("Critical Downstream Issues")

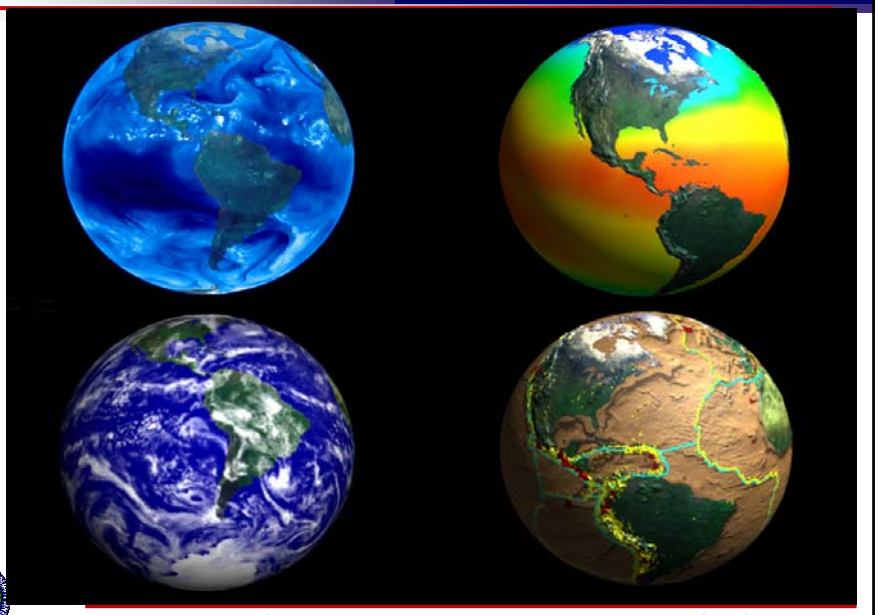
Climate Change & The Global Water Cycle: The Latest News From Earth & Space

Soroosh Sorooshian

Center for Hydrometeorology and Remote Sensing
University of California Irvine

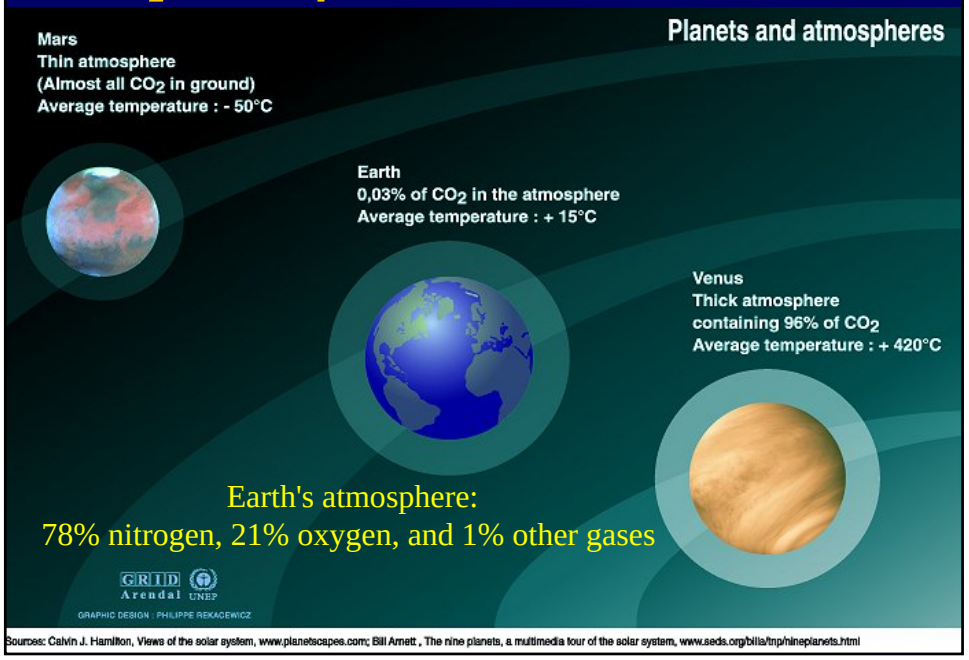
AIHA **-Yuma Pacific Southwest Section 2008 Annual Meeting**
The Crown Plaza, Irvine, California
January 24th, 2008

A Unique Planet: Blue, Green and alive!



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Atmosphere of Earth vs. Mars and Venus



Distribution of Freshwater

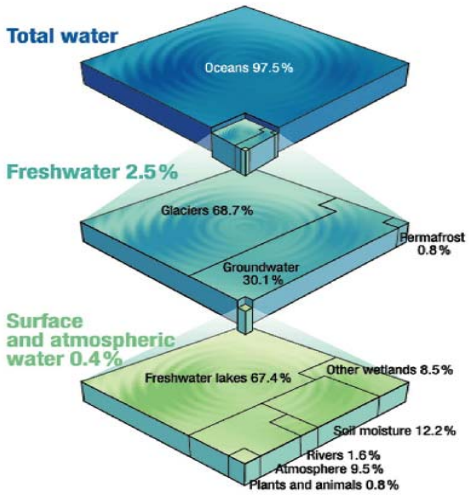


Figure 4.1:
Global distribution of the world's water

Source: Data from Shiklomanov and Rodda, 2003. Freshwater has a global volume of 35.2 million cubic kilometres (km^3).

World Water Assessment Programme

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

The Big Question as to

Whether Our Planet Is Warming Up and The Hydrologic Cycle is Intensifying, has been addressed by The Recent IPCC Report

Evidence for reality of climate change: Glaciers Melting

1909

2000

Toboggan Glacier Alaska

Muir Glacier, Alaska

A. Circa 1900
Photo Source: Munich Society for Environmental Research

B. Recent

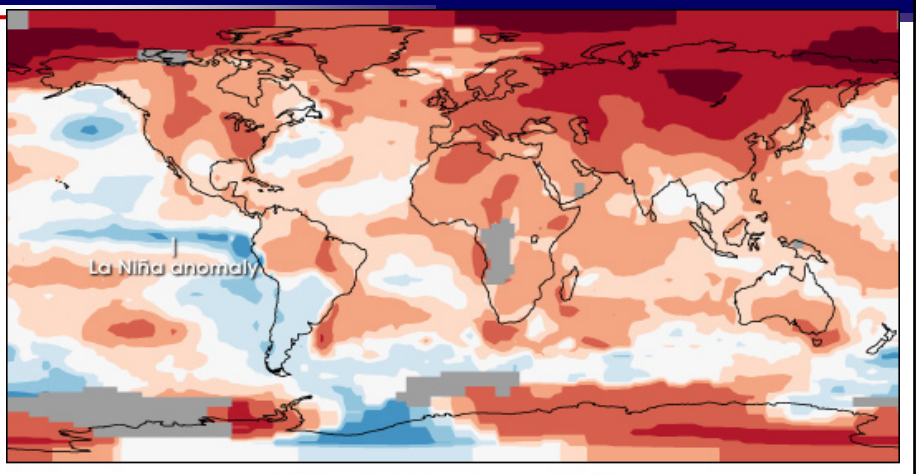
1900 2003

Alpine glacier, Austria

Provided By: Kevin Trenberth

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Global Temperature Anomalies: 2007

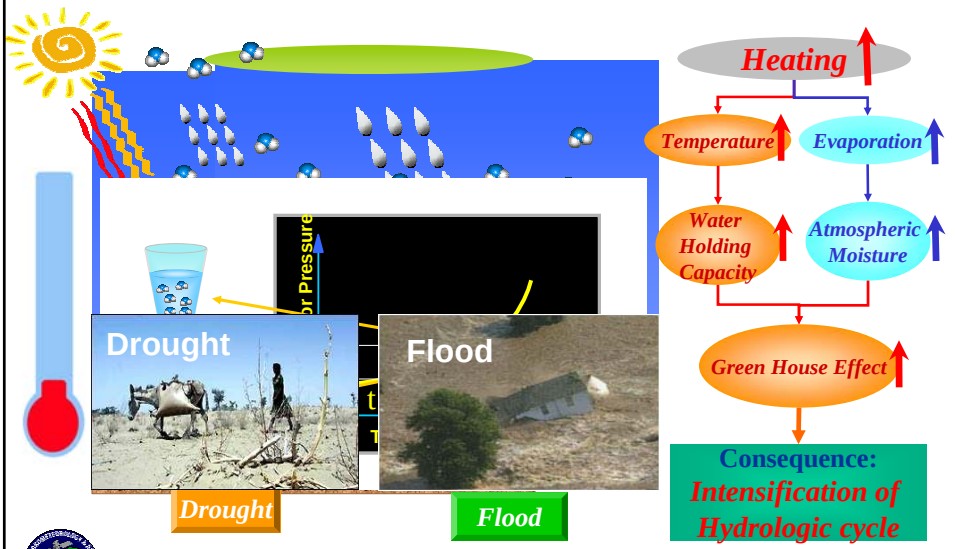


Tied (with 1998) for the second warmest year (2005 Warmest)

Source: NASA GISS 2007

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Global Warming And Hydrologic Cycle Connection



Source: Gi-Hyeon Park

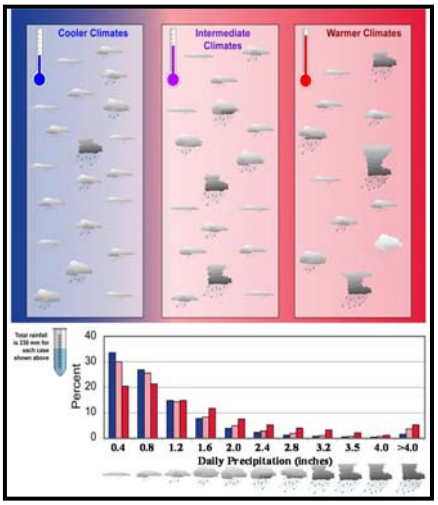
Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Observed changes: Heavy Precipitation

Facts from Observations

- From 1908-2002:
  - Total annual precipitation across the contiguous U.S. increased 7%
  - Heavy daily Precipitation events have increased by 20%

- Rainfall associated with warmer climates are more due to extreme events compared to colder climates



10
0
Confidence Index

Source: Tom Karl NCDC-NOAA 2007

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Record Floods: Among the worst Natural Disasters

Flooding in Tana River Valley, Kenya, due to extended and unseasonal rain

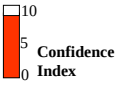
Los Angeles (1955)

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Observed changes: Drought Reconstruction

Drought as documented in the paleoclimatic record?

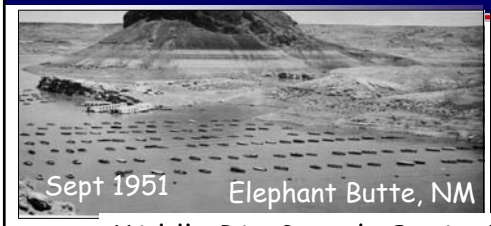
- Within the past millennium there have been severe droughts in both the western U.S. and Midwest that have lasted for multiple decades (50 years).

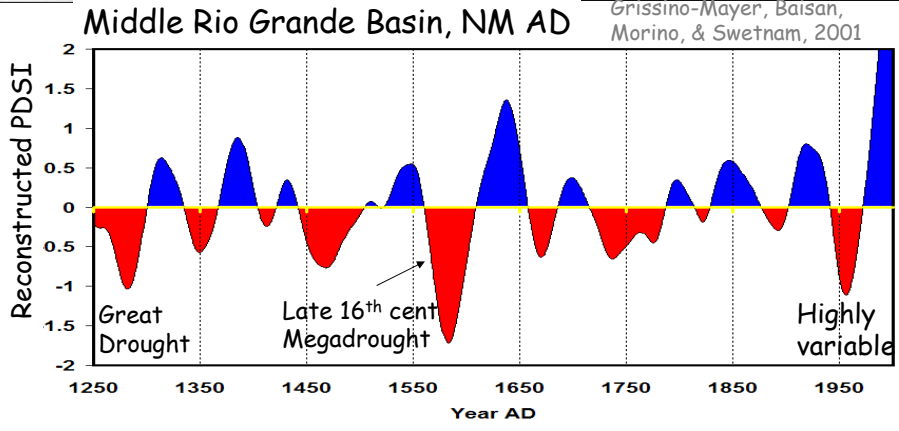


Source: Tom Karl NCDC-NOAA 2007

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Recent US Southwest Drought in Historical Context





SAHRA

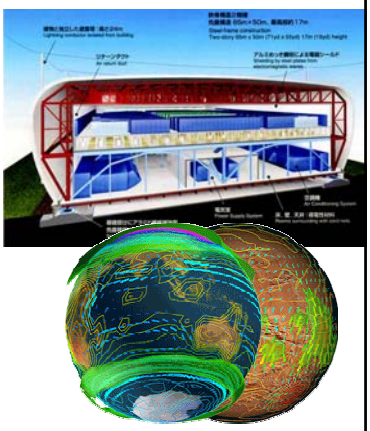
Challenge of predicting the future Climate:

While we Attempt to Improve Our Scientific Understanding of the Climate System, We Face Major Issues With Uncertainties in Information We Can Provide to "Users"

CHRS

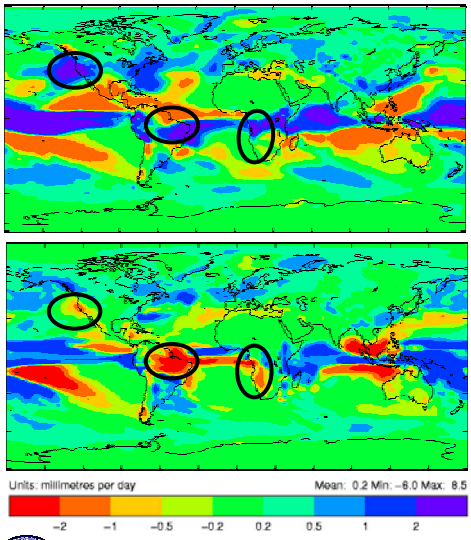
Climate Predictions into the Future!

Some Results at the Seasonal to Inter-annual and Longer time Scales:



CHRS

Climate model Predictions about the future? →globally



DJF Precipitation Changes
CM2 - Old model

CM3 - Updated model

Significant differences in regional outcomes!

Source: Hadley Center (Climate Change Projections)

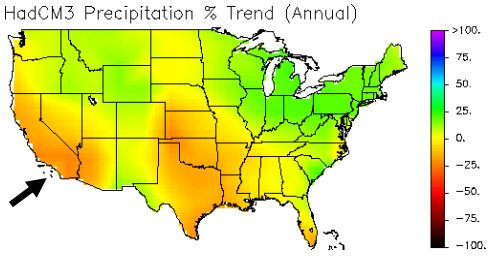
What do climate models tell us about the future?

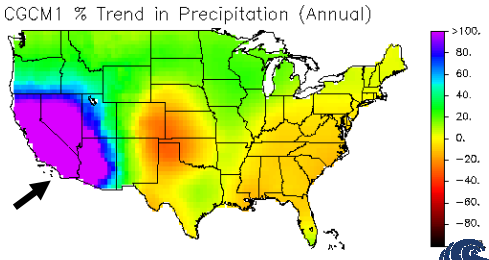
Model annual precipitation trends over 21st century

Hadley Center: Southwest dries out

What to tell water managers?

Canadian Center: Southwest extremely wet





Source: US National Assessment Report, 2000

SAHRA

Recent Extreme Conditions in the U.S. Southwest

Normal Years

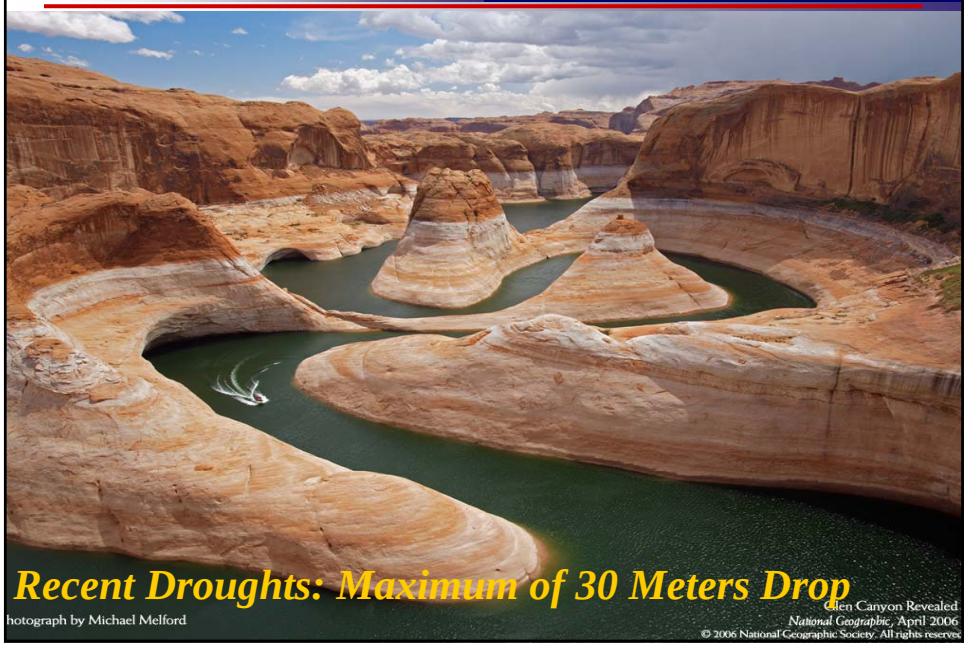
Sever Multi-year Drought through 2004

Lake Powell, Colorado River, USA

Source: J. Kane SRP 2004

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

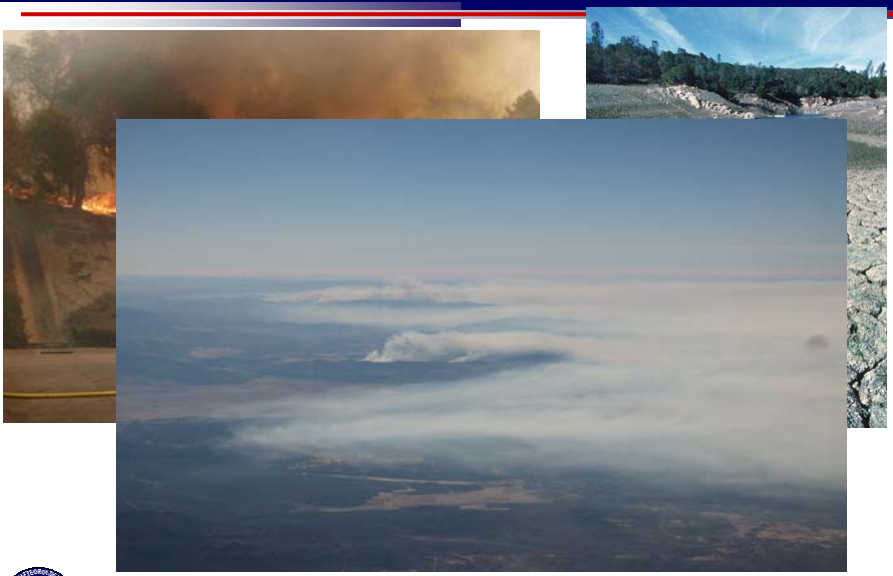
Lake Powell – Glenn Canyon Dam



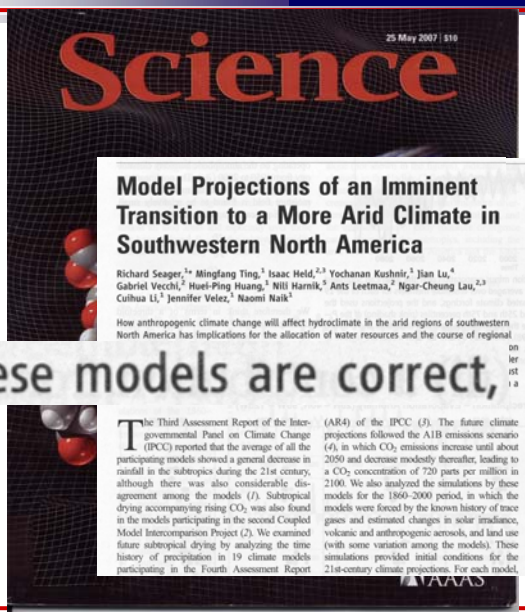
2005 Record Rains in California

Courtesy: NASA's ESE

2007: Lowest Rainfall on Record in California



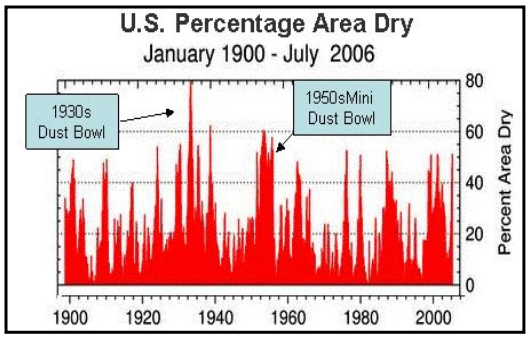
Eye-Catching Article in Science Magazine



Observed changes: Drought

Drought activity during the 20th and early 21st Century

- **U.S. droughts show pronounced multi-year to multi-decadal variability, but no convincing evidence for long-term trends toward more or fewer events.**



Based on Palmer Drought Index
Moderate to Extreme Drought

Source: Tom Karl NCDC-NOAA 2007

Relationship: Drought, Forest Health, Fire

Flagstaff, AZ

Arrowhead Lake, CA

Drought Weakens Tree's Tolerance to Beetle Attack, Causing High Tree Mortality, Perfect Target for Forest Fire

Forest Fires and Hydrologic Impact

Post Fire Processes

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Increased Sediment Transport

Incised channel and deposition due to erosion

Area downstream from erosional Zone increased sediments and runoff

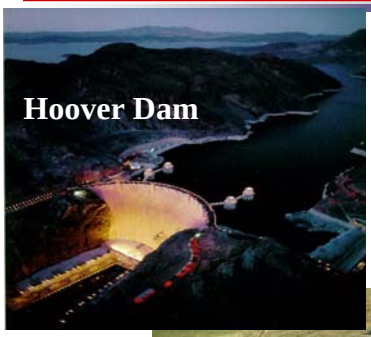
USGS Website (http://wwwbrr.cr.usgs.gov/projects/Burned_Watersheds/)

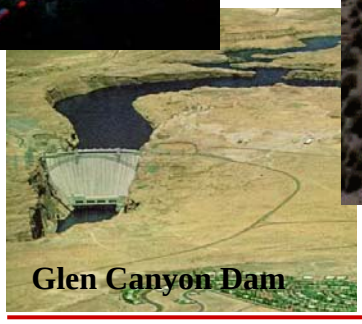
Center for Hydrometeorology and Remote Sensing, University of California, Irvine

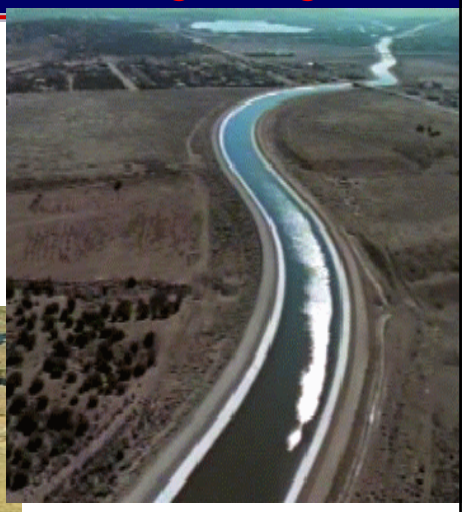
Common Practices in Factoring in Climate:

Engineering Approach: Control, Store, Recycle, Transport & Use for Multi-Purposes

A Century of Water Resources Development: ***Engineering success!***



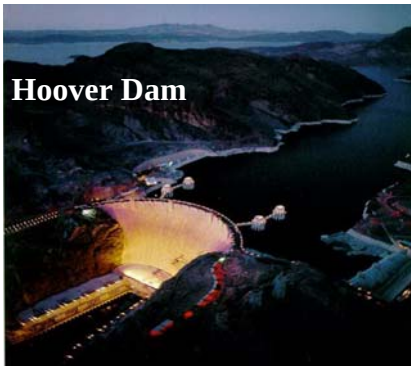




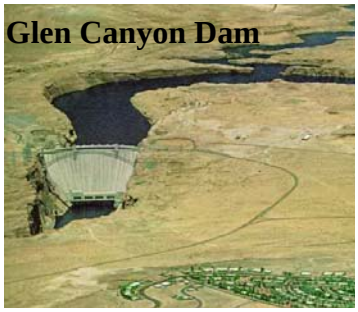
Central Arizona Project Aqueduct

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Built-In Resiliency in water resources Systems!



Time of Construction = 1935
Total Storage Capacity = 38.6 BCM
Annual Inflow = 15.4 BCM
Drainage Area = 432,500 Km²
Time to fill =2.5 Years
Power Generation = 2,074 MW



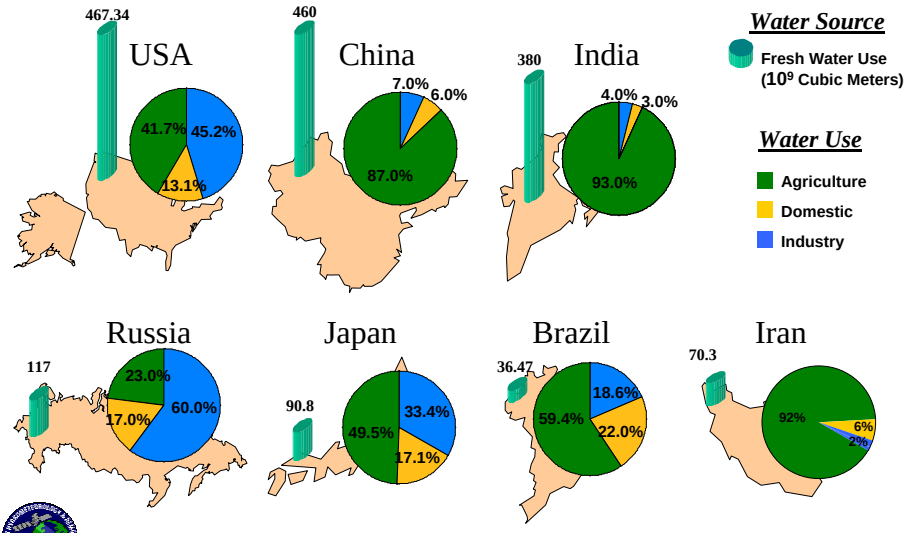
Time of Construction = 1963
Total Storage Capacity = 33.3 BCM
Annual Inflow = 15.4 BCM
Drainage Area = 280,570 Km²
Time to fill = 2.24 Years
Power Generation = 1,356 MW

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Many Advances in Water Treatment: $$$?

Water treated on site at a rubber factory, Malaysia

Distribution of Fresh Water Use

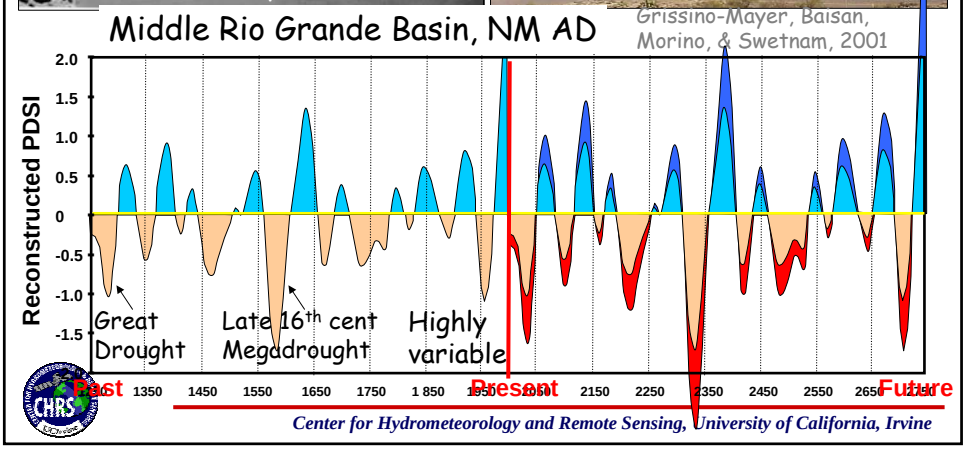


Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Current Practices in Factoring in Climate:

In Water Resources and Hydrologic Planning

Potential Hydrologic Implications: Needs Work!

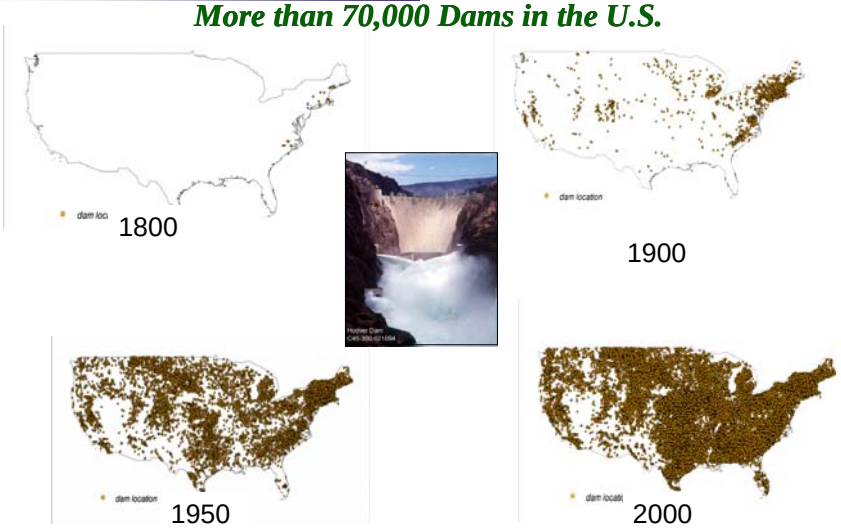


Center for Hydrometeorology and Remote Sensing, University of California, Irvine

What is the Big Deal About Characterizing the Long-Term Uncertainties in Hydro-Climate Variables?

Impact on Design and Operation of Global Infrastructure

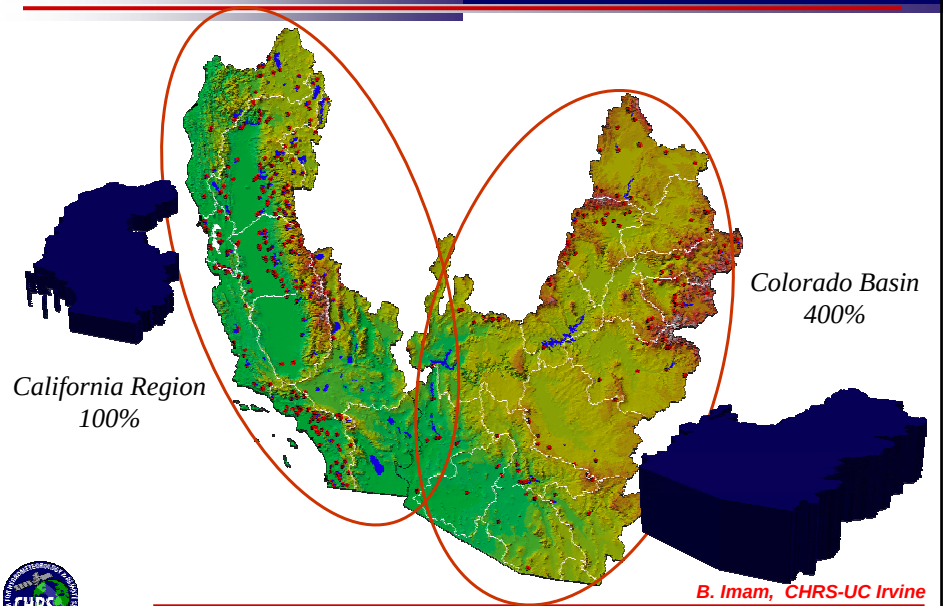
More than 70,000 Dams in the U.S.



Provided by: C. J. Vörösmarty

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

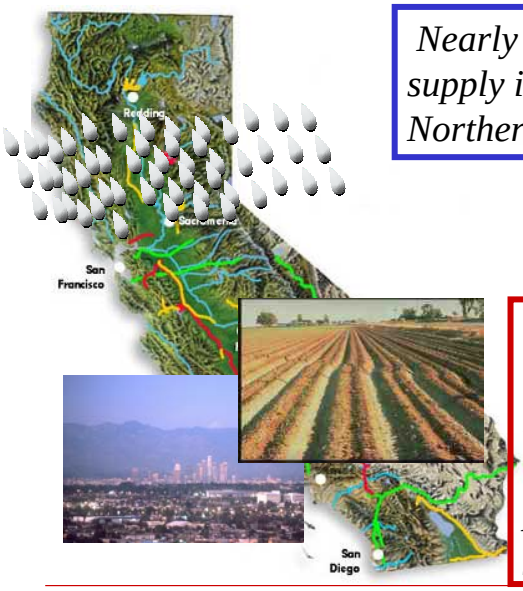
Storage Capacity/Streamflow Relationship



B. Imam, CHRS-UC Irvine

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

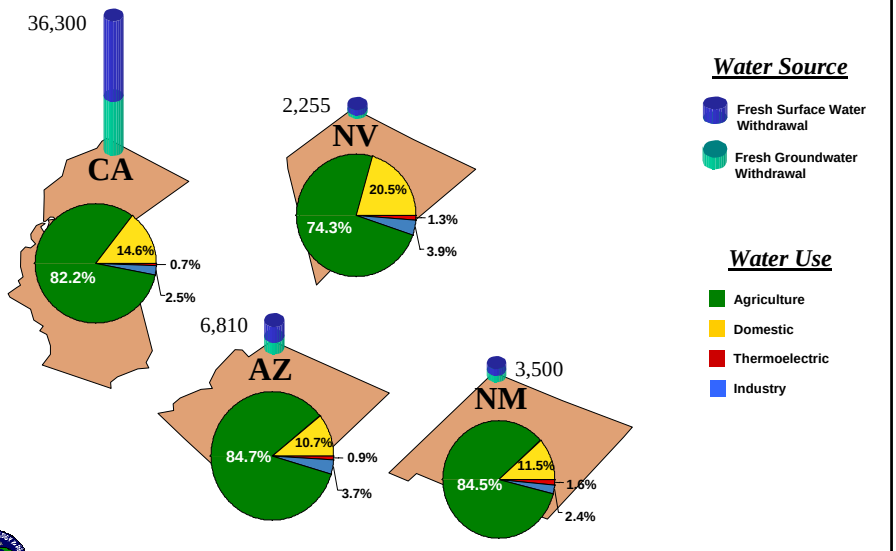
Supply and Demand Variability of California



Nearly 75% of our supply is in Northern half

Almost 65% of our demand is in the Southern half and likely to grow with projected urban growth

Major Water Use Categories

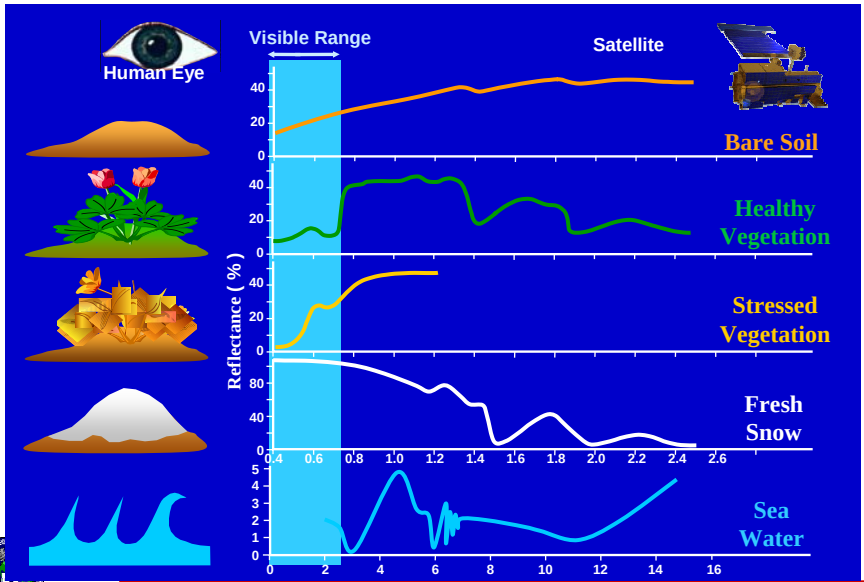


Data in Million Gallon/Day. Source: USGS Water Use Report 1995

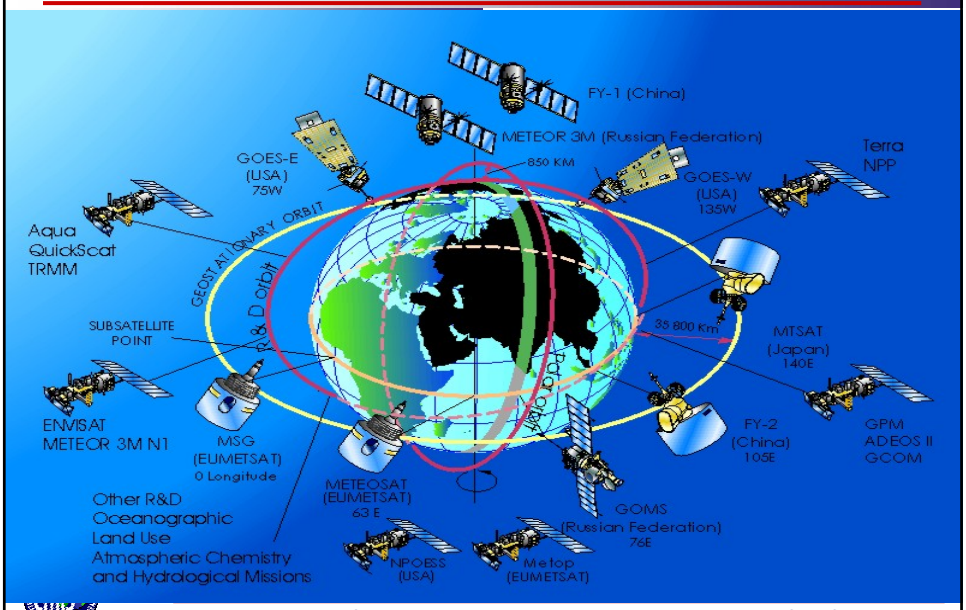
"News From Space"

Satellite Observations

Remote Sensing Systems (Spectral Signal)

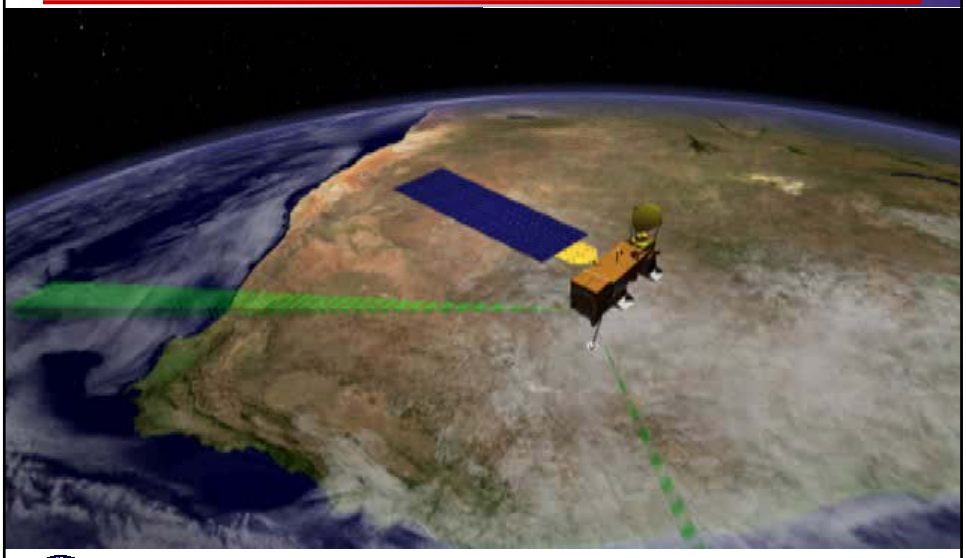


Current Meteorological and Earth Observing Satellites in Space



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Different Instruments Measure Different Things



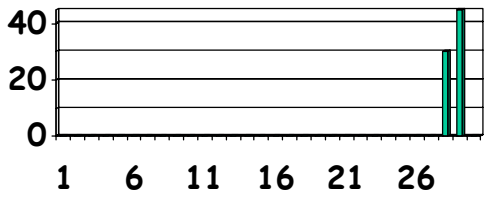
Center for Hydrometeorology and Remote Sensing, University of California, Irvine

A Key Requirement!

Measurement of Rainfall is a Major Challenge

Temporal Scale Importance: *Daily Precip. at 2 stations*

A

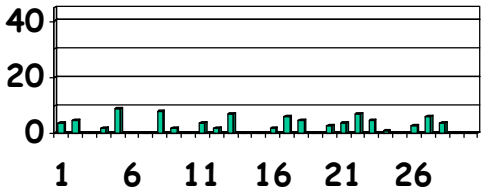


local floods

Monthly
Amount 75 mm

Frequency 6.7%
Intensity 37.5 mm

B



soil moisture replenished
virtually no runoff

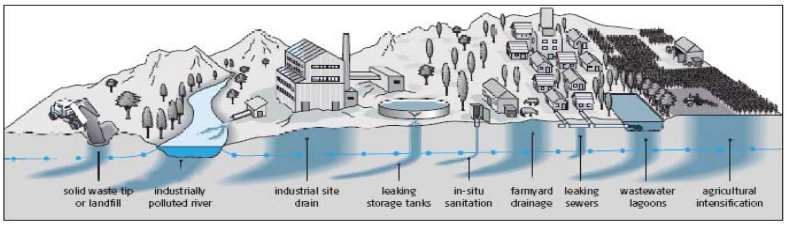
Amount 75 mm

Frequency 67%
Intensity 3.75 mm

Source: K. Trenberth, NCAR

Water Quality Concerns

Figure 4.8: **Primary sources of groundwater pollution**



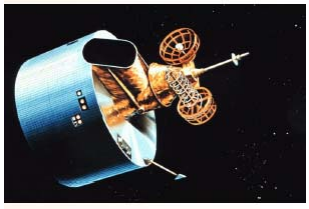
Note: This figure illustrates the type of sources that should be inventoried for cataloging potential sources of groundwater contamination.

Source: Foster et al, 2002.

Precipitation Observations: Which to trust??

Rain Gauges

WSR-88D Radar



Satellite

Sources: R. Fulton, D.-J. Seo. and J. Breidenbach, AMS Short-Course on QPE/QPF, 2002

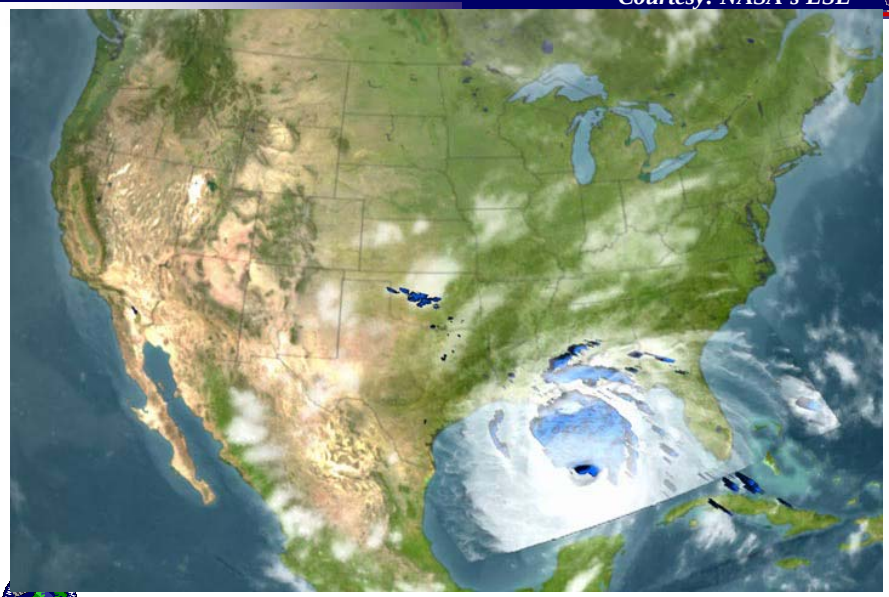
TRMM DATA Swath

Courtesy: NASA's ESE

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

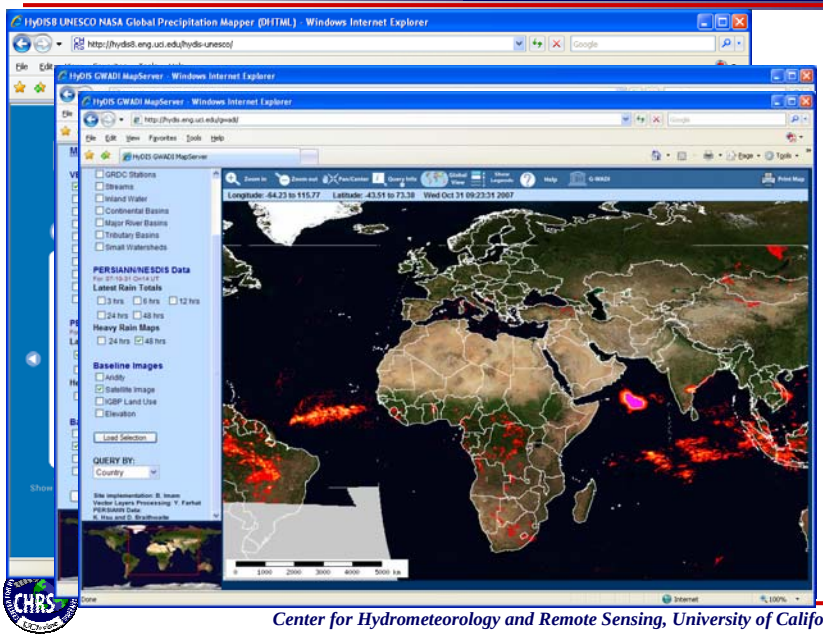
TRMM Radar Capabilities: Katrina August 2005

Courtesy: NASA's ESE



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Satellite Products: Promising future

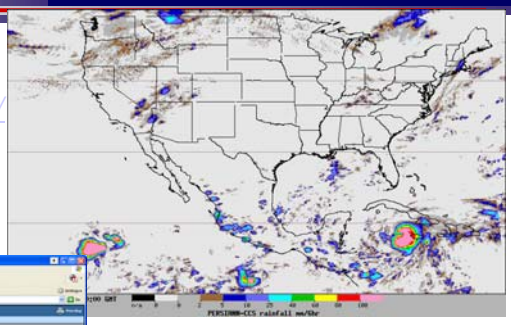


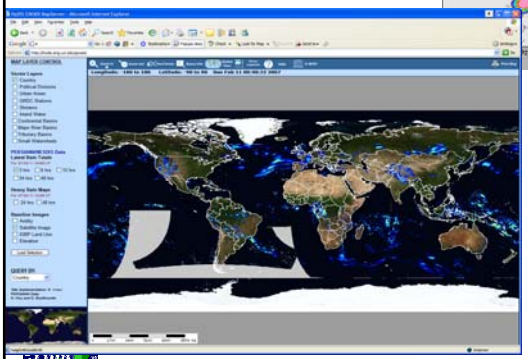
Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Some of the UCI-CHRS Rainfall Data Products

Animations of PERSIANN/CCS Images
25km, 6 hour rainfall

http://hydis8.eng.uci.edu/GCCS/





G-WADI GeoServer:
Near real-time 4km, 30 minute

http://hydis.eng.uci.edu/gwadi/

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

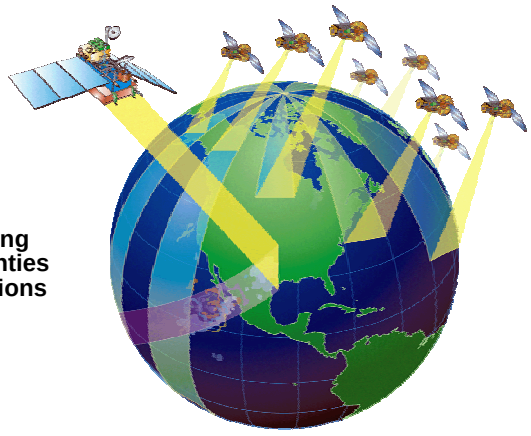
Use of Satellite Precipitation Products for Hydrologic Applications:

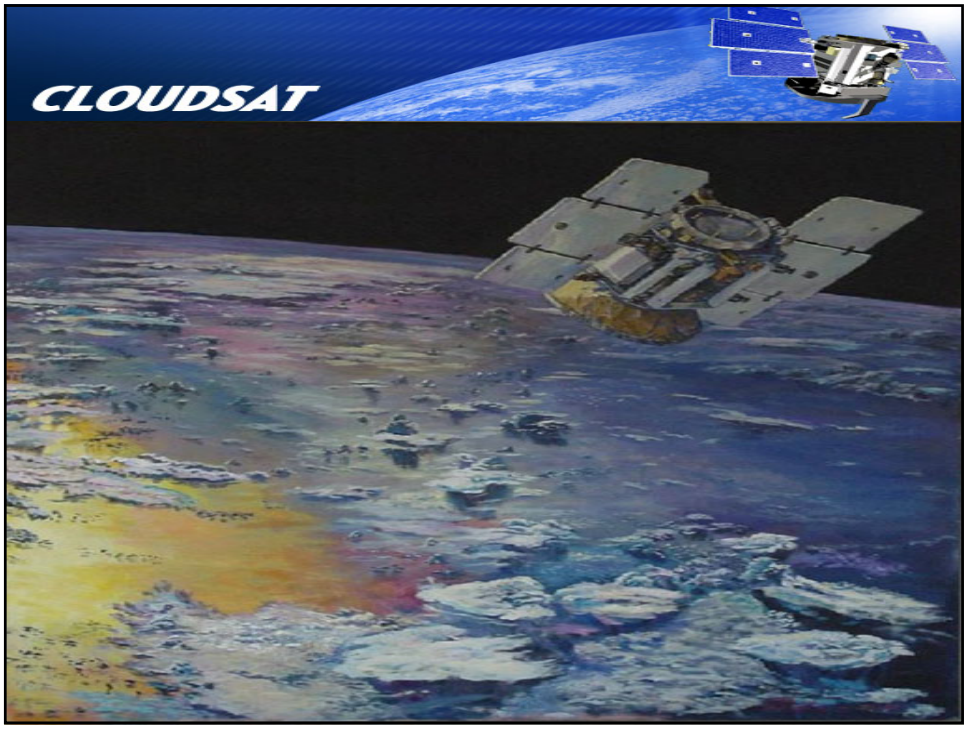
Very Promising

GPM Mission: Target Date 2012?

OBJECTIVES

- **1 Main satellite + 8 Smaller Satellites **
- **Provide sufficient global sampling to significantly reduce uncertainties in short-term rainfall accumulations**



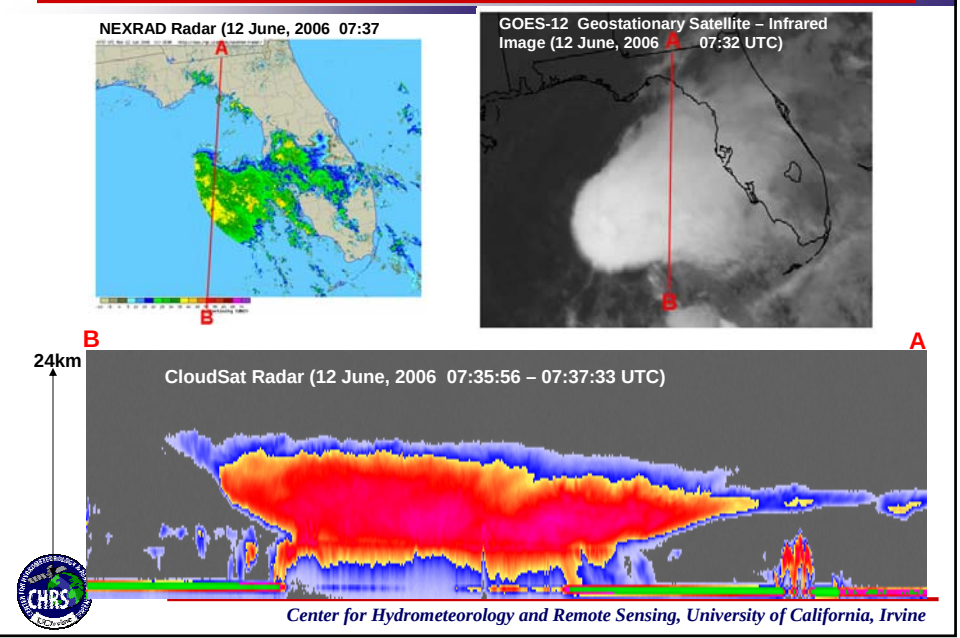


CLOUDSAT Animation

Courtesy: NASA's ESE

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

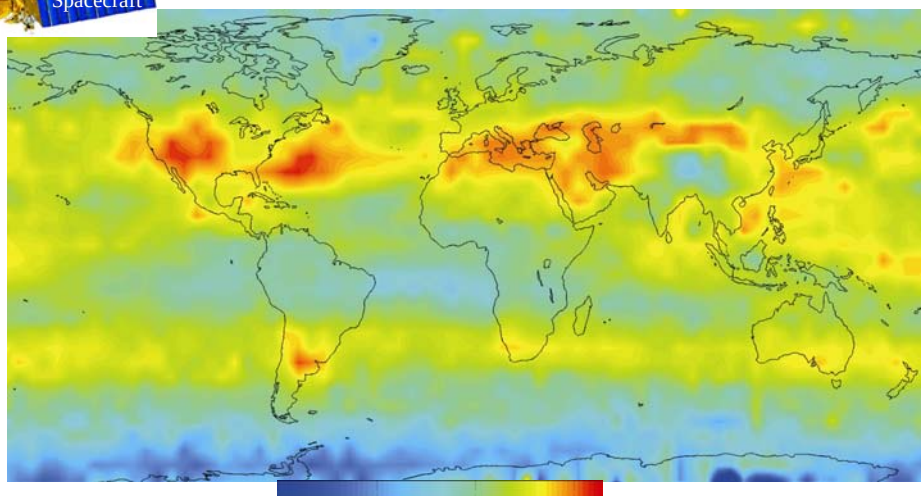
CloudSat View of Tropical Strom Alberto



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

NASA AIRS Mid-Tropospheric Carbon Dioxide: July 2003

Atmospheric InfraRed Sounder(AIRS) **In Space since 2002**

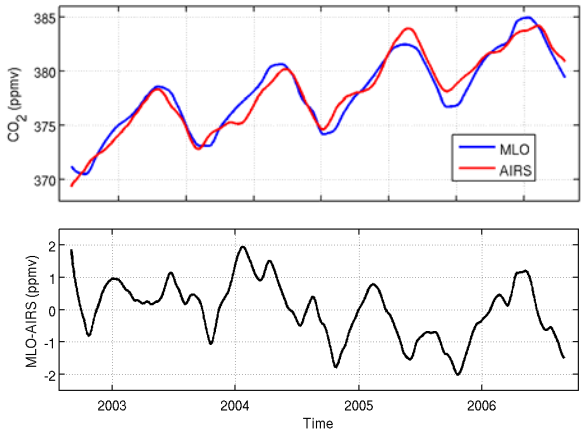


Provided By: Mous Chahine

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Comparison of CO2 Annual Variations -- Mona Loa Observatory (MLO) and AIRS

AIRS CO_2 for "Cloud-Free" Tropical Oceans

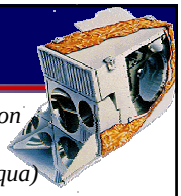


Larrabee Strow, U Maryland

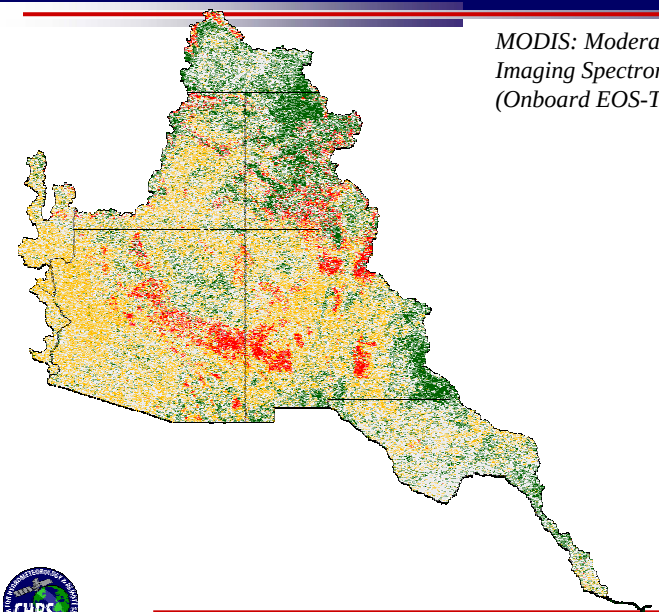
Provided By: Mous Chahine

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Early Detection of "Wild-Fire" Risk



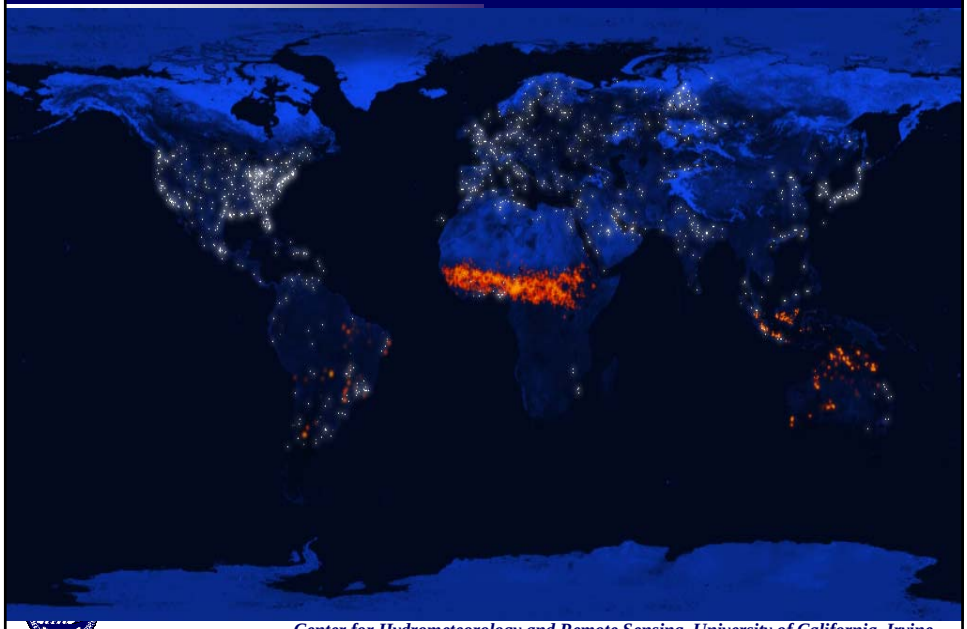
MODIS: Moderate Resolution Imaging Spectrometer (Onboard EOS-TERRA &Aqua)



B. Imam, CHRS-UC Irvine

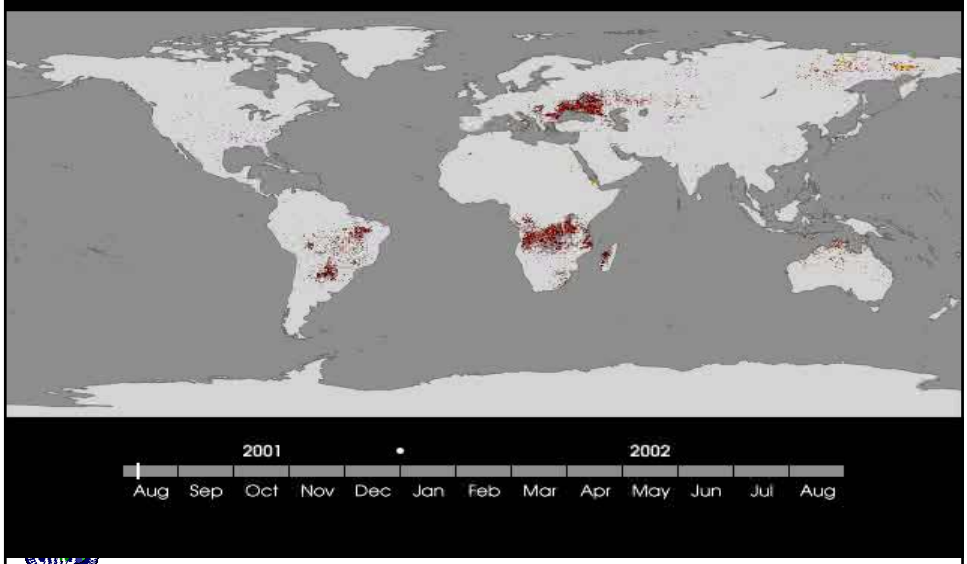
Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Global Fire Map from Space



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Monitoring of Global Fires from Space



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

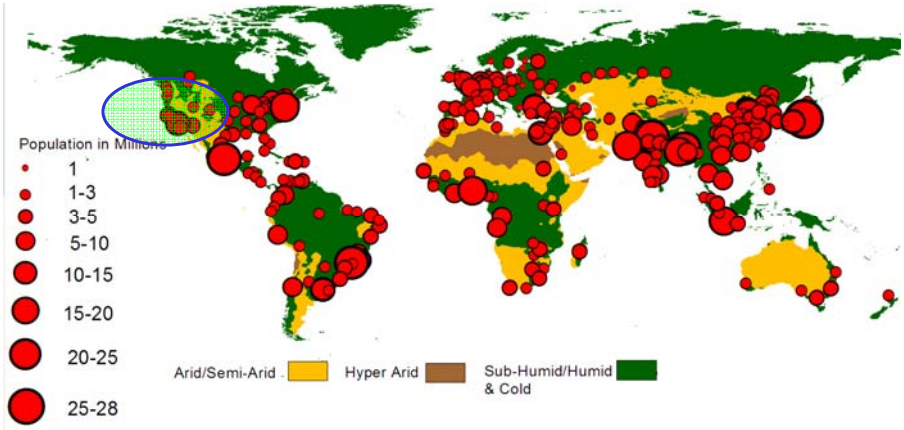
In Brief:

While some of these results are based on very short life span of recent Earth Observing missions

They Are Very Promising!

Increasing Population: Number of Mega Cities

Projected Global Population: 8.3 Billion by 2025



Global Urban population 1970: ~37%
2010: ~53%

Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Urban Effect on Rainfall

Courtesy: NASA's ESE

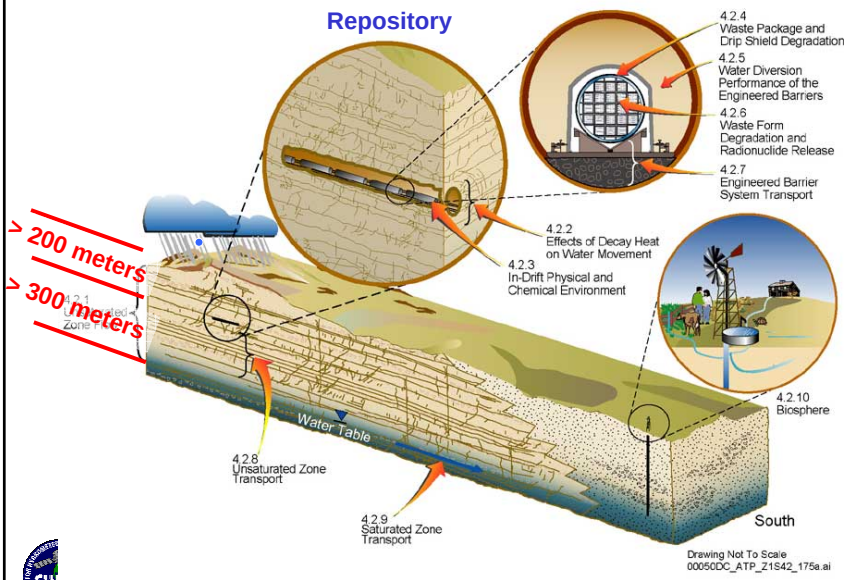
Approaching Climate- and Weather-Scale Issues in planning

Simulation of Net Infiltration Over the Proposed Nuclear Waste Repository Site: Yucca Mountain, Nevada (Time Horizon: 10,000 years)

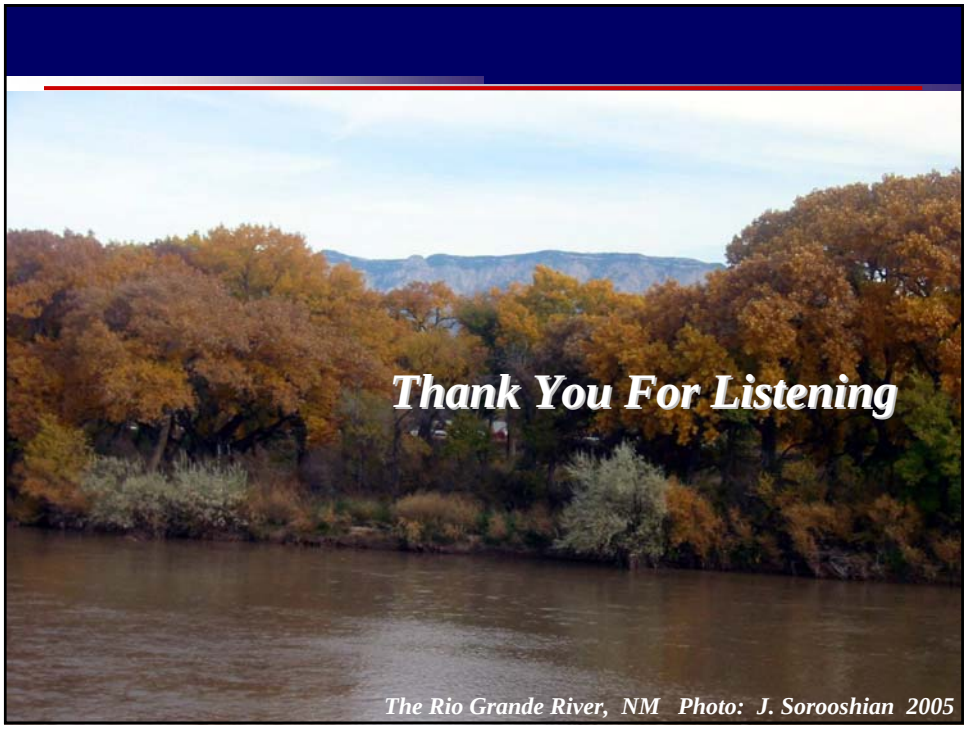
Climate Scenarios:

- *Present-Day climate to persist for the next 400 to 600 yrs.*
- *Followed by Warmer and Wetter Monsoon climate (Lasting 900 to1400 years)*
- *Followed by Cooler and Wetter Glacial-Transition Climate*

Yucca Mountain: Nuclear Waste Repository



CHRS Web Site



Observing the Oceans!

Center for Hydrometeorology and Remote Sensing, University of California, Irvine