NASA's Applied Sciences for Water Resources
Water Census Meeting

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5 Aug 2010

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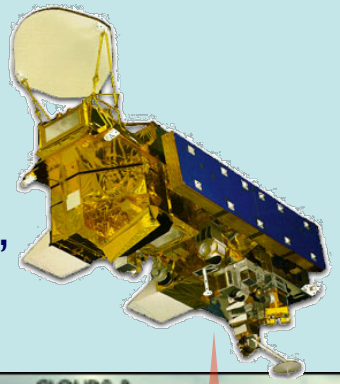
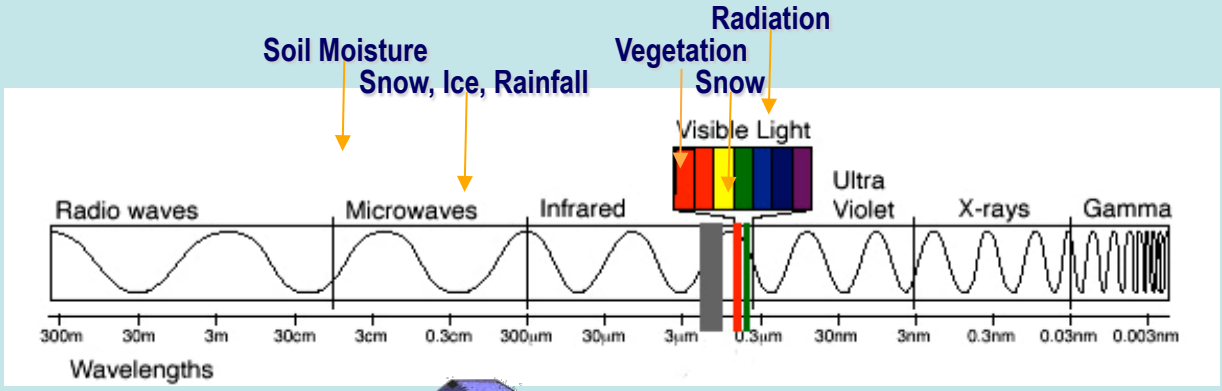
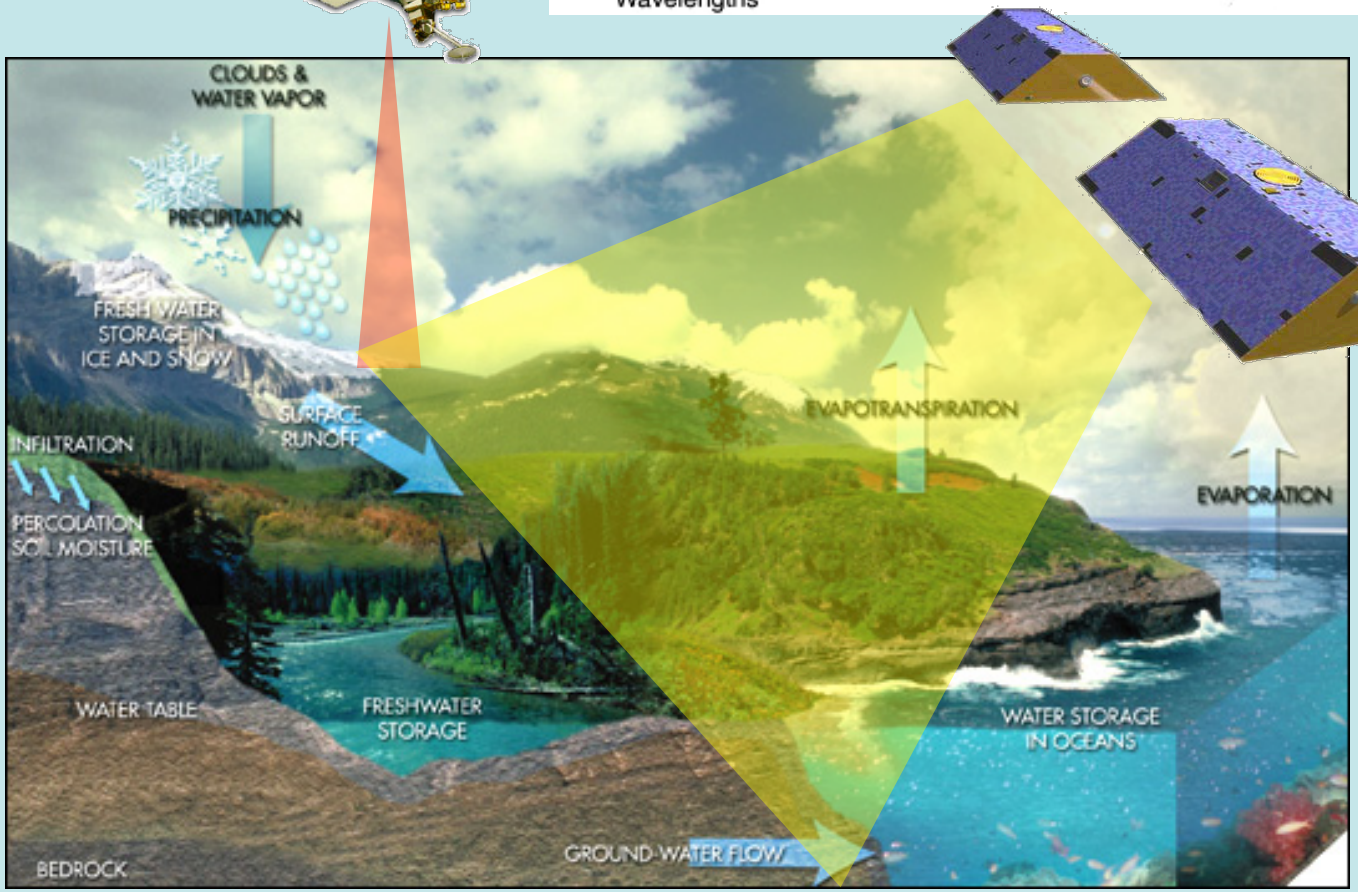
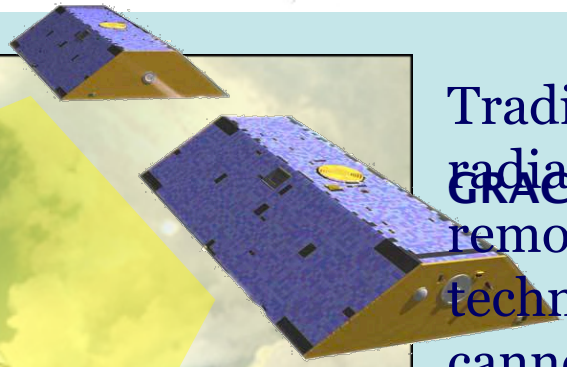
Remote Sensing of the Water Cycle

Aqua:
MODIS,
AMSR-E,
etc.







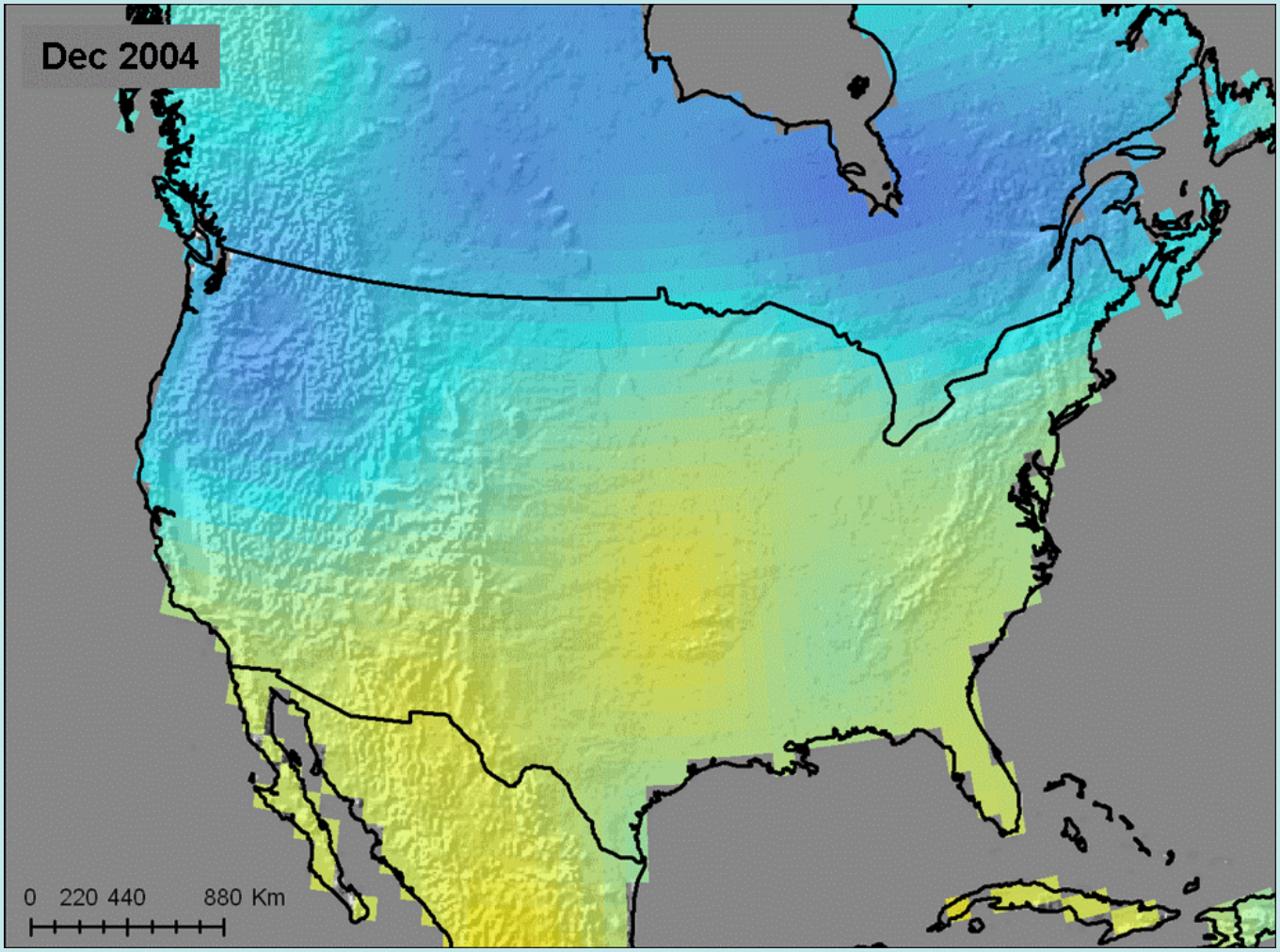


GRACE

Traditional radiation-based remote sensing technologies cannot sense water below the first few centimeters of the snow-canopy-soil column

GRACE is unique in its ability to monitor water at all levels, down to the deepest aquifer

Terrestrial Water Storage Anomalies from GRACE



-15.0 15.0

Water Storage Anomaly (cm)

Isolating Groundwater from GRACE-Derived Terrestrial Water Storage

$P - ET - Q = \Delta TWS$ [terrestrial water balance]

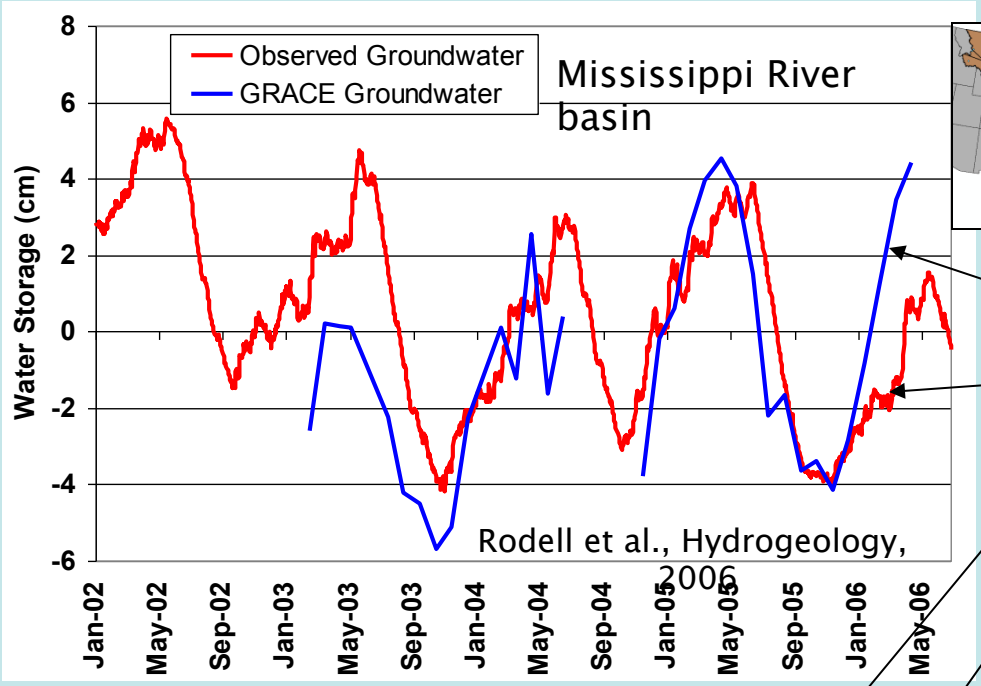
$\Delta TWS = \Delta GW + \Delta SM + \Delta SWE + \Delta SW$

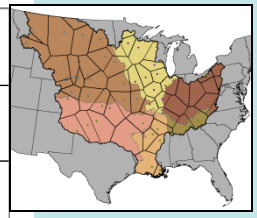
$\boldsymbol{\Delta GW = \Delta TWS - \Delta SM - \Delta SWE - \Delta SW}$

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 [from Global Land Data Assimilation System (GLDAS) models]
ΔSWE = change in snow water equivalent [from GLDAS]
ΔSW = change in surface water storage [insignificant in many areas and on an interannual basis]

Terrestrial Water Storage Disaggregation

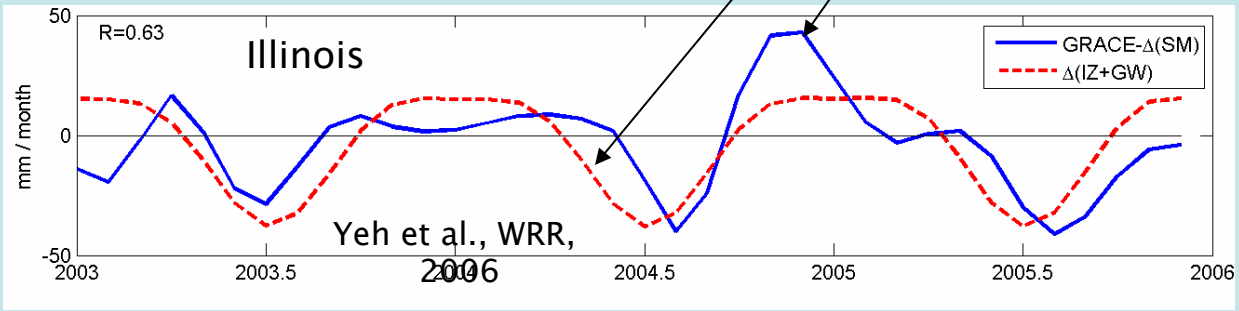




GRACE groundwater estimate

Groundwater well observations

GRACE groundwater estimates (smoothed)



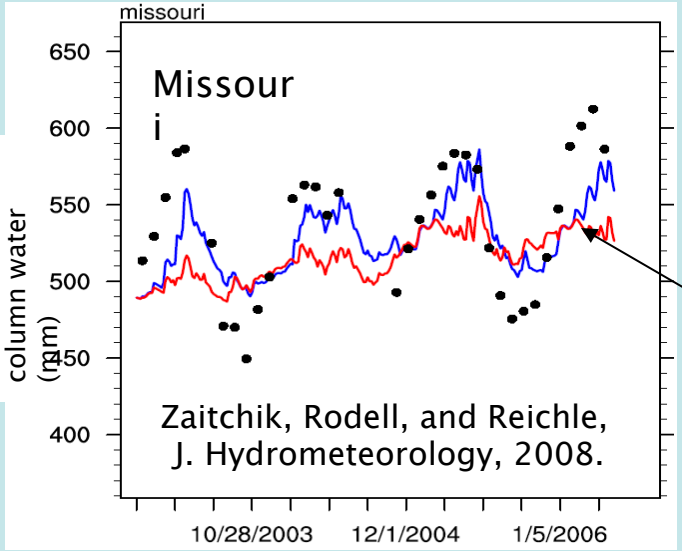
Soil moisture from a numerical model (top) or in situ observations (bottom) can be used to isolate groundwater from GRACE total water storage

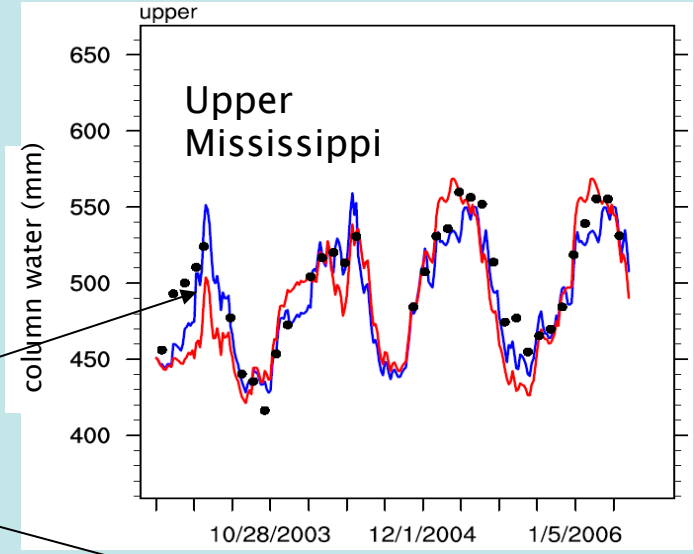
Matt Rodell
NASA GSFC

Assimilation of GRACE TWS Data

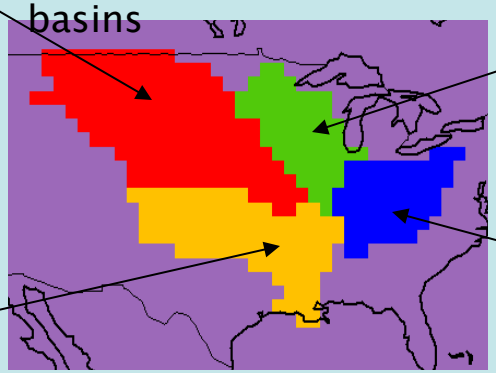
Models produce continuous time series.

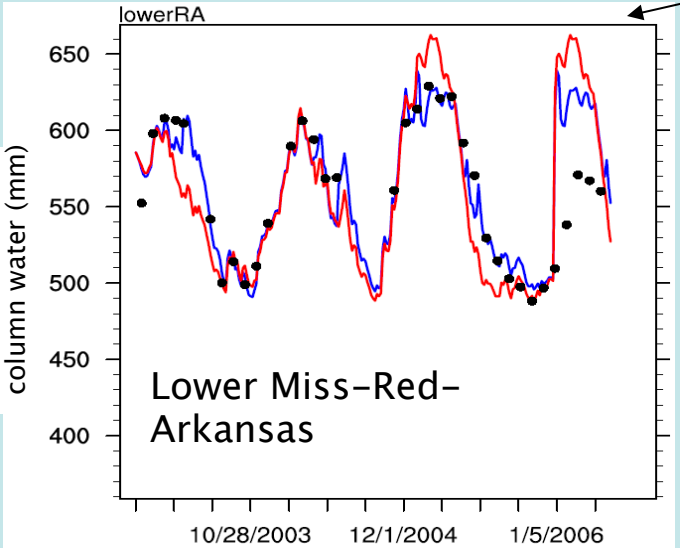
Monthly GRACE data anchor model results in reality



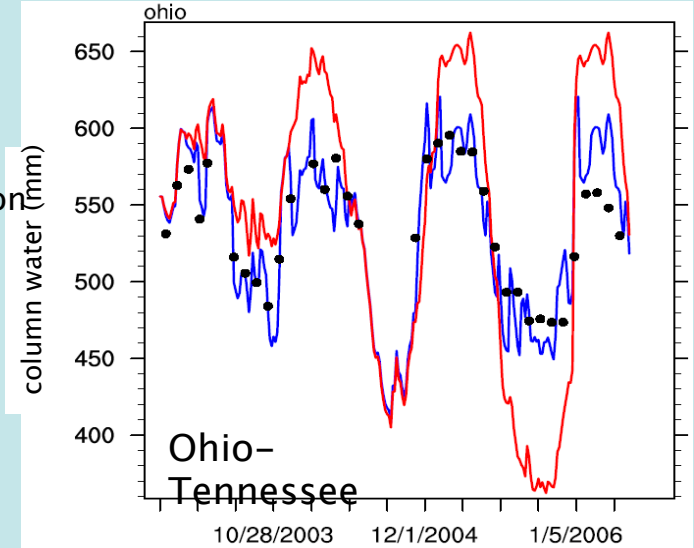


Mississippi River sub-basins





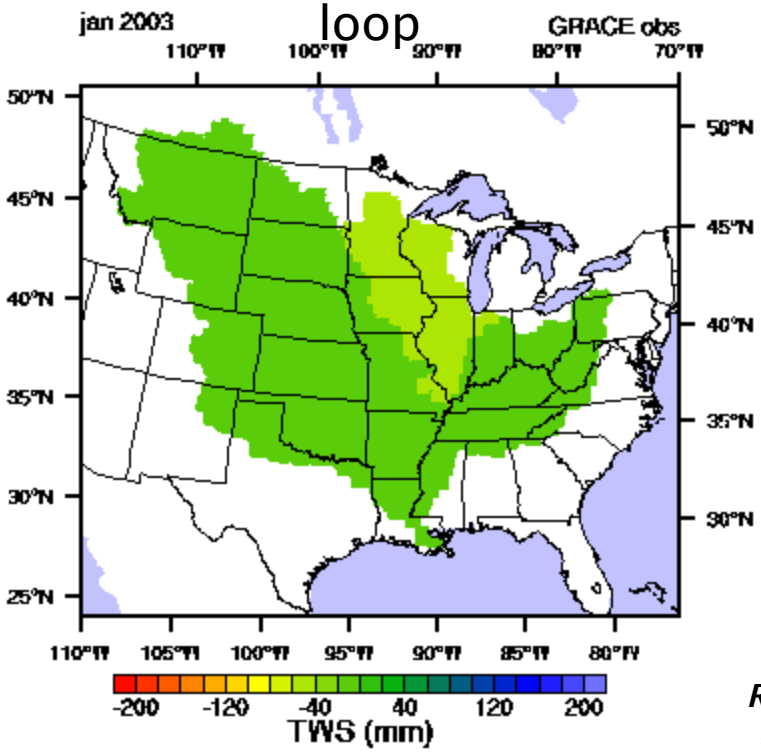
- GRACE Water Storage
- Modeled Water Storage
- Model-GRACE Assimilation



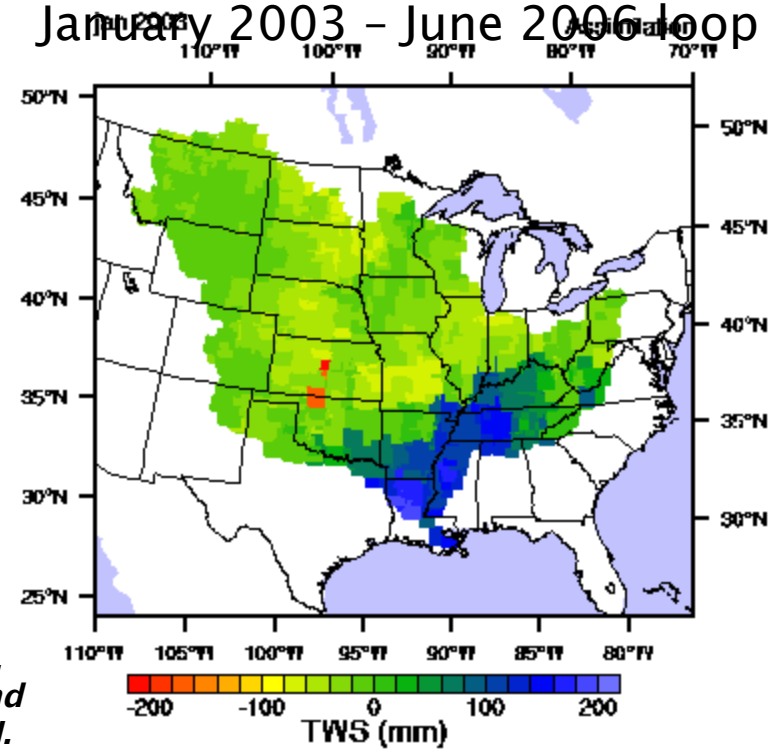
Daily estimates are critical for operational applications

Assimilation of GRACE Terrestrial Water Storage Data

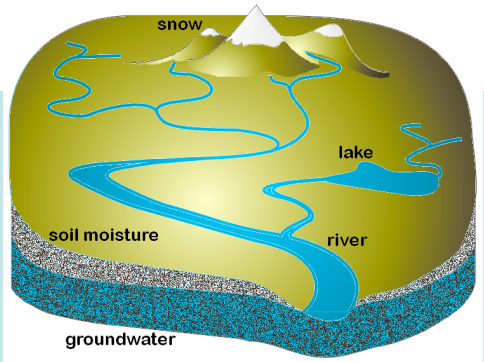
GRACE water storage, mm
January 2003 – June 2006
loop

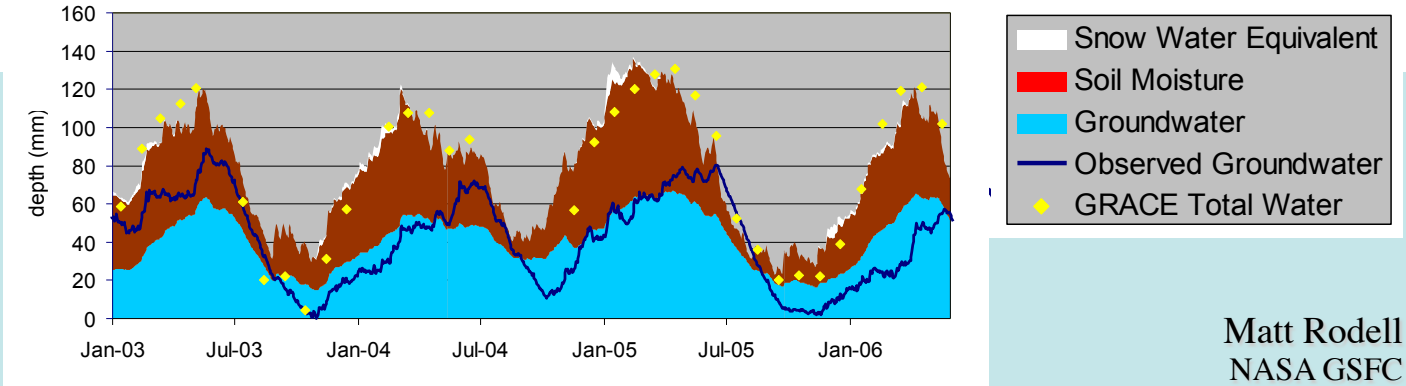


Model assimilated water storage, mm
January 2003 – June 2006 loop



Zaitchik, Rodell, and Reichle, J. Hydromet





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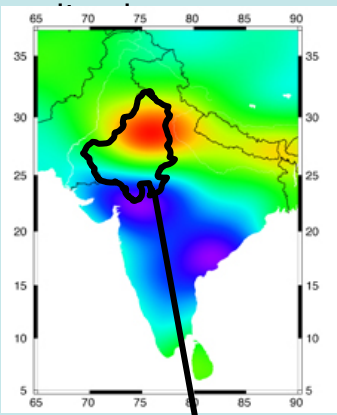
GRACE Satellites Monitor Groundwater Depletion

Matt Rodell, Code 614.3, NASA GSFC

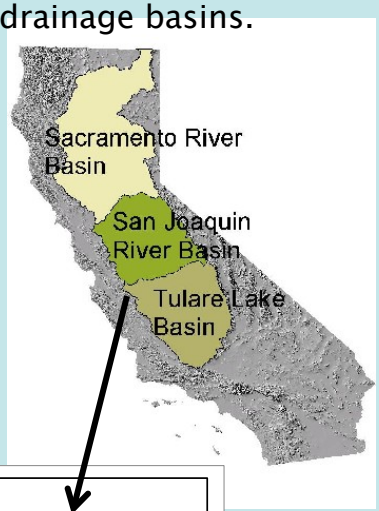
with contributions from Jay Famiglietti (UC Irvine), Isabella Velicogna (UC Irvine), and Sean Swenson (NCAR)

Figure 1: Trends in groundwater storage in India during 2002–08, with decreases in red. The study region is



Groundwater is a vital source of fresh water. In some parts of the world it is being withdrawn for agricultural, industrial, and domestic uses faster than it is naturally recharged, causing groundwater depletion. We have used the GRACE satellites to identify regions where aquifer levels are declining and to quantify that depletion. Two such northwes ia.

Figure 3: Location of the study region in central California, which consists of three drainage basins.



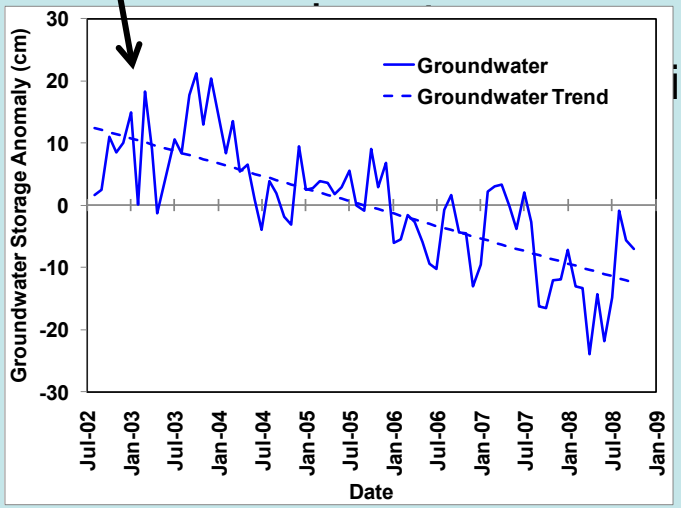


Figure 2: Time series GRACE-estimated groundwater (with linear trend) as an equivalent height of water averaged over the study region in northwest India.

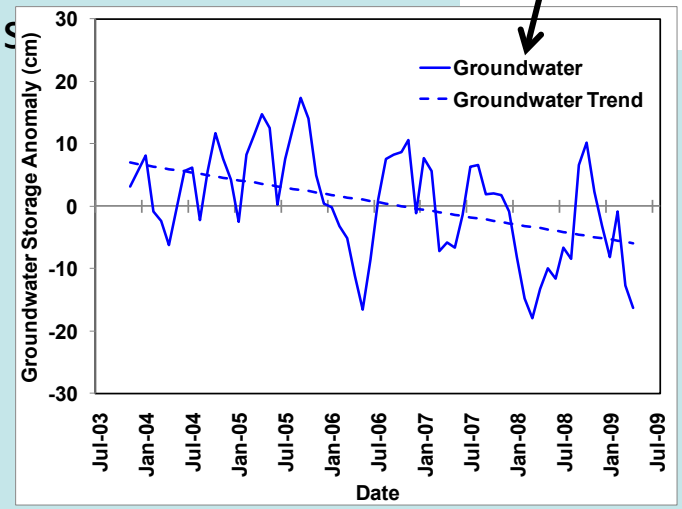
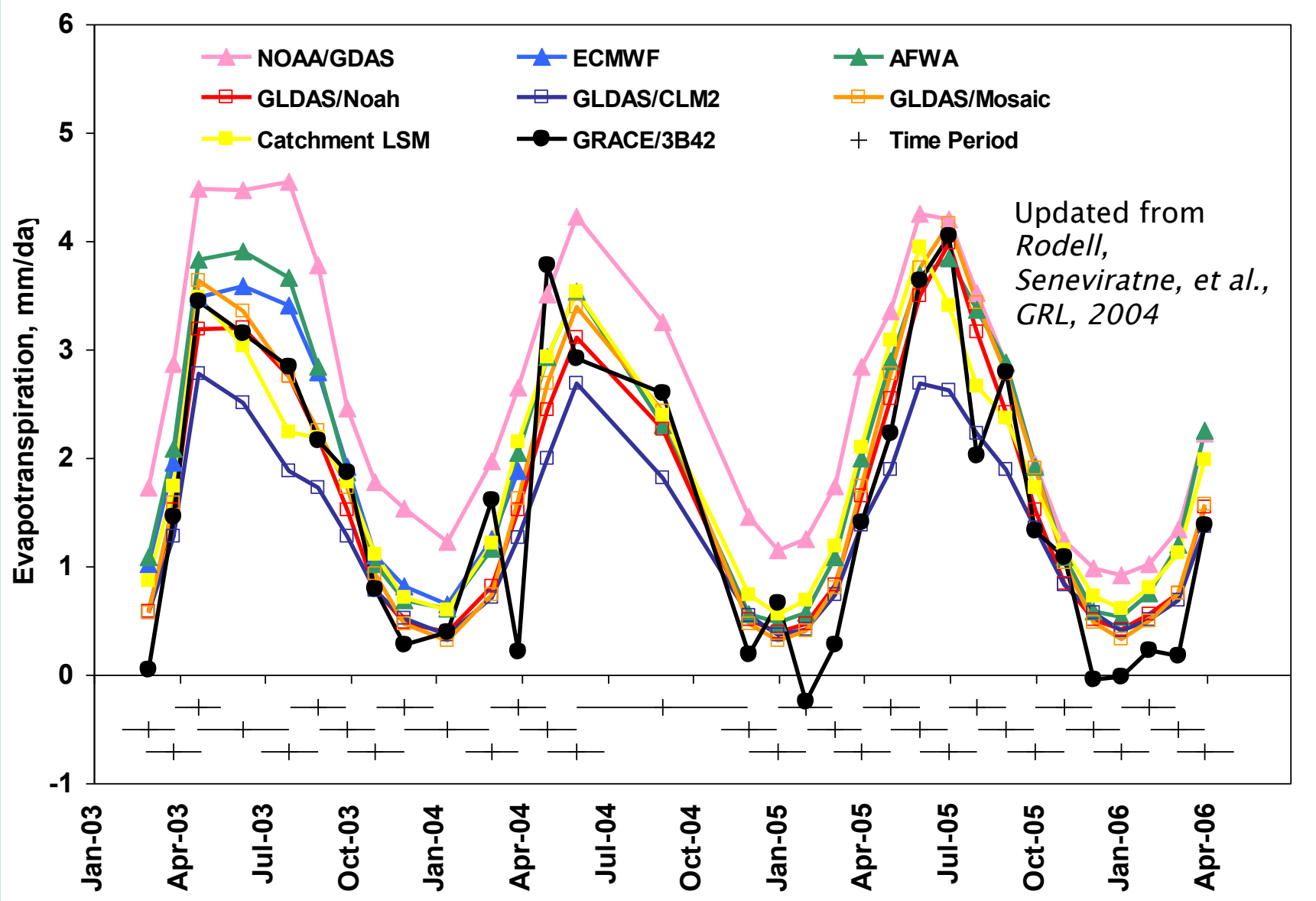


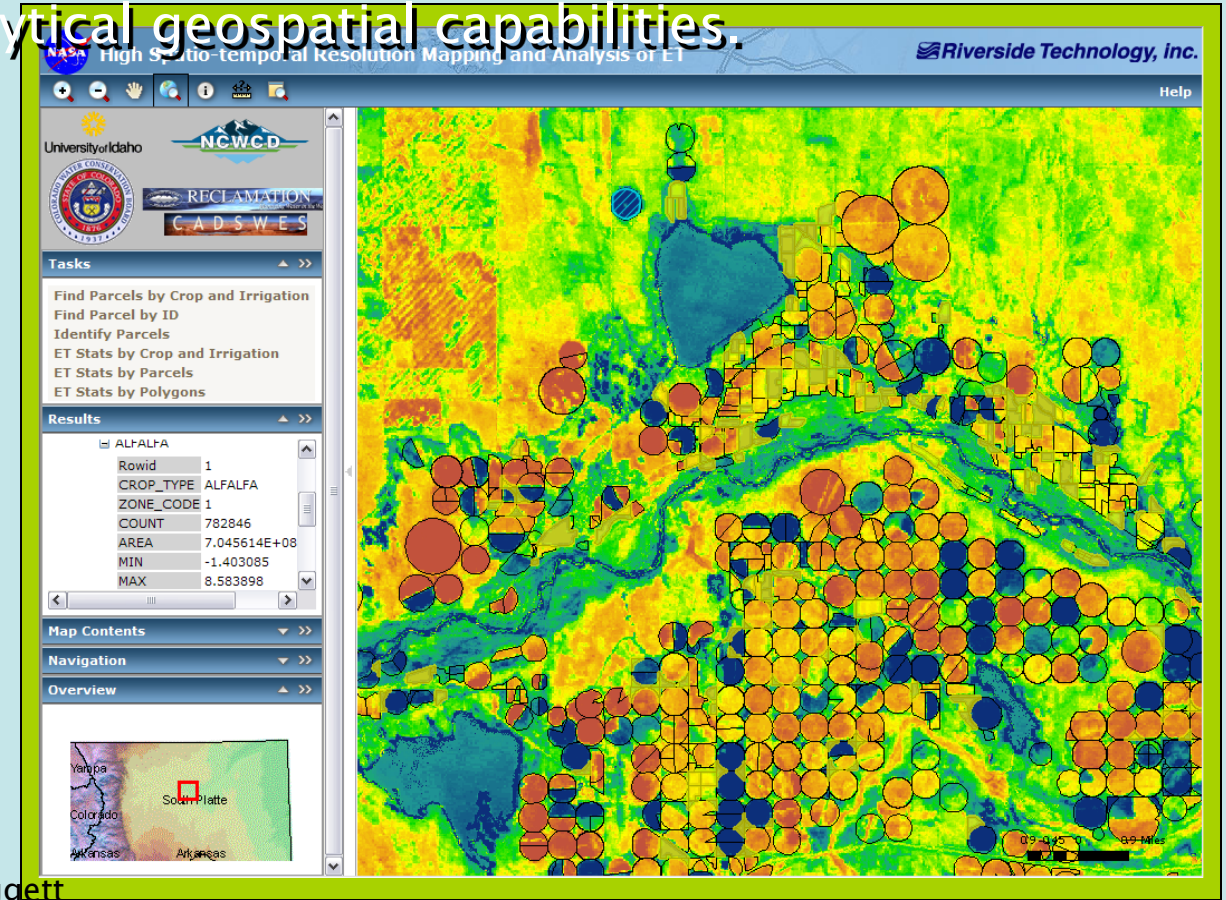
Figure 4: Time series of GRACE-estimated groundwater (with linear trend) as an equivalent height of water averaged over California's Sacramento, San Joaquin, and Tulare Lake basins.

Comparison of ET Estimates Over the Mississippi River Basin



Using NASA Evapotranspiration for Agriculture Water Consumptive Use

- Modeler can select an area of interest (e.g. return flow contributing area) by digitizing on-screen, and compute ET for that area.
- Internet map server, powered by ESRI ArcServer technology. Web mapping tool has analytical geospatial capabilities.
- Streamlines flow of data into Decision Support Systems
- Developed for the Northern Colorado Conservancy District DSS



Land Information System - *Hydrologic Data Integration & Assimilation System*

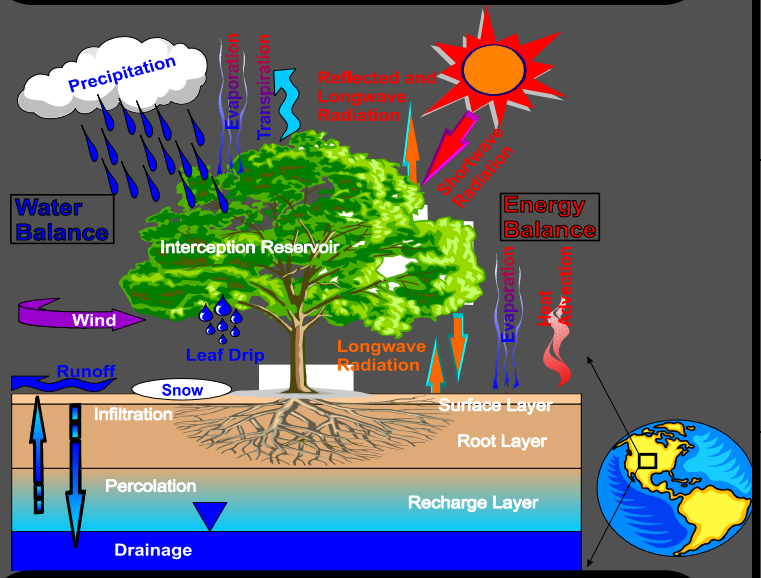
Users – AFWA, NOAA NCEP, NOAA NOHRSC, USGS FEWS-NET

Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- Meteorological Forecasts, Analyses, and/or Observations
- *Snow Soil Moisture Temperature*

Physics

Suite of Land Surface Models Flexible Add-ons



Data Assimilation Modules Continuously Updated with new Modules and Capabilities

Outputs

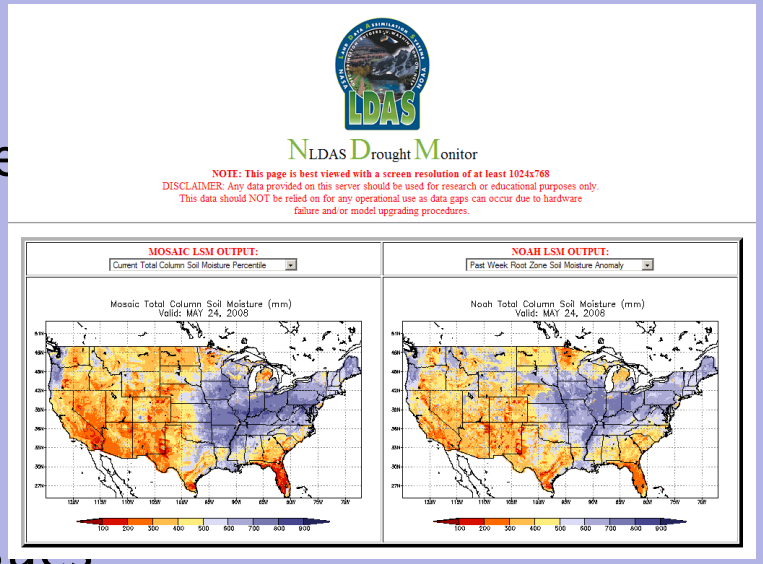
- Soil Moisture & Temperature
- Evaporation Sensible Heat Flux
- Runoff
- Snowpack Properties

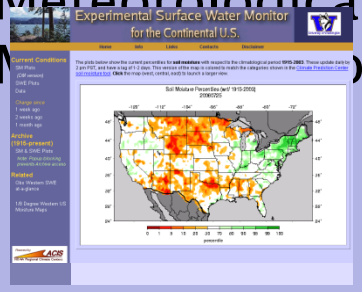
Applications

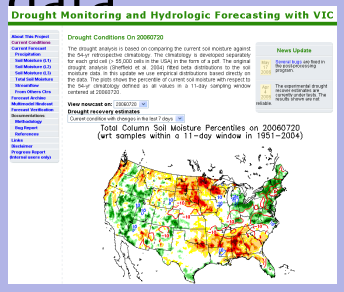
- Weather/ Climate
- Water Resources
- Agriculture
- Drought
- Military Ops
- Natural Hazards

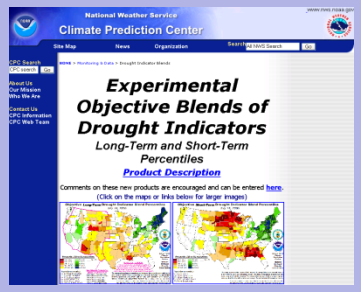
Project Status

- Ongoing collaborations with US Drought Monitor and NLDAS, links to NASA Water Management Program drought project
- Real-time drought monitor on NLDAS website
- Follows in footsteps of existing website (U. Washington, Princeton, and CPC)
  - http://www.hydro.washington.edu/forecast/monitor/index.shtml
  - http://hydrology.princeton.edu/forecast/
  - http://www.cpc.ncep.noaa.gov/soilmst/
- Mosaic, Noah, SAC, and VIC runs performed, highlighting several key issues for further investigation
  - Climatology length
  - Meteorological forcing data
  - M[illegible]on



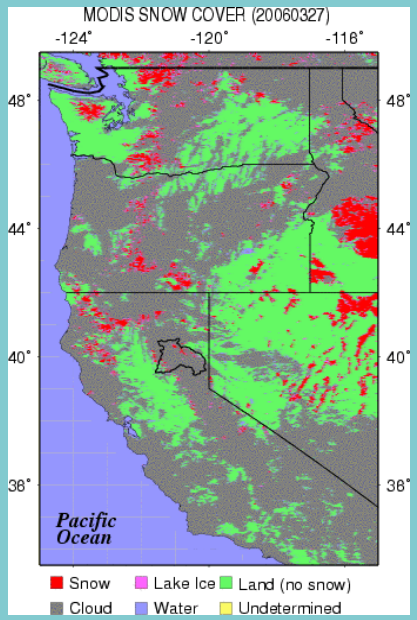


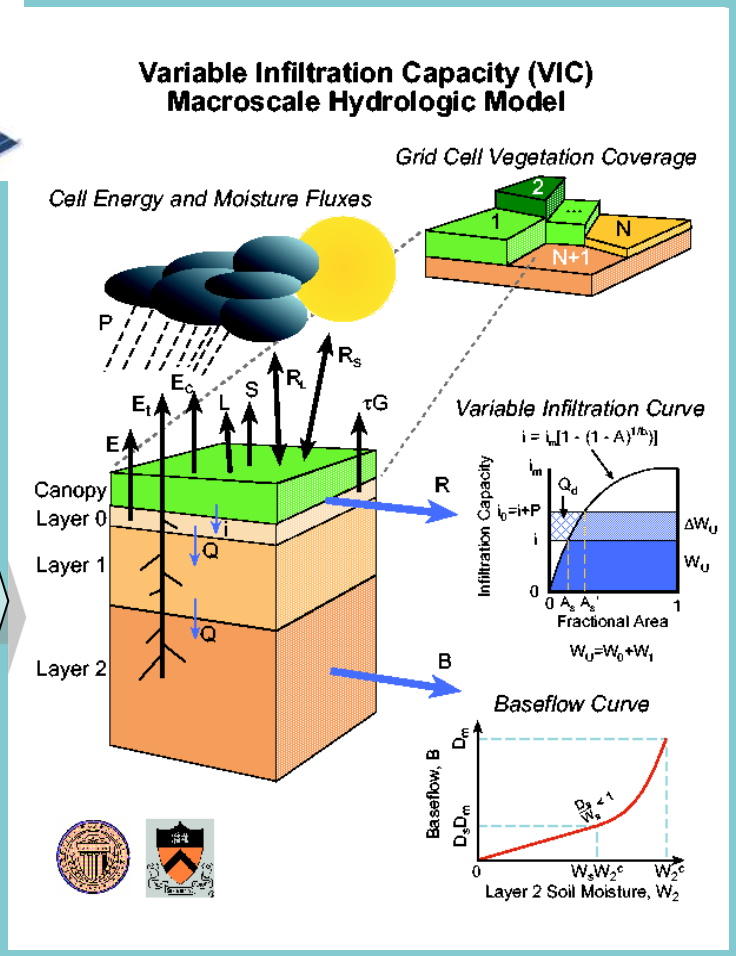


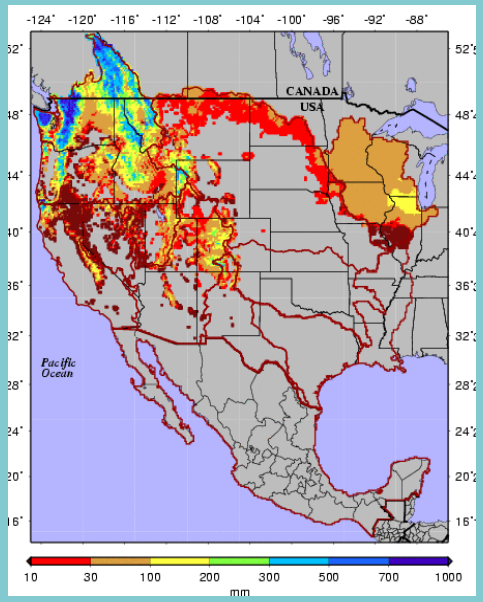


Hydrologic Forecasting(USDA-DOI-CA DWR)
Snow Pack

Snow Data







Snowpack Initial Condition

Reservoir Regulation

D. Lettenmaier/U. Wash.

Surface Water Ocean Topography (SWOT)

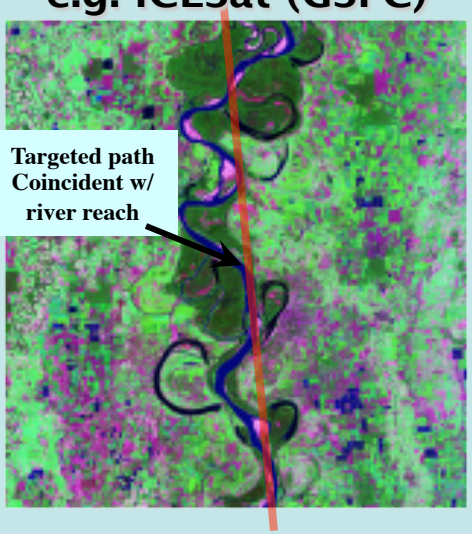
Stream Discharge and Surface Water Height

Planned Mission – 2 (Post 2013)
Motivation:

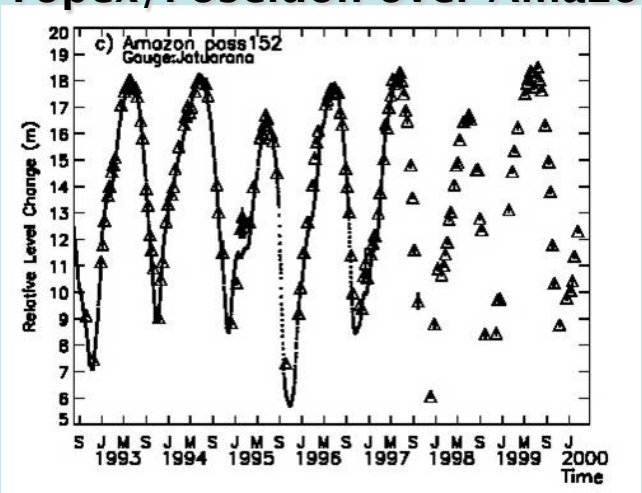
- critical water cycle component
- essential for water resource planning
- stream discharge and water height data are difficult to obtain globally

Mission Concepts:

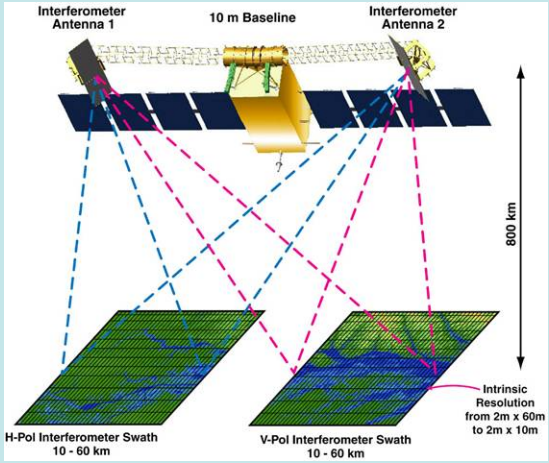
Laser Altimetry Concept e.g. ICESat (GSFC)



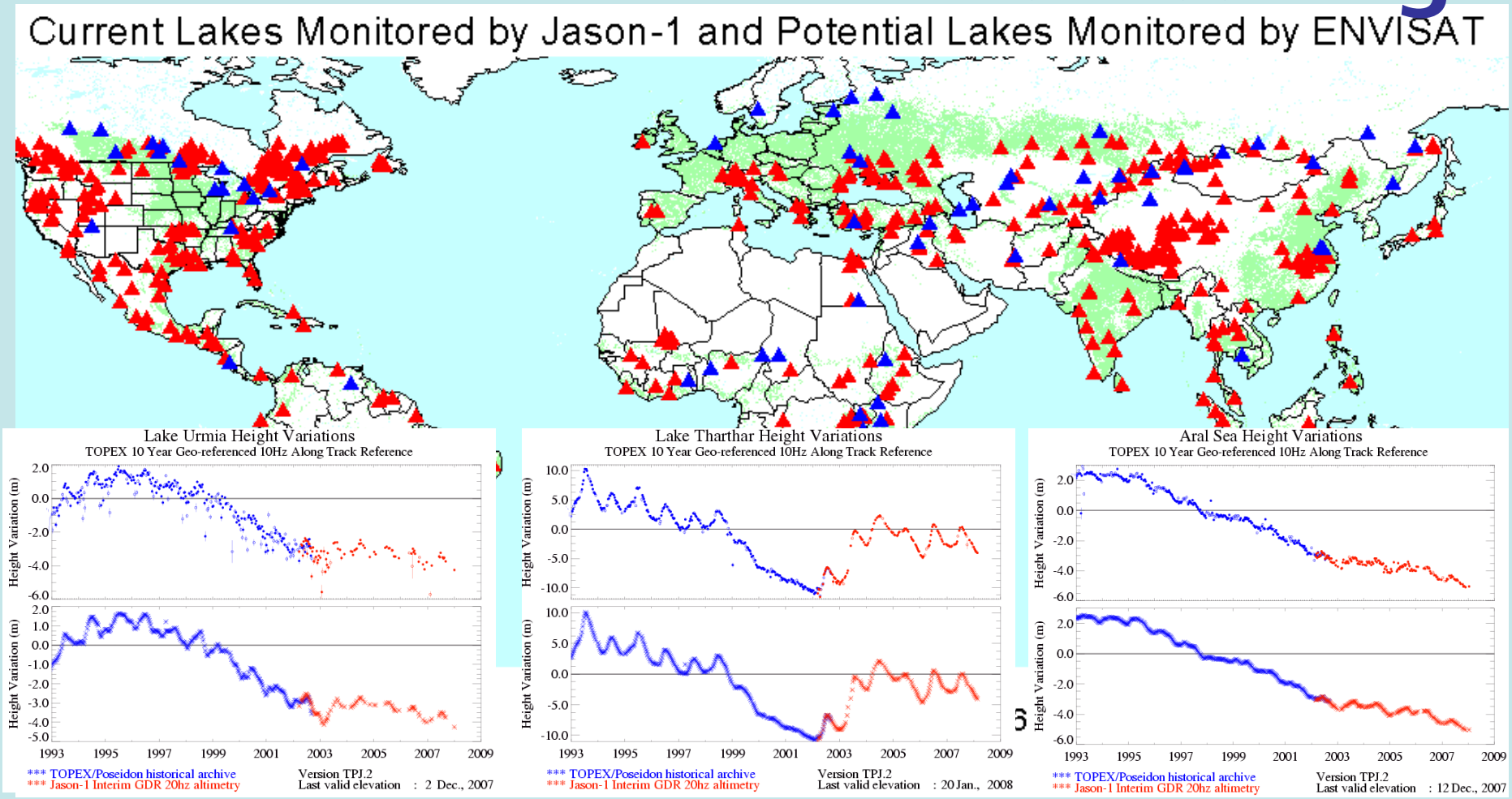
Radar Altimetry Concept e.g. Topex/Poseidon over Amazon R.



Interferometer Concept (JPL)

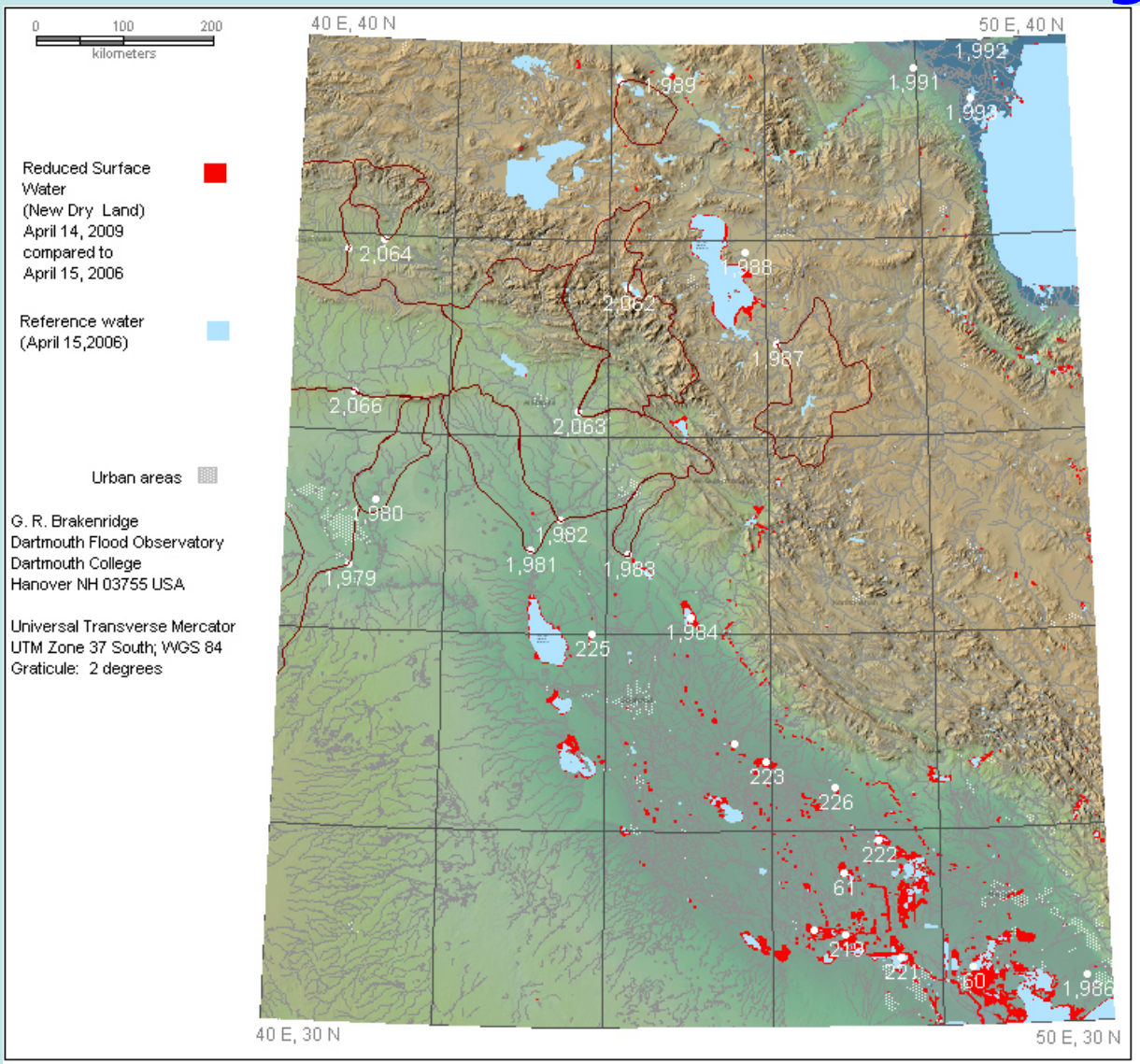


Lake and Reservoir Monitoring



http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir

Surface Water Mapping for Verification of Drought Reservoir Extent Change



Dartmouth Flood Observatory

Soil Moisture Active/Passive (SMAP) Mission

Soil Moisture Mapping

A *dedicated* soil moisture mission selected as a new Earth science mission

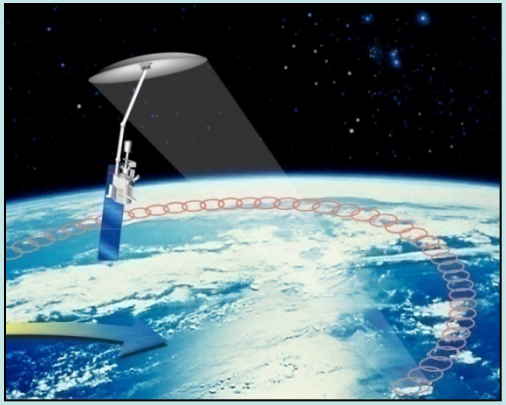
NASA fly an active / passive microwave soil moisture with mission in the 2013 timeframe

SMAP consists of an L-Band radar & radiometer in a low Earth, sun-synchronous orbit

SMAP falls in the Medium Cost Class ($300 – 600 M)

Extends soil moisture to deeper depths with

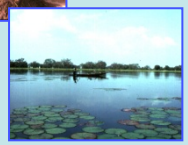
Societal Benefits:



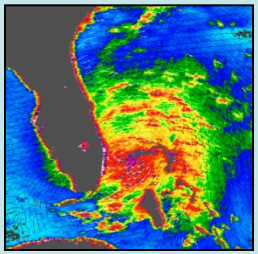
§ Water, Energy & Carbon Cycles

§ Water and Food

§ Water Quality and Human Health



§ Water and the Environment

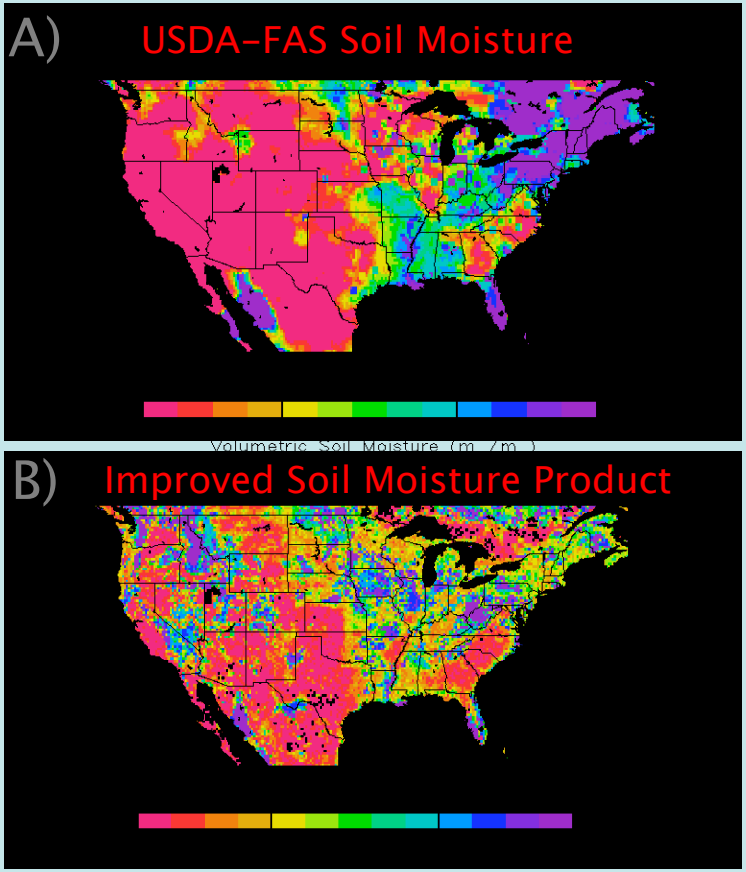


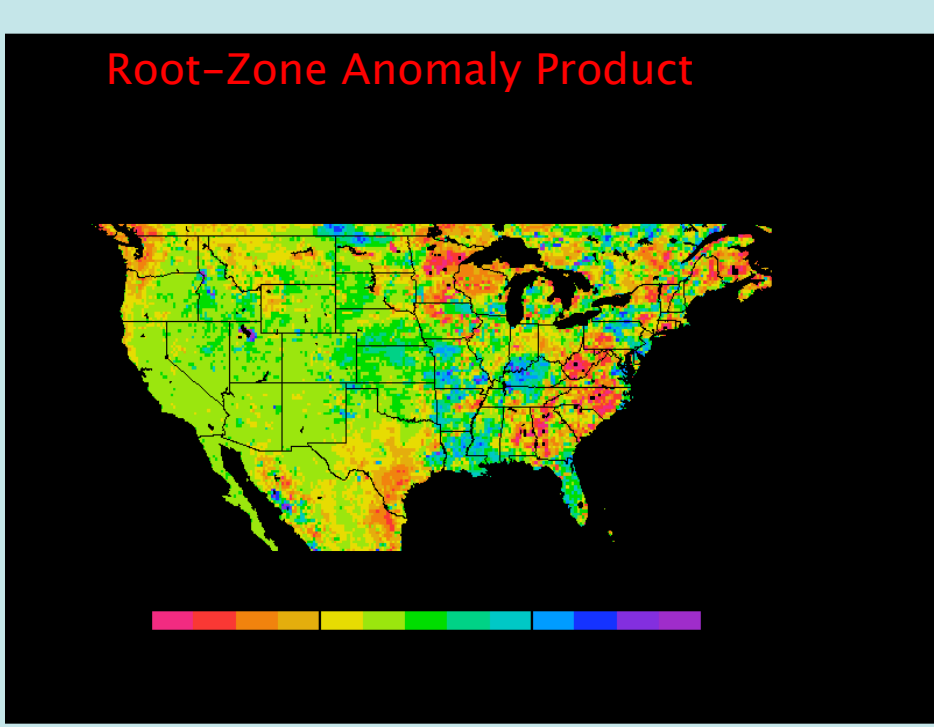
§ Weather & Climate Prediction
§ Severe Storm Forecasts
§ Agriculture Food Production
§ Drought Monitoring and Assessment
§ Flood Prediction, Assessment and Inundation Mapping

SMAP Applications web site
http://smap.jpl.nasa.gov/benefit/

Assimilation of AMSR-E Soil Moisture into the USDA-FAS Global Crop Production Decision Support System

P.I. - Wade Crow USDA-ARS-HRSL
Co. I. - John D. Bolten NASA GSFC 614.3





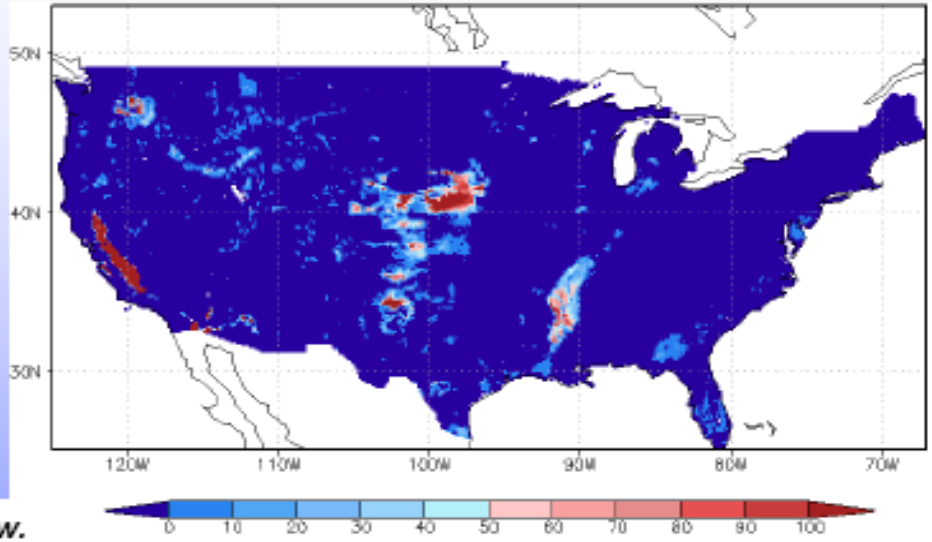
§Contribution: provide global soil moisture observations at higher accuracy, finer spatial resolution, and over broader geographic domains than existing USDA-FAS product, improved ROOT ZONE ANOMALY observations

§Benefits: more accurate crop monitoring and drought prediction, greater agricultural economic security, improved food shortage warnings, increased agricultural efficiency, policy and resource management decision support

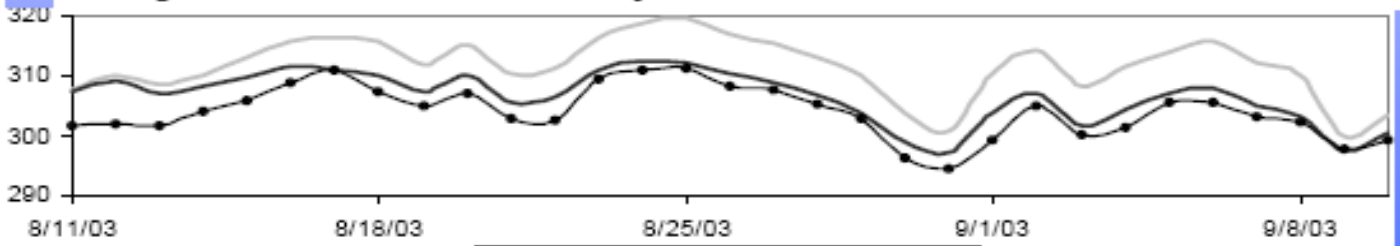
Simulating Irrigation Based on MODIS Observations

MODIS derived intensity of irrigation

Difference (%) in evapotranspiration between irrigation and control runs, Aug-Sep 2003



Ozdogan, Rodell, Kato, and Toll, J. Hydrometeor., in review.



Max surface temperature (K) at an irrigated site, from control run (gray line), irrigation run (black line), and observations (dots)

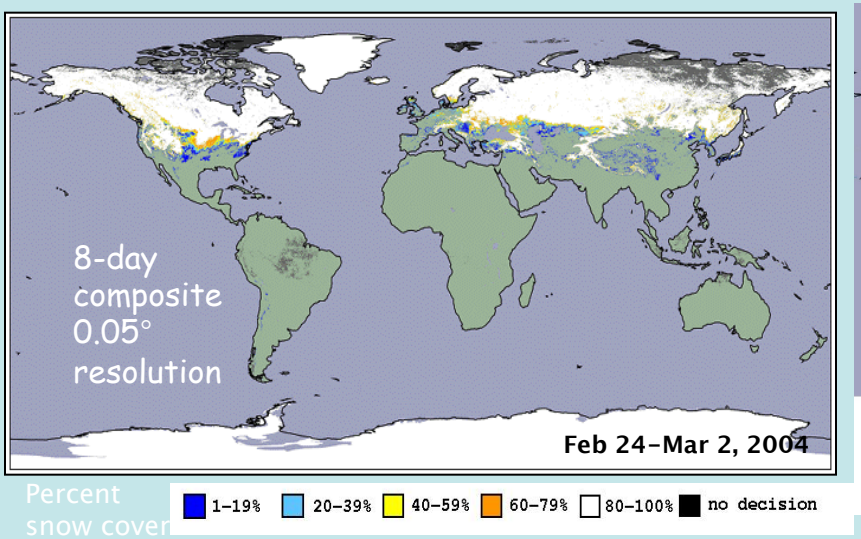
Innovative algorithm applies irrigation based on MODIS map, crop type, time of year, soil dryness, and common irrigation practices, to improve modeled fluxes

Extending to Mid-East and North Africa.
Also Iraqi emphasis with USDA Foreign Agriculture Service

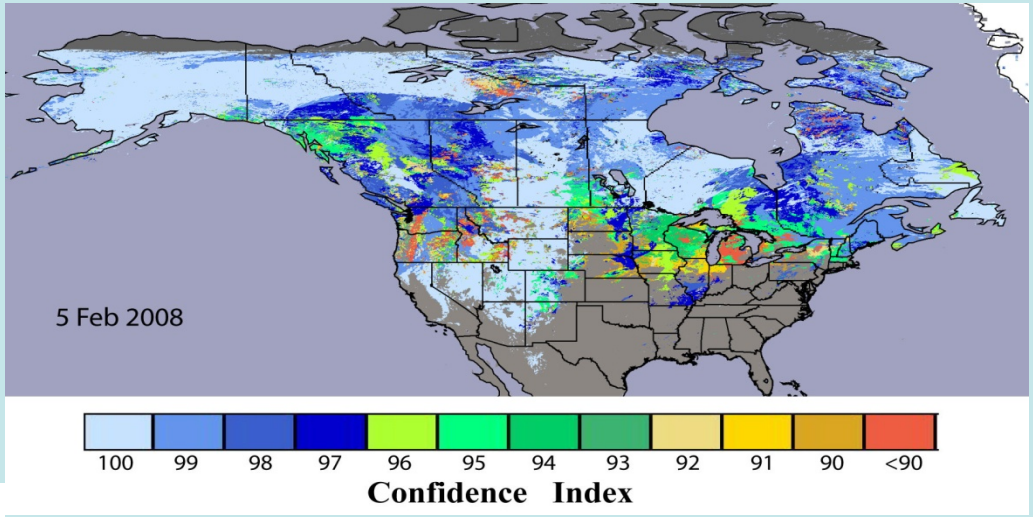
M. Ozdogan/U. Wisc

MODIS Snow-Cover Map Products & Snow Water Equiv.

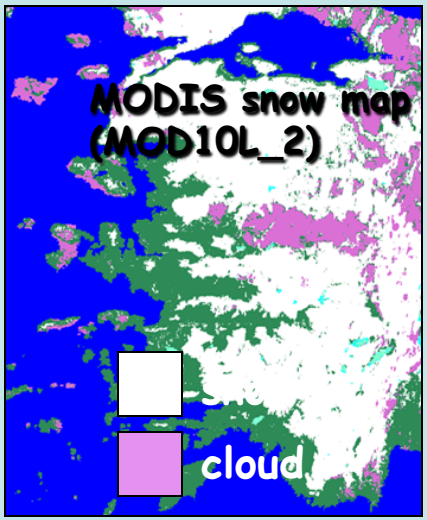
MODIS 5-km resolution snow map



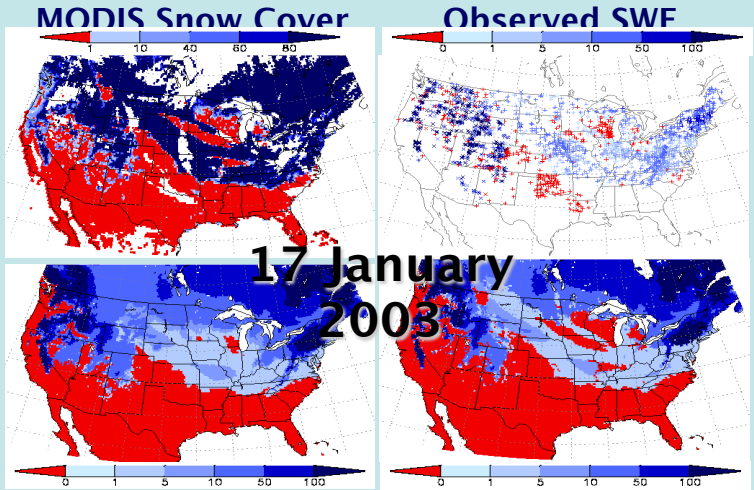
MODIS cloud-gap-filled snow map



Western Turkey 27 Jan 2004 500-m resolution



'GLDAS' Assimilated Snow Water Equivalent



Summary Space-Based Hydrologic Observations Current Capability

	Sensor	Technology	Horizontal Resolution	Repeat Frequency	Swath Width
Precipitation	TRMM	Precip Radar (JAXA) TMI, VIRS	25 km 0.25x0.25deg	daily	247 km 878 km
Soil moisture	SSMI AMSR-E	Multifrequency Radiometers	12-56 km	5-day	1445 km
Groundwater	GRACE	gravity	100,000 km2	30 days	
Lake/reservoir levels	Topex/ Poseidon Jason-1	Altimetric radar	350 m	10 day	Single track
Evapo-transpiration	MODIS	Visible/NIR	250-1000m	1-2 days	
Stream discharge	Topex Poseidon Jason-1	Altimetric radar	350m	10-day	Single track
Snow water equivalent	SSMI AMSR-E	Multifrequency Radiometers	12-56 km	5-day	1445 km
Snow cover	MODIS	Vis/NIR	250-1000m	1-2 days	2330 km
Roughness	MODIS		1 km	monthly	

Determining the Feasibility of Mapping and Monitoring the Extent of Cladophora in the Laurentian Great Lakes

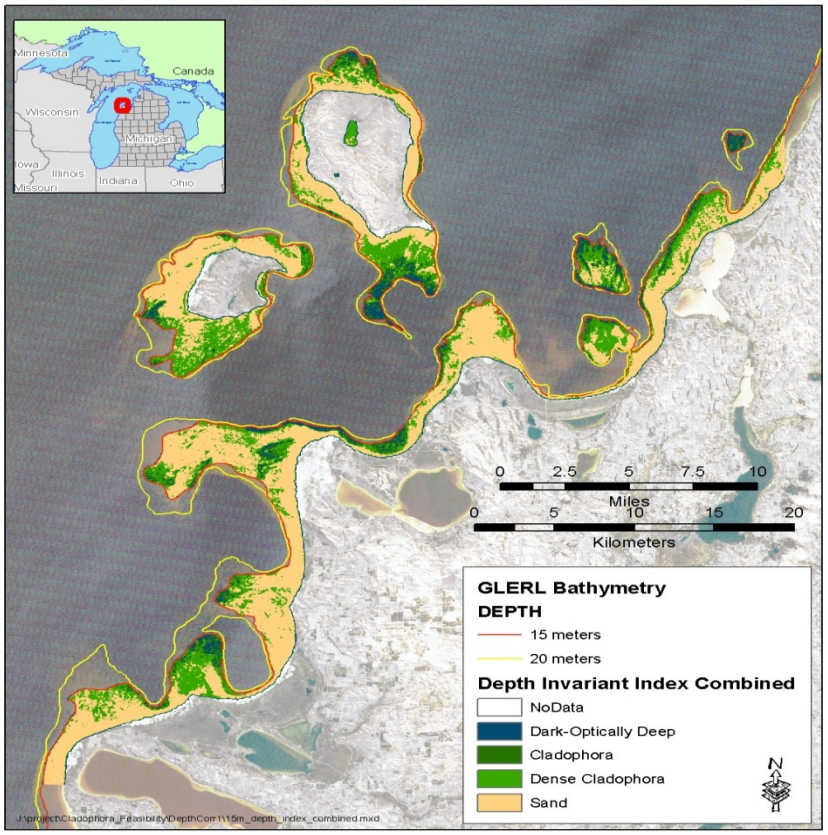
Dr. Robert Shuchman, Michigan Tech Research Institute

A depth invariant algorithm has been generated and successfully tested to map Cladophora in 0-15 meters depth using multi-spectral visible EO satellite data such as Landsat and GeoEye.

New methodology can be utilized in EPA's Great Lakes Restoration Initiative (GLRI) to create baseline Cladophora extent and biomass maps to support remediation efforts by resource managers of this nuisance algae.

Bottom Type	Dry Weight Density (g/m^2)	Area (m^2)	Dry Weight Biomass (grams)	Approximate Dry Weight Biomass (tonnes)	Approximate Wet Weight Biomass (tonnes)
Dark-Optically Deep	0	41,069,700	0	0	0
Cladophora (Darker green)	31	19,947,600	618,375,600	618	6,184
Dense Cladophora (Lighter green)	53	81,578,700	4,323,671,100	4,324	43,237
Sand	0	167,585,400	0	0	0
				4,942	**49,420**

Figure 1. Cladophora map created using combined depth invariant index 4/11/2009 Landsat 5 data



Example of a NASA Water Quality Project. NASA supports over 10 water quality projects in the US including directly estimating water quality parameters such as of nutrients and sediments and the evaluation of non-point source pollution (e.g., vegetation stress and land cover change) sources.