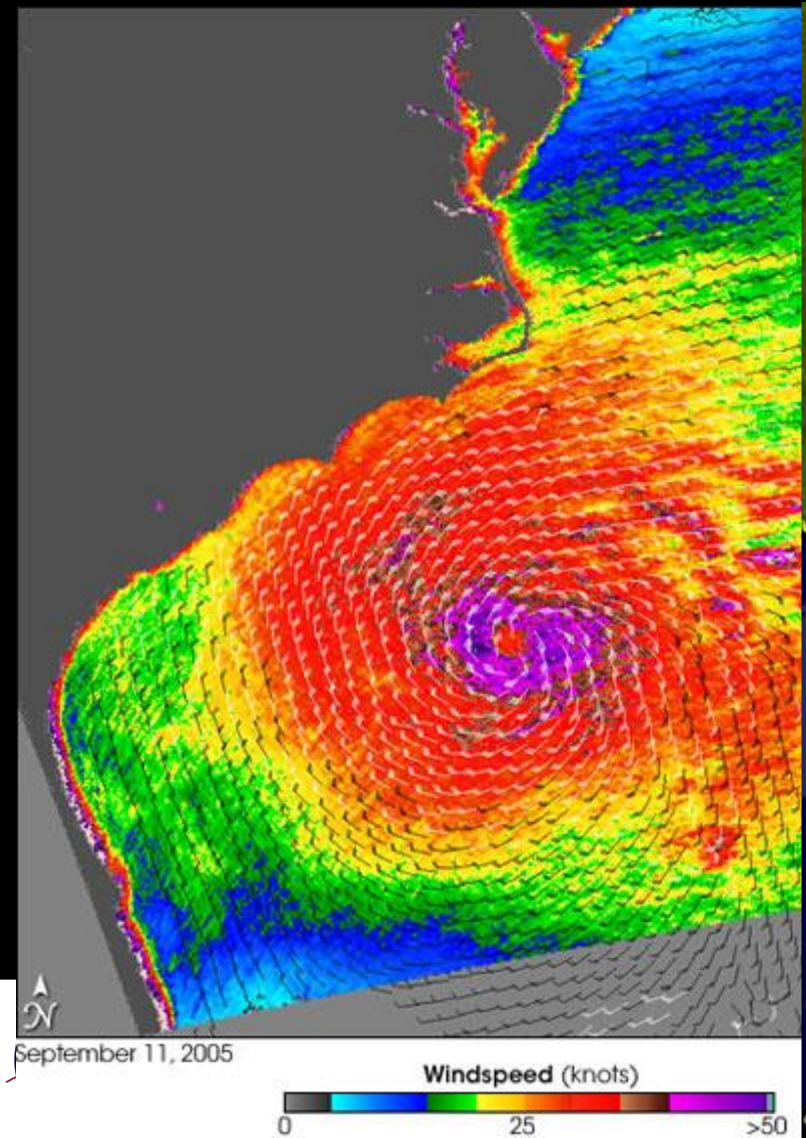
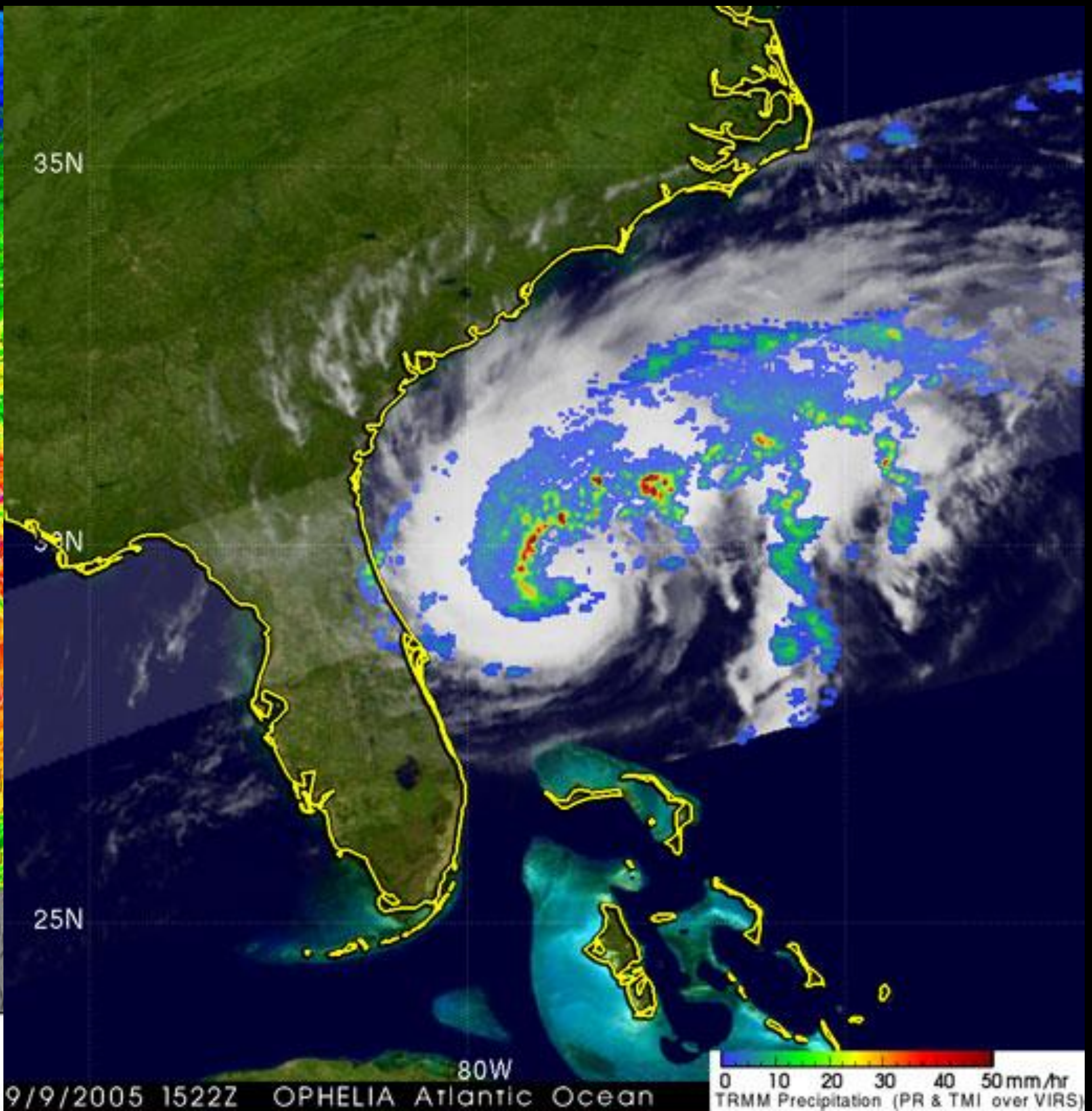
# Weather Monitoring & Forecasting



# Outline

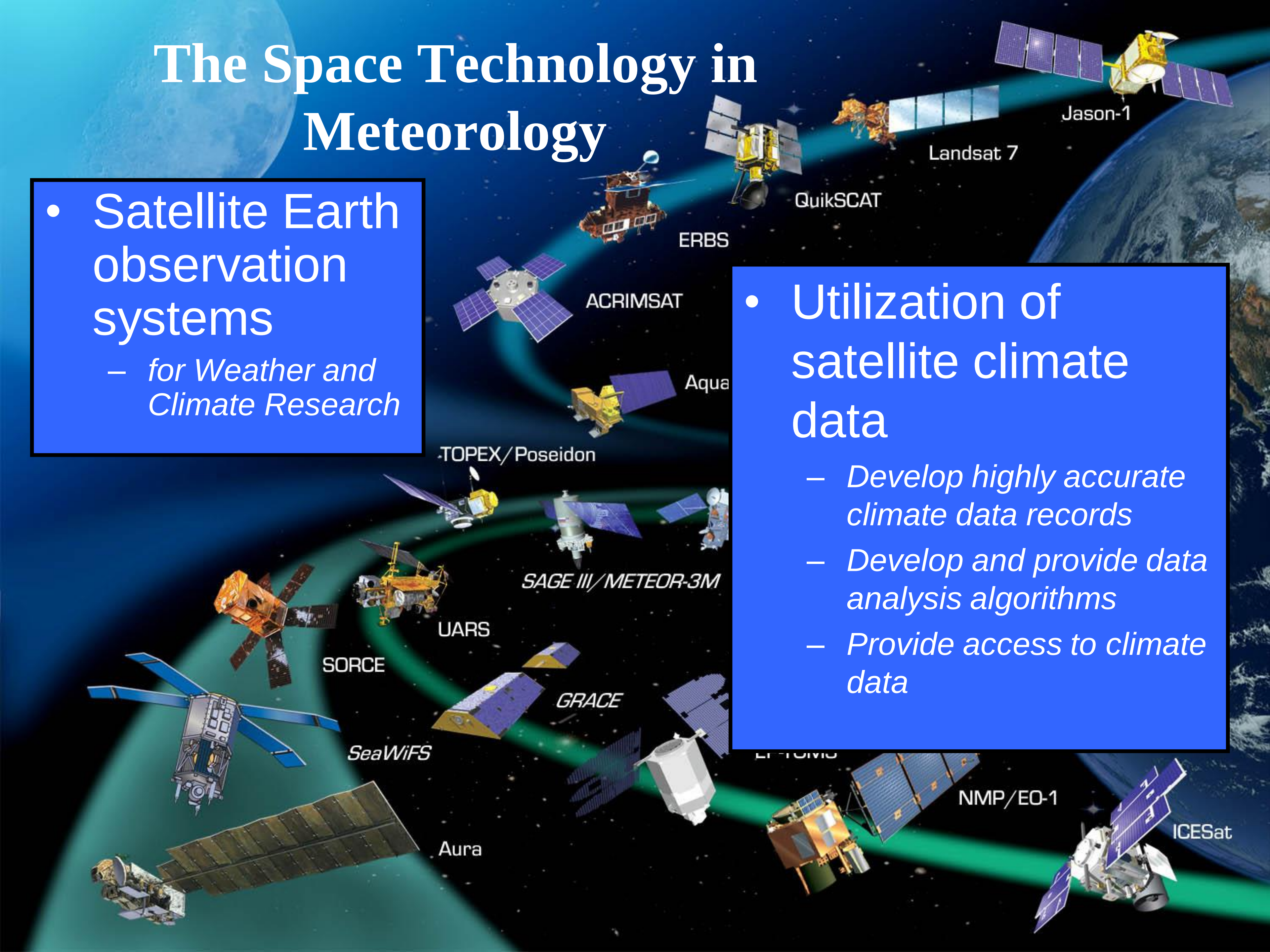
1. Introduction
   – Hydrology: Why NASA?
2. Floods
   – Precipitation
   – Water Levels
3. Droughts
   – Soil Moisture
   – Groundwater
4. Water Resources
   – Snow Pack
   – Forecasting and Assimilation
5. Summary

# Water for Life on Earth

# The Space Technology in Meteorology

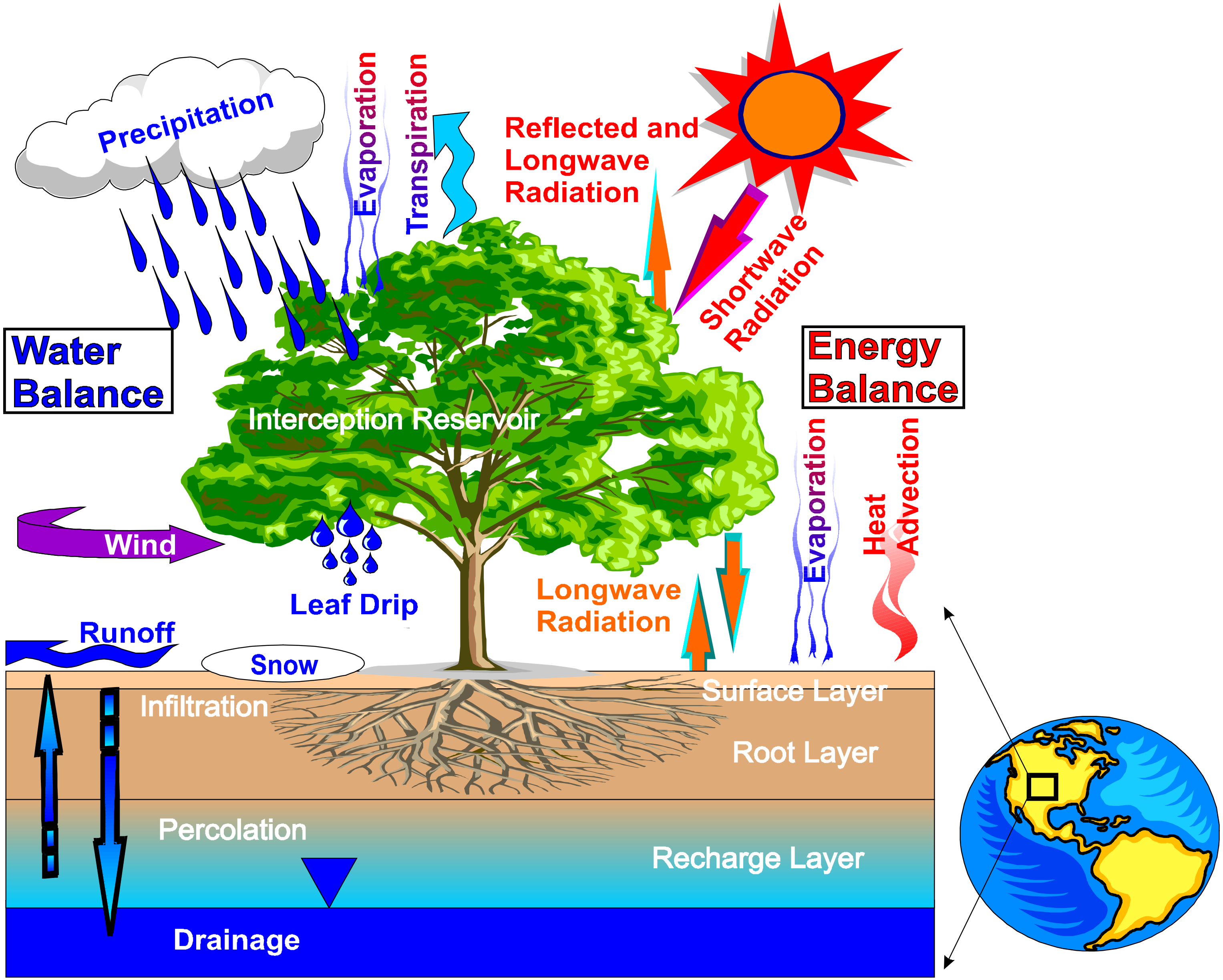
- Satellite Earth observation systems
  - *for Weather and Climate Research*

- Utilization of satellite climate data
  - *Develop highly accurate climate data records*
  - *Develop and provide data analysis algorithms*
  - *Provide access to climate data*

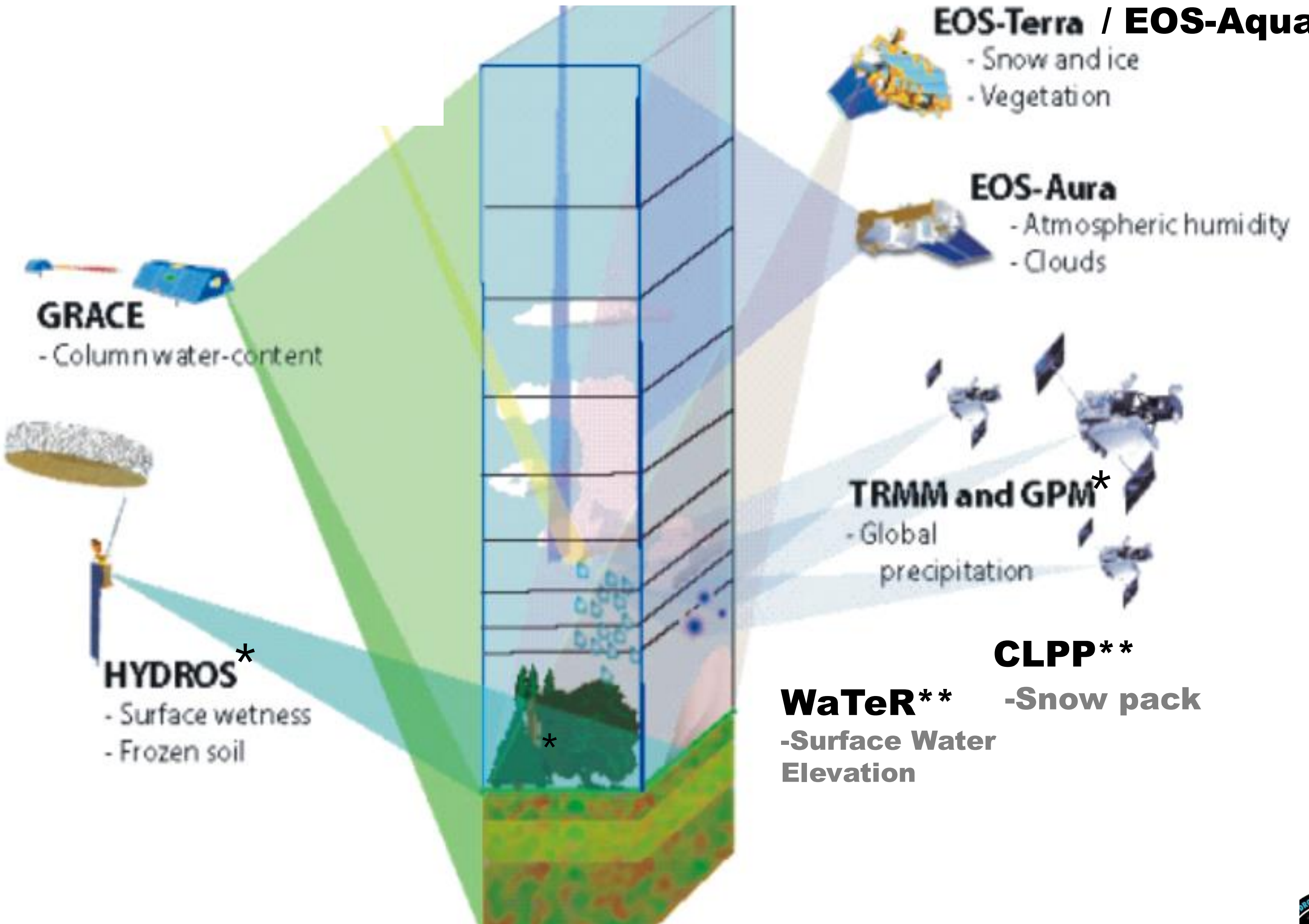


# Hydrology 101: The Hydrologic Cycle

# Hydrology 201: Water and Energy Balance



# NASA's Hydrologic Observations




* *Not yet launched* ** *Proposed*

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# 2. Floods

•In the United States, an average of 100 people lose their lives in floods annually, with flood damage averaging more than $2 billion.

•The Midwest's "Great Flood of 1993" cost 48 lives and more than $12 billion.

•Flash floods are the number one weather-related killer in the United States—

- •2,200 deaths in Johnstown, Pennsylvania, May 31, 1889
- •238 fatalities in Rapid City, South Dakota, June 9, 1972
- •140 killed in the Big Thompson Canyon nr Denver July 31, 1976
- •26 dead in Shadyside, Ohio, June 14, 1990

**Source: NOAA**

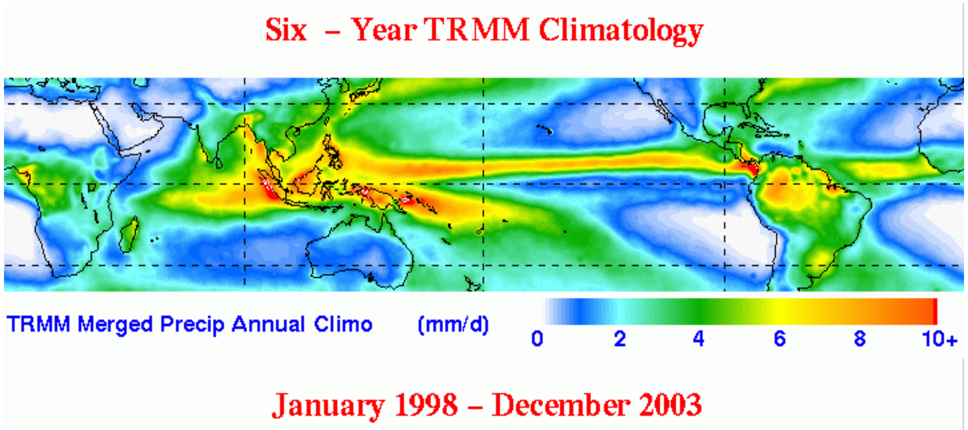
# Precipitation and Floods from Space


# NASA's Precipitation Missions

## TRMM: Tropical Rainfall Measurement Mission

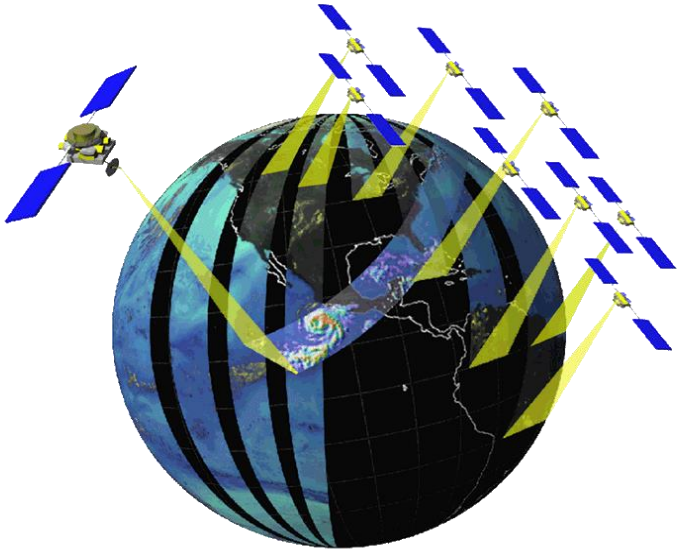
## GPM: Global Precipitation Measurement

**TRMM**



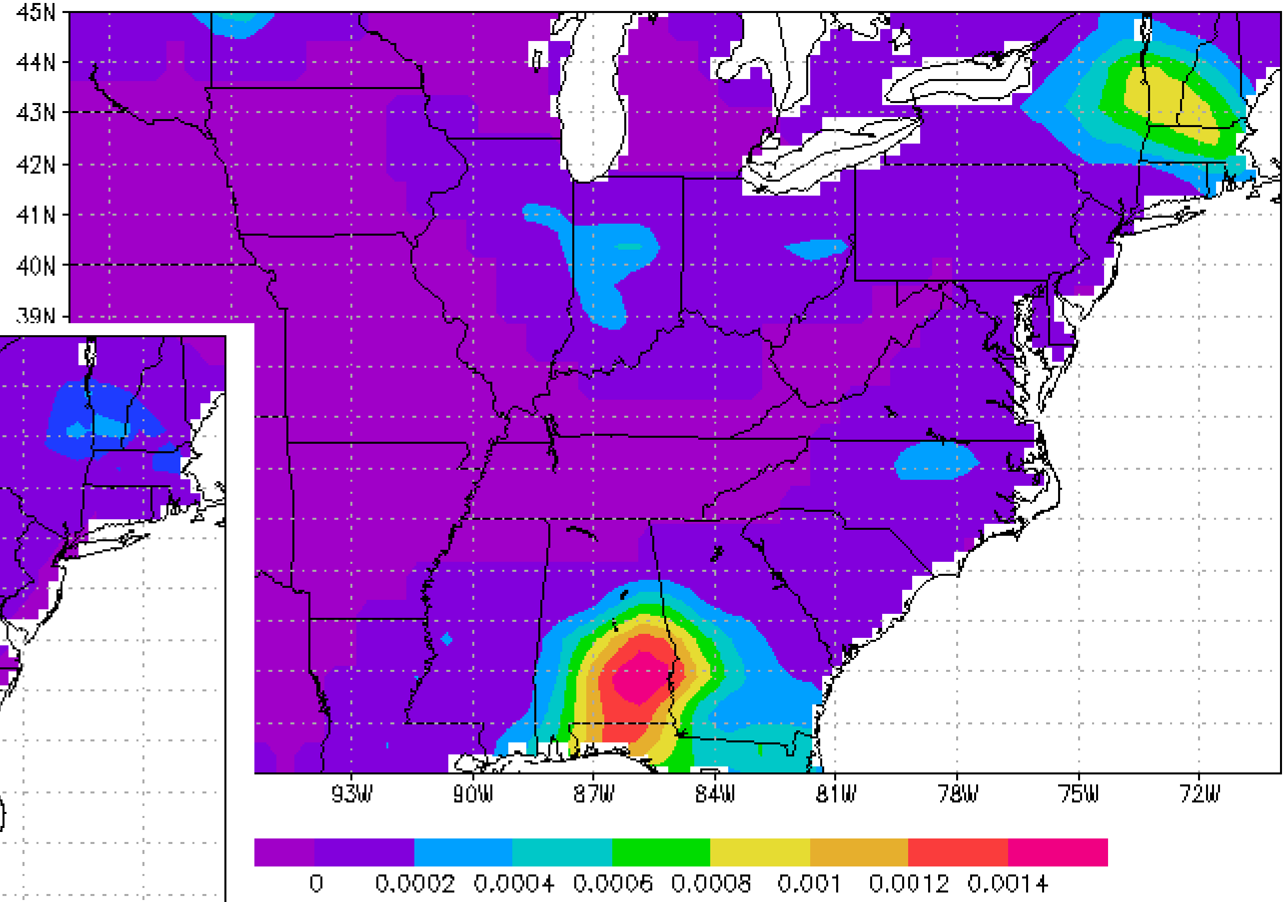

- Global precipitation measurement with TRMM: *a great leap forward!*
  - 10 ↔ 85 GHz radiometers
  - 13.6 GHz precipitation radar (FIRST!)

**GPM**

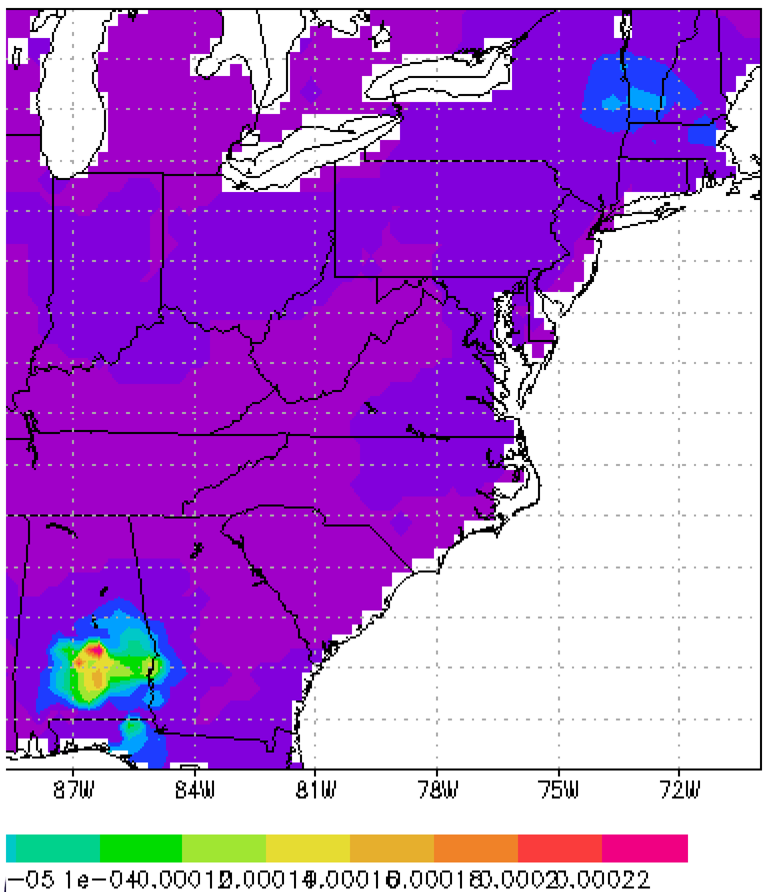


- Needed improvements:
- Longer record length
- High latitude precipitation including snowfall
- Better accuracy
- Spatial-temporal sampling
- Improved vertical resolution

# Flood Forecasting Example (1): Runoff



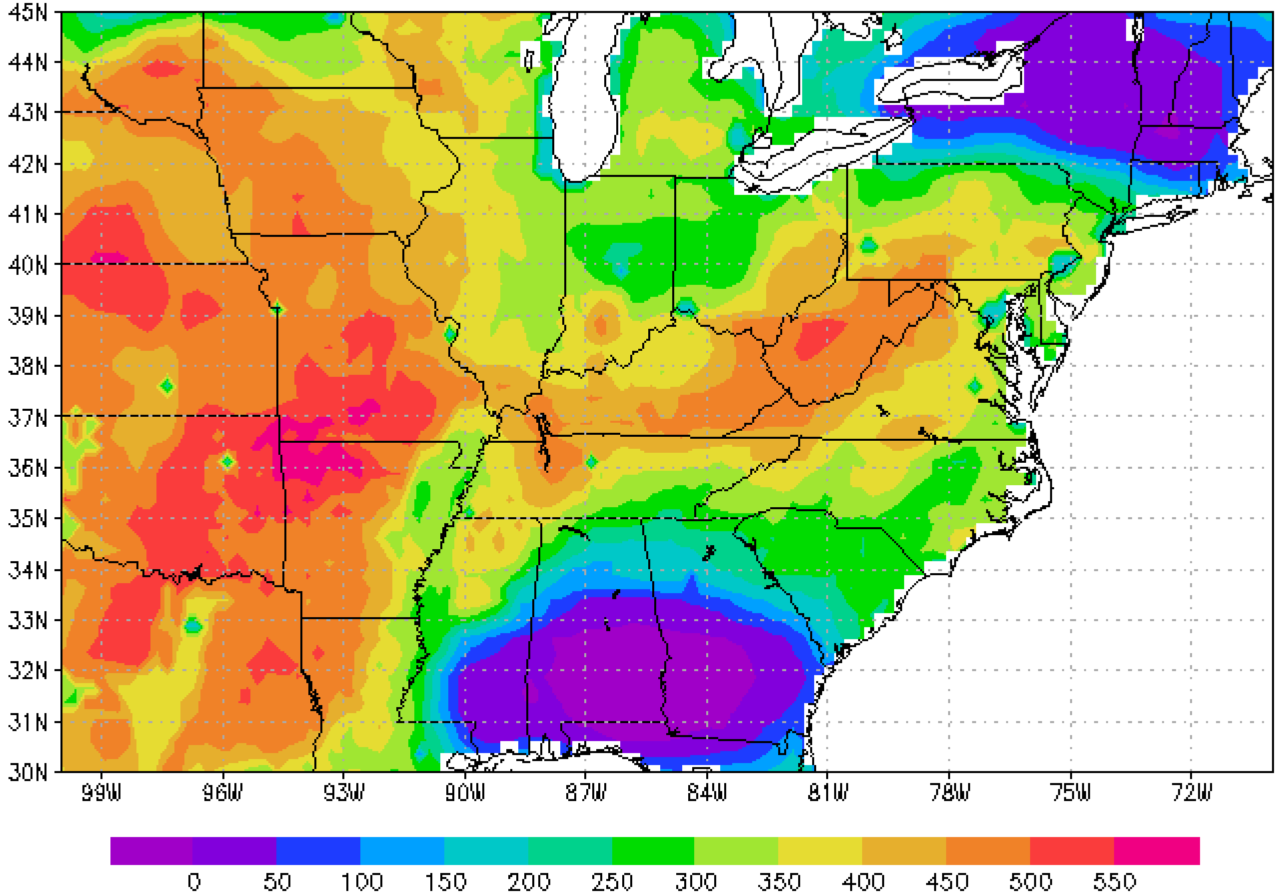

Rainfall→

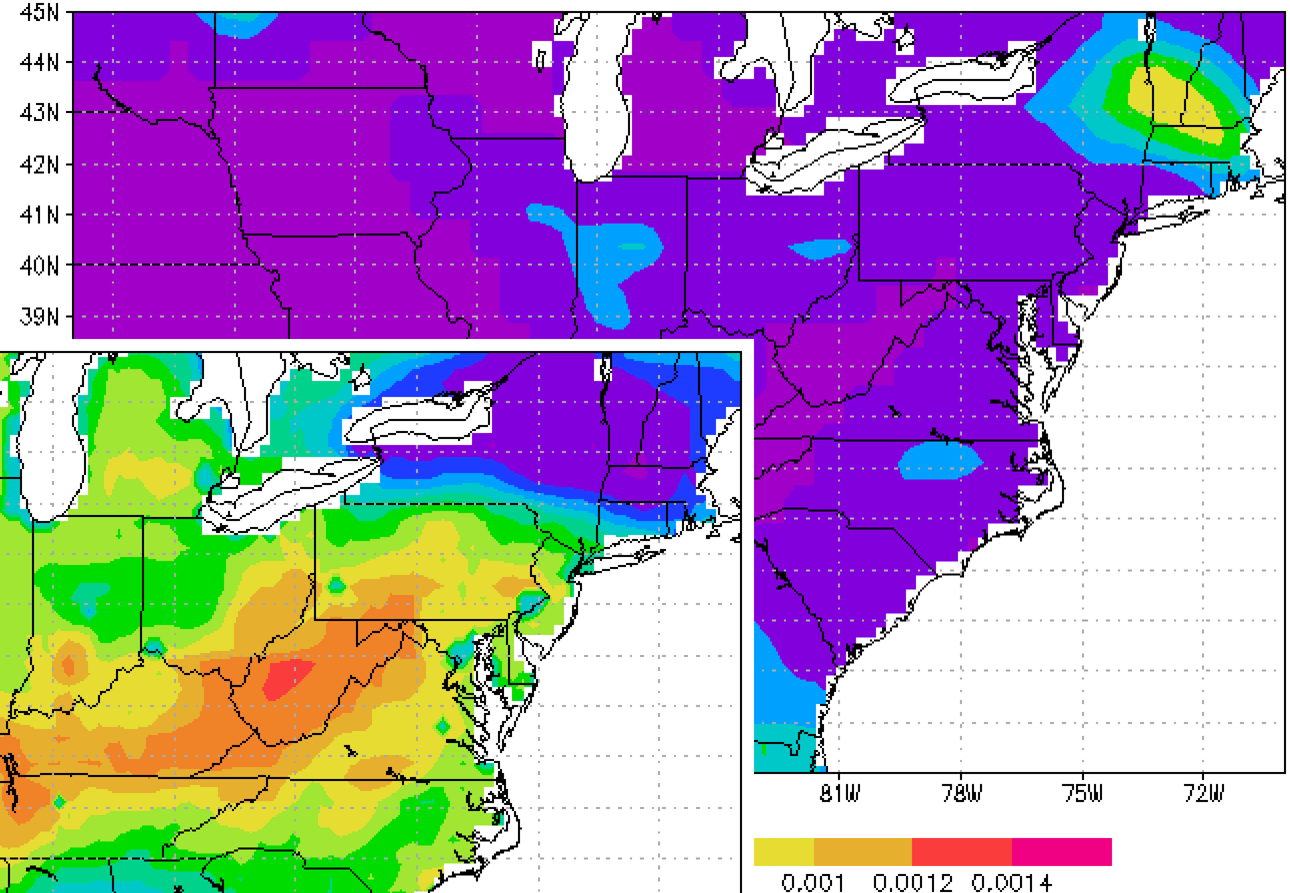



←Runoff

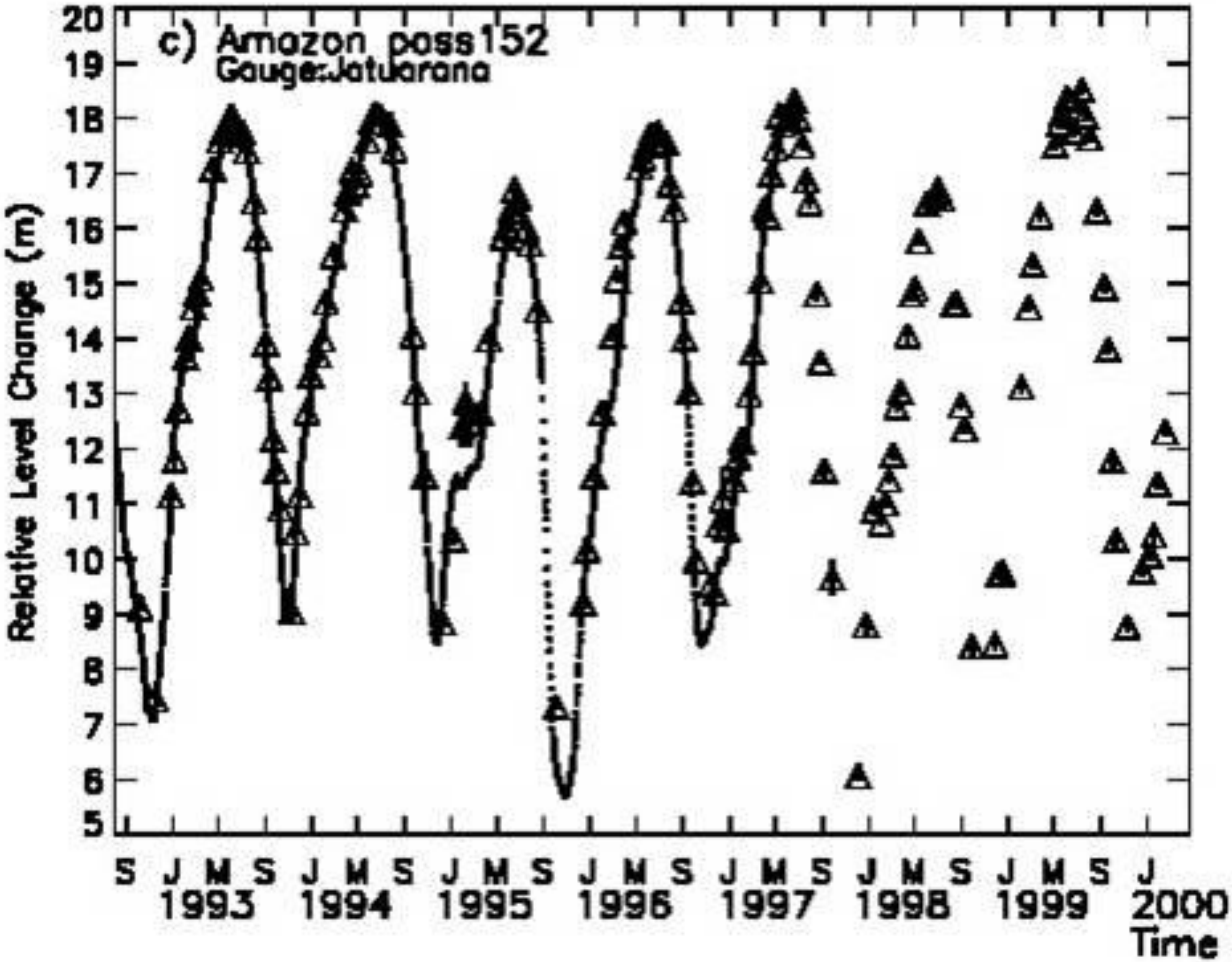
# Flood Forecasting Example (2): Evaporation

**Rainfall→**




**←Evaporation**



c) Amazon pass152
Gauge:Jatuarana
Relative Level Change (m)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
S J M S J M S J M S J M S J M S J M S J M S J
1993 1994 1995 1996 1997 1998 1999 2000
Time

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# 3. Droughts

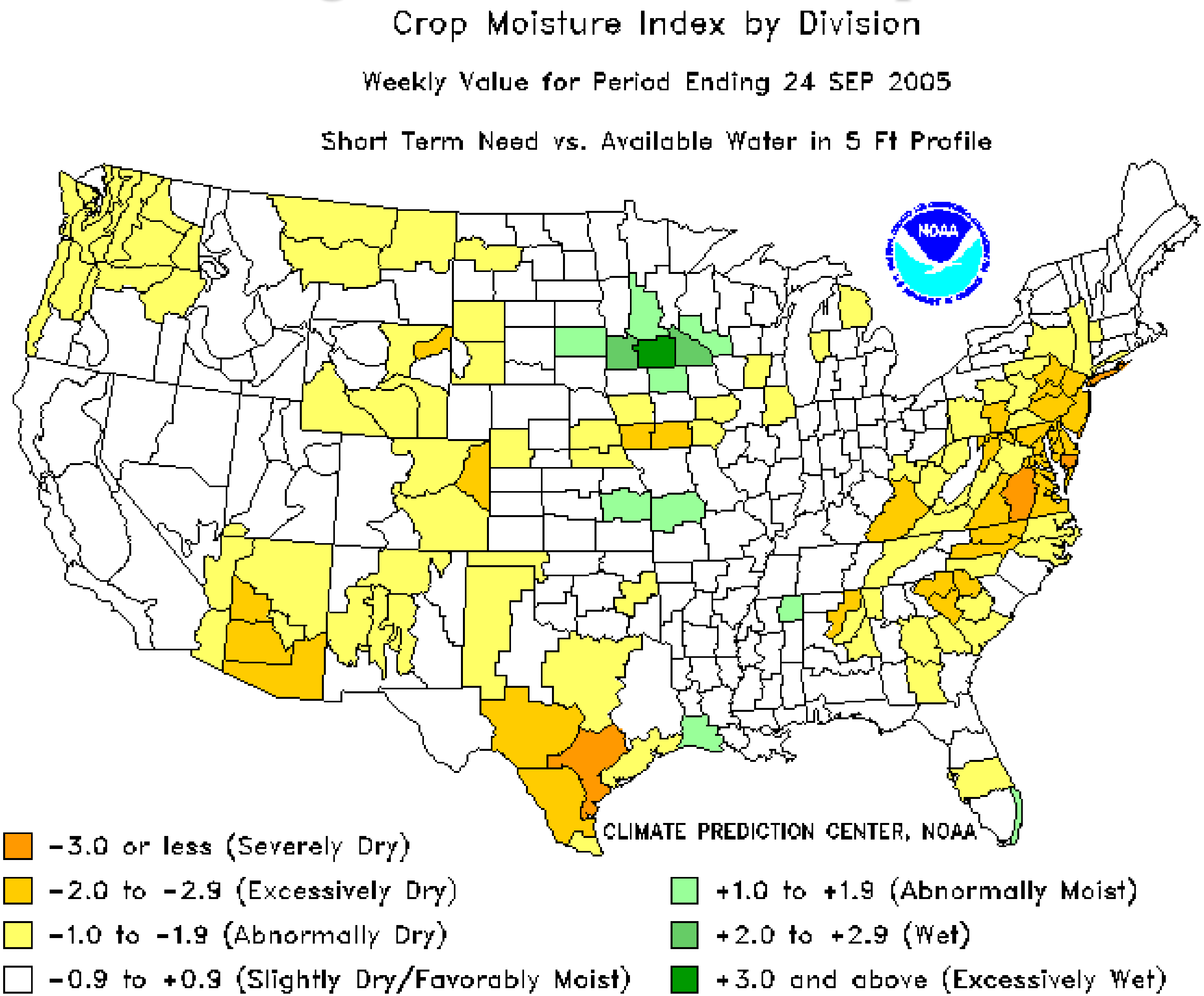
- Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event.
  - **Occurs in virtually all climatic zones**
  - **Characteristics vary significantly from one region to another.**
  - **Temporary aberration; it differs from aridity (permanent)**

- Drought originates from a deficiency of precipitation over an extended period of time, usually a season or more.
  - **Results in a water shortage for some activity, group, or environmental sector**.

- Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration (i.e., evaporation + transpiration) and runoff in a particular area

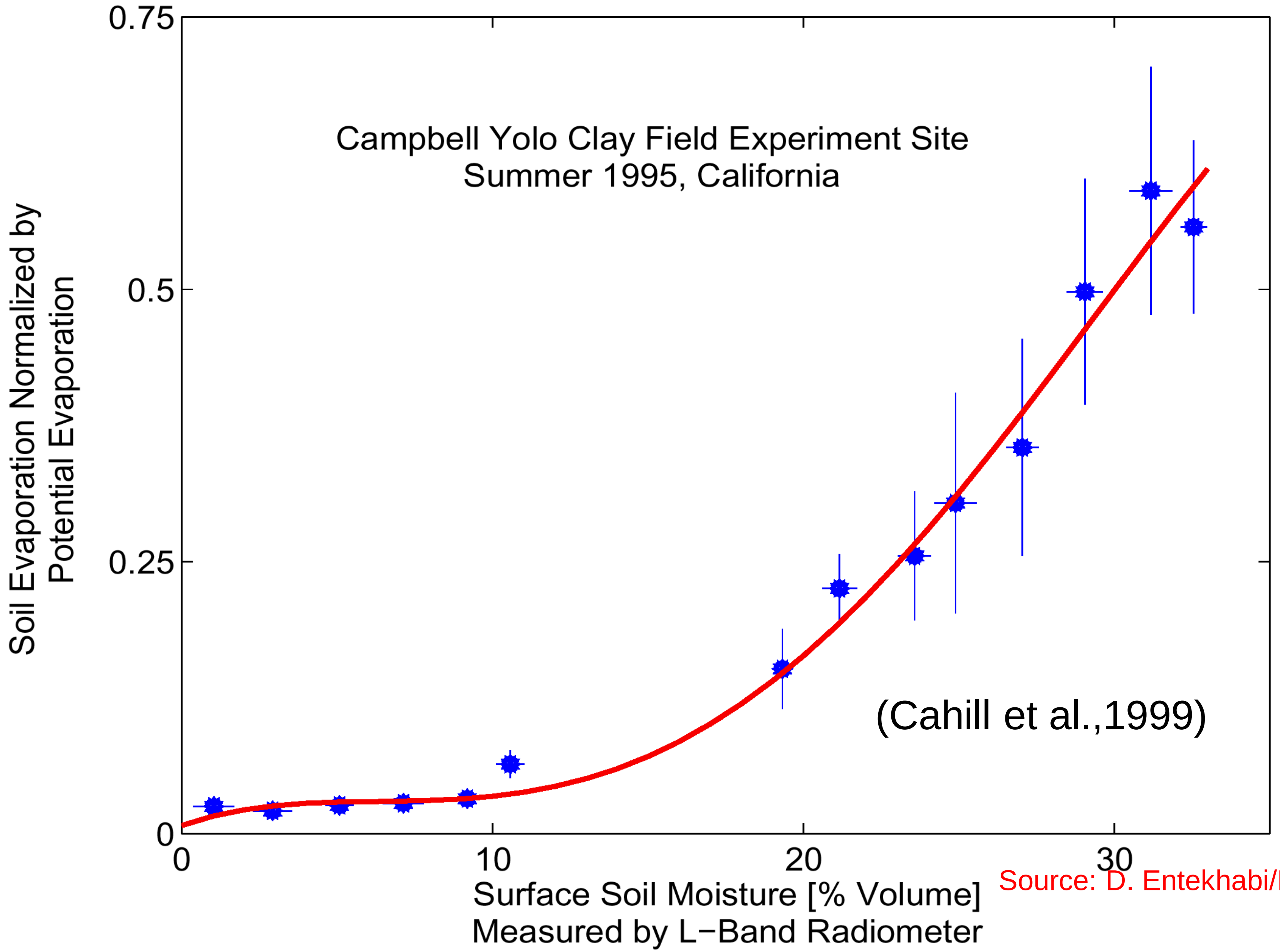
**Source: National Drought Mitigation Center (NDMC)**

# Drought Assessment and Impacts



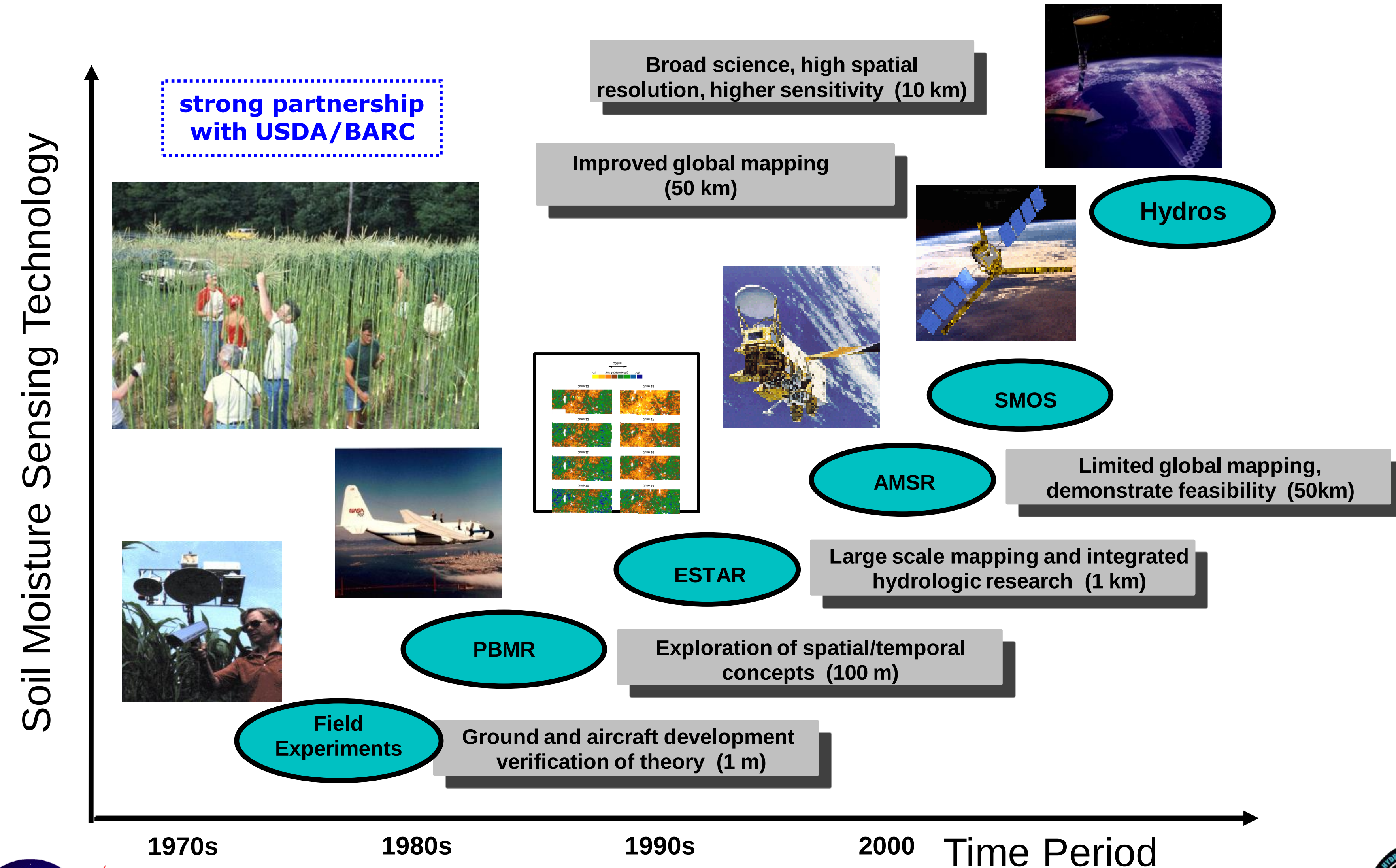

**Source: NDMC**

# Why is Soil Moisture Important for Droughts?




Source: D. Entekhabi/MIT

# GSFC's Soil Moisture Remote Sensing




Source: P. O'Neill/614.3 and T. Jackson/USDA/ARS

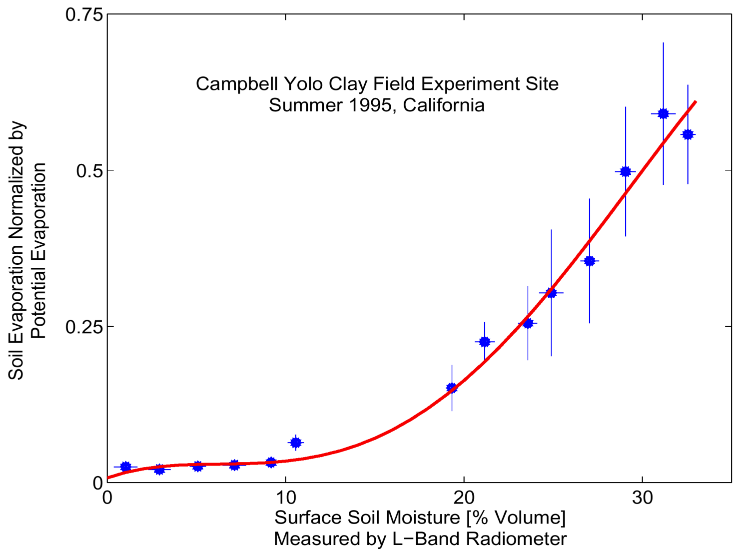
# HYDROS: HYDROSphere States Mission

HYDROS provides the first global view of the Earth's changing soil moisture and surface freeze/thaw conditions, enabling new scientific studies of global change and atmospheric predictability, and making new hydrologic applications possible.

## What: Soil Moisture and Freeze/Thaw

- 3km L-Band Radar
- 40km L-Band Radiometer
- 1000 km Swath
- 1-3 Day Revisit
- 670 km, Sun-Synchronous
- Two Year Baseline Mission
- 2010 Launch

## Why: Weather Forecasting and Applications



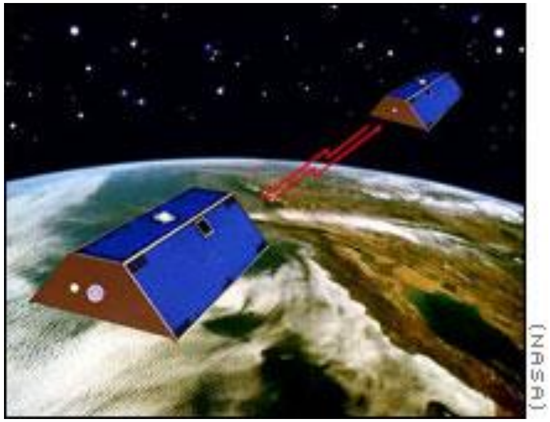


**PI:** Dara Entekhabi (MIT)
**GSFC Project Scientist:** Peggy O'Neill
**JPL Project Scientist:** Eni Njoku


MIT JPL NASA Goddard Space Flight Center SPECTRUMASTRO

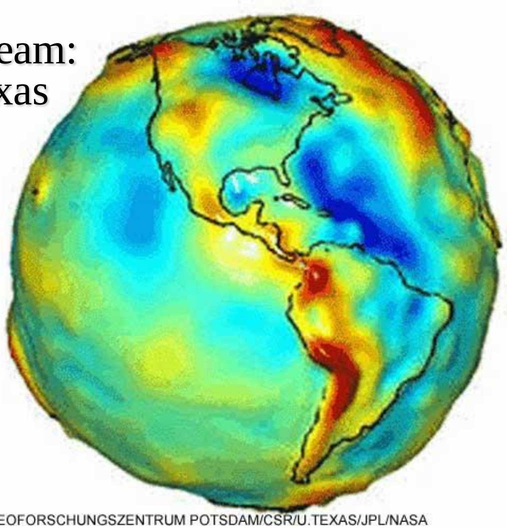
# NASA's Groundwater Measurement Mission

## GRACE: Gravity Recovery And Climate Experiment




GRACE senses water storage changes as variations in the Earth's gravity field

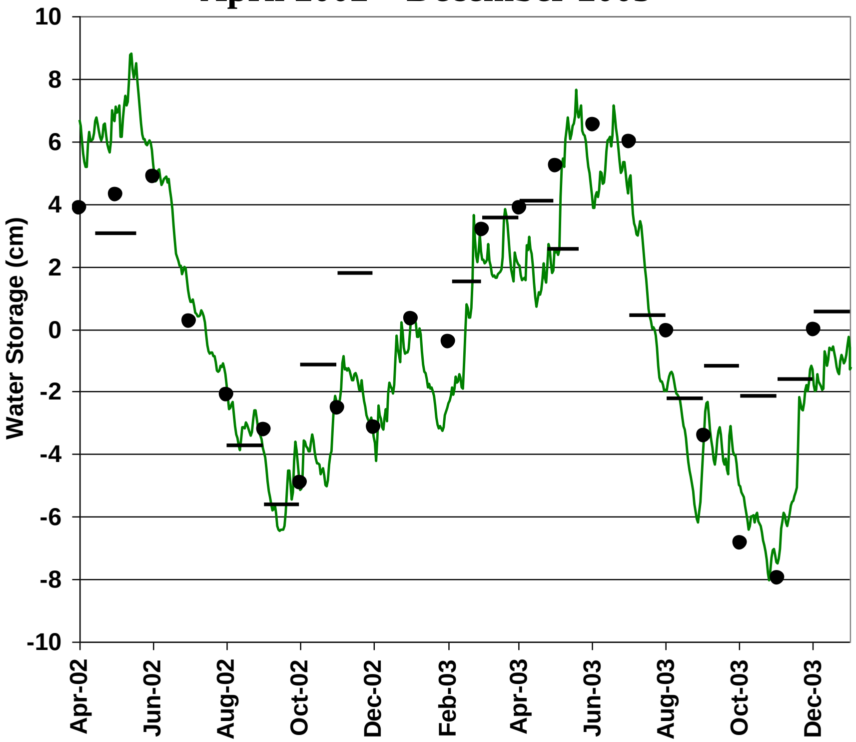
GRACE team:
- U. of Texas
- JPL
- GSFC



GEOFORSCHUNGSZENTRUM POTSDAM/CSR/U.TEXAS/JPL/NASA

**Terrestrial Water Storage Anomalies in the Mississippi River Basin,**

**April 2002 – December 2003**




**Bars** = GRACE terrestrial water storage
**Dots** = Atmospheric-terrestrial water balance
**Green line** = terrestrial water storage from GLDAS models and groundwater observations

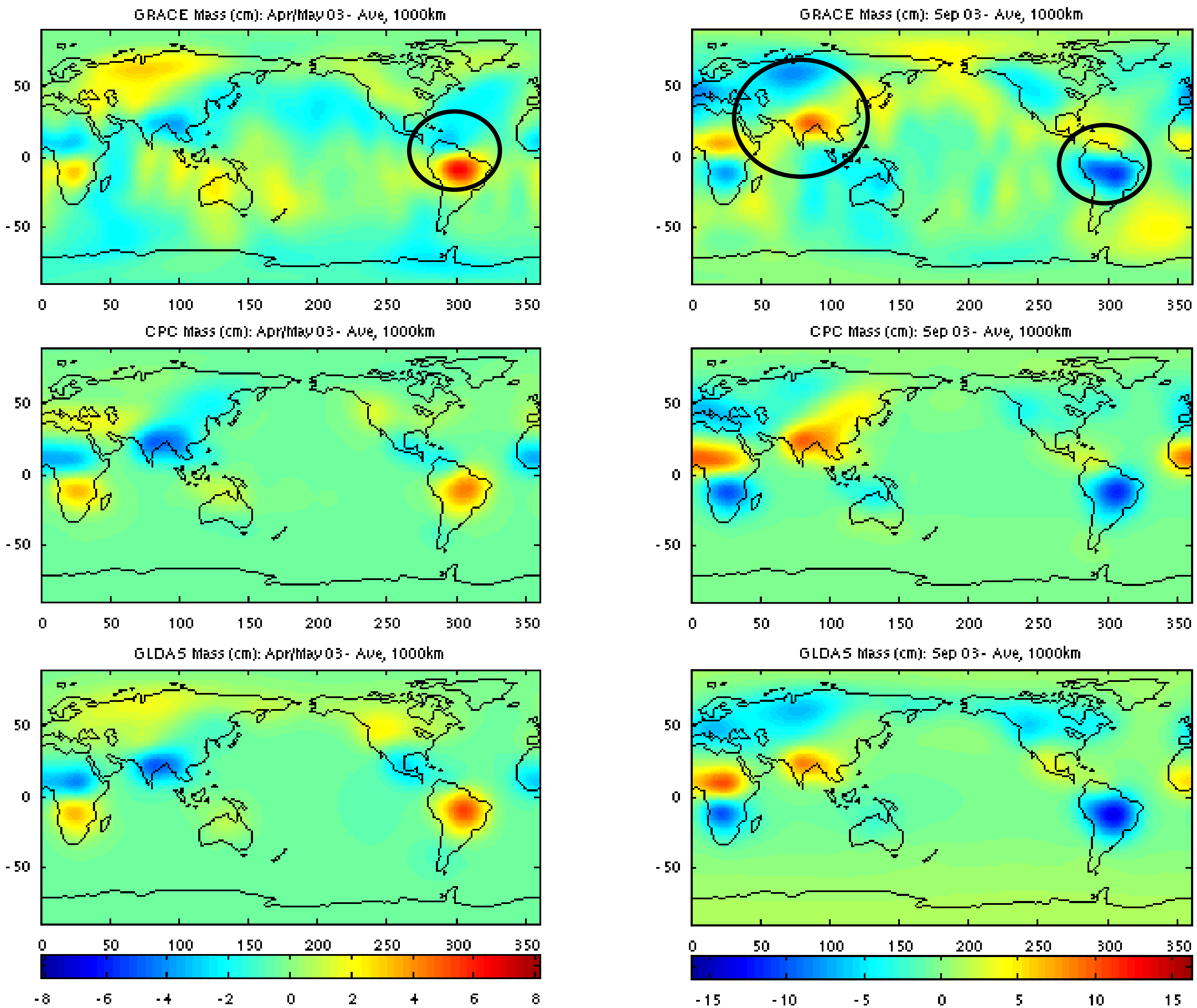
Source: M. Rodell/614.3

# GRACE Observed vs. Modeled Total Water Storage Anomalies (cm)

**GRACE Observed**

**NOAA CPC Modeled**

**GSFC GLDAS Modeled**




Rodell et al., 2004

**April/May 2003**

**September 2003**

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# 4. Water Resources

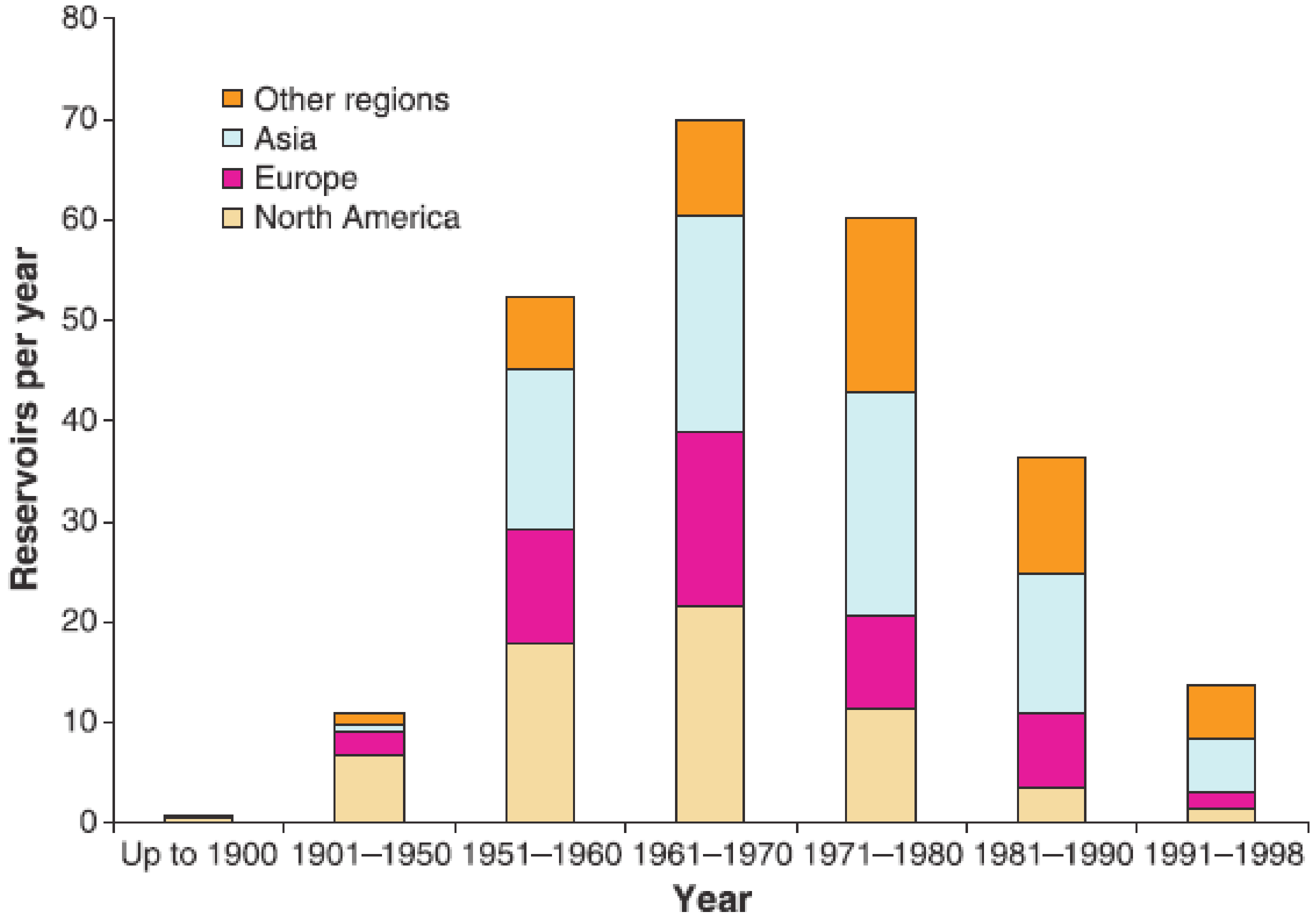
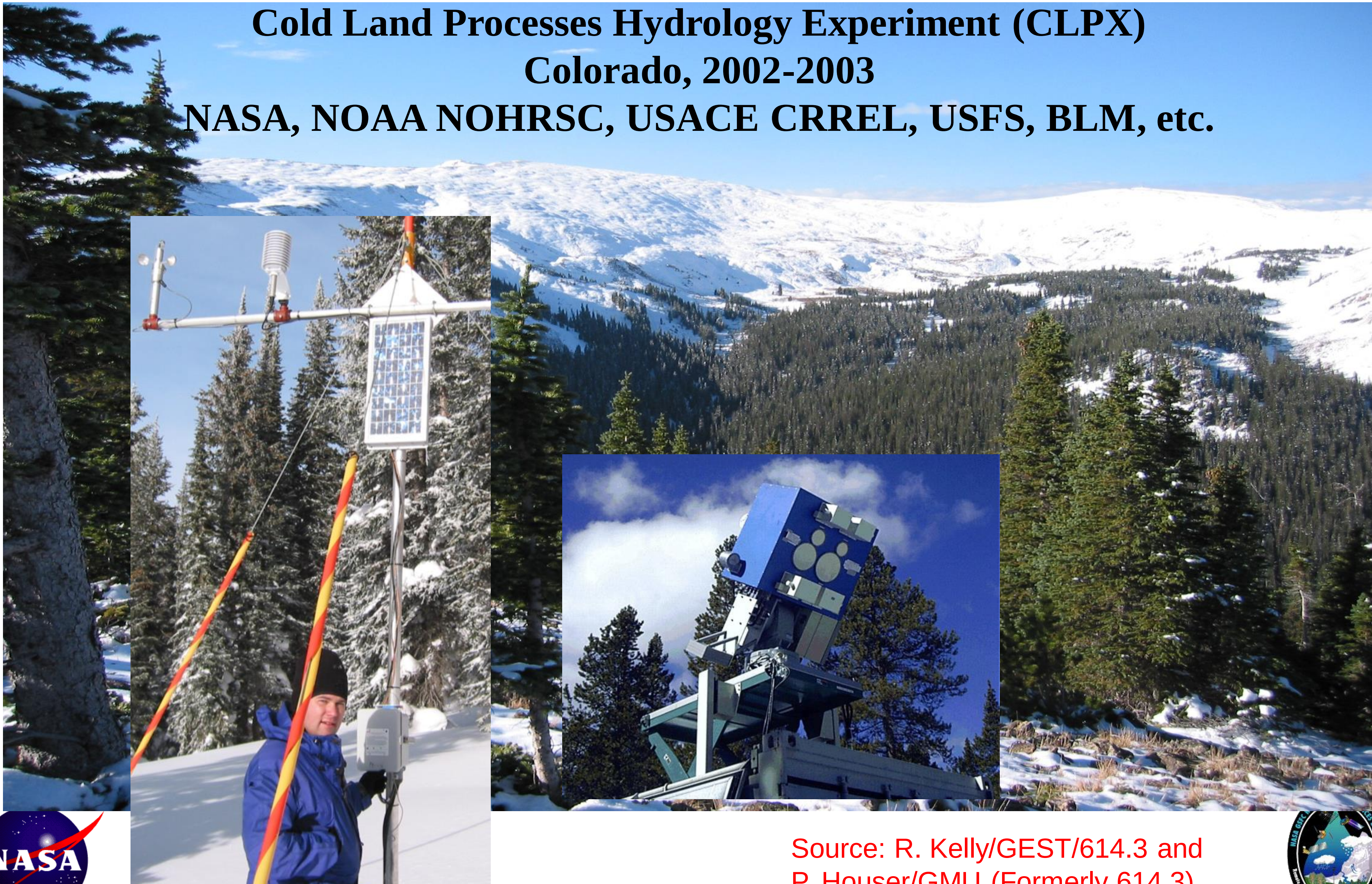



**Fig. 4.** Construction of large reservoirs worldwide in the 20th century. Average numbers of reservoirs with volume greater than 0.1 $km^3$ built by decade, through the late 1990s, are normalized to dams per year for different periods. Note that there was a peak in construction activities in the middle of the 20th century, tapering off toward the end of the century. The period 1991 to 1998 is not a complete decade; note also that the period 1901 to 1950 is half a century. "Other regions" include Latin America, Africa, and Oceania (*46*).

2003.

# How do we measure snow pack?

**Cold Land Processes Hydrology Experiment (CLPX)**
**Colorado, 2002-2003**
**NASA, NOAA NOHRSC, USACE CRREL, USFS, BLM, etc.**



Source: R. Kelly/GEST/614.3 and
P. Houser/GMU (Formerly 614.3)

# Cold Land Processes Pathfinder

CLPP

## CLPP Science Objectives

**Primary: To improve our ability to quantify snow water storage at multiple space/time scales:**

- **100 m land cover scale**
- **5 km watershed scale**
- **sub-weekly**

**Secondary: Quantify changes in snow on ice sheets & sea ice--especially in melt zones.**

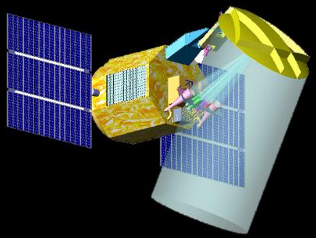
**Fundamental quantities:**
- **Snow water equivalent**
- **Snow wetness**

## CLPP Mission Concept

**Dual Ku-band SAR (VV, VH)**
- **100 m Resolution (50/100 looks)**
- **Incidence Angle ~$20^{o}$**

**K/Ka-band Radiometer (V,H)**
- **7/4 km resolution**

**Antenna**
- **1.95 m Pushbroom Reflector**
- **26 Feedhorns**



**Narrow 40-km Swath**

**Sun-synchronous orbit**
**-613-km, 5-6 pm ascending**

R.Kelly & E. Kim

# Projected Global Water Withdrawls
# Gleick et al., Science, 2003.

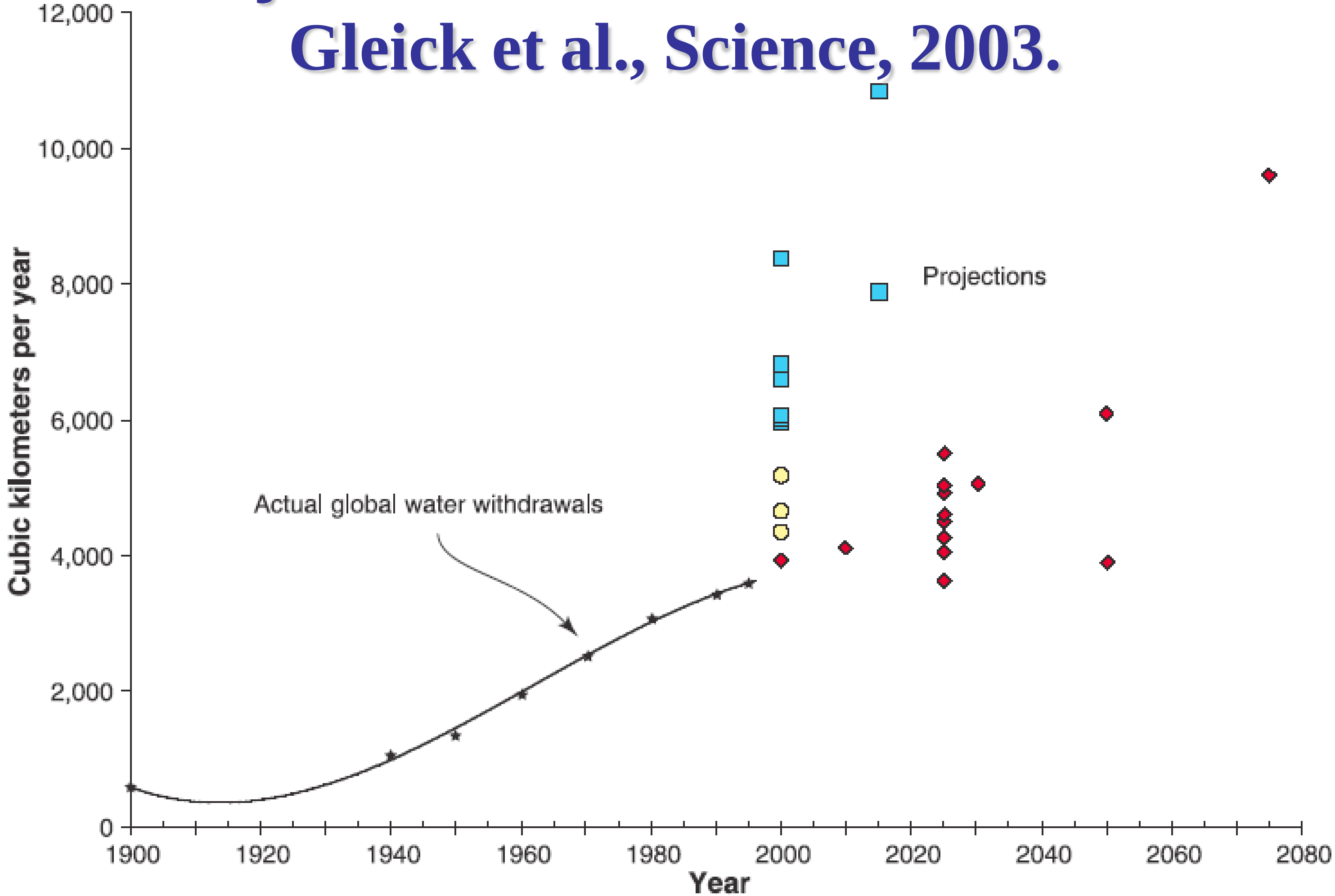
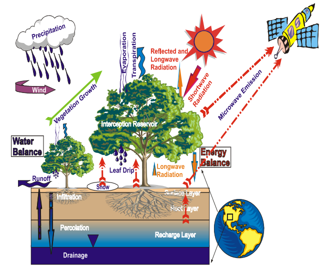


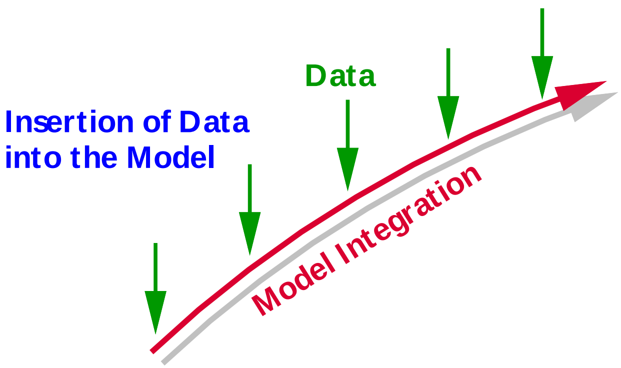

**Fig. 3.** Projections of water use and actual global water withdrawals, as compiled from various projections of global water withdrawals made since the 1960s (*44*), together with an estimate of actual global water withdrawals, as estimated in (*45*). Note that projections made before 1980 forecast very substantial increases in water use; more recent forecasts have begun to incorporate possible improvements in water productivity to reflect recent historical experience. Symbols: squares, projections made before 1980 (includes forecasts for 2000 or 2015); circles, projections made between 1980 and 1995 (includes forecasts for 2000); diamonds, projections made after 1995 (includes forecasts for 2000, 2010, 2025, 2030, 2050, and 2075).

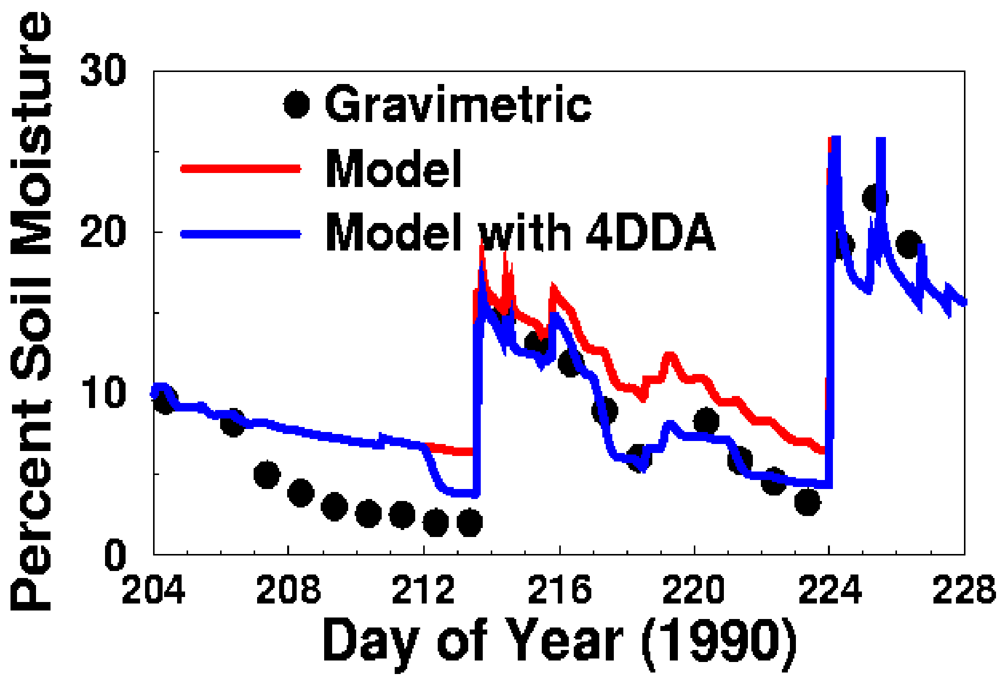
# Data Assimilation

**Data Assimilation merges observations & model predictions to provide a superior state estimate**

+



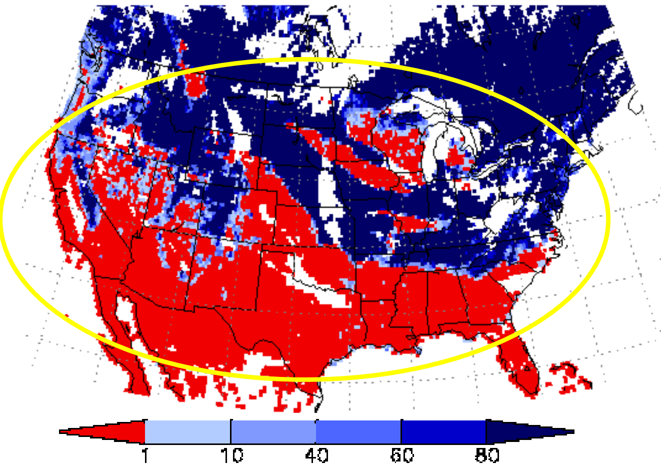




Source: P. Houser/GMU (Formerly 614.3)

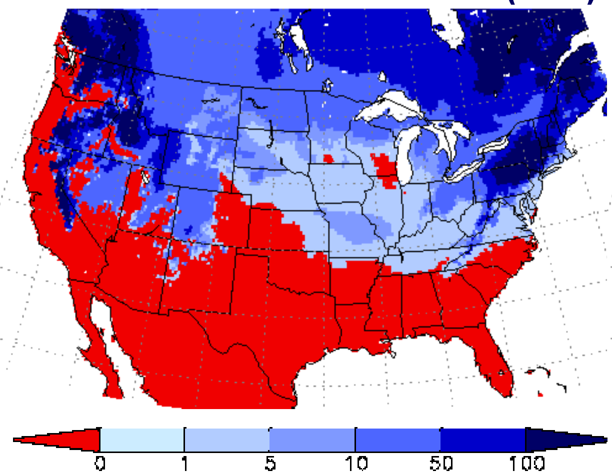
# Data Assimilation Example:
# Global LDAS Snow Updates Using MODIS Data

**21Z 17 January 2003**

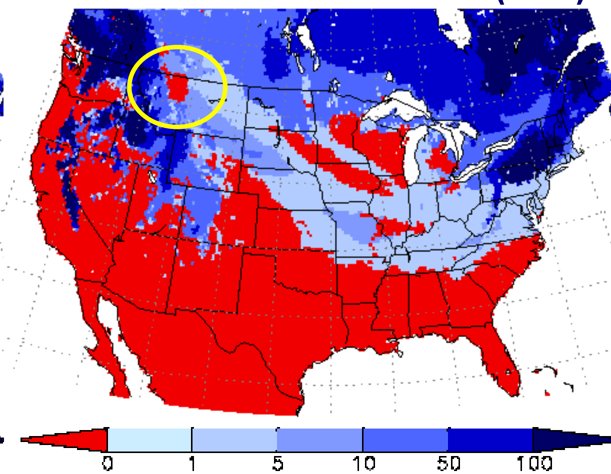
**Enhanced MODIS Snow Cover (%)**



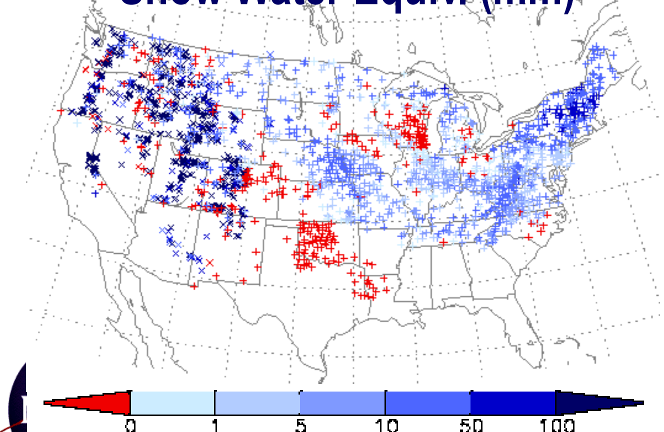

**Control Run Mosaic SWE (mm)**

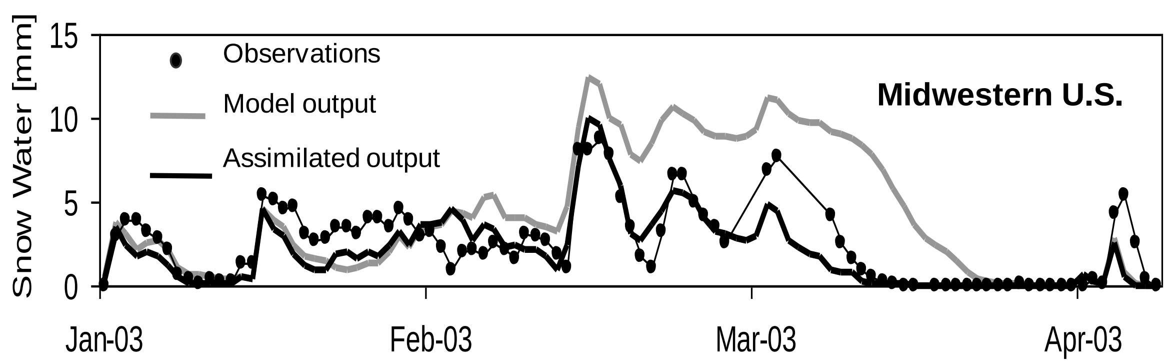



**Assimilated Mosaic SWE (mm)**




**SNOTEL and Co-op Network Snow Water Equiv. (mm)**




**Source: Rodell and Houser, 2004**

# 5. Summary

1. Why does NASA study hydrology?
   – To understand and protect our home planet
2. Flood Applications
   – TRMM/GPM: Rainfall
   – WatER: River/Wetland Levels
3. Drought Applications
   – Hydros: Soil Moisture
   – GRACE: Groundwater
4. Water Resources
   – CLPP: Snow Pack
   – Forecasting and Assimilation

# Thank you!

For more information

please visit

http://neptune.gsfc.nasa.gov/

# References and Acronyms:

- Tropical Rainfall Measurement Mission (TRMM):
  - http://trmm.gsfc.nasa.gov
- Global Precipitation Measurement Mission (GPM):
  - http://gpm.gsfc.nasa.gov
- Hydrosphere States Mission (Hydros):
  - http://hydros.gsfc.nasa.gov
- Gravity Recovery and Climate Experiment (GRACE):
  - http://www.ess.uci.edu/~famiglietti/grace

- Cold Land Processes Pathfinder (CLPP):
- Water Elevation Recovery (WatER):
  - http://www.geology.ohio-state.edu/water

- Land Data Assimilation Systems (LDAS):
  - http://ldas.gsfc.nasa.gov
- Land Information System (LIS) http://lis.gsfc.nasa.gov

- Goddard Water Cycle: http://watercycle.gsfc.nasa.gov