data for October 2010

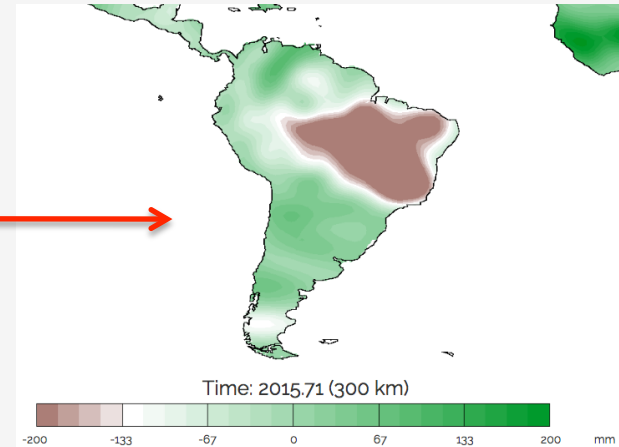


Monthly Terrestrial Water Storage Anomaly Visualization

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

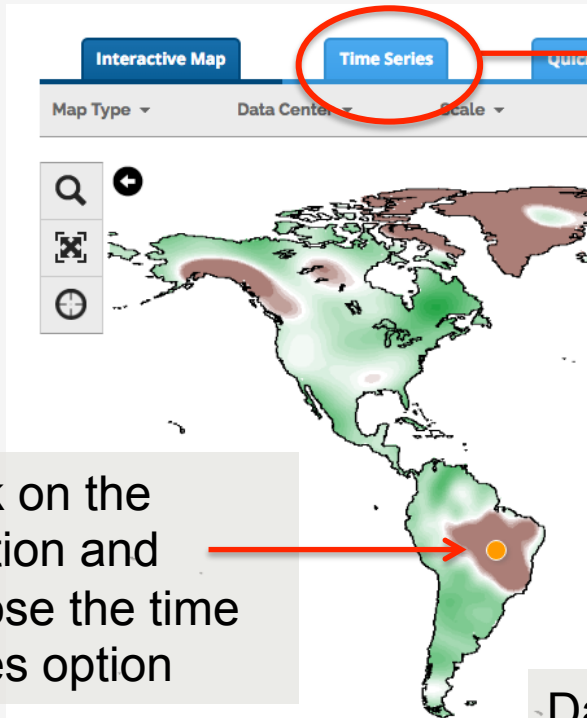


Terrestrial Water Anomaly for September 2015 showing deficit over Brazil



Time Series of Monthly Terrestrial Water Storage Anomaly

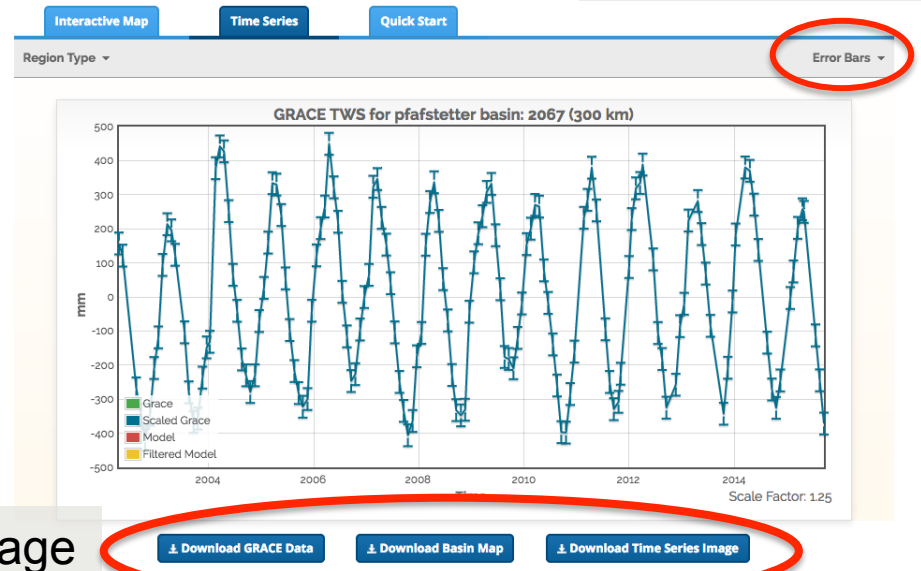
<http://geoid.colorado.edu/grace/dataportal.html>




Click on the location and choose the time series option



Error Bar Display Option



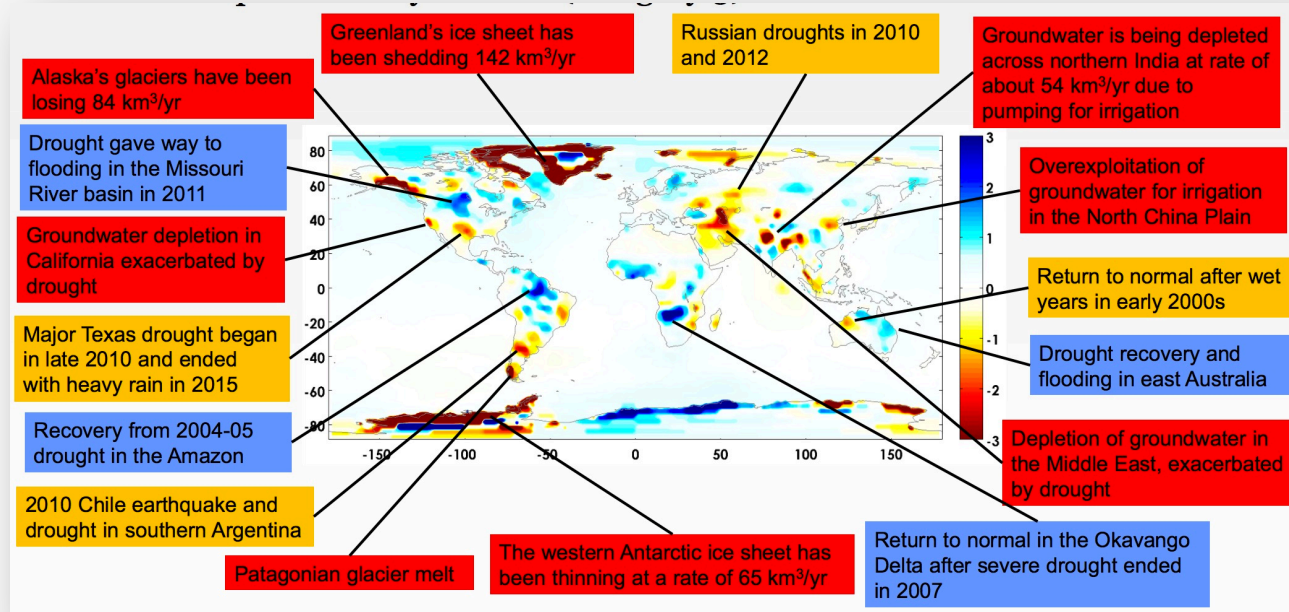
Data & Image Download

An aerial photograph of a lush, green, mountainous region in Colombia, likely the Cauca department. A semi-transparent white rectangular box is centered over the map. The text "GRACE Applications" is displayed in a large, black, sans-serif font within this box. A thin black horizontal line is positioned below the text. The background map shows various geographical features, including rivers, roads, and numerous small place names in Spanish. The text "GRACE Applications" is the primary focus of the image.

GRACE Applications

GRACE Provides Emerging Trends in Freshwater Resources

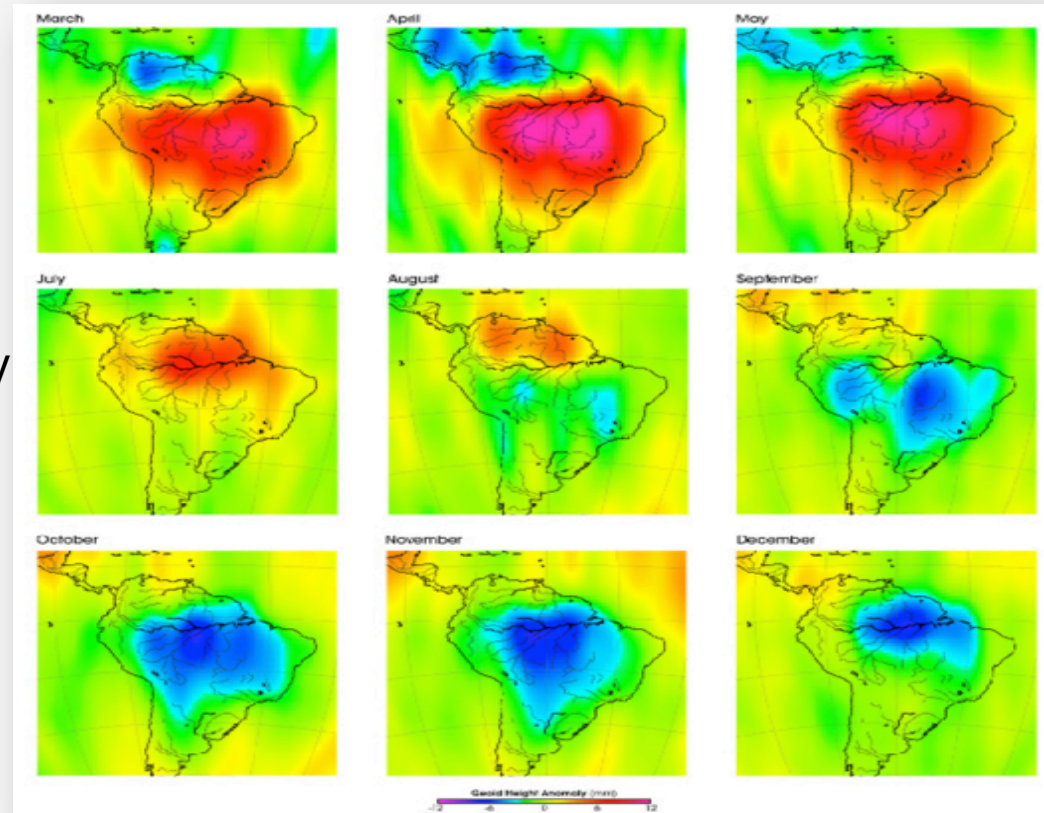
Rate of Change of Terrestrial Water Storage (TWS) as an Equivalent Height of Water (cm/yr) from GRACE, 2002 - 2015



*Source: Matt Rodell (NASA-GSFC)

GRACE Observes the Seasonal Hydrologic Cycle in the Amazon Basin

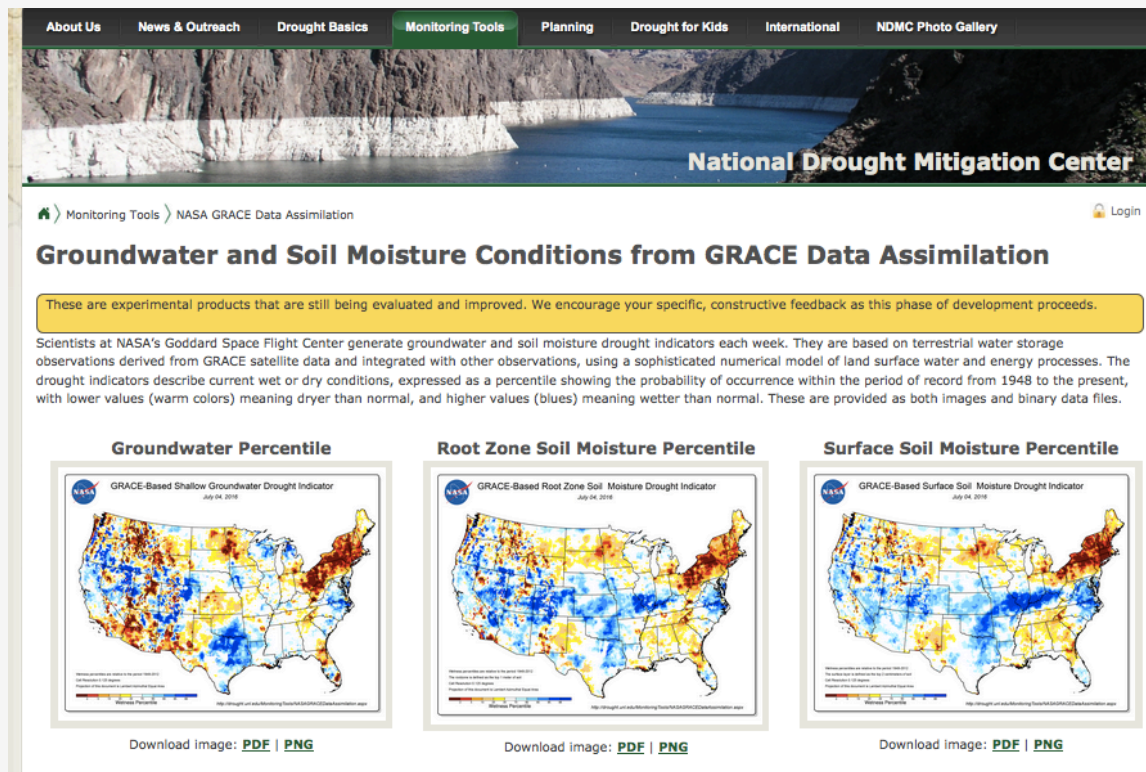
- GRACE data has relatively low spatial resolution
- Useful in monitoring large-scale terrestrial water changes
- Image on the right shows monthly change (2003) compared to 14-month average



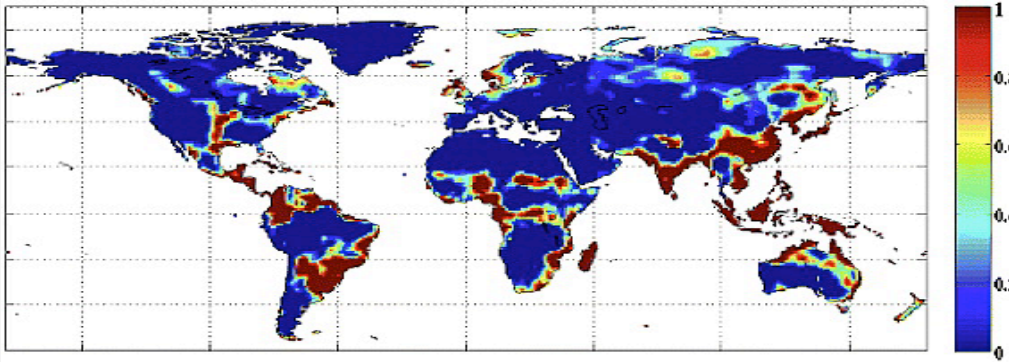
*Courtesy of: Paul Thompson, GRACE Science Team

GRACE Ground Water Data Used for Drought Monitoring

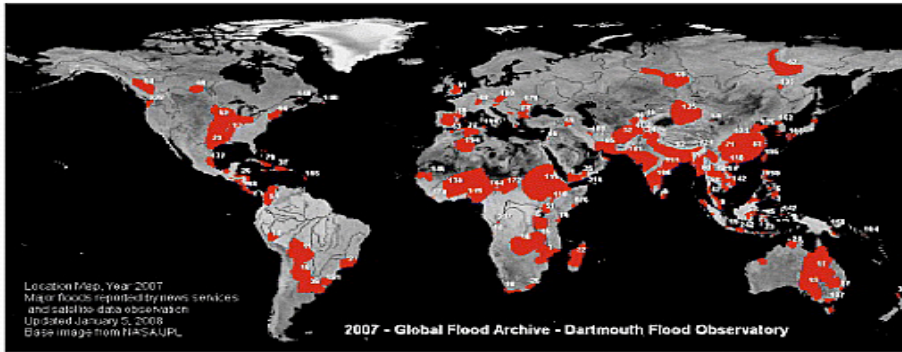
<http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx>



Potential for Flood Prediction



GRACE-Based Flood Index
Maxima, May 2007

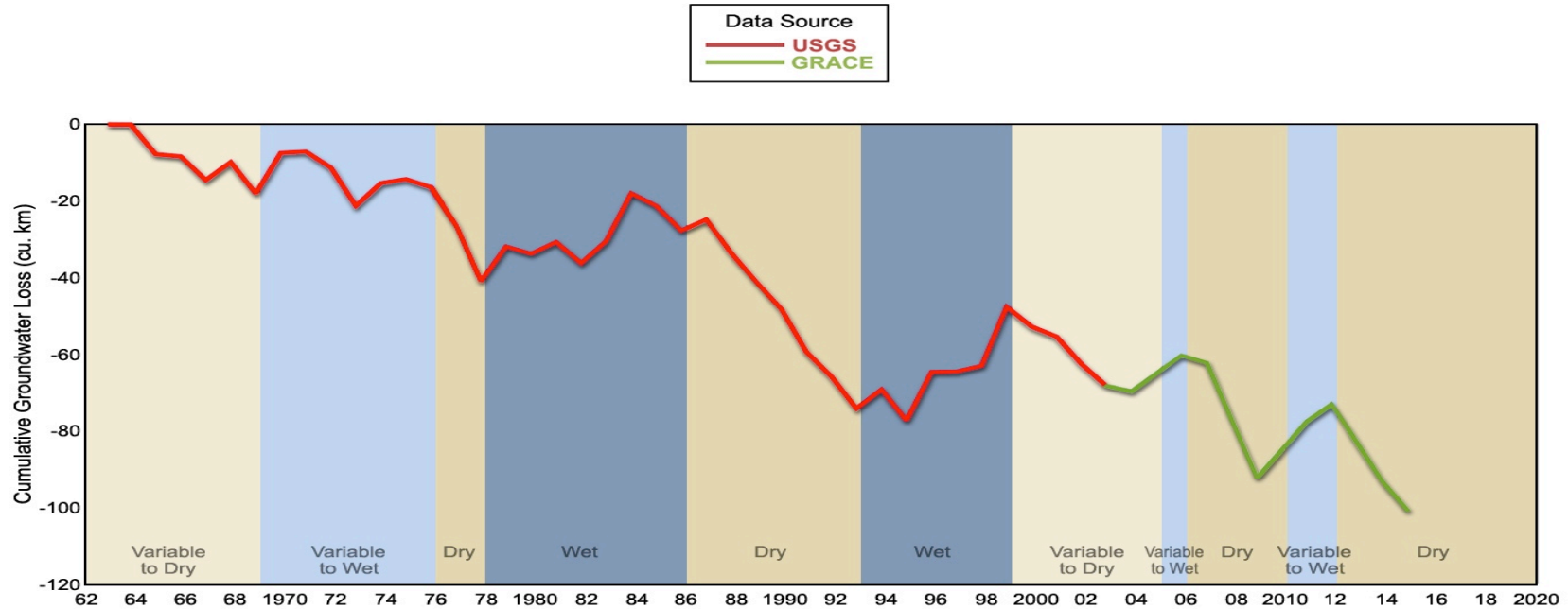


Recorded Floods, Dartmouth
Flood Observatory, May 2007

*Reference: J.T. Reager (JPL) and J. Famiglietti (JPL), 2009

Regional Groundwater Studies

California Central Valley

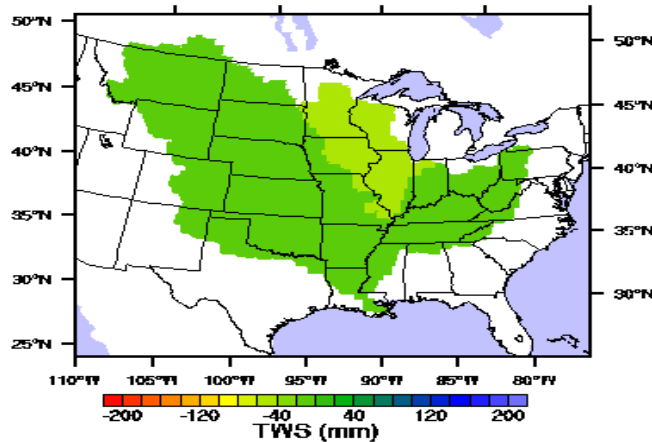


*Reference: Thomas et al., in prep

Assimilation of GRACE Terrestrial Water Storage (TWS) Data

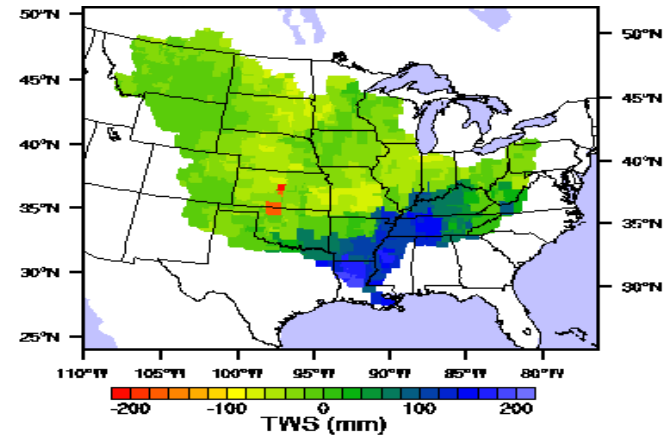
Results in Higher Resolution & Better Accuracy Than Models Alone

GRACE TWS Anomaly
January 2003 – June 2006



From scales useful for water cycle and climate studies...

GRACE Assimilating Catchment LSM TWS
Anomaly, mm
January 2003 – June 2006



...to scales needed for water resources and agricultural applications

*Reference: Matt Rodell (NASA-GSFC)

National Aeronautics and Space Administration

Applied Remote Sensing Training Program

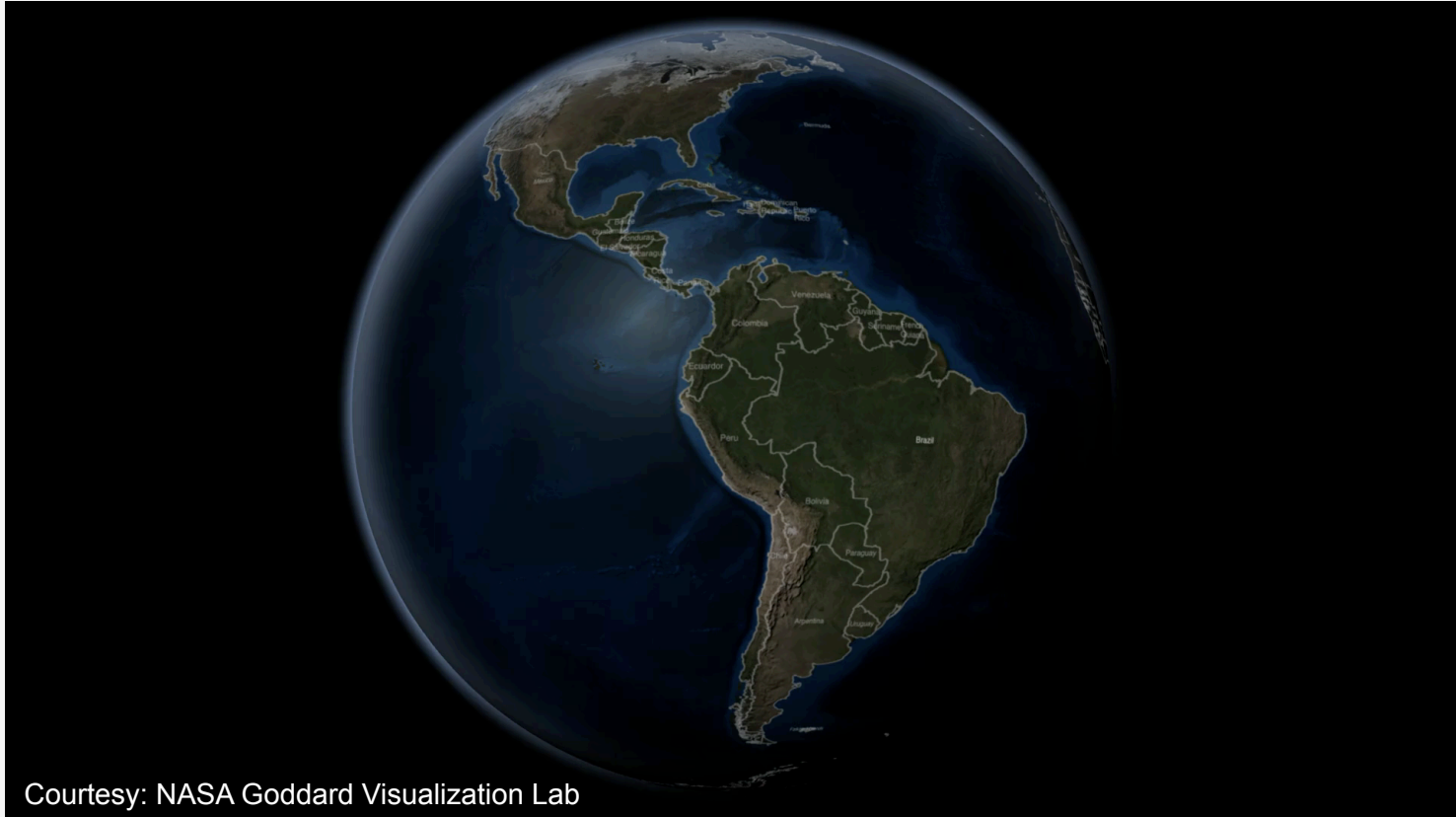
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GRACE- Monitoring Groundwater Depletion in India



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>
