NASA Water Cycle Road Map and Land Use

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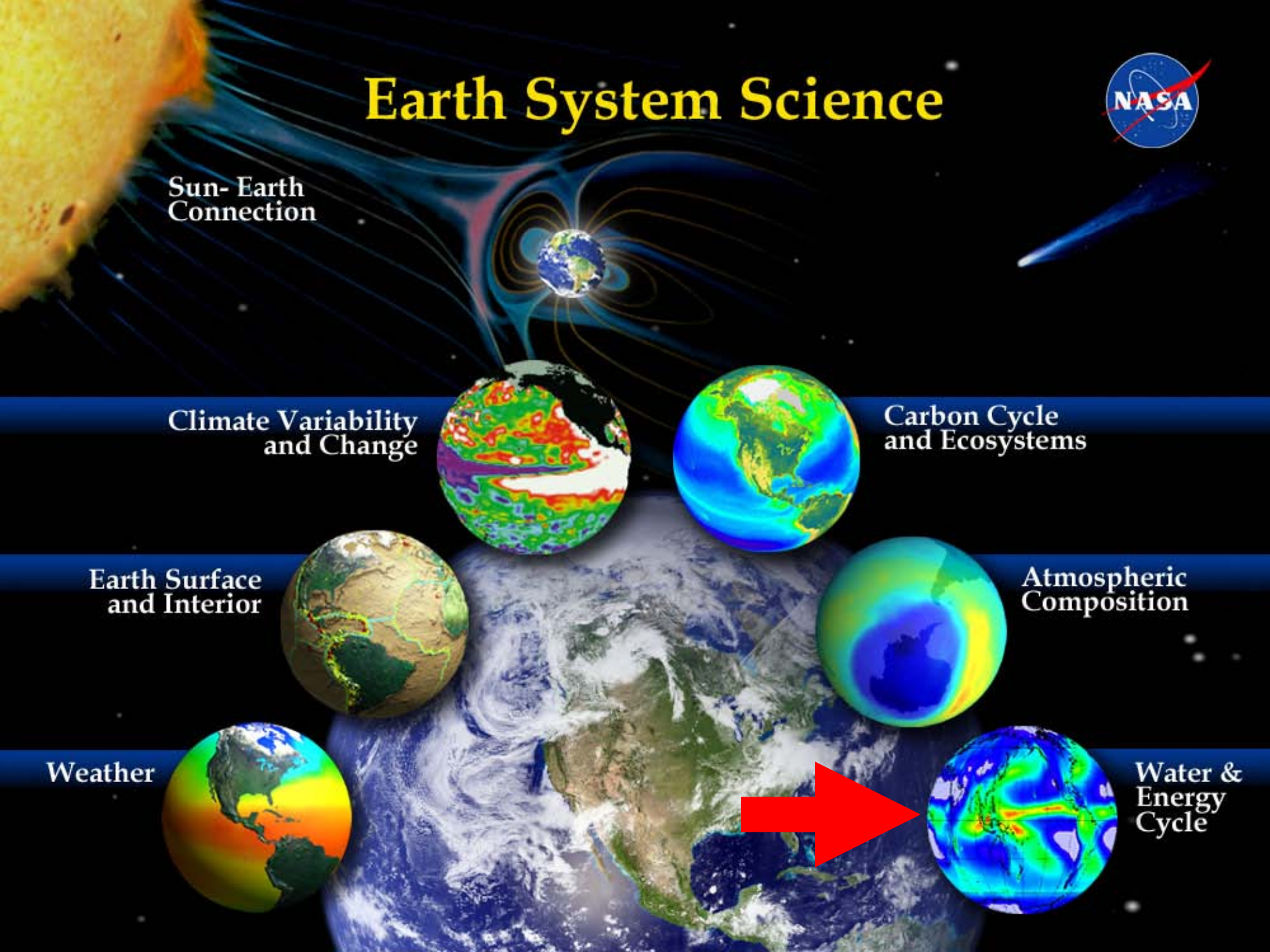
NASA Land Use Land Cover Change Science Team Meeting

January 12, 2005

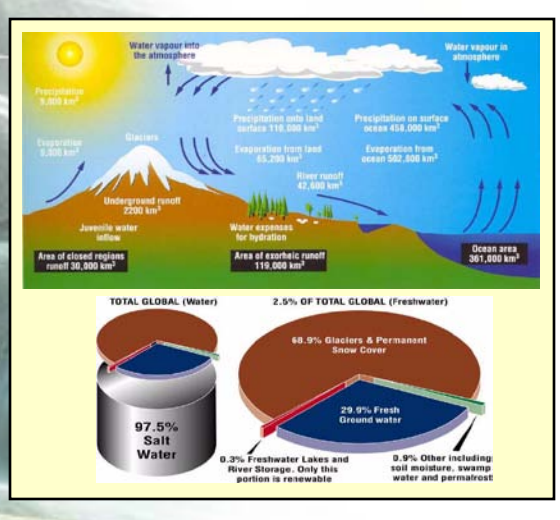
Earth Science Enterprise
National Aeronautics and Space Administration

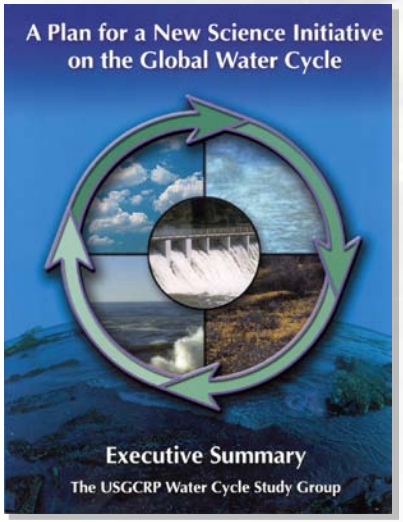
NASA ENERGY AND WATER CYCLE STUDY
NEWS

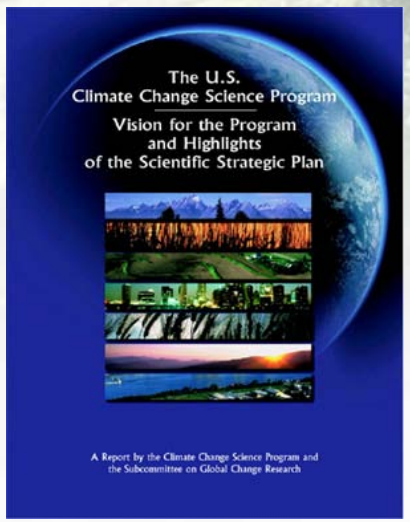
Earth System Science



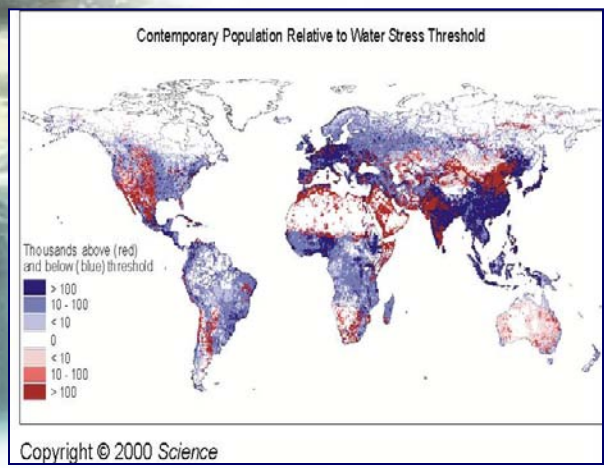
Motivation







What are the causes of water cycle variations?
Are variations in the global and water cycle predictable?
How are water and nutrient cycles linked?



NASA-ESE Water & Energy Cycle Science Ques (7 of 24):

- How are global precip, evaporation and the cycling of water changing?
- What are the effects of clouds and surface hydr. proc's on Earth's climate?
- How are variations in local weather, precipitation and water resources related to climate variation?
- What are the consequences of climate change and increased human activities for coastal regions?
- How can weather forecast duration and reliability be improved?
- How can predictions of climate variability and change be improved?
- How will water cycle dynamics change in the future?

NASA Energy and Water Cycle Study (NEWS)

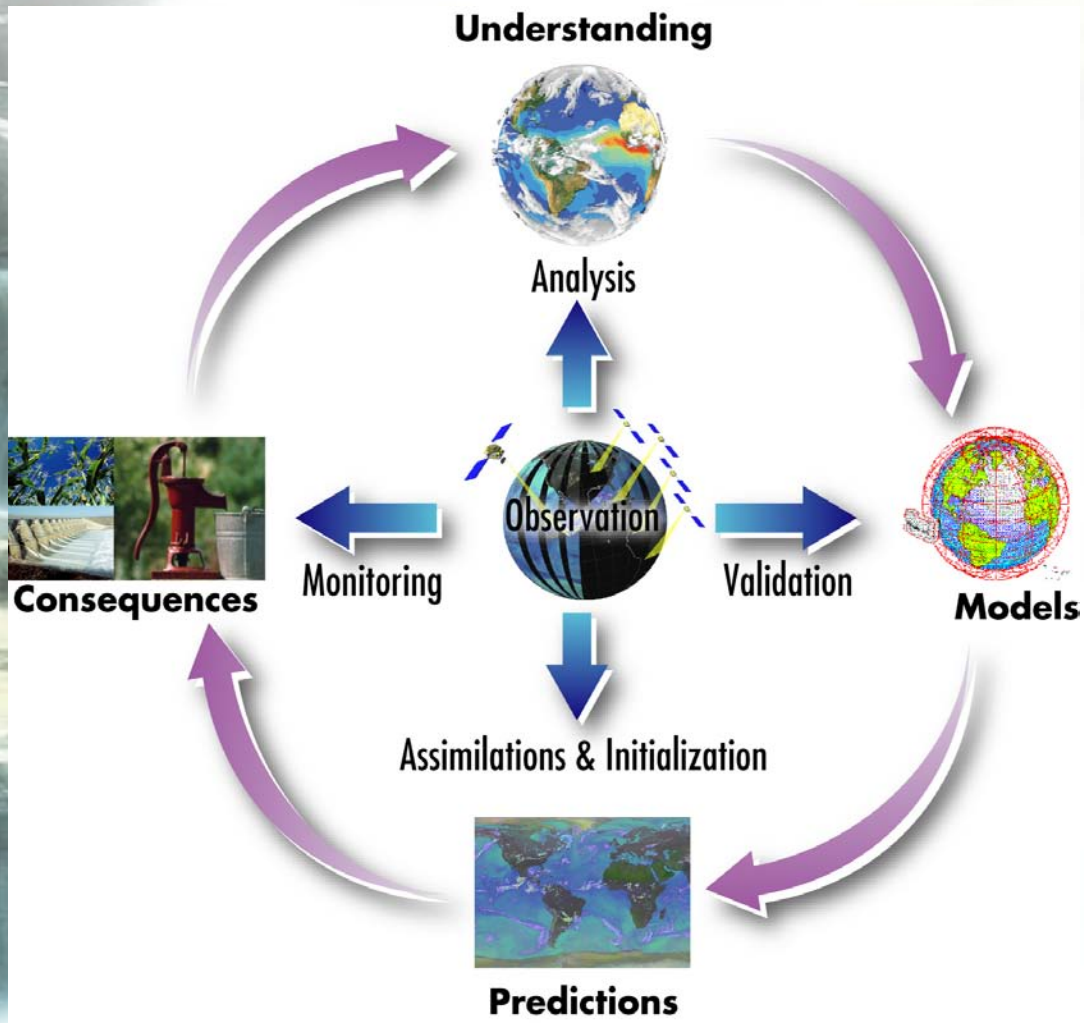
NASA's integrated plan for energy and water cycle research.

NEWS Goal

"To document and enable improved, observationally-based, predictions of energy and water cycle consequences of Earth system variability and change"

NEWS Integrated Water and Energy Cycle Research

From Observations to Consequences



Interdisciplinary Linkages:

- **Aerosols:** *link to precipitation development, interaction with energy/radiation cycles*
- **Carbon:** *link to transpiration and radiation absorption*
- **Weather and Climate**: *water and energy are at the heart of weather and climate physics*
- **Modeling, Assimilation, and Computing**: *essential tools for integration and prediction*
- **Technology**: *development of new observation technology*
- **Applications**: *consequences of change delivered through water & energy cycle*

NEWS Key Components

- Cloud, Radiation, and Precipitation Processes
- Land Hydrologic Processes
- Ocean Fluxes and Atmospheric Transport
- Indirect Radiative Effect of Aerosols

Land Cover/Land Use within the Energy & Water Cycle

Impact on E&WC

- radiation fluxes through albedo, surface T, emissivity
- partitioning of sensible and latent heat fluxes
- runoff through vegetation retention, soil water holding capacity and infiltration, snowmelt processes
- momentum fluxes through surface roughness
- feedback on cloud and precipitation processes

Example areas of mutual interest

- direct human and natural changes
  - agricultural and grazing practices
  - fires, forest exploitation and clearing
  - urbanization and wetlands loss
- indirect effects
  - streamflow regulation, diversions, impoundments
  - impact on aerosols, industrial emissions, atmospheric dispersion

Specific NEWS Objectives

- Develop and deploy experimental E&WC global observing system
- Document the global E&WC by obtaining complete observational record of all relevant geophysical quantities
- Create global surface and atmosphere data assimilation system for E&WC variables
- To build a fully integrated global climate model encompassing E&WC processes
- Assess variability of the global E&WC over a range of time/space scales
- Support the use of climate prediction capabilities for water resources applications

NEWS Approach

- Advanced Global Observations
- Advanced Radiative Transfer Methods
- Analysis of Multiple/Merged Data Sets
- Improved Process Models
- Data Assimilation within Coupled Models

Earth Science Enterprise
National Aeronautics and Space Administration

NASA Energy and Water Cycle (NEWS) Road Map

FT Unofficial Version (3.17.2004)

Focus Area Linkages
- C = Carbon
- V = Climate variability
- A = Atmospheric composition
- W = Weather
- S = Surface & interior

T = Technology development
+ = Field campaign
= Funded = Unfunded

Knowledge Base

Focus Area Challenge:
Document and enable improved, observation-based water and energy cycle consequence predictions (floods and droughts) of earth system variability and change

Exploiting current capabilities and preparing for the future

Phase 1 Deliverables:
- First coordinated global W&E description
- Current prediction system evaluation
- Identify required system improvements

Application
- Selected demonstrations
- Climatology baselines V
- Establish requirements T

Prediction
- Land-cloud model C V A W +
- Multi-platform analysis T
- Physics-based modeling T
- New climate datasets V
- OSSEs +

Observation
- Advanced Analysis T
- TRMM TERRA AQUA GRACE ICESAT S C W A V
- AURA CloudSAT CALIPSO V A W

Address deficiencies and build prediction system

Phase 2 Deliverables:
- Fix model problems with new observations
- New measurement approaches developed
- End-to-end prediction system developed

- Observations used in planning
- Test prediction of extremes W V
- Develop application metrics
- Enhanced RT models T V W +
- Improved physics C V W + Model convergence
- Super-parameterization T T W V
- Multi-platform analysis T
- Advanced multi-platform retrievals T +
- Experimental W&E observation system T +
- First Coordinated W&E Obs W V C
- GPM AQUARIUS HYDROS T
- Cold seasons T +
- Surface water T +

Address the ESE vision; deliver and evaluate system

Phase 3 Deliverables:
- Dataset gaps filled and extended
- Intensive prediction system testing
- Prediction system delivery

APPLICATION:
- Improved water & energy cycle forecasts for use in decision support systems

- Predict consequences of climate change
- Global hydrologic warning system T
- Demonstrate useful predictions T W V

ANALYSIS & PREDICTION:
- Understand variability in stores and fluxes
- Accurate cloud prediction
- Improve latent heating & convection models

- Reprocess combined observation record V
- Demonstrate prediction capacity W V
- Full end-to-end system test T
- Comprehensive W&E cycle data management and retrieval system T +
- Coordinated W & E system T

OBSERVATION:
- Quantify mean state, variability, and extremes of the water & energy cycles
- Quantification of fluxes and storages

Systematic observations of water and energy cycle including national and international partners

2004 IPCC Report 2006 2008 IPCC Report 2010 2012 IPCC Report 2014 2016 IPCC Report 2018

NEWS Status

- Draft NEWS Implementation Plan (~70 pages)
- NEWS NRA under review (awards ~ summer 2005)
- Formulation of current and planned satellite systems (e.g. GPM, HYDROS)

For further information see: http://watercycle.gsfc.nasa.gov

NEWS implementation includes:

- **Product-driven investigations**

- Combine and interpret past and current observations

- Derive global prediction tools and products,

- **Independent discovery-driven investigations**

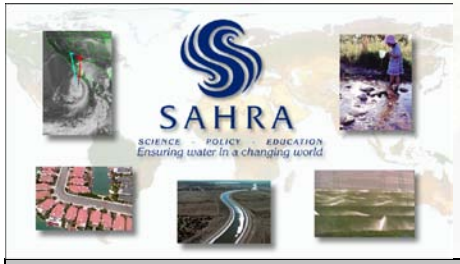
- Explore scientific E&WC frontiers

- Examine cross-cutting boundaries,

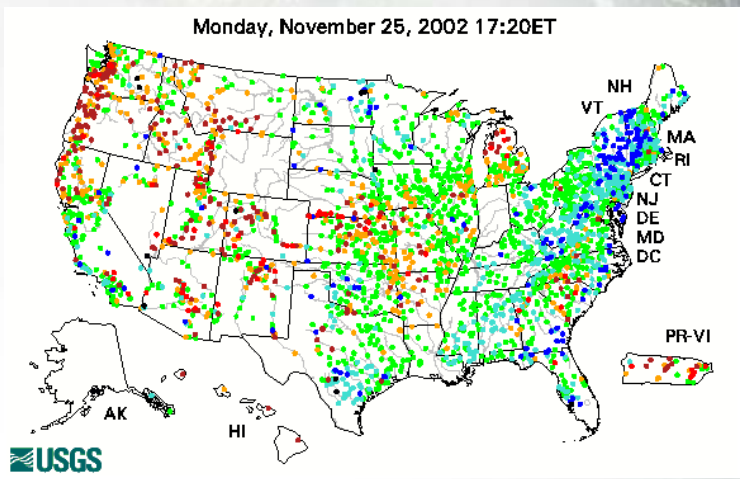
- **NEWS Science Integration Team**

- Interfaces with other ESE, national and international research activities

Coordinate with Other US Agencies, e.g.



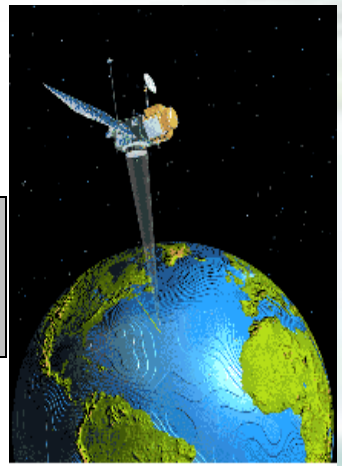
UNDERSTANDING
NSF, **NASA**, DOE

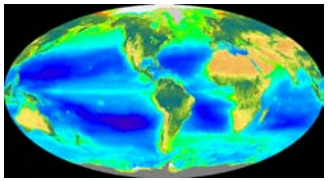


USDA
USGS
APPLICATIONS
EPA BoR
USACE

PREDICTION
NOAA, DOE, **NASA**

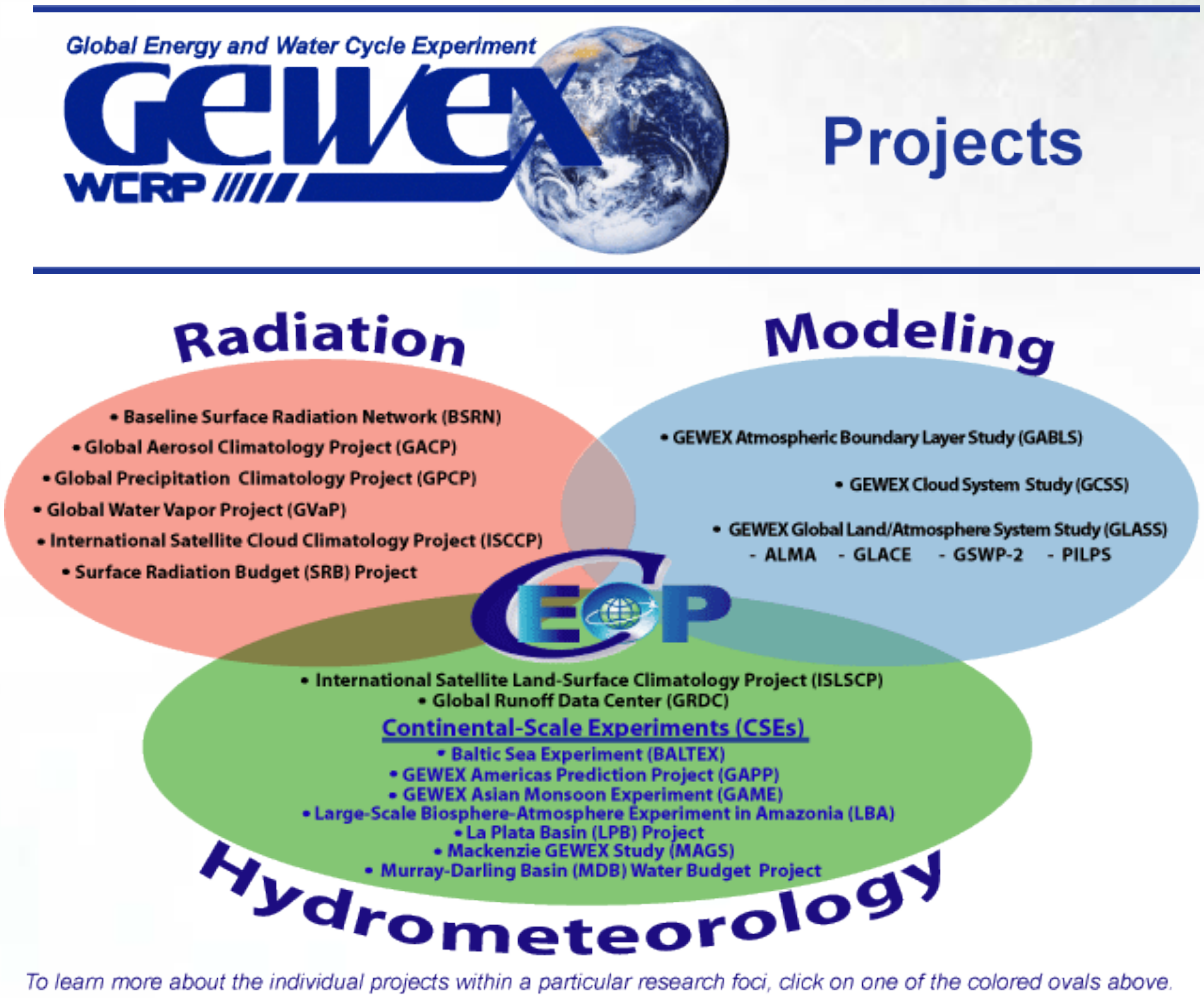
OBSERVATIONS
NASA, NOAA (DOE, USGS, USDA)





TOPEX/Poseidon Satellite
Over the earth

Coordinate with International Partners, e.g.

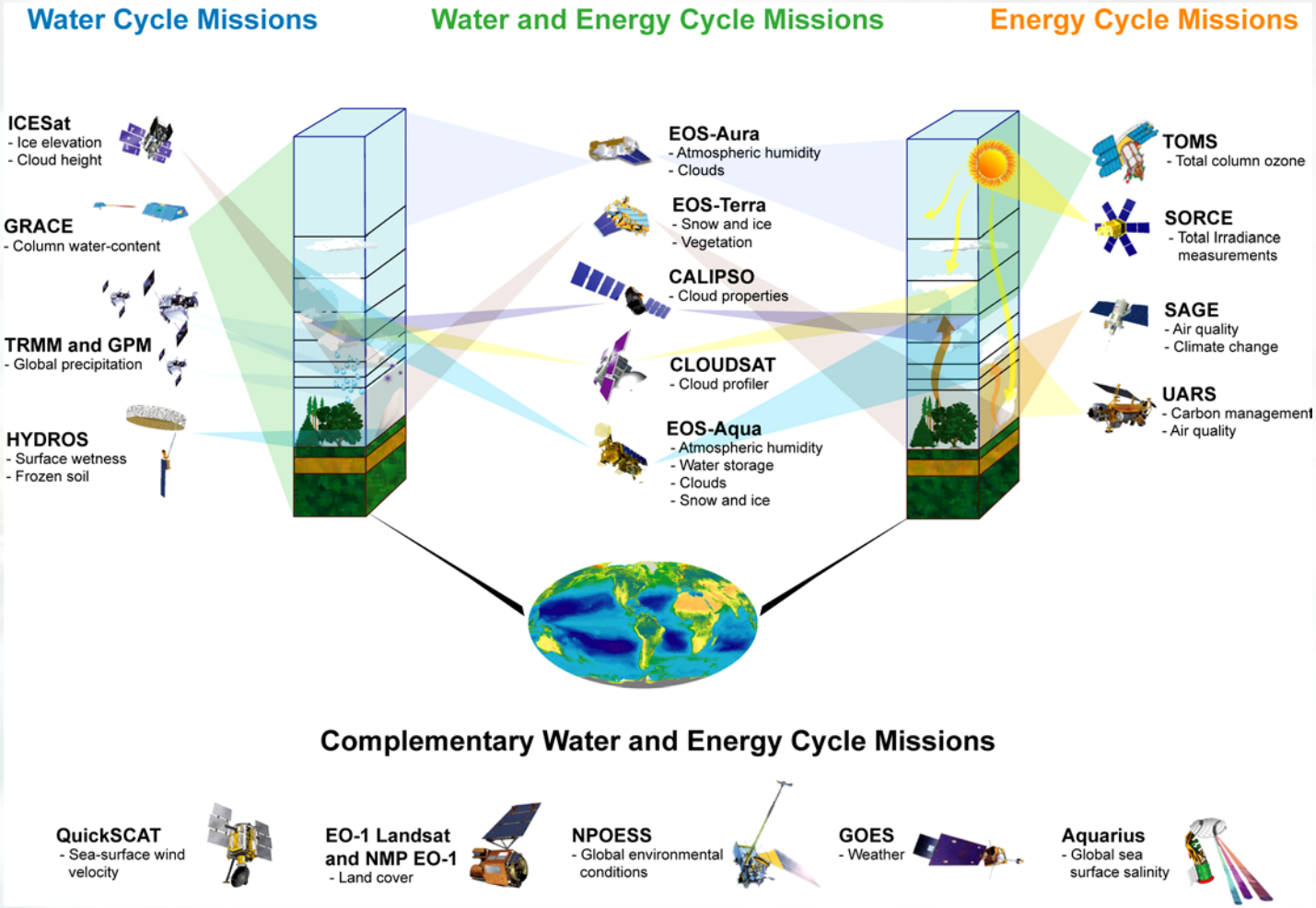


Emerging NASA Hydrologic Missions for NEWS Research

1. Global Precipitation (GPM)
2. Soil Moisture
3. Water Level and Discharge
4. Cold Land Processes
5. Water Storage

Observations

- In terms of current and pending missions, an orbiting fleet of eighteen NASA research satellites provides relevant energy and water-cycle observations



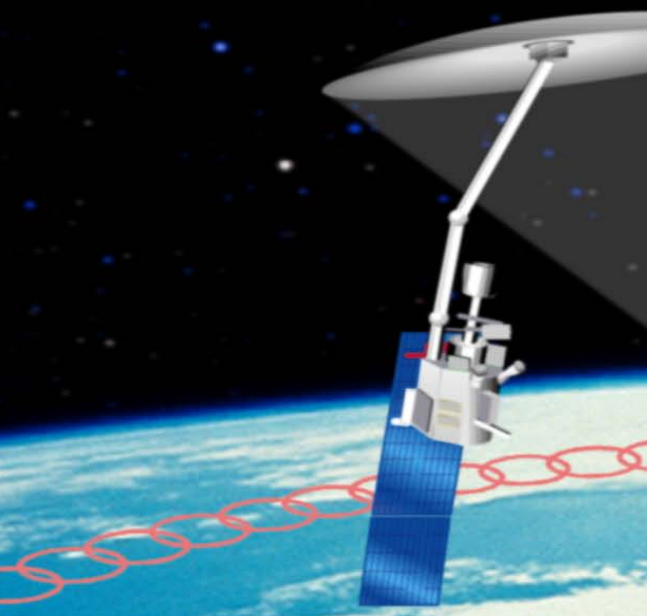
HYDROS

A NASA EARTH SYSTEM SCIENCE PATHFINDER
HYDROSPHERIC STATES MISSION

PI: Dara Entekhabi (MIT)
Project Scientists: Paul Houser (GSFC), Eni Njoku (JPL)

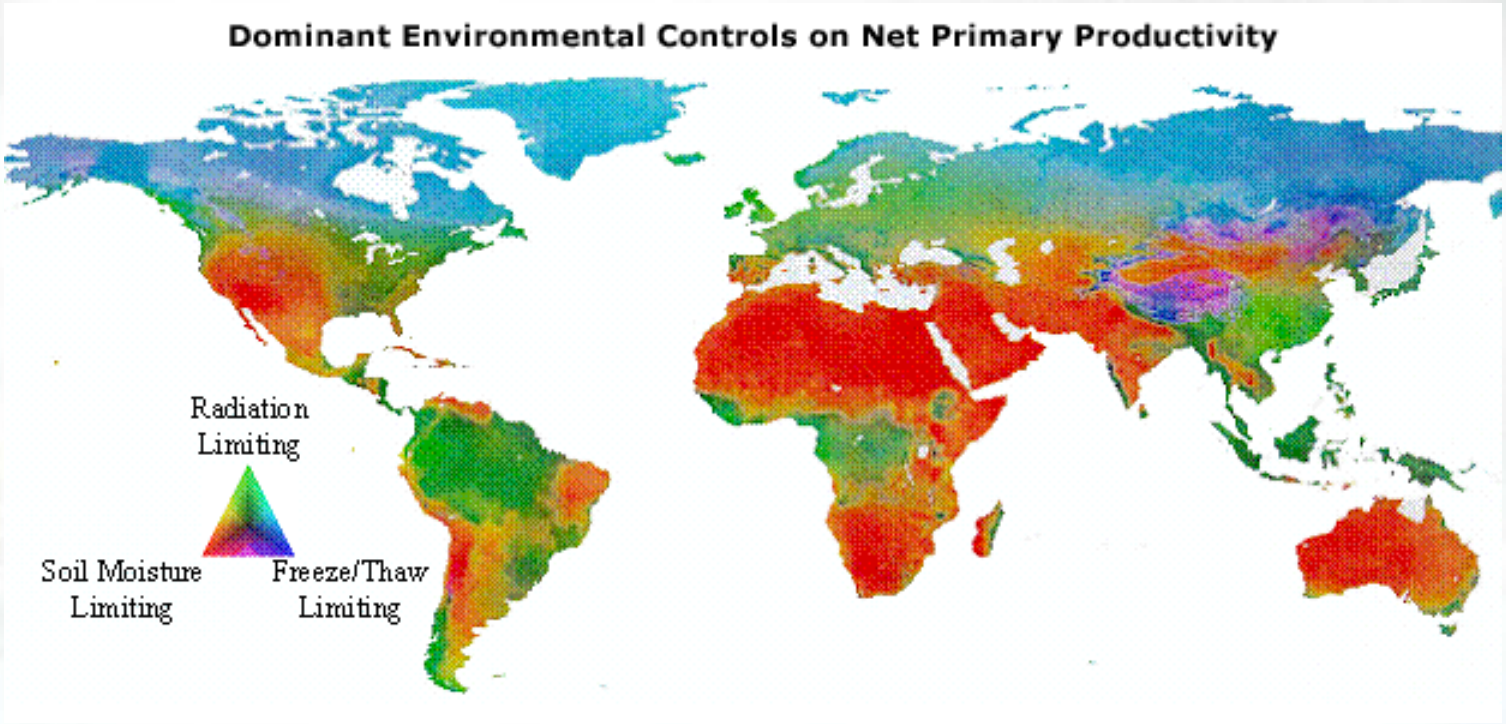
MISSION DESIGN

Instruments: L band active/passive with shared 6-m rotating antenna
Polarization: H, V, U (radiometer)
HH, VV, HV (radar)
Accuracy: 0.5 dB (radar), 1 K (radiometer)
Resolution: 3 km (radar), 40 km (radiometer)
Orbit: 6 am/pm sun-synch at 670 km; wide swath (1000 km) at constant look angle of 39°



HYDROS will provide the first global views of the land hydrosphere state (soil moisture and surface freeze/thaw), which exerts the primary control on land-atmosphere exchanges of water, energy, and carbon over most of the Earth.

Dominant Environmental Controls on Net Primary Productivity



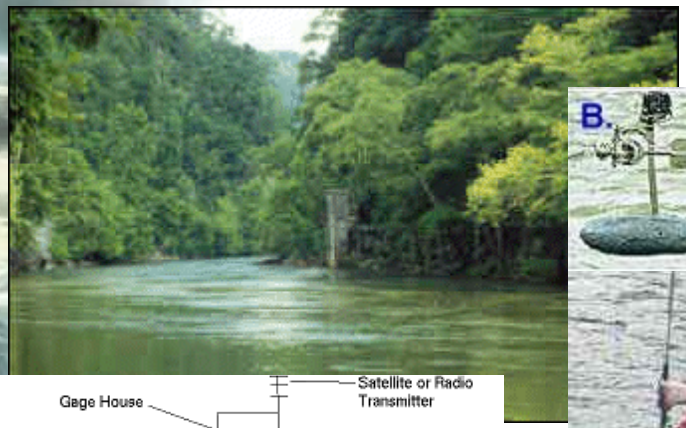
Surface Water Measurements from Space?

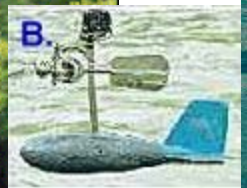
Non-Channel Flow

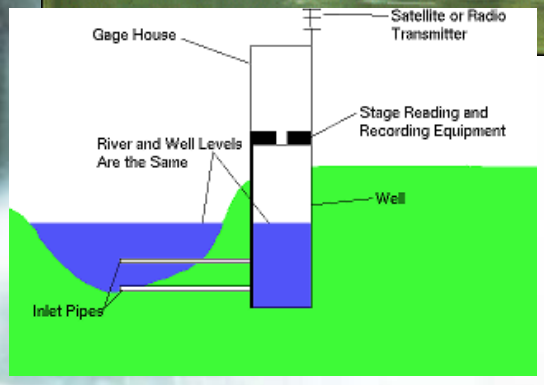
100% Inundated

Braided Rivers

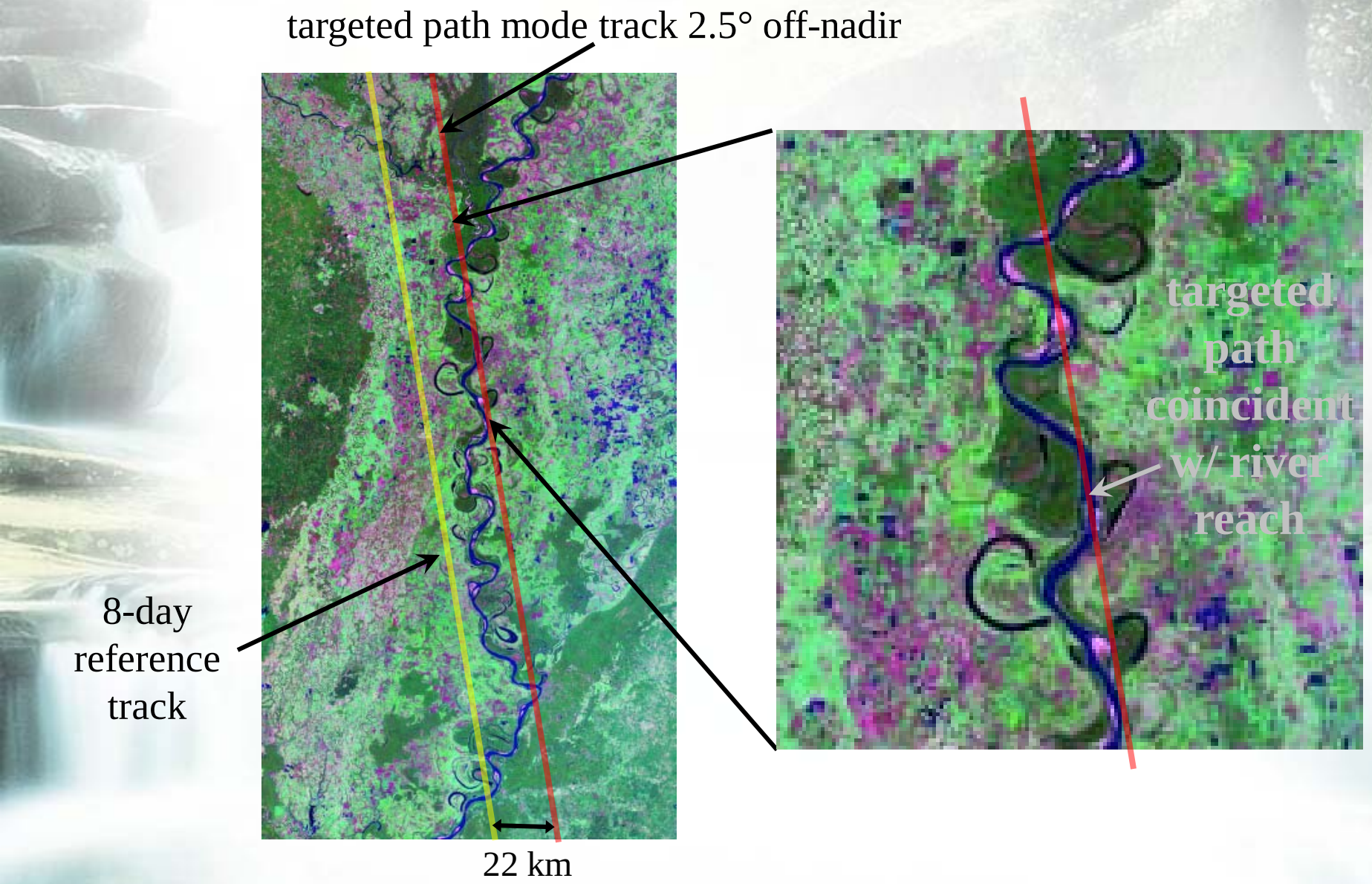
Variable land surface







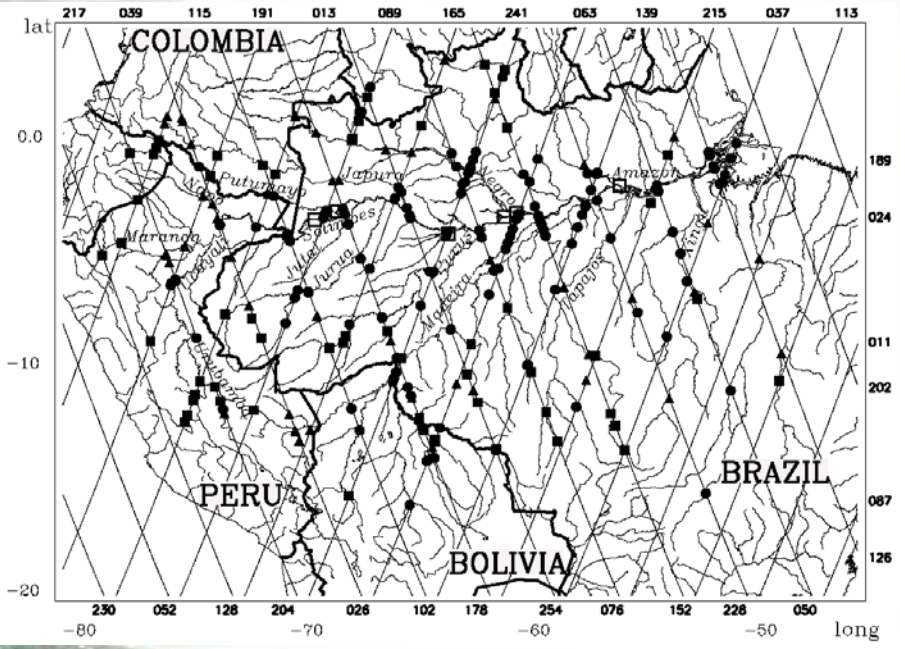
ICESat Targeting of Lower Mississippi River



ICEsat Lower Mississippi River Extent, Stage & Slope

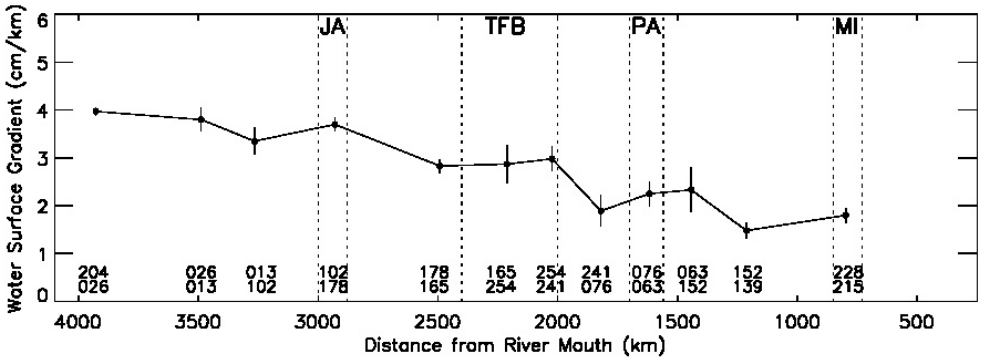
2.5° Off-Nadir

Storage Change & Discharge from Altimetry



Presently, altimeters are configured for oceanographic applications, thus lacking the spatial resolution that may be possible for rivers and wetlands.

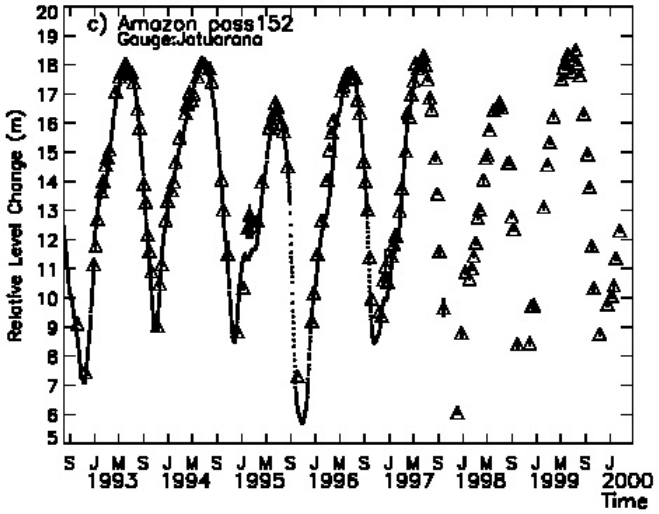
Water Slope from Altimetry



+ Manning's n + Channel Geometry =Q

Topex/Poseidon Over Amazon River

+



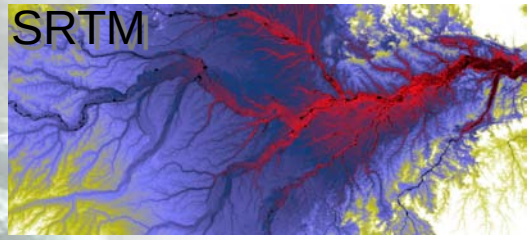
=ΔS

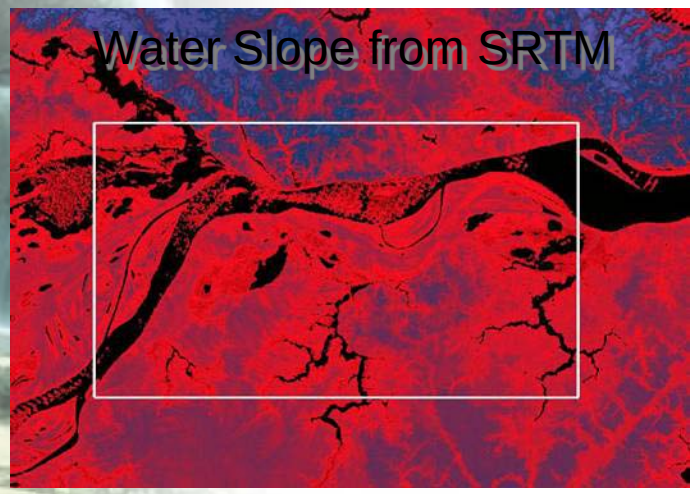
Note: loss of gauge data post 1997

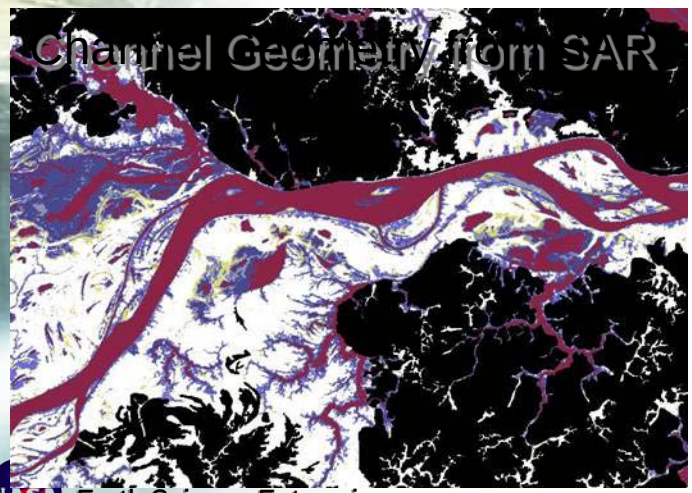
Birkett, C.M., ***Water Resources Res.,***1223-1239, 1998.
Birkett, C.M., L.A.K. Mertes, T. Dunne, M.H. Costa, and M.J. Jasinski,***Journal of Geophysical Research***, 107, 2002.

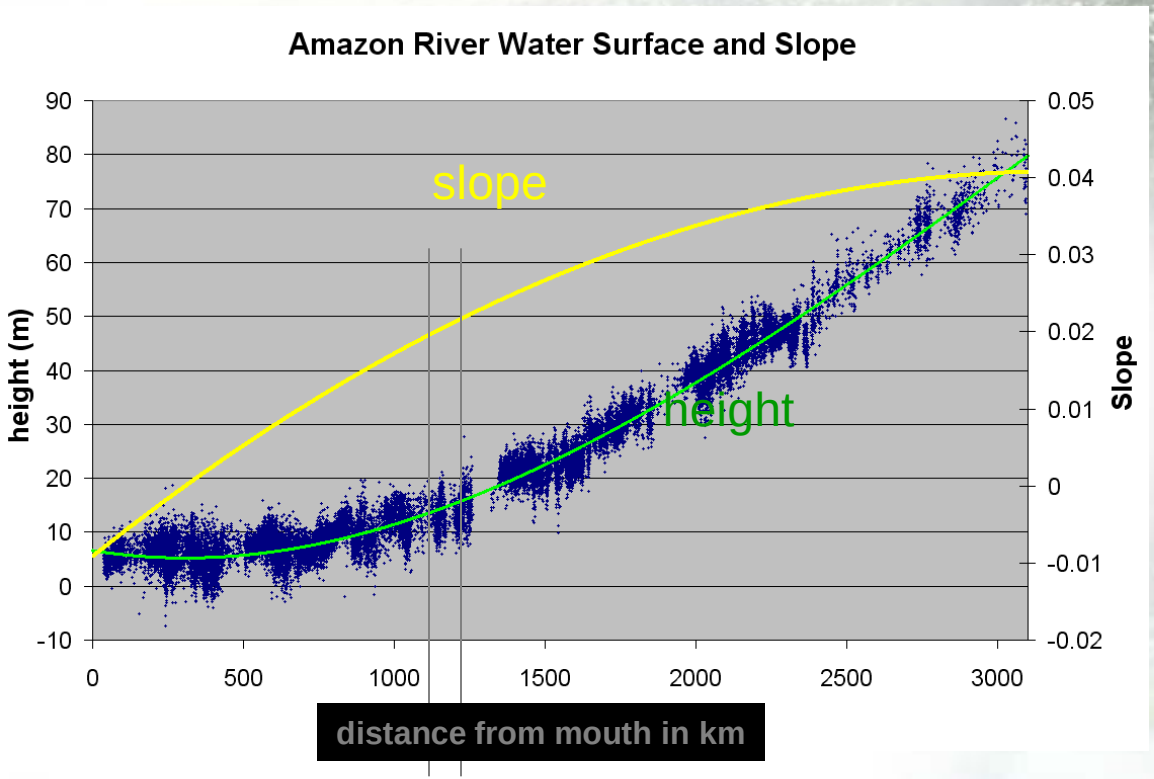
Channel Slope and Amazon Q from SRTM

Shuttle Radar Topography Mission





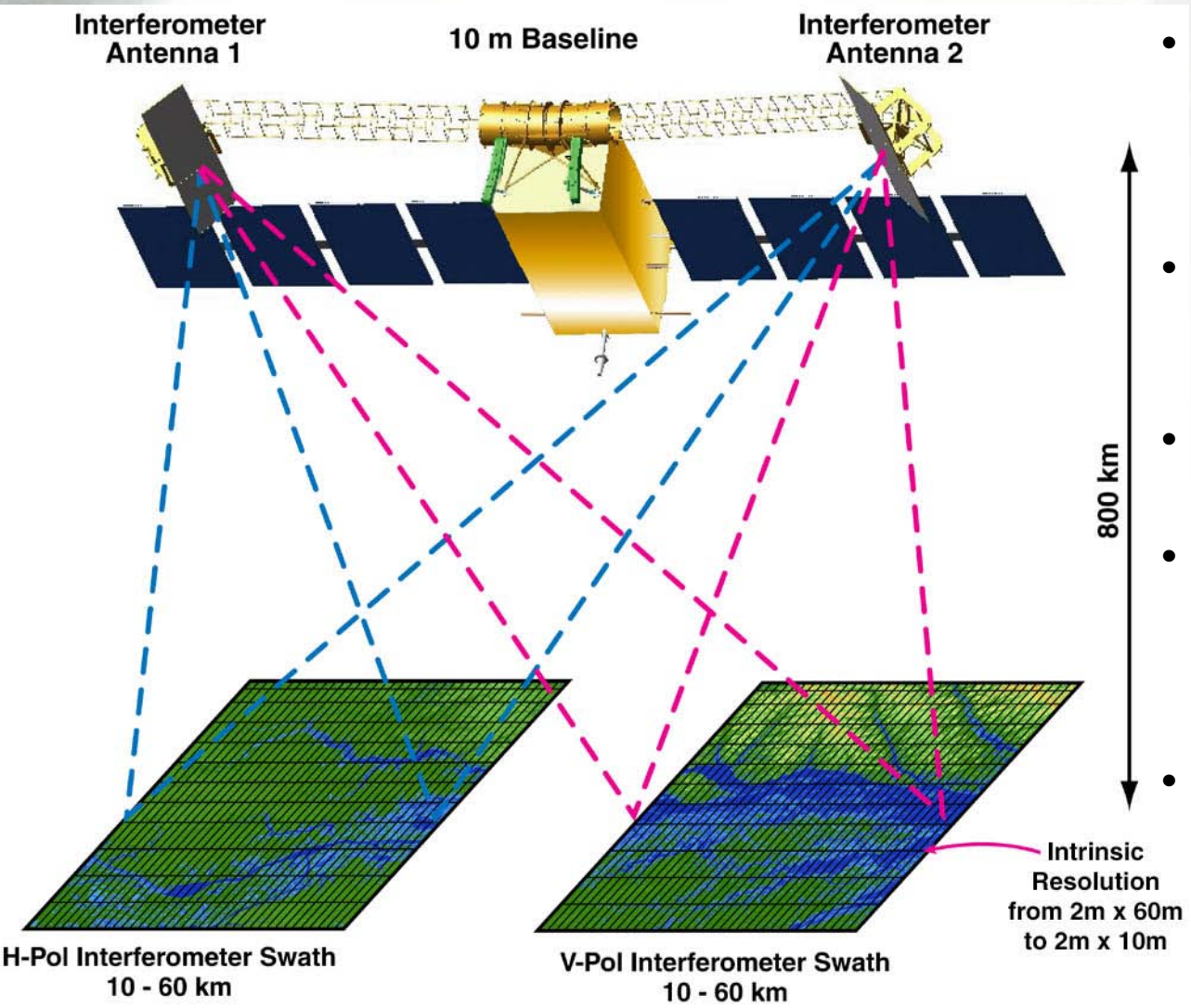




Observed at Manacapuru Gauge = 96300 m^3/s
Estimated from SRTM and Manning's n = 93500 m^3/s

Hendricks, Alsdorf, Pavelsky, Sheng, *AGU Abstract*, 2003

Surface Water Interferometer Concept



- Ka-band SAR interferometric system with 2 swaths, 50 km each
- Produces heights and co-registered all-weather imagery
- 200 MHz bandwidth (0.75 cm range resolution)
- Use near-nadir returns for SAR altimeter/angle of arrival mode (e.g. Cryosat SIRAL mode) to fill swath
- No data compression onboard: data downlinked to NOAA Ka-band ground stations

Cold Land Processes Pathfinder (CLPP)

Winter Weather Forecasts

Snow on the ground has important affects on the atmosphere and weather patterns. Air temperature, visibility, cloud development, and precipitation are effected by the extent of snow cover, the amount of water in the snow, and the temperature of the snowpack. The new *National Snow Information Service* will provide better, more comprehensive snowpack information that will improve weather prediction models during winter conditions.

Water Supply Forecasts

In the western U.S., most of the annual precipitation occurs as snowfall and as much as 85% of streamflow originates as snowmelt. The new *National Snow Information Service* will provide several hundred new airborne measurements of the water content of the snowpack in the western U.S. and AK each year. These measurements will be integrated with all other available observations to provide the best possible estimates of water supply.

Climate Forecasts

The effects of snowpacks on the atmosphere can persist long after snow disappears from the ground. Changes in weather patterns due to winter snowcover result in "downstream" effects in both space and time. Better snow information will help climate models represent these effects.

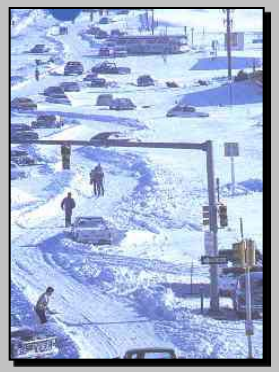
SNOW & ICE

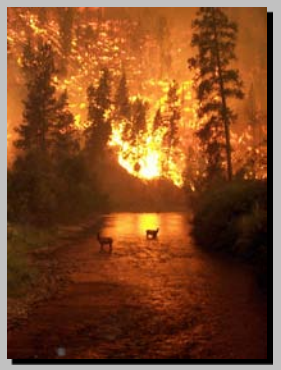
Snowmelt Flood Forecasts

Many of the last century's most significant floods resulted from snowmelt, and caused billions of dollars in damages. Products from the new *National Snow Information Service* will provide forecasters with better estimates of water volumes, as well as rate and timing of melt.

Winter Transportation Advisories

Winter storms affect the nation's transportation system each year, resulting in several billion dollars of snow removal costs annually. The high-resolution snow information provided by the new *National Snow Information Service* will enable improved winter transportation advisories by giving forecasters a better picture of which areas and routes are most affected during a winter storm, how much snowfall occurred, and whether blowing snow conditions exist.





Drought and Wildfire Planning

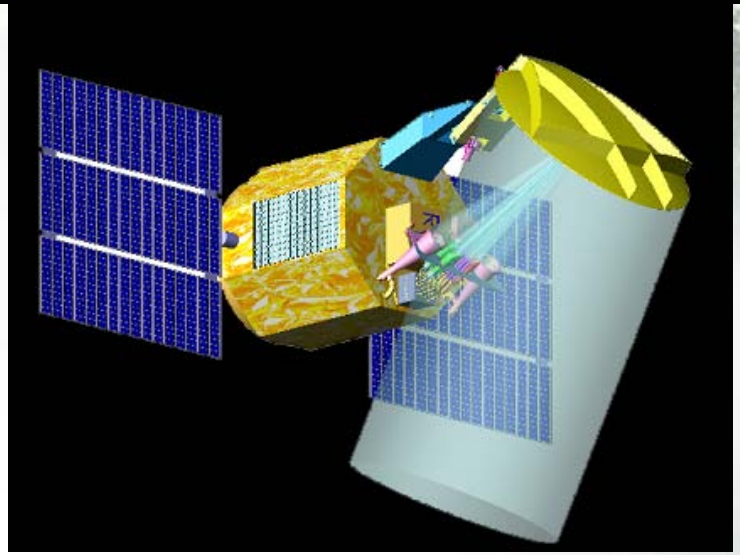
The first indication of an impending severe drought and fire season is a dry winter. Low snowpacks result in dry soil and fuel moisture conditions going into the spring and summer. Improved snowpack information from the new *National Snow Information Service* will assist drought monitoring nationwide and will provide firefighting planners with state-of-the-art tools and data to assess moisture conditions resulting from the previous winter.

Cold Land Processes Pathfinder

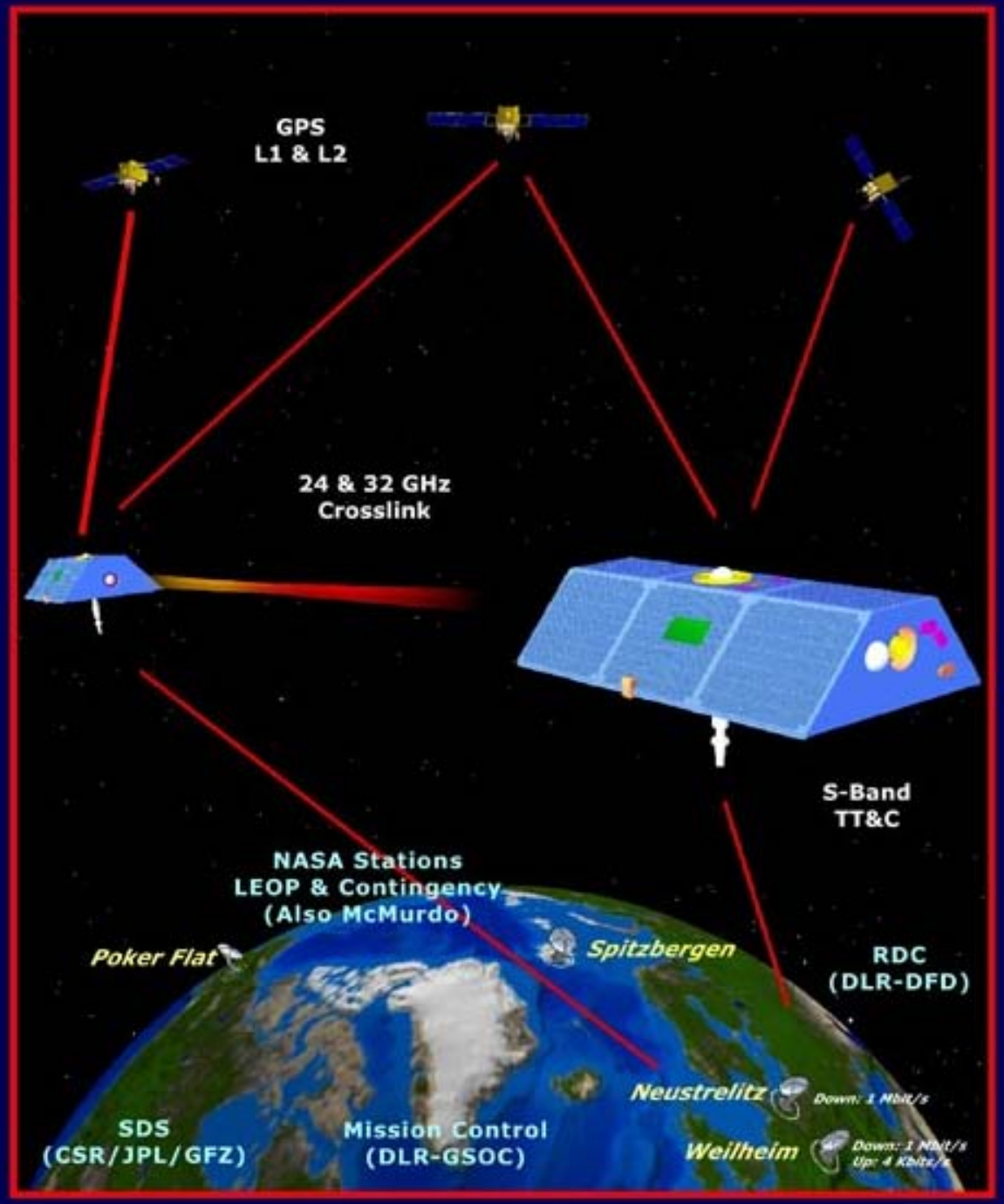
CLPP

Major Science Objectives

1. Characterize global distribution of cold-season precipitation, water storage, and surface fluxes.
2. Understand the processes that relate global-, regional-, and local-scale climate and water-cycle variations.
3. Improve interpretation and utility of the existing low-resolution climate record of remotely sensed global snow and ice variations.
4. Provide a benchmark for detecting future changes in cold-season water, weather, and climate.



- Ku-/C-band SAR
  - –100 m resolution
- K/Ka-band Radiometer
  - –7/4 km resolution



GRACE Mission

Science Goals

High resolution, mean & time variable gravity field mapping for Earth System Science applications.

Mission Systems

Instruments

- KBR (JPL/SSL)
- ACC (ONERA)
- SCA (DTU)
- GPS (JPL)

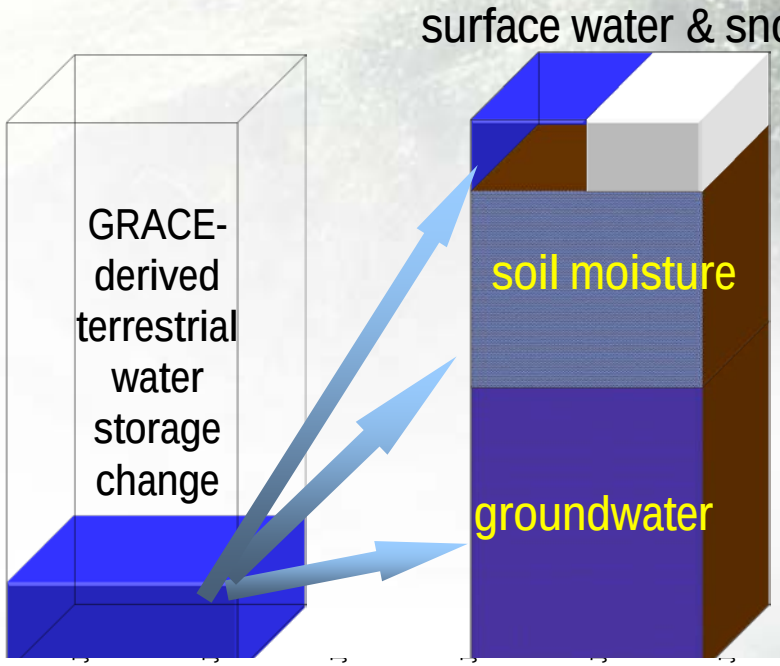
Satellite (JPL/DSS)
Launcher (DLR/Eurockot)
Operations (DLR/GSOC)
Science (CSR/JPL/GFZ)

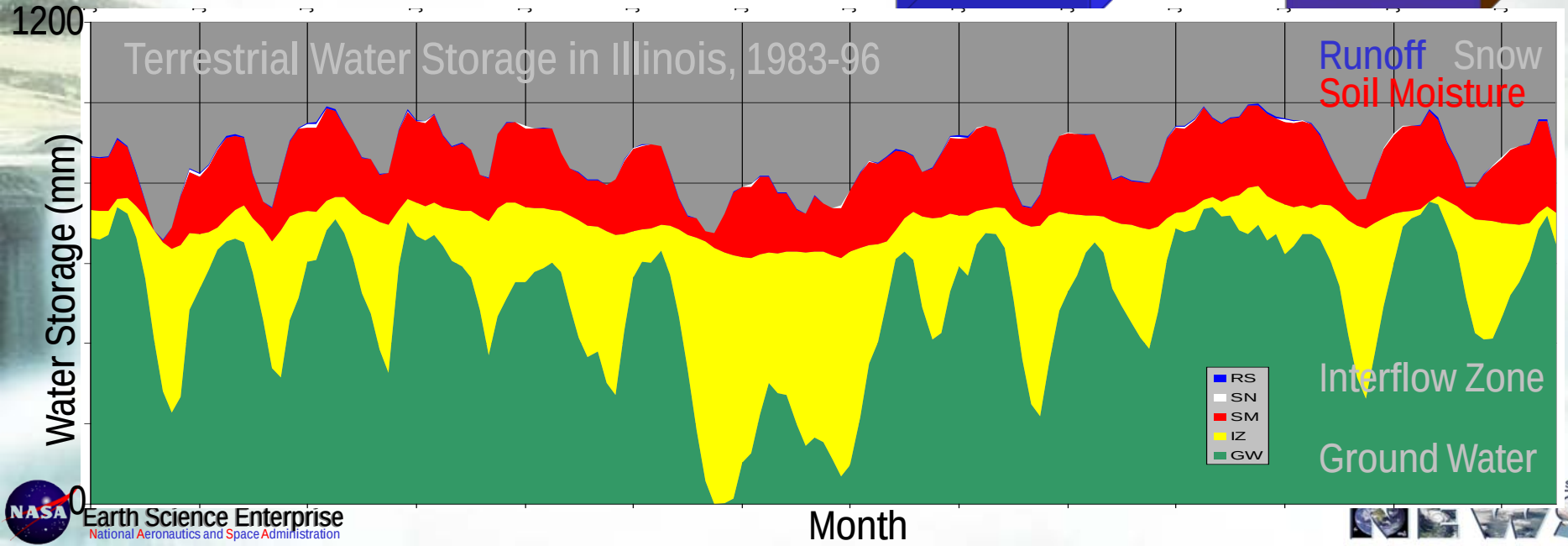
Orbit

Launch: November 2001
Altitude: 485 km
Inclination : 89 deg
Eccentricity: ~0.001
Lifetime: 5 years
Non-Repeat Ground Track
Earth Pointed, 3-Axis Stable

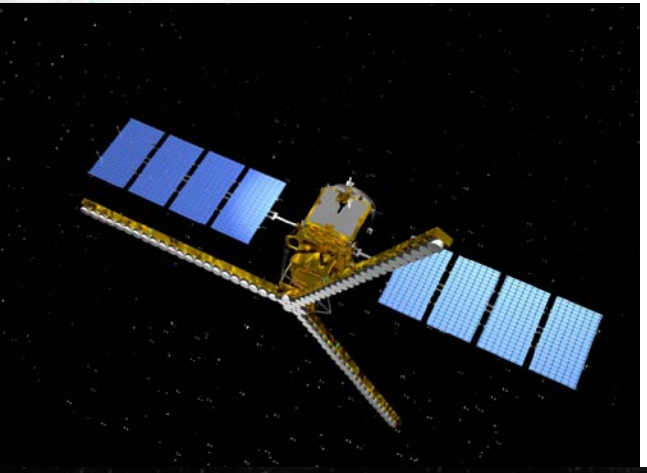
GRACE

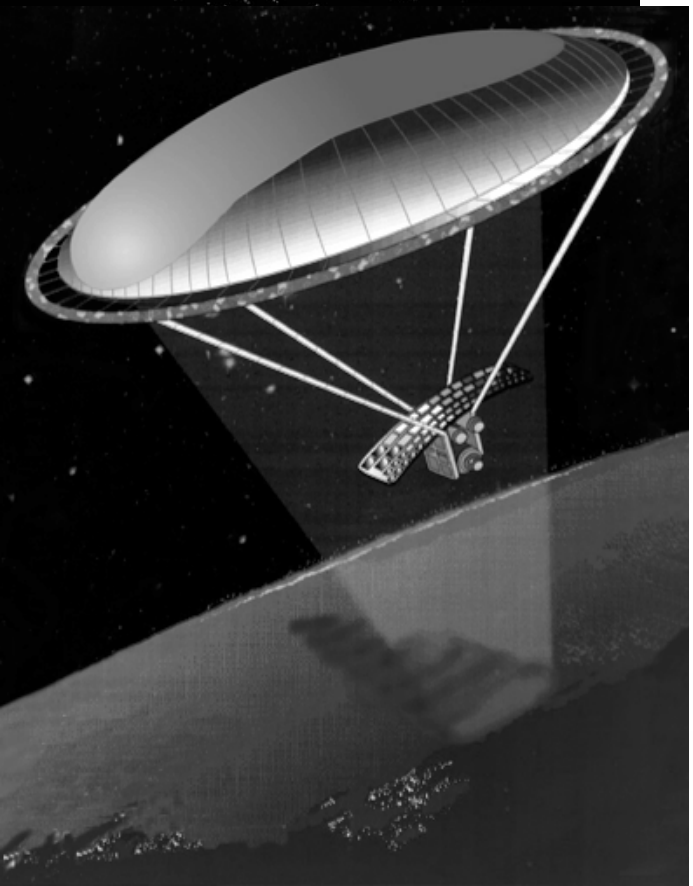
Change in stored terrestrial water mass

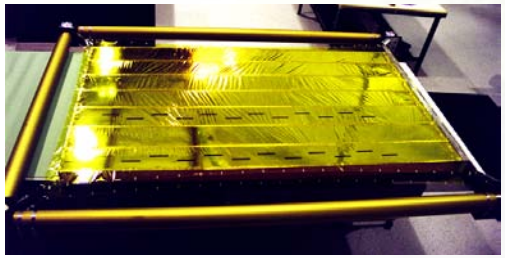


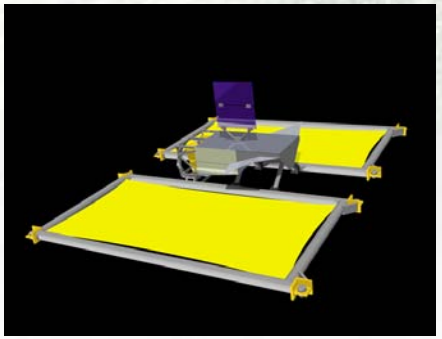


Eventual Water Cycle Mission?









Quantity	Spatial Resolution	Temporal Resolution	Frequency
Groundwater	50 km	2 weeks	100 MHz?
Soil Moisture	10 km	3 days	1.4 GHz
Salinity	50 km	2 weeks	1.4 GH
Freeze/thaw	1 km	1 day	1.2 GHz
Rain	5 km	3 hour	10-90 GHz
Falling Snow	5 km	3 hour	150 GHz
Snow	1-5 km	1 day	10-90 GHz
TPW	10 km		
	(sea)	3 hour	6-37 GHz
	(land)	3 hour	183 GHz
Temperature	10 km		
	(sea)	3 hour	6-37 GHz
	(land)	3 hour	6-37 GHz
ET (4DDA)	5 km	3 hour	1.4-90 GHz

NASA ENERGY AND WATER CYCLE STUDY

AGU Spring Meeting

New Orleans, May 23-27, 2005

Special Session H19 on
"Remote Sensing of Large-Scale Evaporation"

followed by

Open panel discussion on
"Feasibility of Estimating Evaporation from Space-Based Platforms"