Assessment and Impact of regional water resources variability on energy production and development

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11th Scientific Forum: The Future Role of the IAEA
52nd IAEA General Conference
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CHRS Staff Affiliations: International Team (UA)

A Brief Review of Global Water Resources Issues!

Will We Be Running Out of Water?

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Distribution of Freshwater

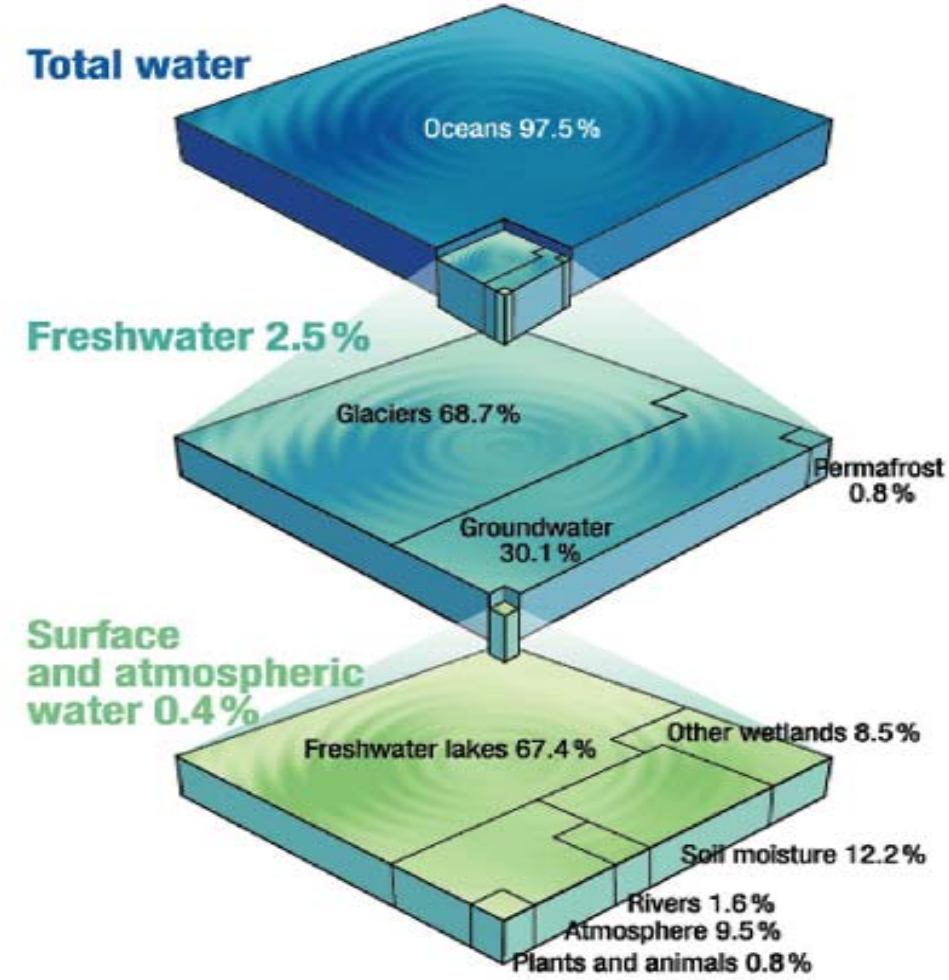


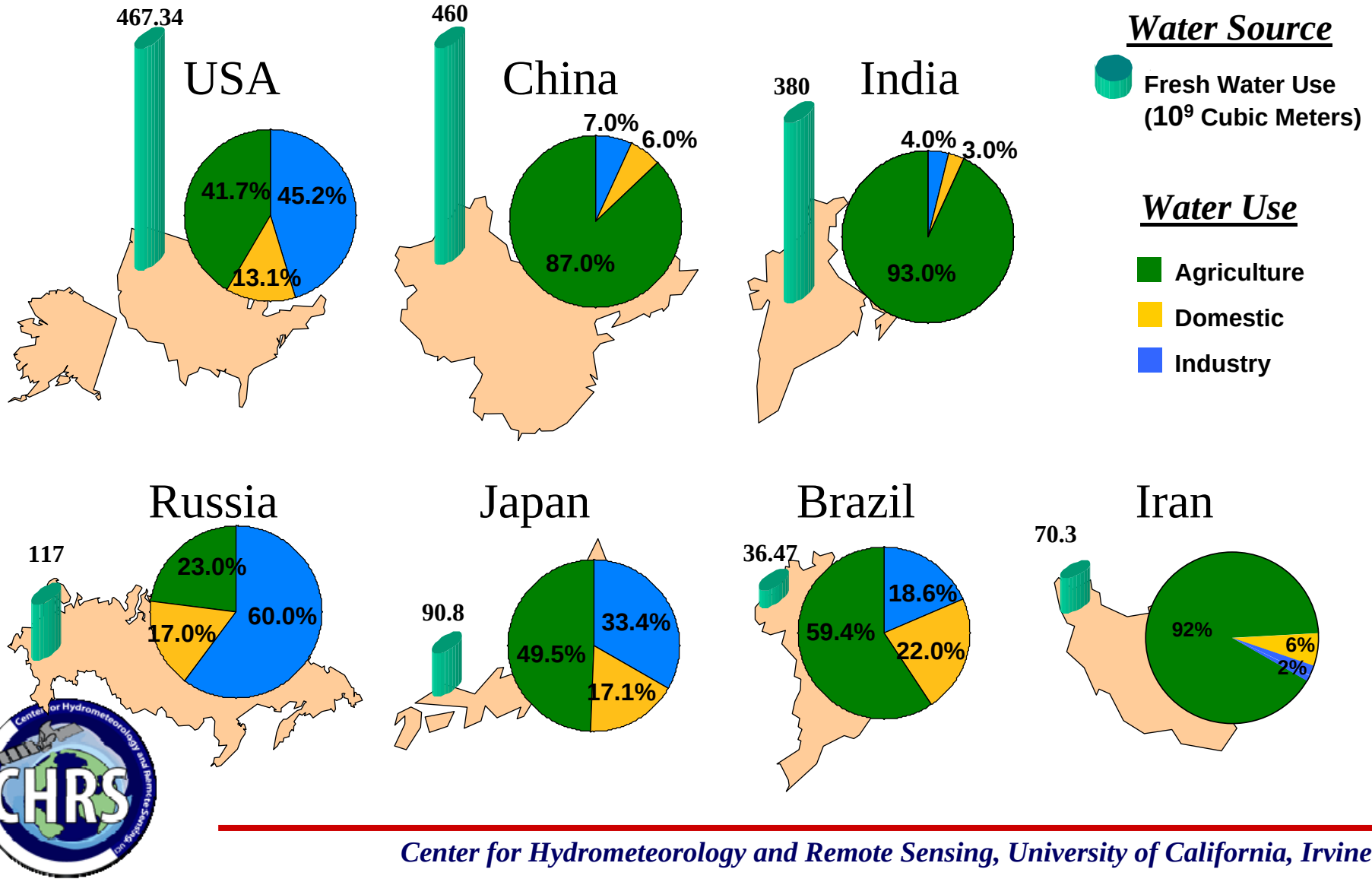
Figure 4.1:
Global distribution of the world's water

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

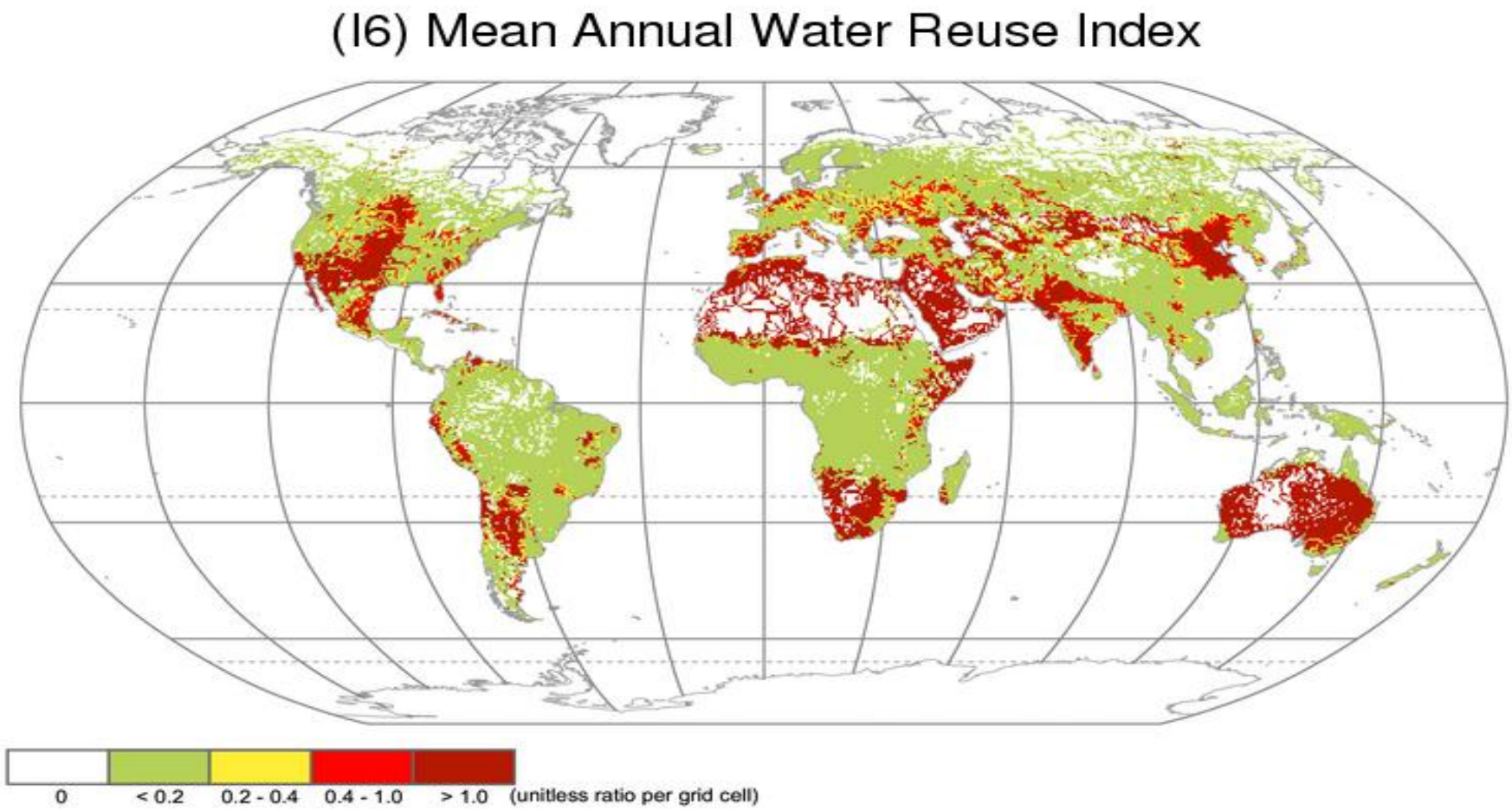
World Water Assessment Programme

Nature's Way of Making Freshwater: The Hydrologic Cycle

Distribution of Fresh Water Use



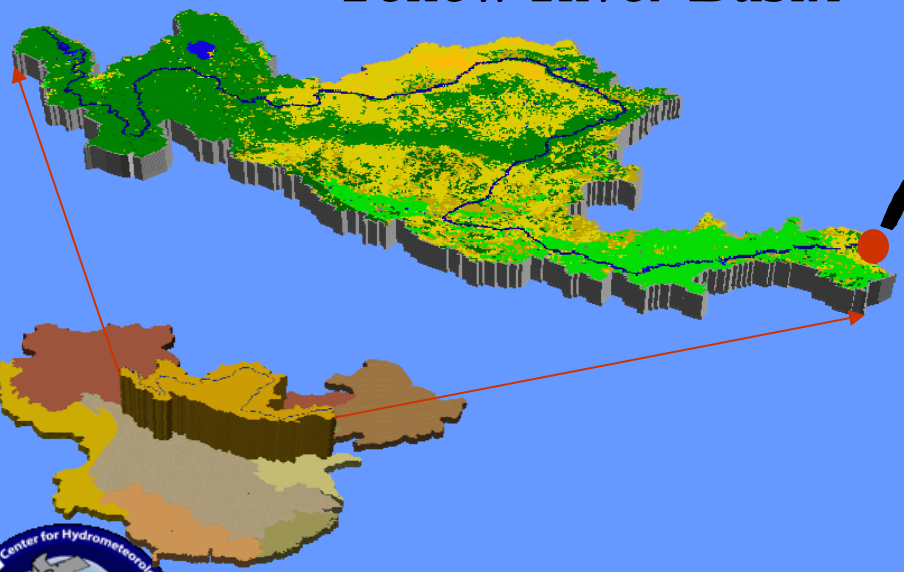
Expected Water Scarce Regions

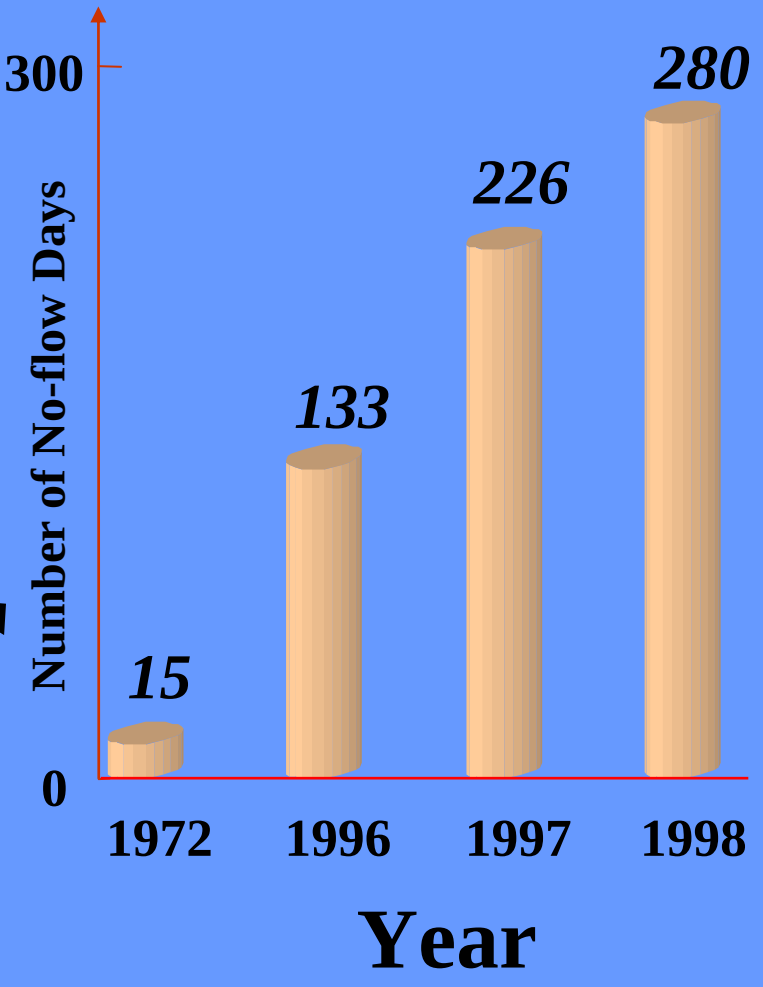


Decreased Flow to the Sea: Excessive Utilization

Increasing number of minimal to no-flow days in the lower reaches of the Yellow River due to near-full utilization of the streamflow.

Yellow River Basin

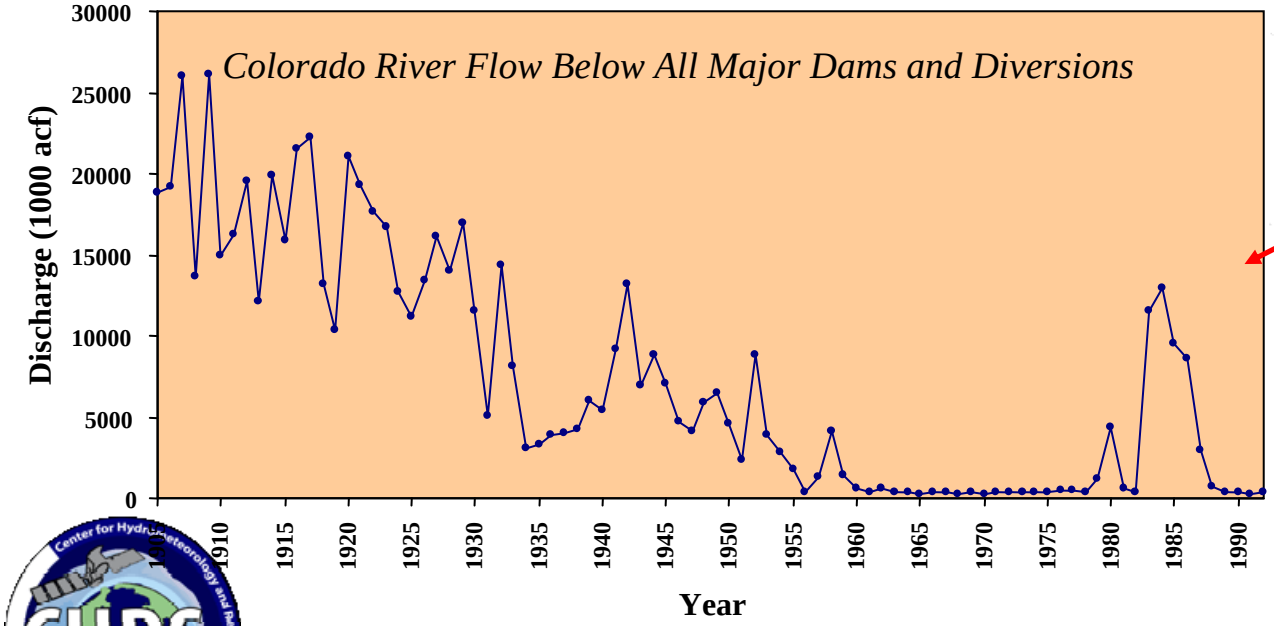




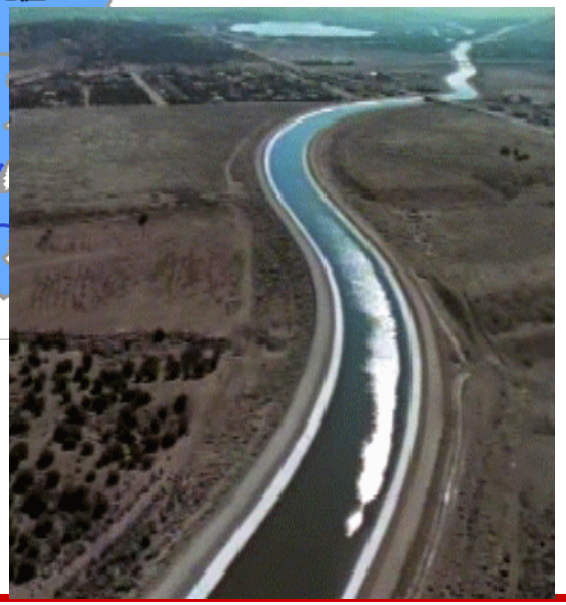
Source: Dr. Sun, Chinese Academy of Sci.

Colorado River: Great Source, But for How long?

- *The Colorado River is the most regulated stream in the world.*
- *Since 1962, the river flow has been fully utilized.*
- *Salinity levels increase 15 folds from mountain headwaters to the Mexican border*



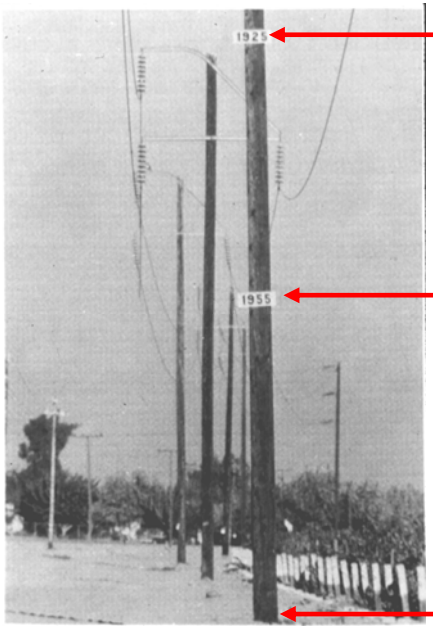
The Colorado River Salinity Problem



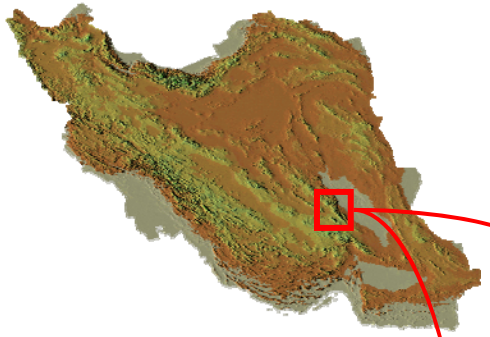
Salt loads continue to be an issue today

The Central Arizona Project currently brings about 1.5 million tons of salt per year to the center of the state. This amount of salt would fill 50,000 railroad cars.

Groundwater Overdraft, land subsidence and sinkholes

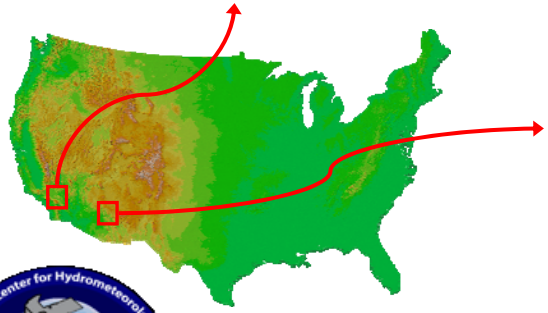


Near Kerman, Iran



Eloy, Arizona

San Joaquin Valley, CA



In the US

Global Water Resources Development:

Engineering Approach

Control, Store, Use for Multi-Purpose Uses

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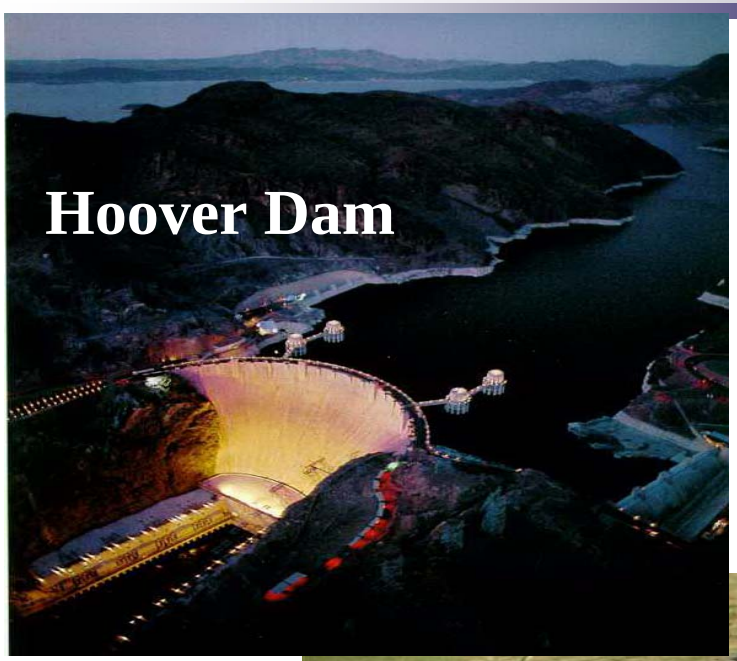
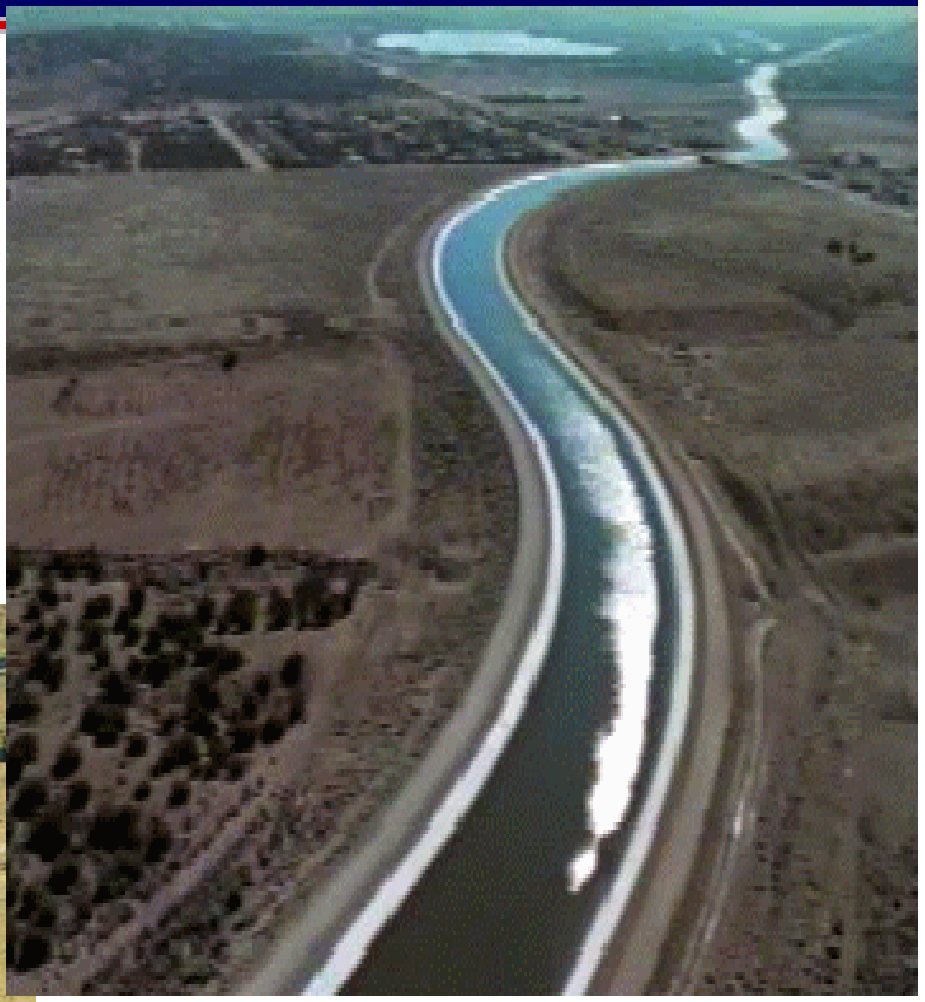
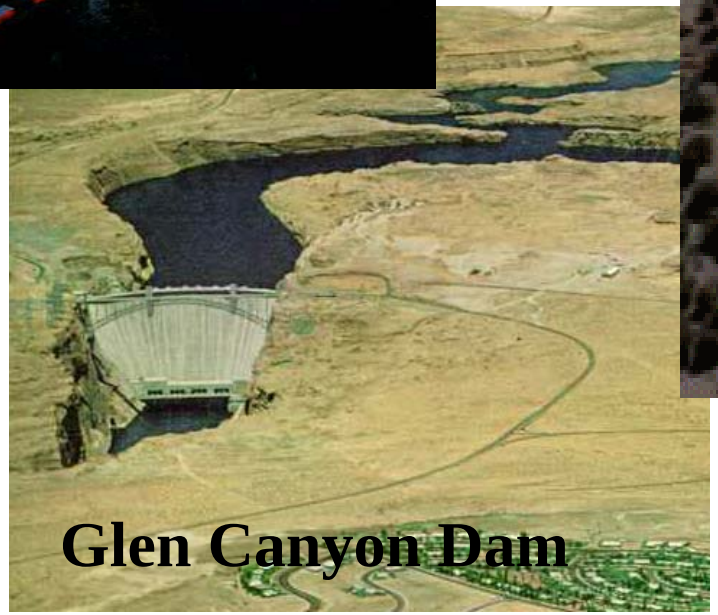
A Century of Water Resources Development: Engineering success!

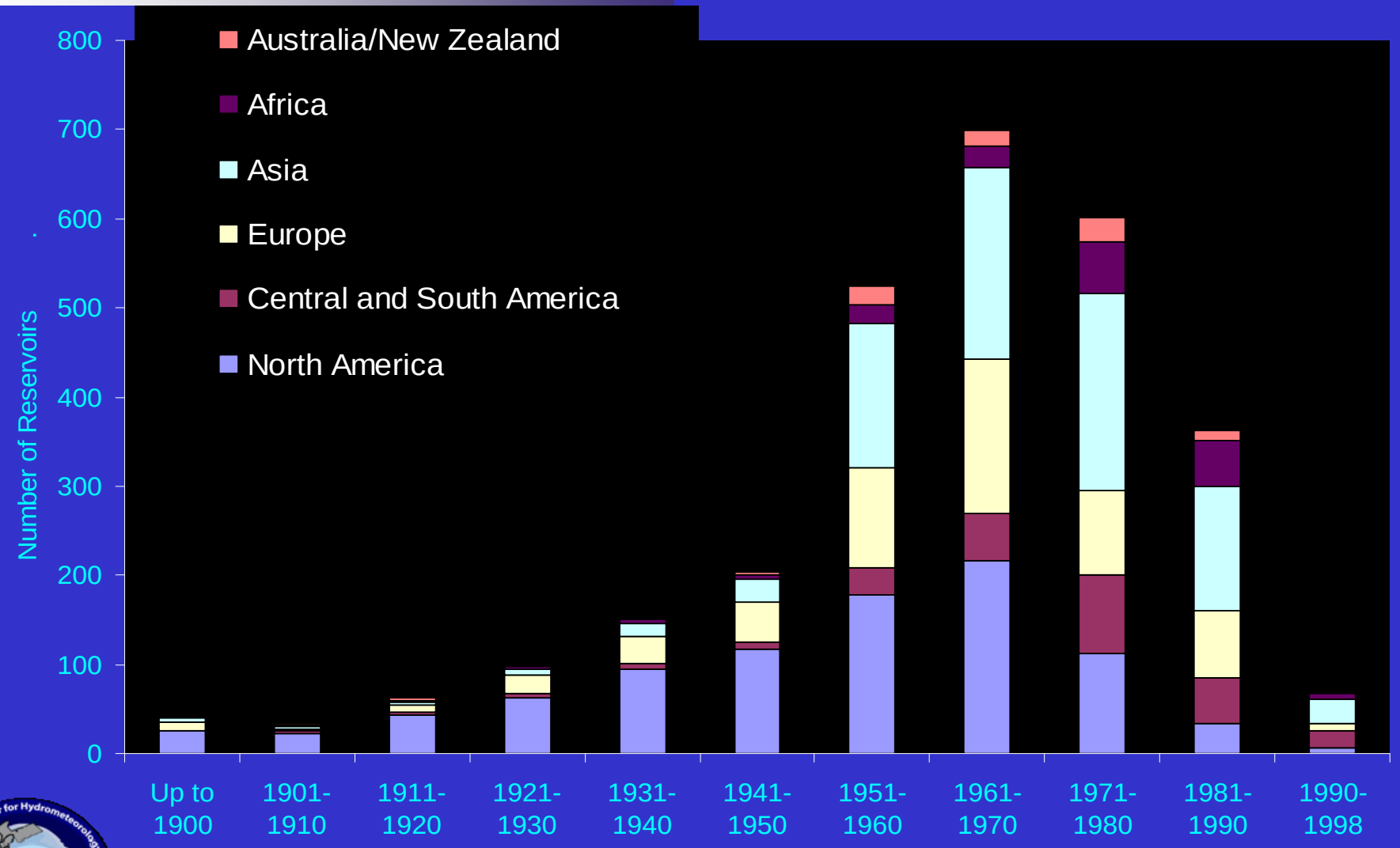




Central Arizona Project Aqueduct



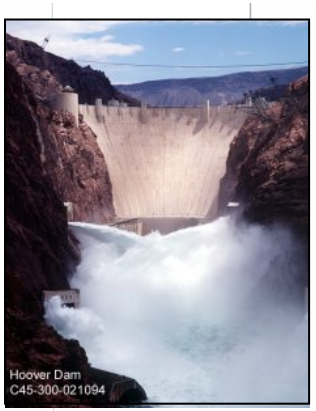
Reservoir construction has slowed.

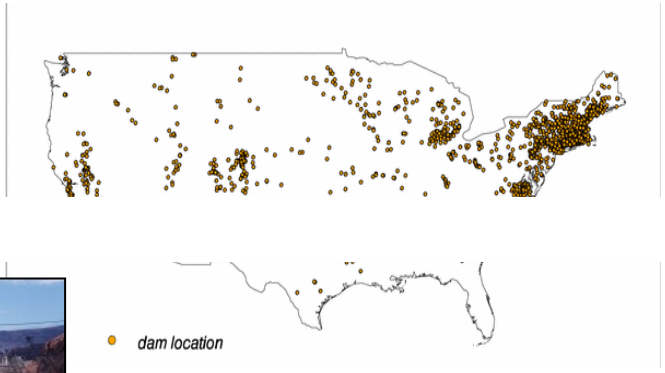


SOURCE: Dr. Peter H. Gleick, Pacific Institute for Studies in Development

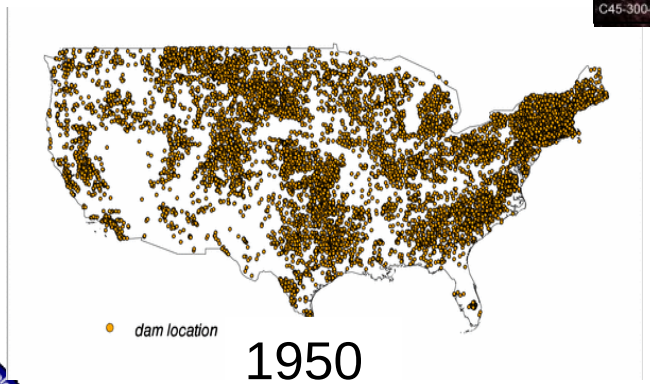
Impact of Dam & Reservoir Construction

1800

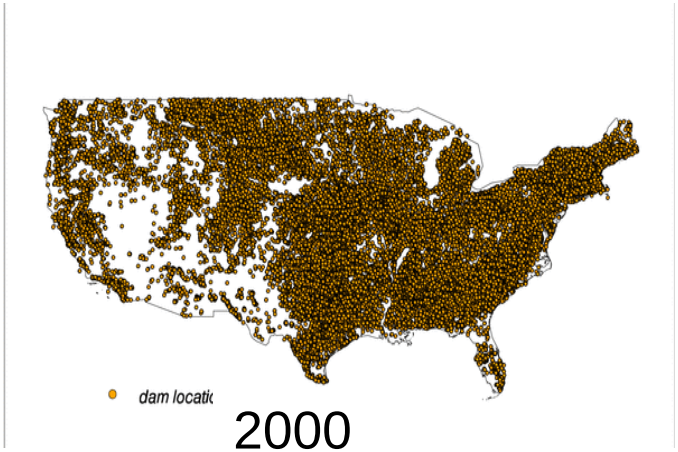




1900



1950

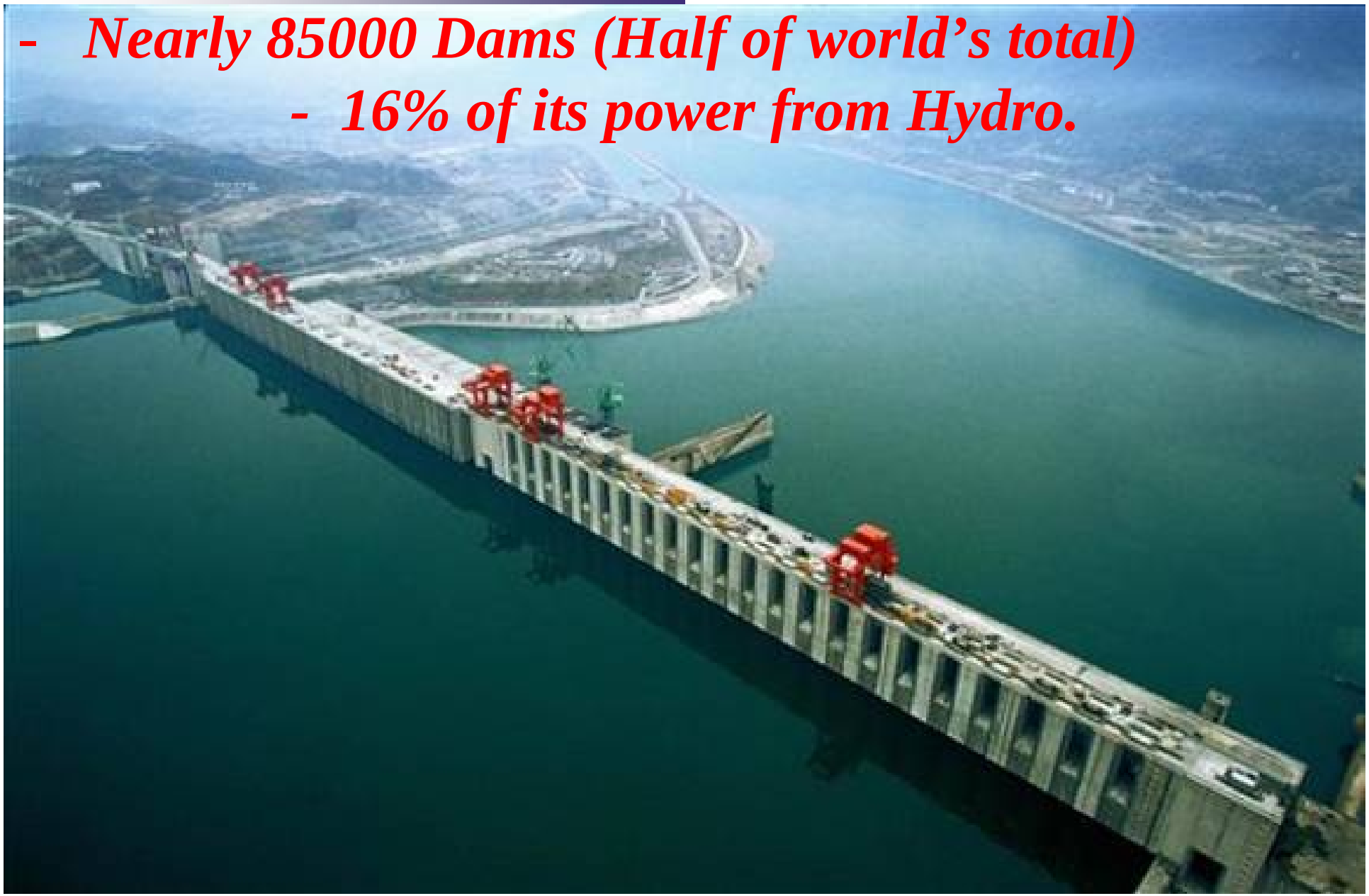


2000

More than 70,000 Dams in the U.S

Some Facts about China's hydro power potential

- *Nearly 85000 Dams (Half of world's total)*
- *16% of its power from Hydro.*



Three Gorges Dam - China: Some Facts

Cost: $25 Billion U.S.

Labor: 25000 at any given time

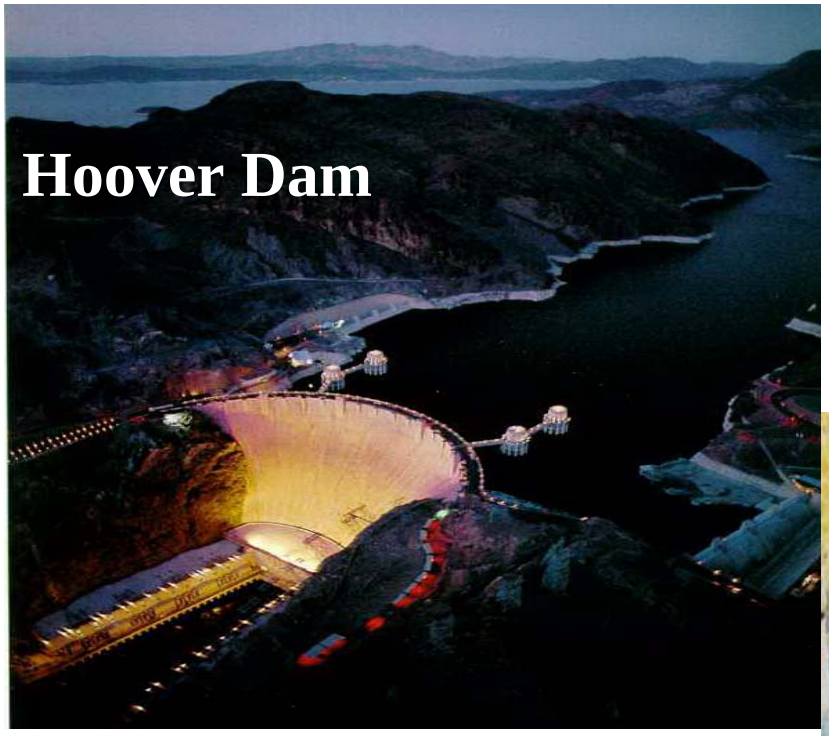
***Lake Size:* 39.3 BCM**

Power Capacity:

26 generators, 85 BKW-Hr/yr

(compared to Hoover Dam of 4 BKW-Hr/yr)

Two Major Dams in the World: same capacity, different Rivers



Time of Construction = 1935
Total Storage Capacity = 38.6 BCM
Annual Inflow = 15.4 BCM
Drainage Area = 432,500 Km^2
Power Generation = 2,074 MW

Time to fill = 2.5 years

Time of Construction = 2003
Total Storage Capacity = 39.3 BCM
Annual Inflow = 451 BCM
Drainage Area = 1,000,000 Km^2
Power Generation = 17,680 MW

Time to fill = 32 days

Strong Link Between Water and Energy

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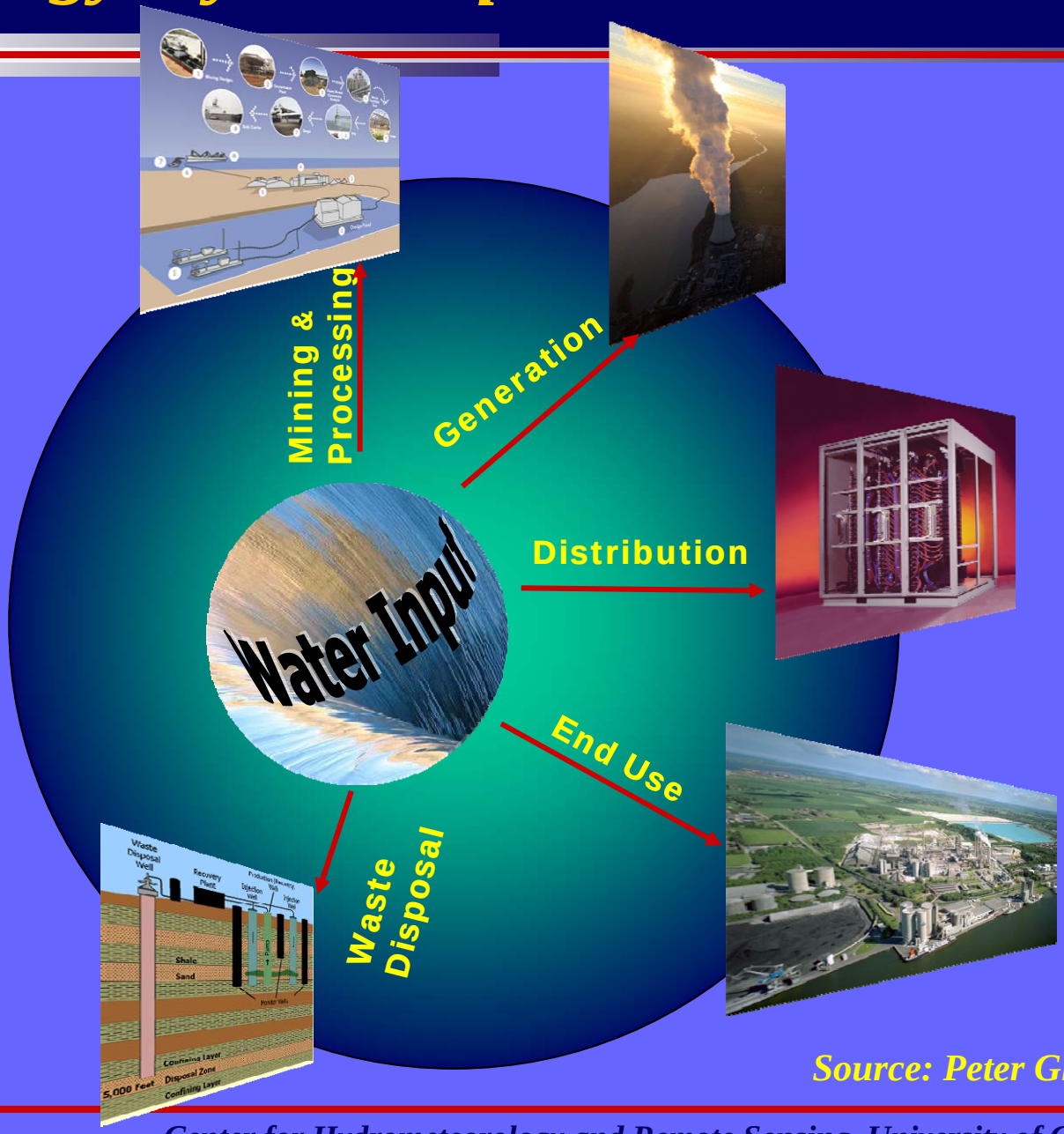
The Energy Cycle Requires Water

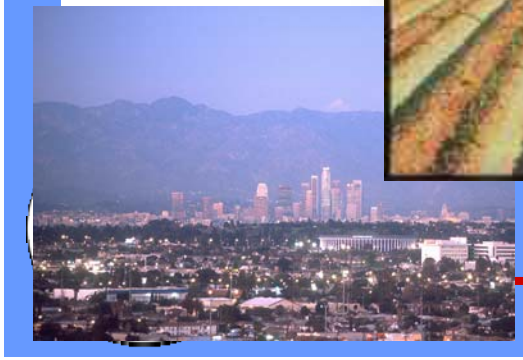


Source: Peter Gleick of Pacific Institute

Water Supply – Use – Disposal: All Require Energy

Source: Peter Gleick of Pacific Institute

Example: The California State Water Project (SWP)



- Is the single largest user of energy in California.
- It requires an average of 5 billion $kWhr_e$ /yr to operate.
- Pumping 1 acre-foot of water through the system to Los Angeles requires 3,000 $kWhr_e$.

[1 acre-foot is 326,000 gallons or 1233 cubic meters]

Source: Peter Gleick of Pacific Institute

Palo Verde Nuclear Power Plant: Arizona U.S.A.

- Palo Verde is the only nuclear energy facility in the world not adjacent to a large body of water.
- The plant uses recycled water from the City of Phoenix for cooling. More than 20 billion gallons of this water are recycled each year.
- Palo Verde is the only nuclear energy plant that uses treated wastewater for cooling.

Source: Peter Gleick of Pacific Institute

What Can We Say About Future Stresses On Water and Energy Resources?

- ***Population Impact*** *(Certain!)*

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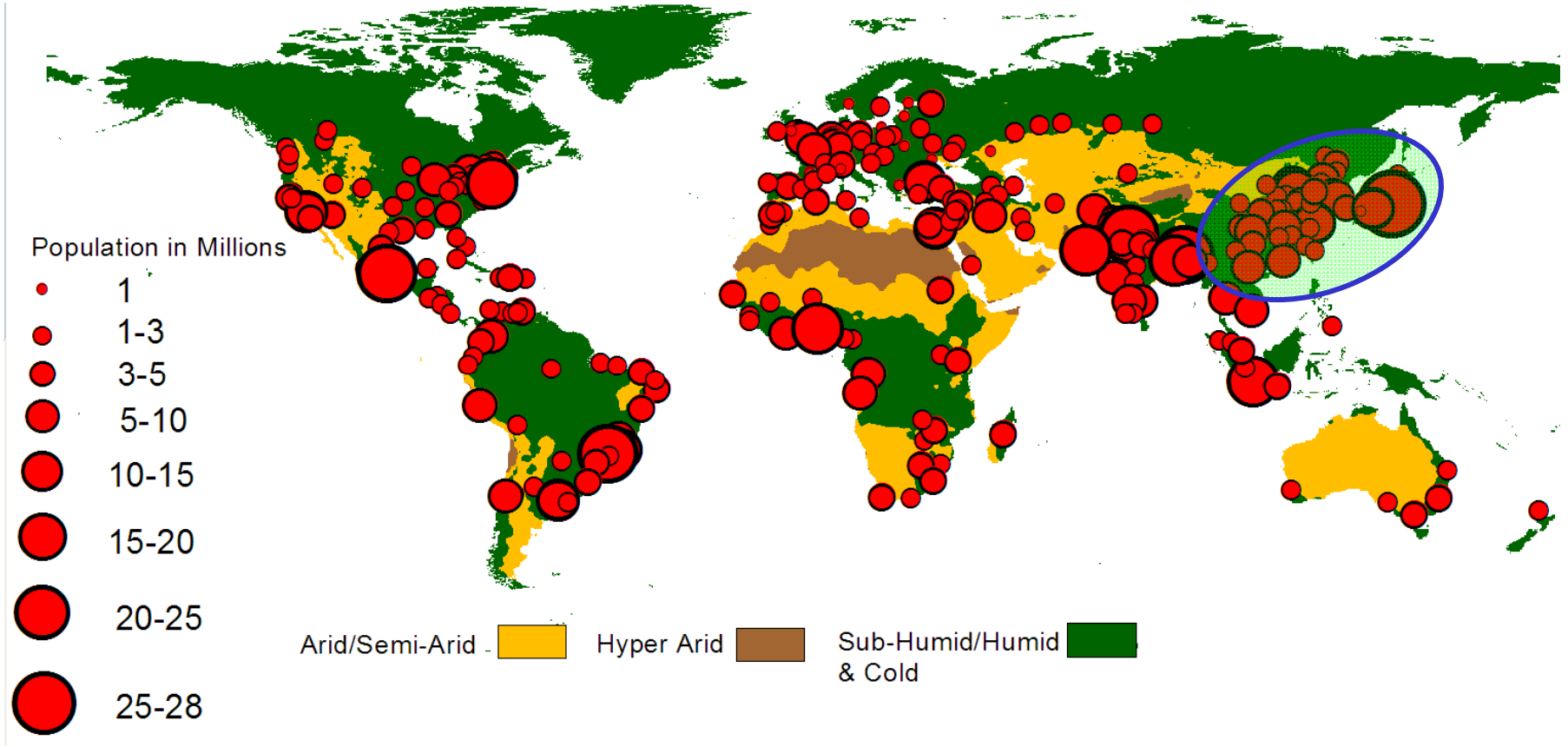
Increasing Population: Number of Mega Cities

Projected Global Population: 8.3 Billion by 2025



Global Urban population 1970: ~37%

2010: ~53%

What Can We Say About Future Stresses On Water and Energy Resources?

- ***Population Impact*** *(Certain!)*
- ***Climate Impact***

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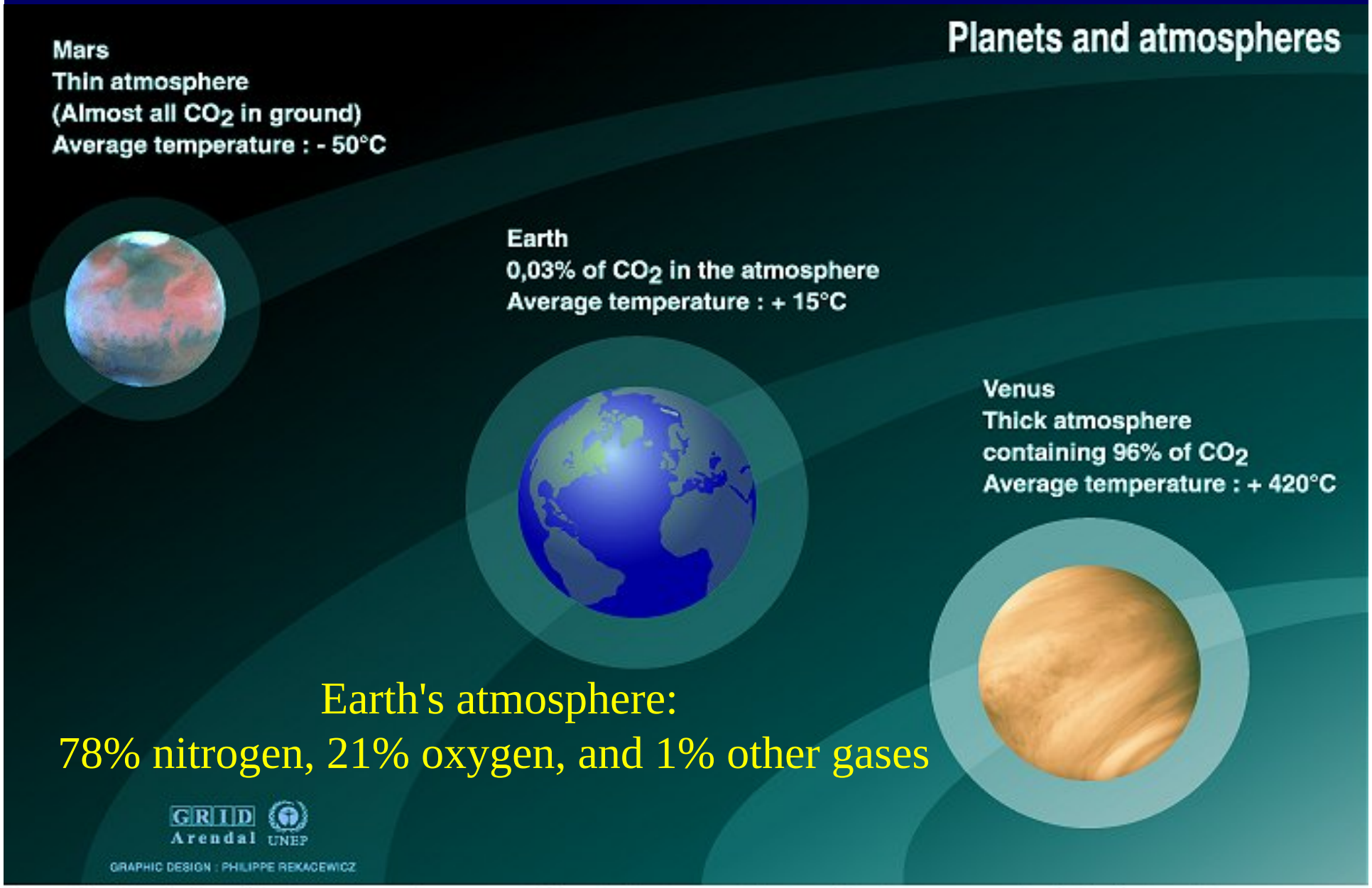
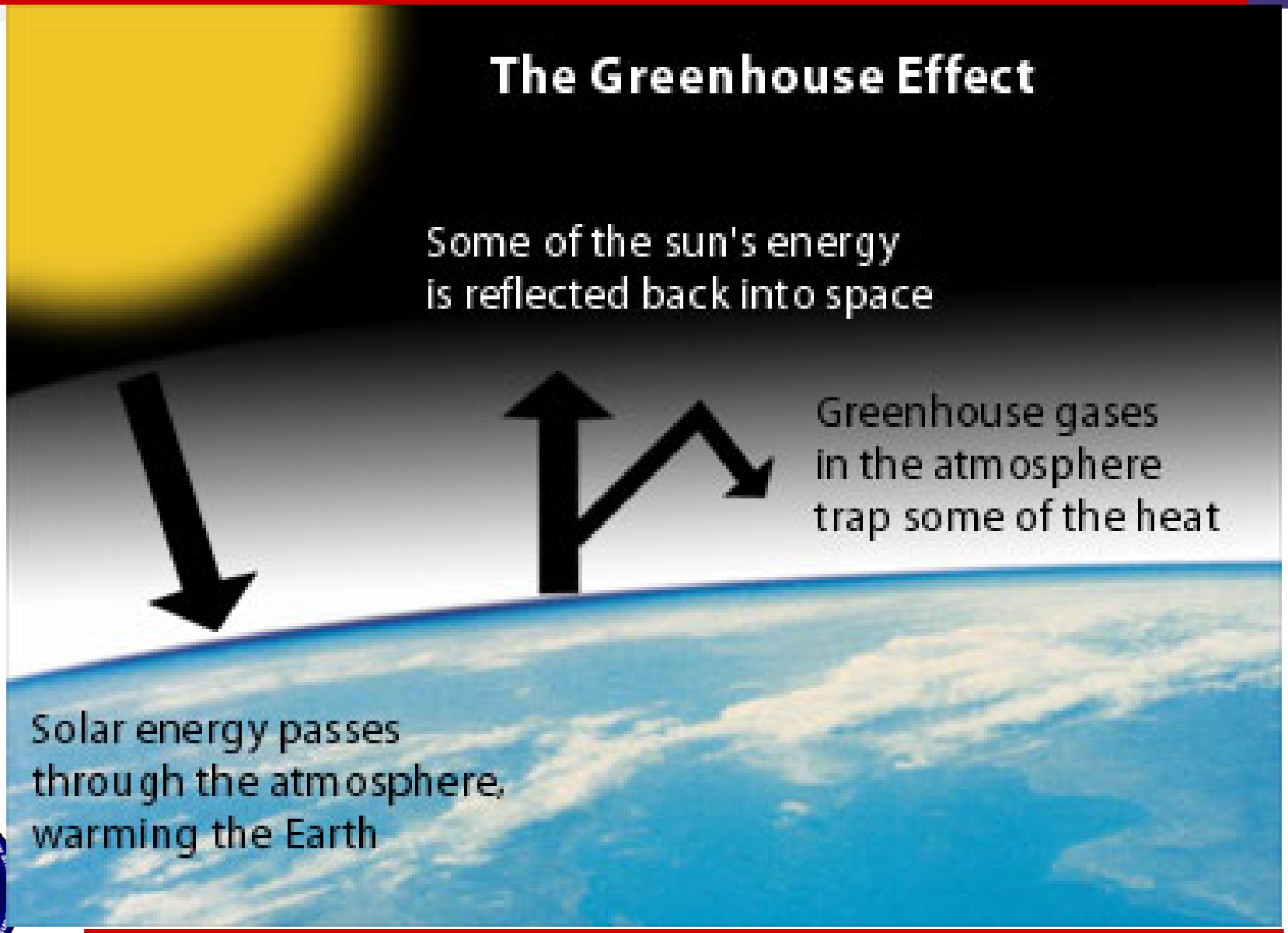
Atmosphere of Earth, Mars and Venus

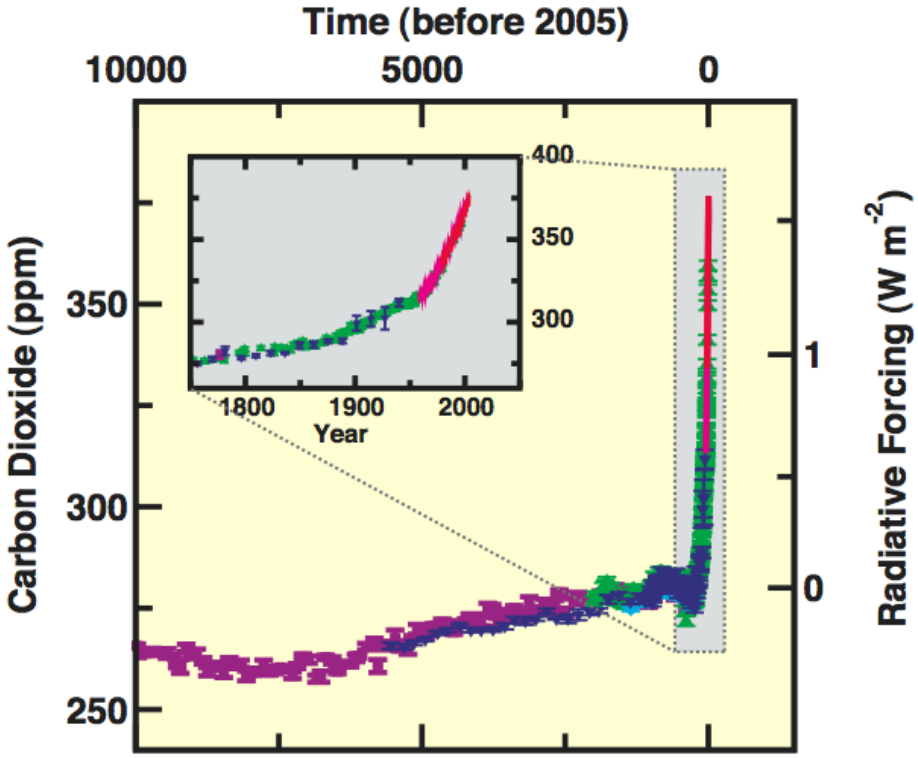


Sources: Calvin J. Hamilton, Views of the solar system, www.planetscapes.com; Bill Arnett , The nine planets, a multimedia tour of the solar system, www.seds.org/billa/tnp/nineplanets.html

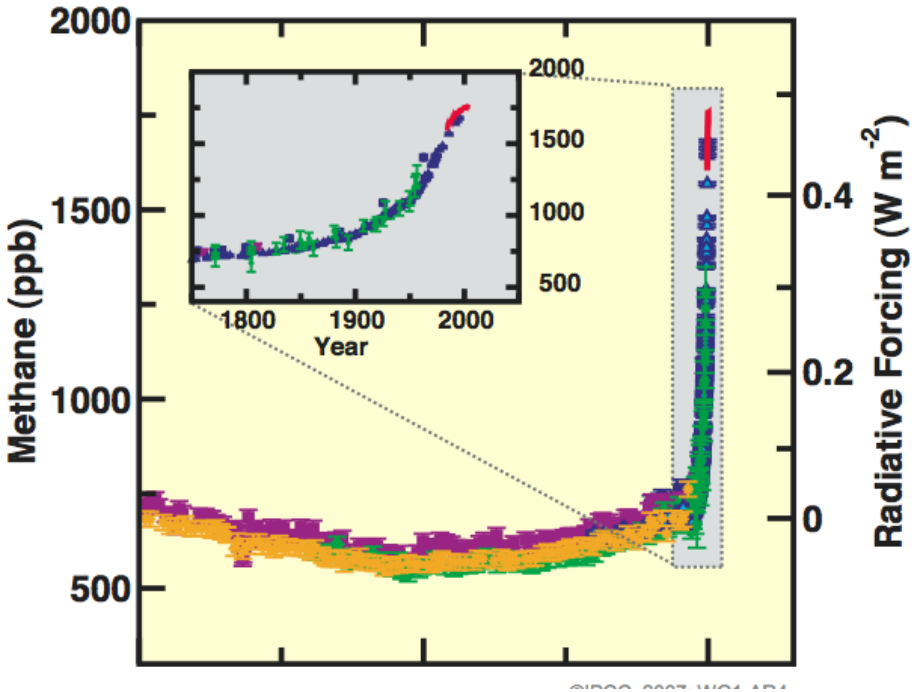
But There Are Greenhouse Gases



What is causing the problem?



Carbon-Dioxide concentration in atmosphere over last 10,000 years



Methane concentration in atmosphere over last 10,000 years

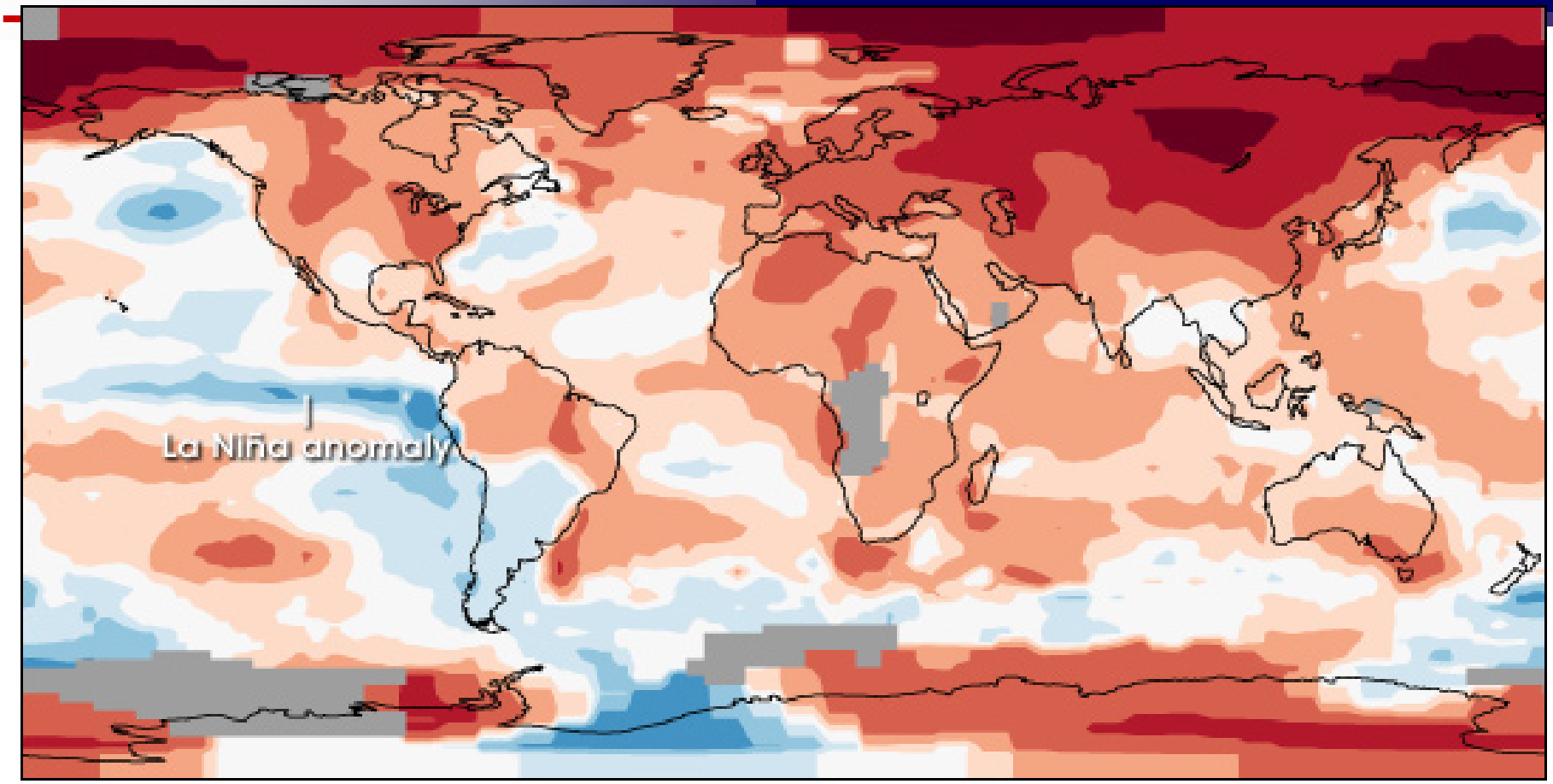
Green-House Gases (GHG)

Source: D. Entekhabi 2008

The Important Question as to Whether:

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

Global Temperature Anomalies: 2007



Surface Temperature Anomaly (°C)

-3.5 -3 -2 -1 -0.5 -0.2 0.2 0.5 1 2 3 4

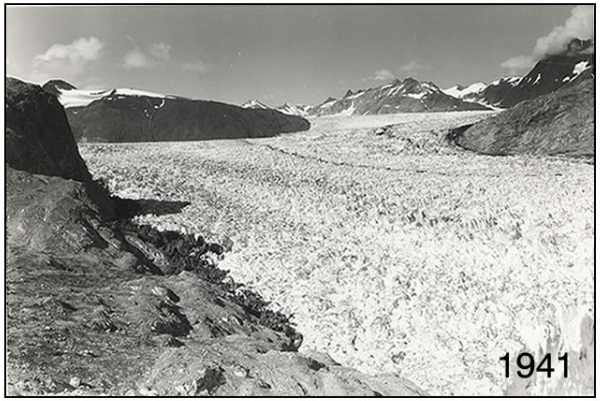
Source: NASA GISS 2007

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

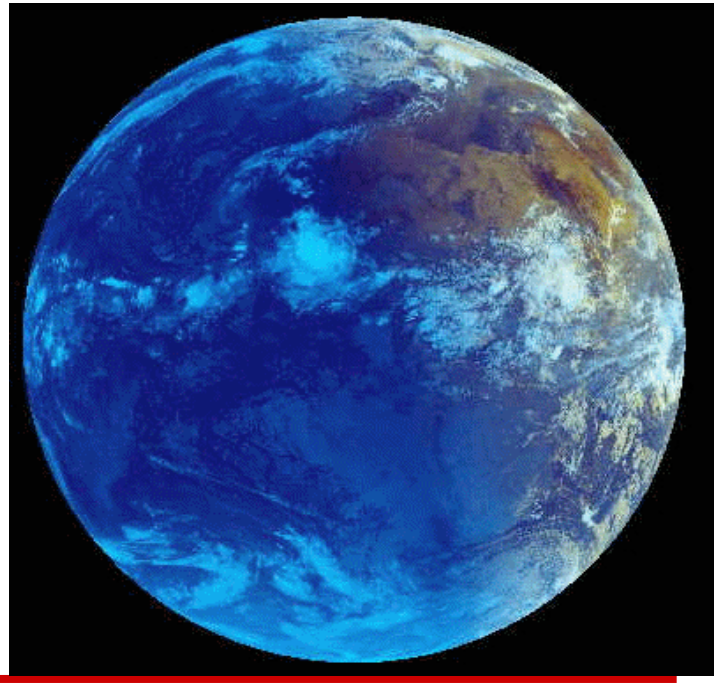
Provided By: Kevin Trenberth

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

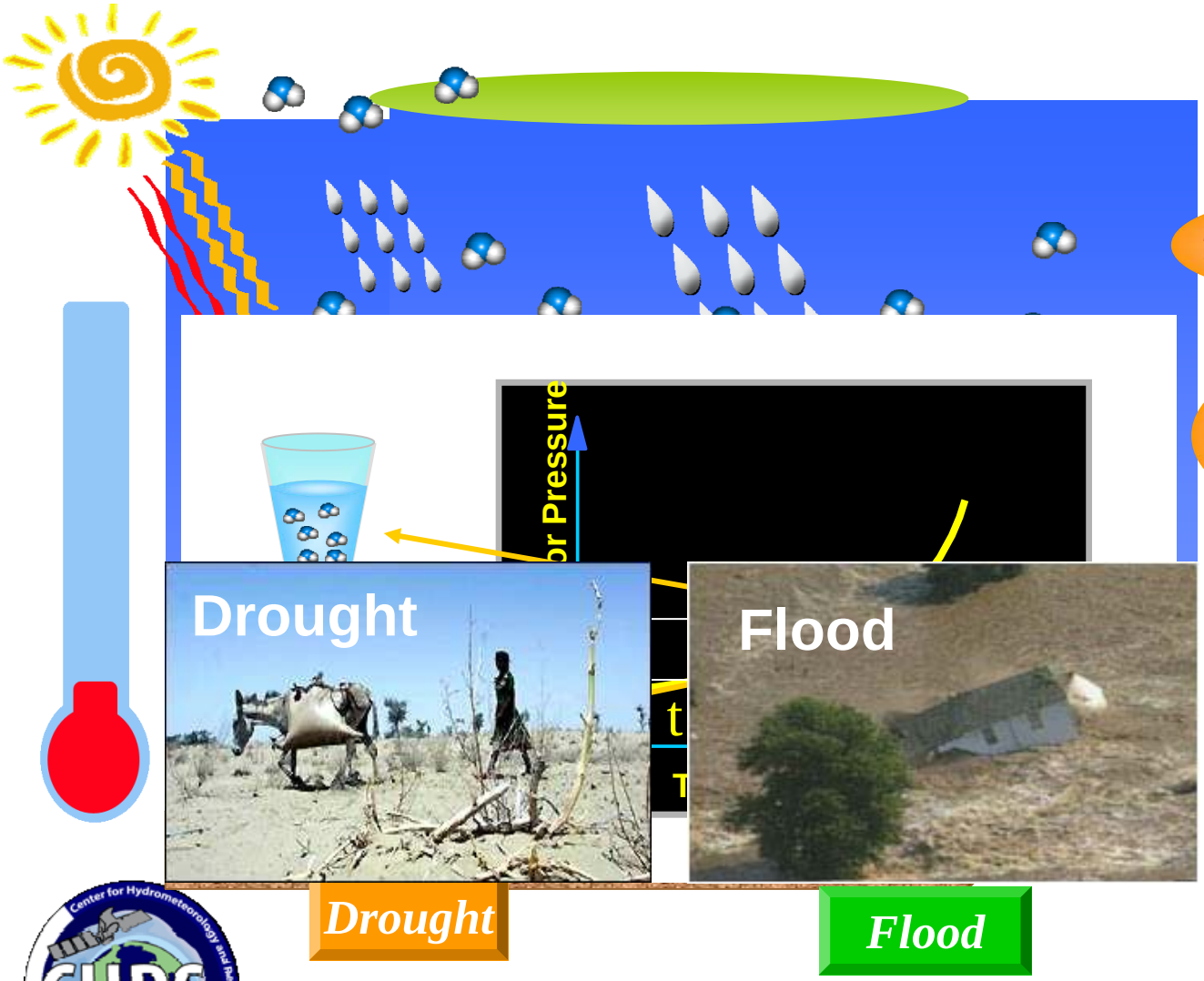
Climate, Hydrology and Water Resources

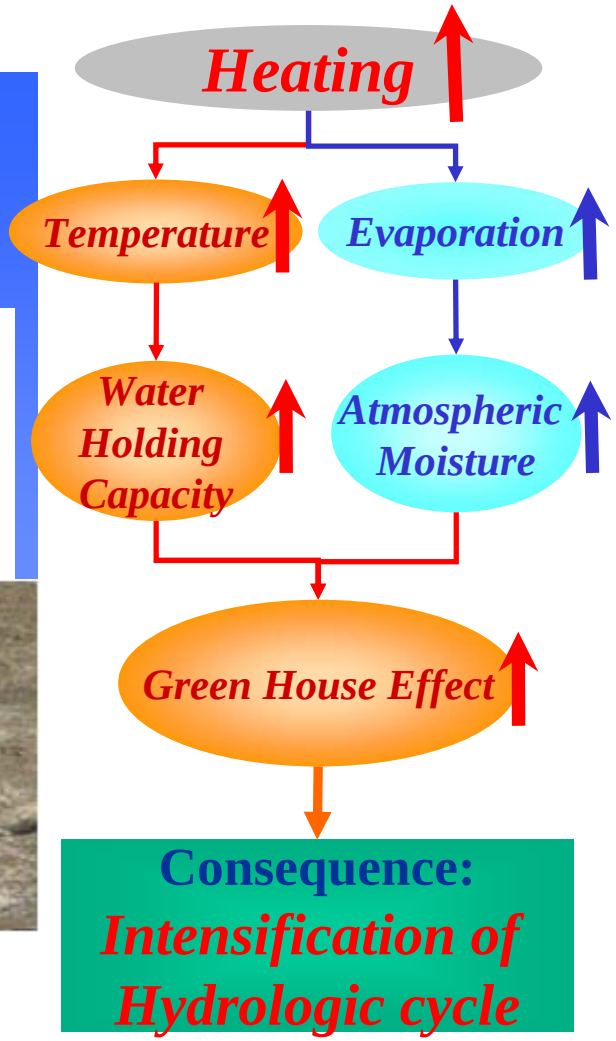
- ***How will Climate effect water Availability?***

- ***Can we predict the future changes which are responsive to "user" needs?***



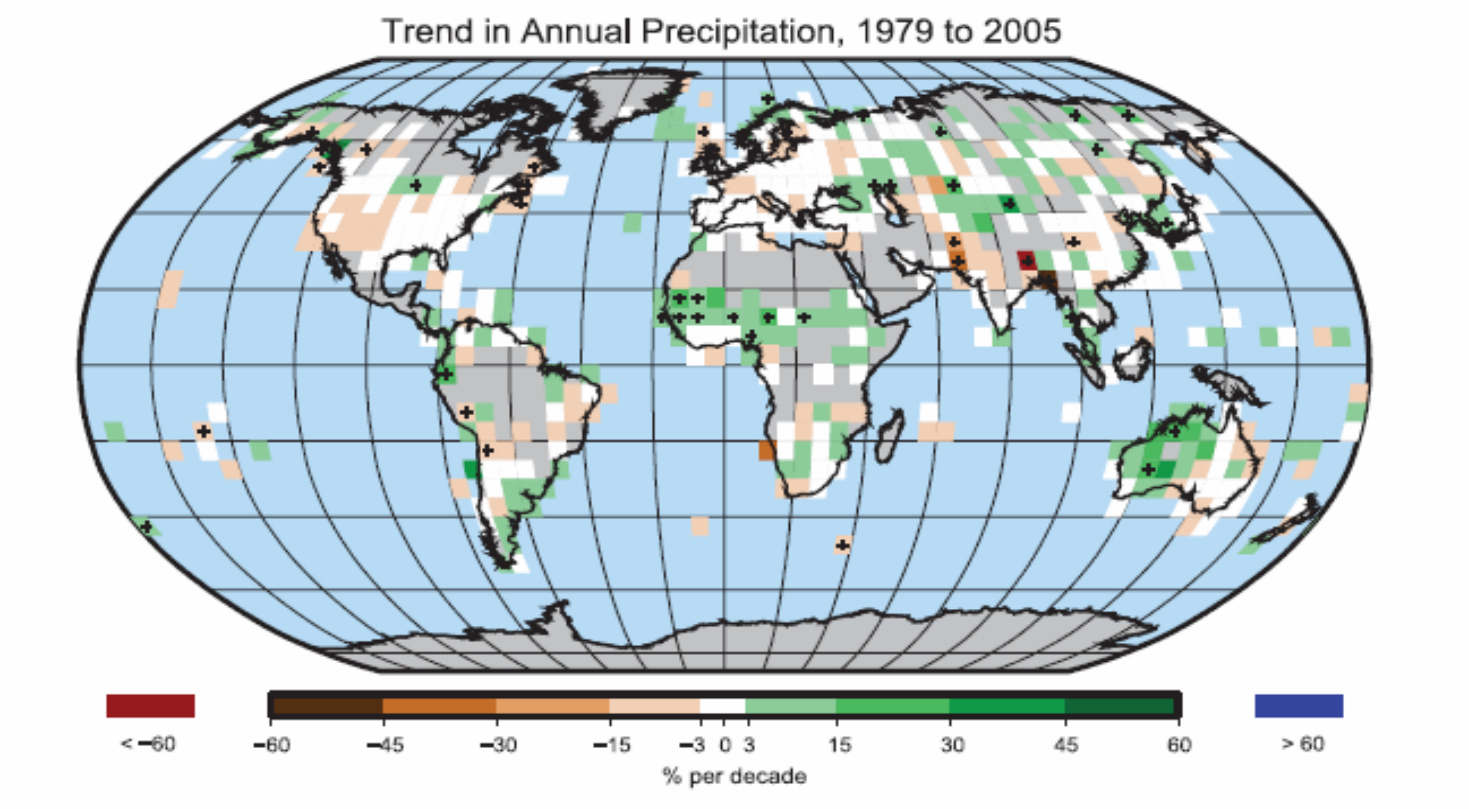
Global Warming And Hydrologic Cycle Connection





Source: Gi-Hyeon Park

Trend in Annual Precipitation, 1979 to 2005

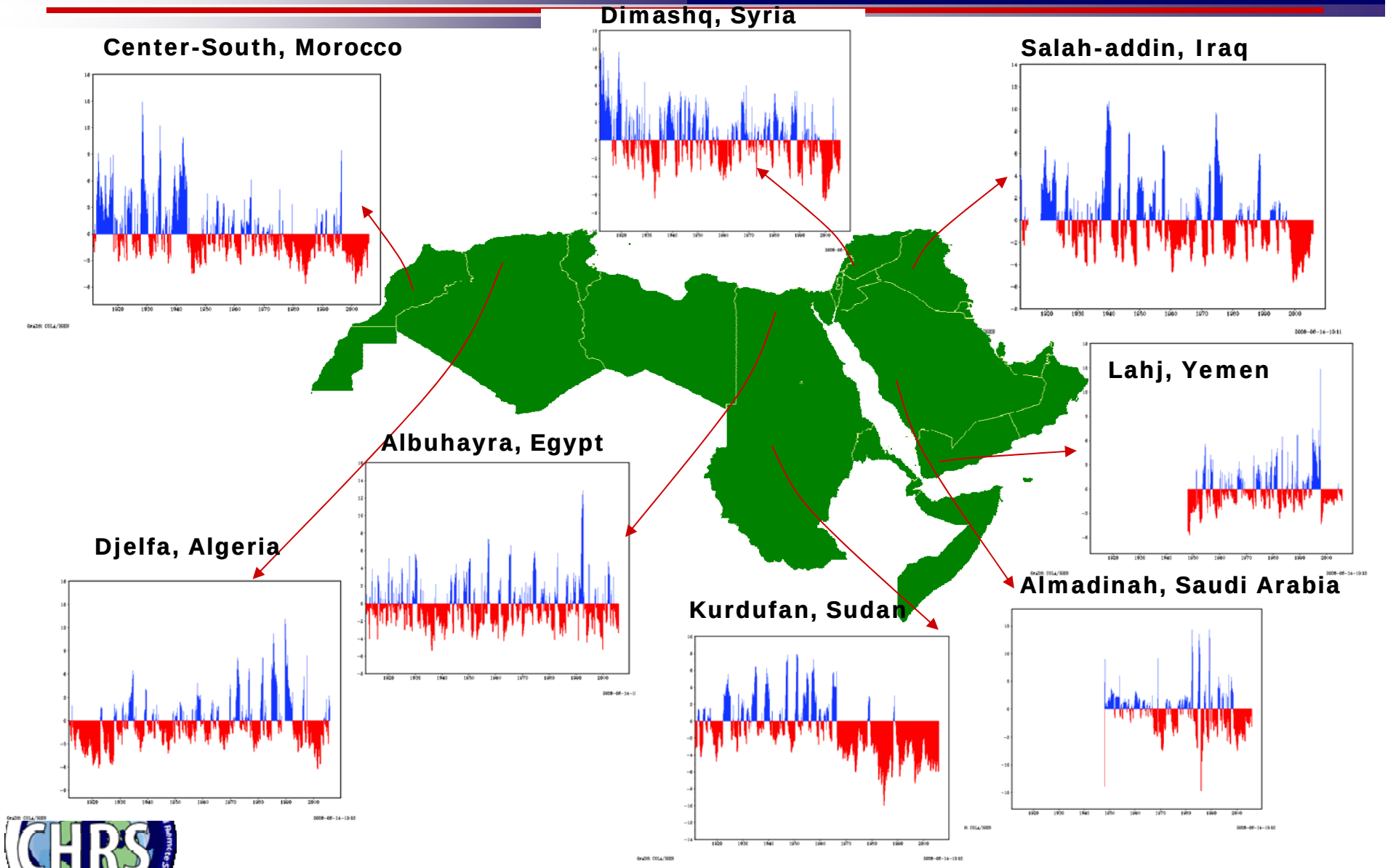


Record Floods: Among the worst Natural Disasters

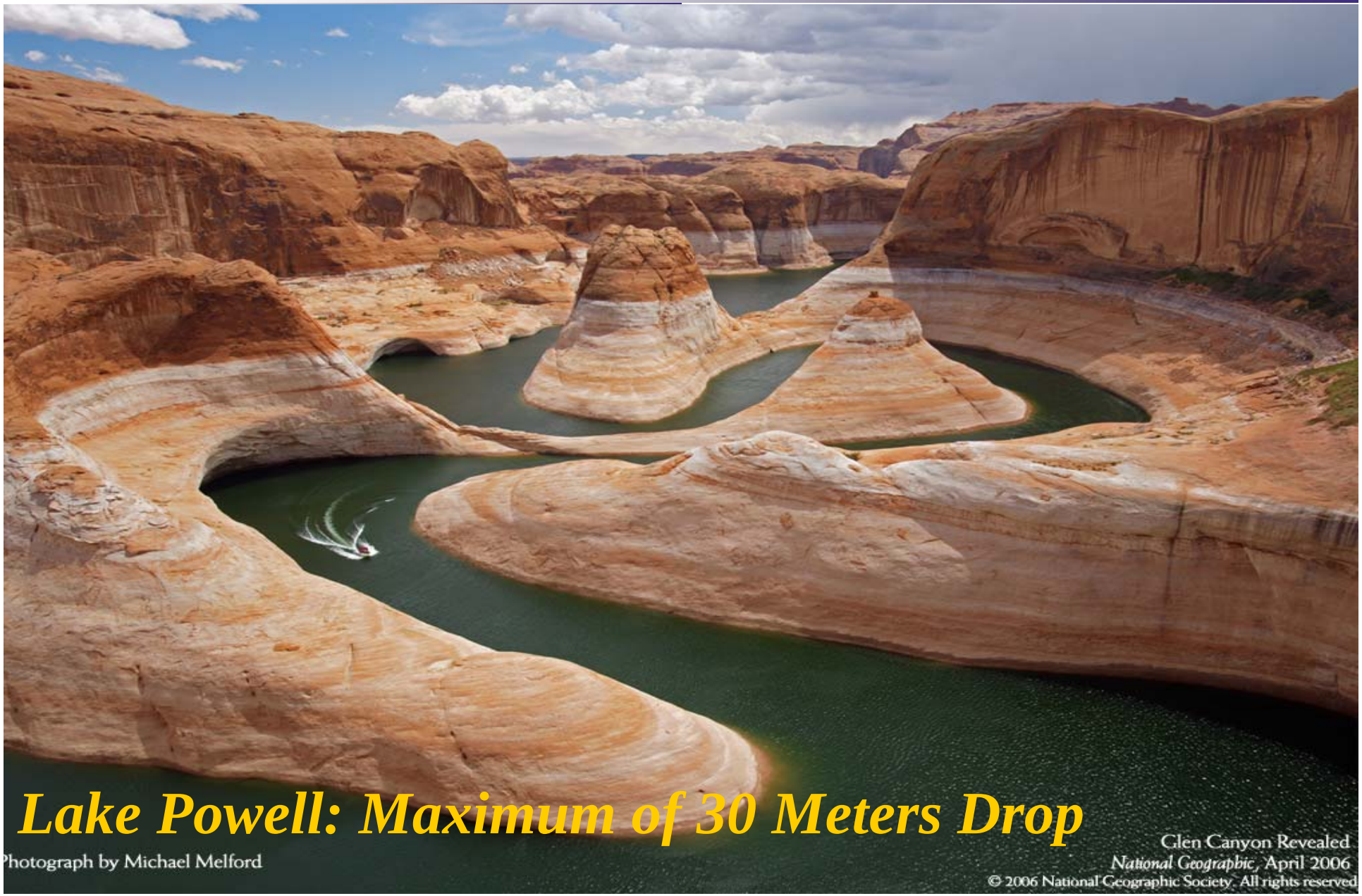
Flooding in Tana River Valley, Kenya, due to extended and unseasonal rain

More Powerful Hurricanes are Occuring!

Drought Patterns in Selected Regions (1920-2005)

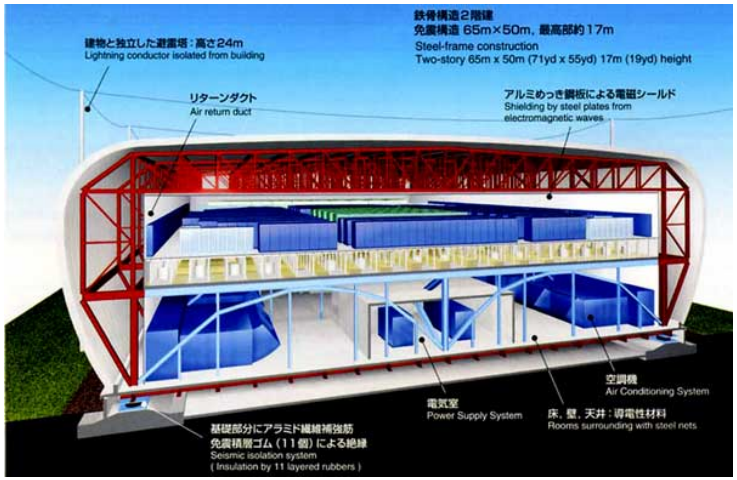


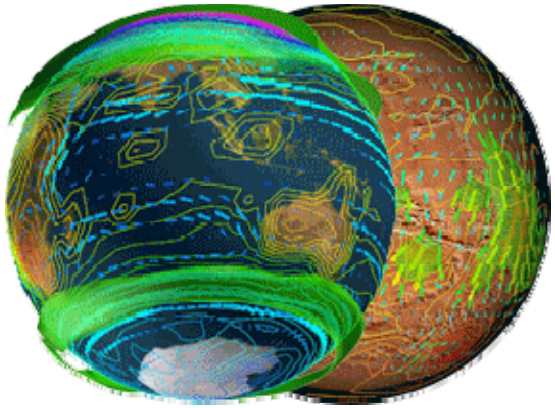
Recent Extreme Drought Conditions in the U.S. Southwest



Lake Powell: Maximum of 30 Meters Drop

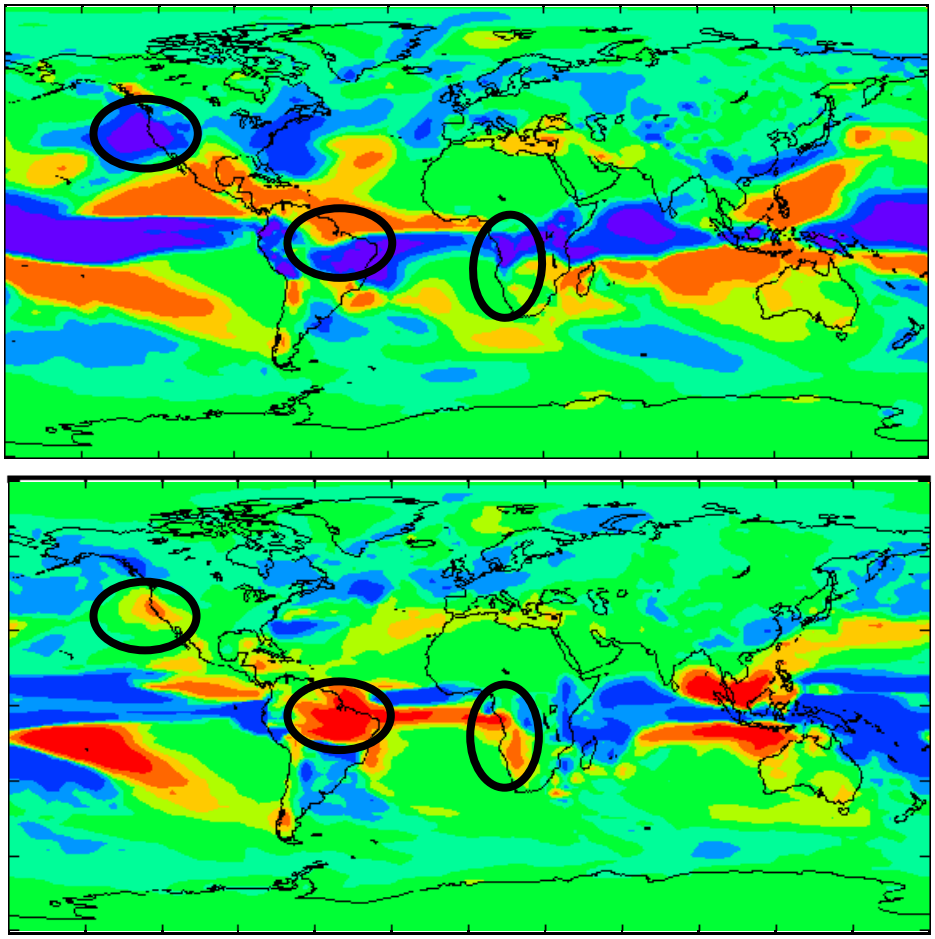
Climate Predictions into the Future!





Some Results from Long Time-Scales

Climate model Predictions about the future? → globally



DJF Precipitation Changes
CM2 - Old model

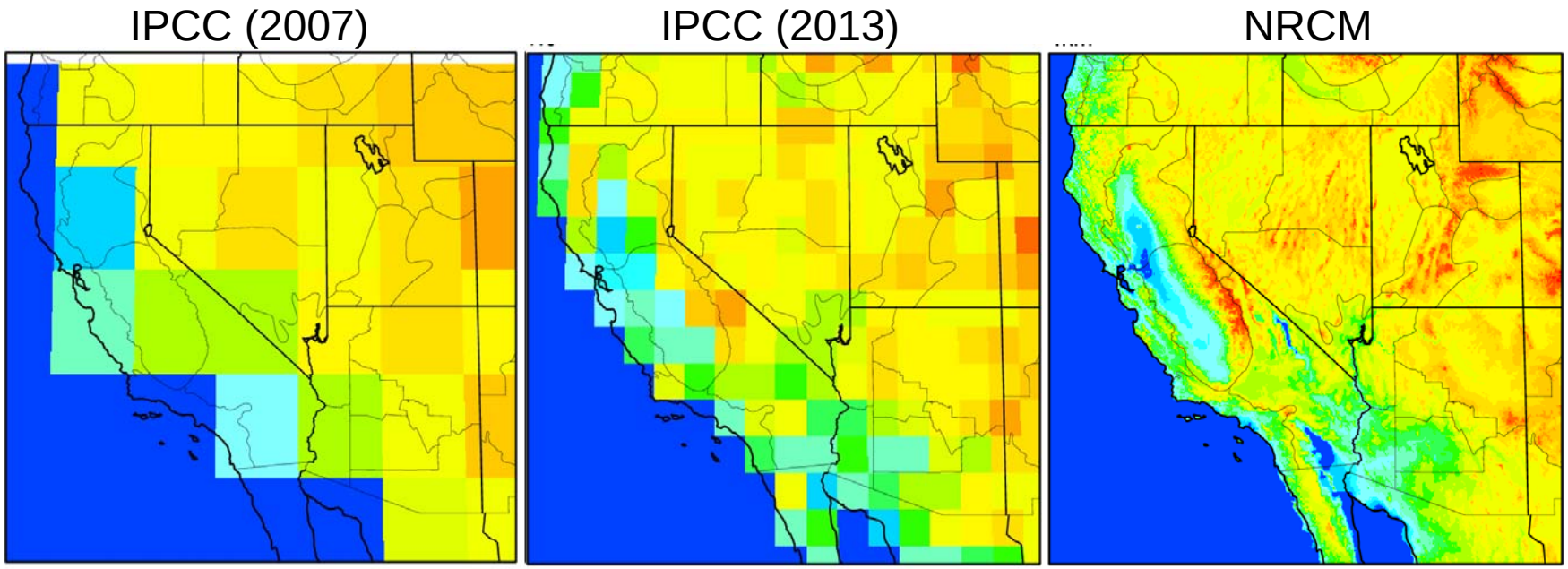
CM3 - Updated model

Significant differences in regional outcomes!

Source: Hadley Center (Climate Change Projections)

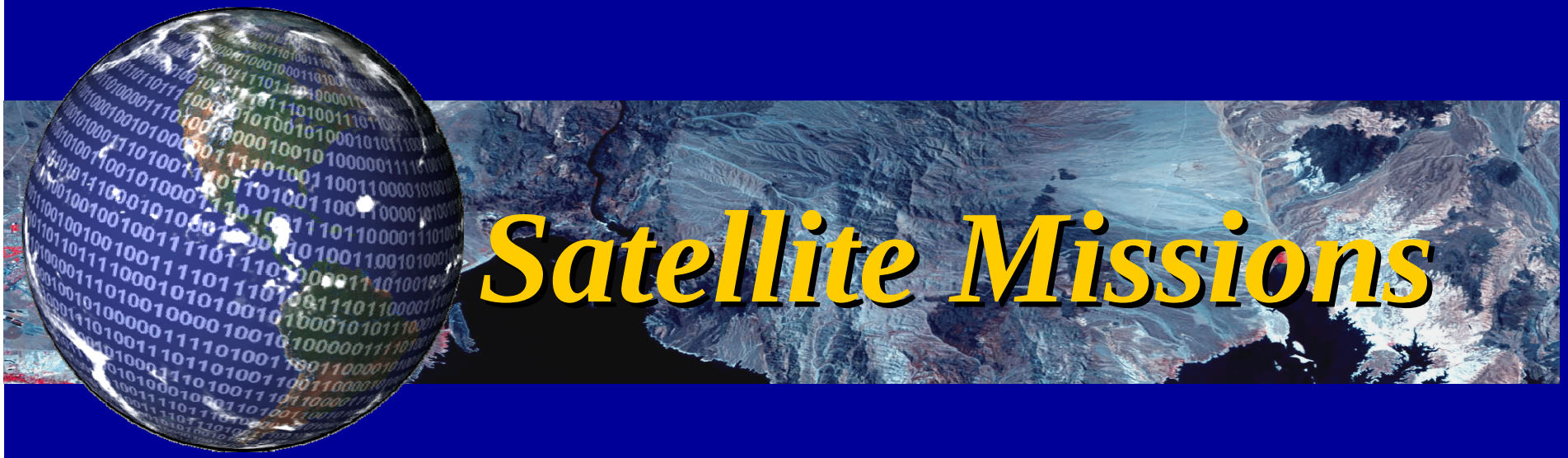
The Nested Regional Climate Model

High Resolution Climate Modeling

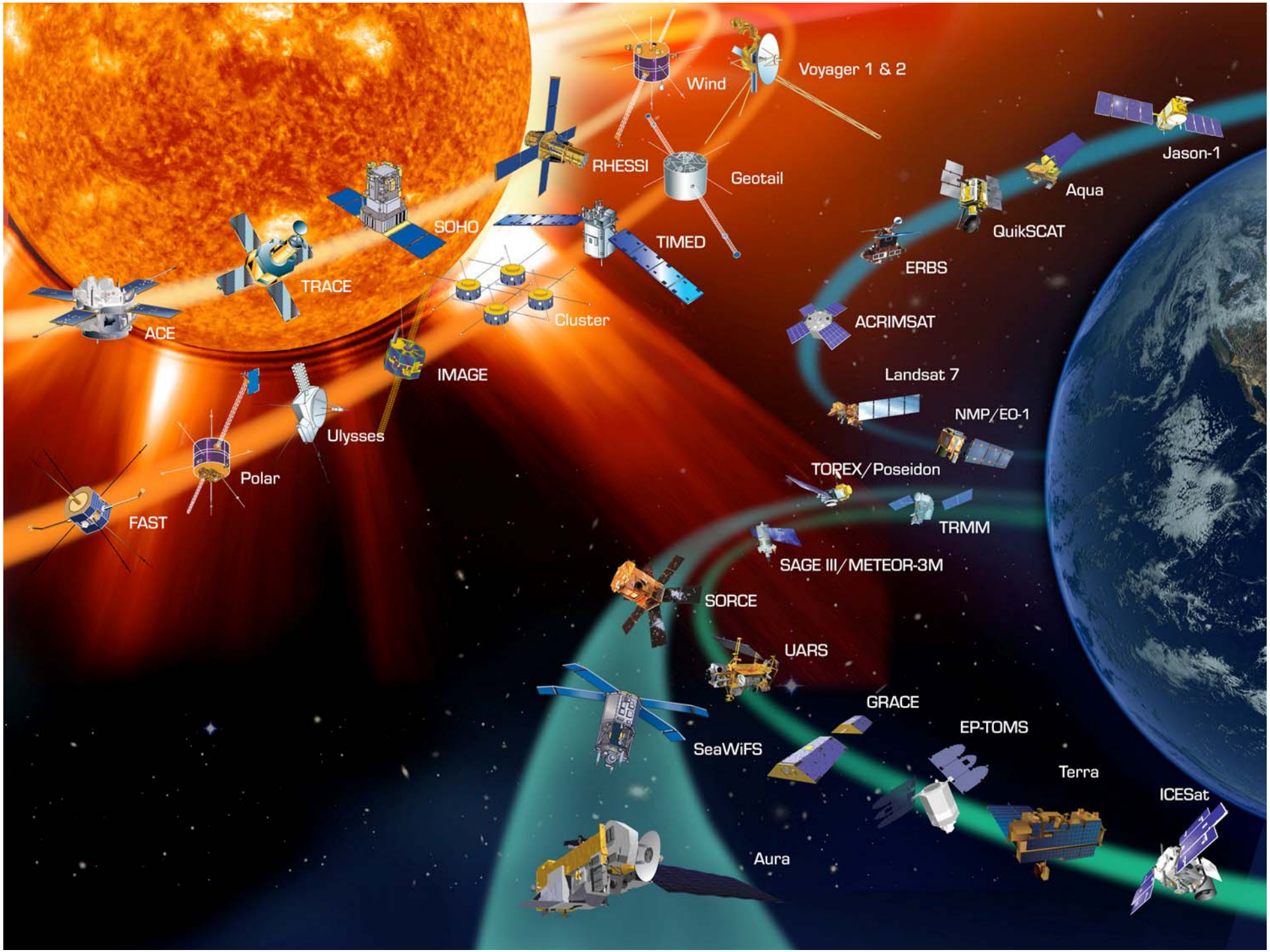


Source: Dr. J Hurell – NCAR 2008

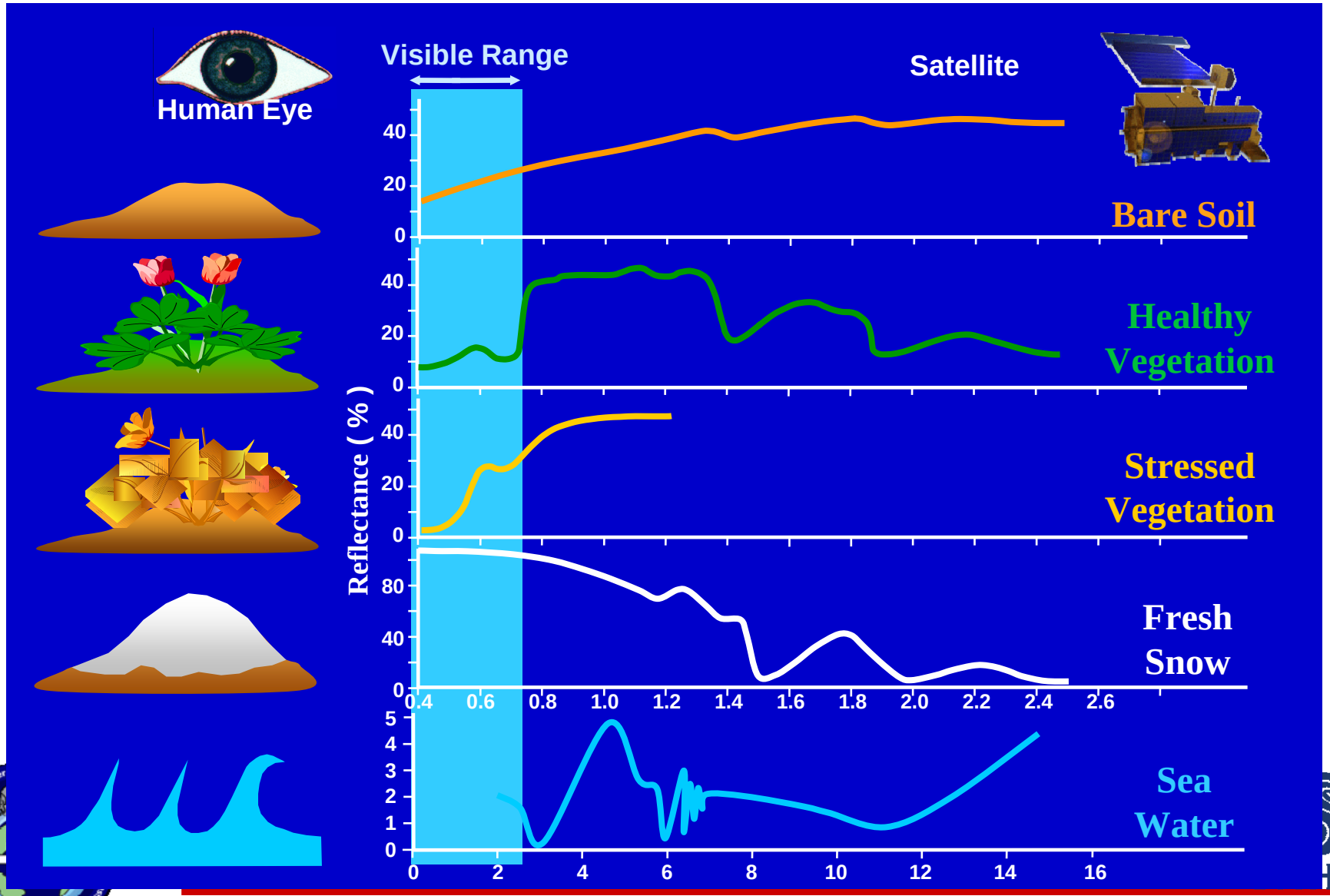
Remote Sensing Contributions



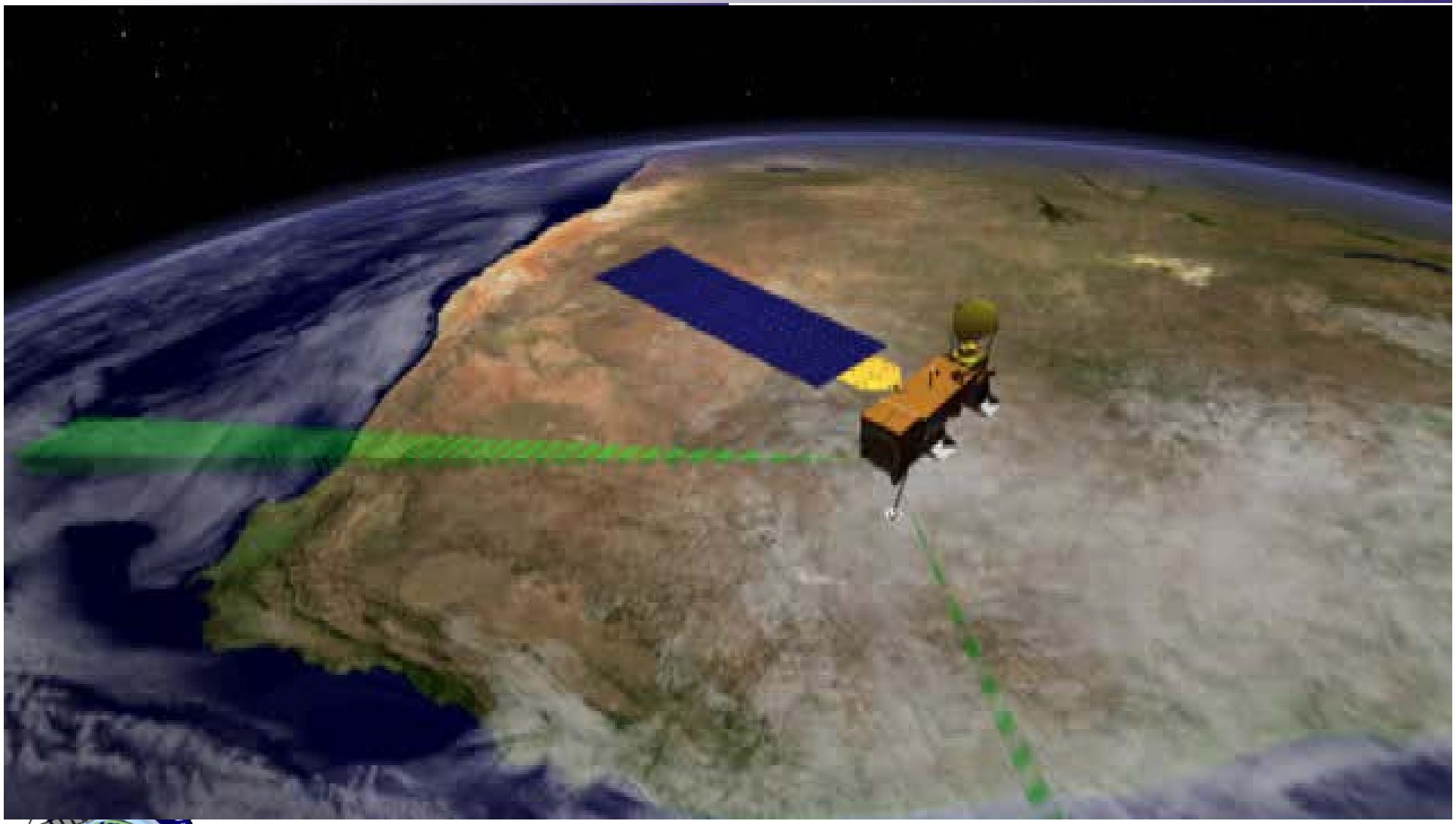
Satellite Missions


Wind
Voyager 1 & 2
RHESSI
Geotail
Jason-1
Aqua
SOHO
TIMED
QuikSCAT
ERBS
TRACE
ACE
Cluster
ACRIMSAT
IMAGE
Landsat 7
NMP/EO-1
Ulysses
TOREX/Poseidon
Polar
TRMM
FAST
SAGE III/METEOR-3M
SORCE
UARS
GRACE
SeaWiFS
EP-TOMS
Terra
ICESat
Aura

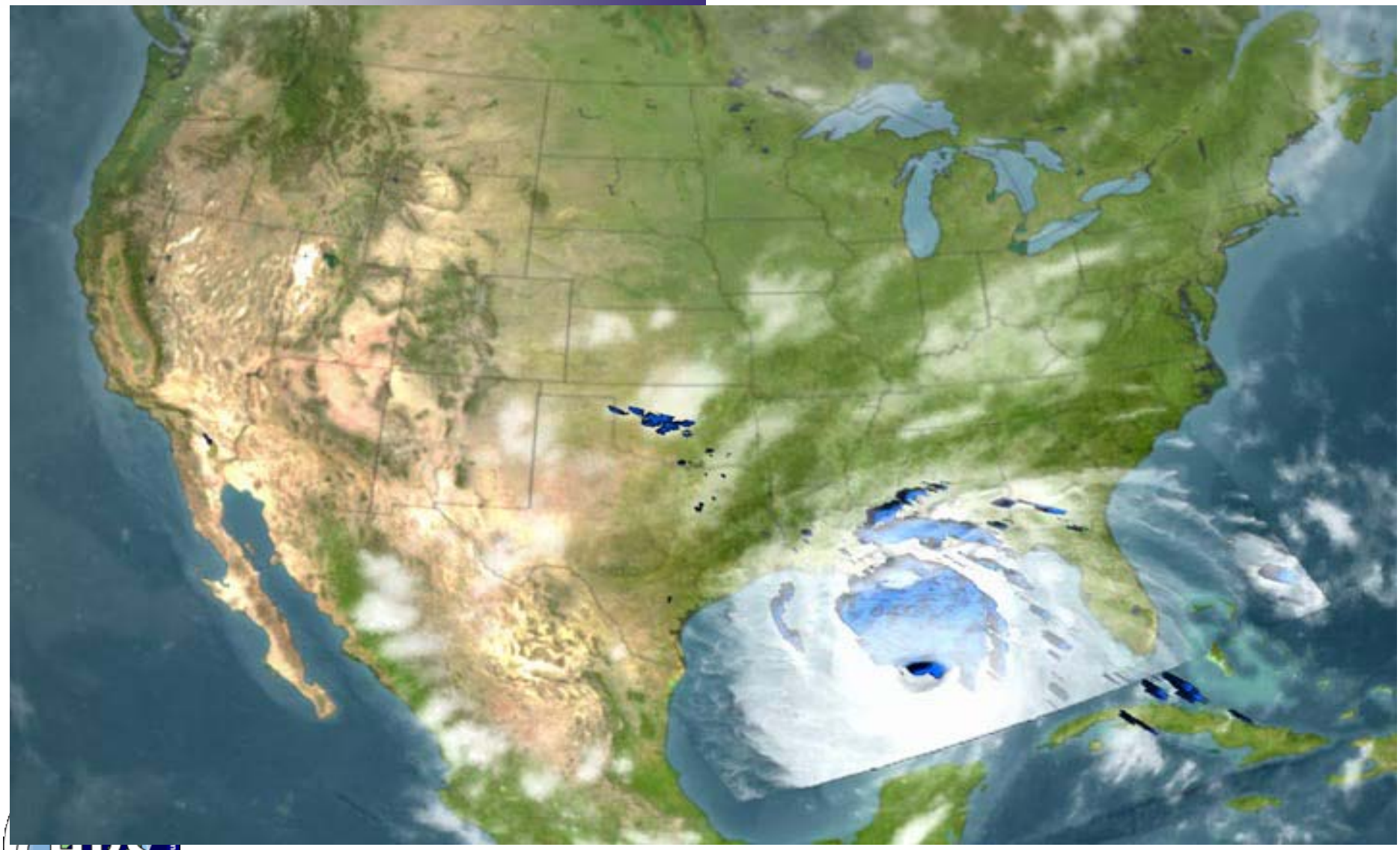
Remote Sensing Systems (Spectral Signal)



Different Instruments Measure Different Things



Hurricane Katrina from TRMM: August 28, 2005



The Role of the IAEA In Filling Critical Data Gaps

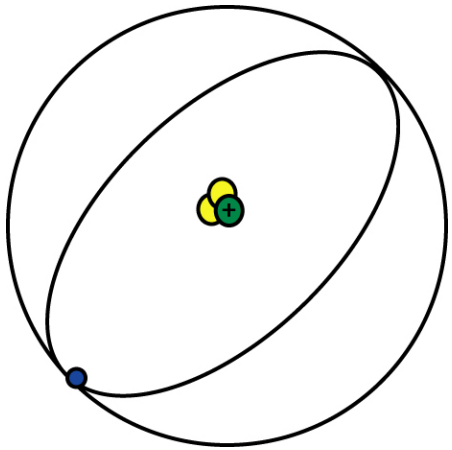
20/20 Vision for the Future: IAEA Director General's Report – February 2008

"the IAEA will facilitate the use of isotope hydrology and other nuclear tools to support the integrated management of water resources…"

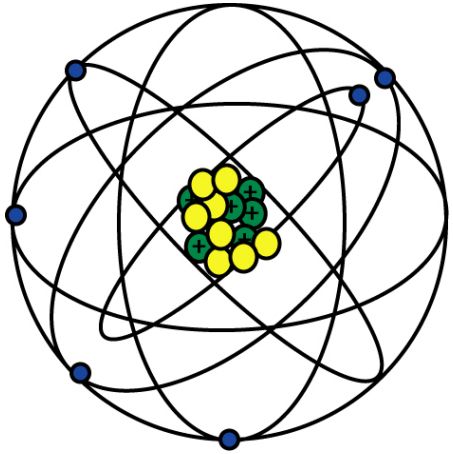
The Role of the IAEA In Water Resources Development:

1. *Provide the "Know-How" For Water Resources Monitoring*
2. *Reconstruction of Past Climate History*
3. *Safe Disposal of "Nuclear Waste" From Nuclear Power Plants*

IAEA Hydrology Program

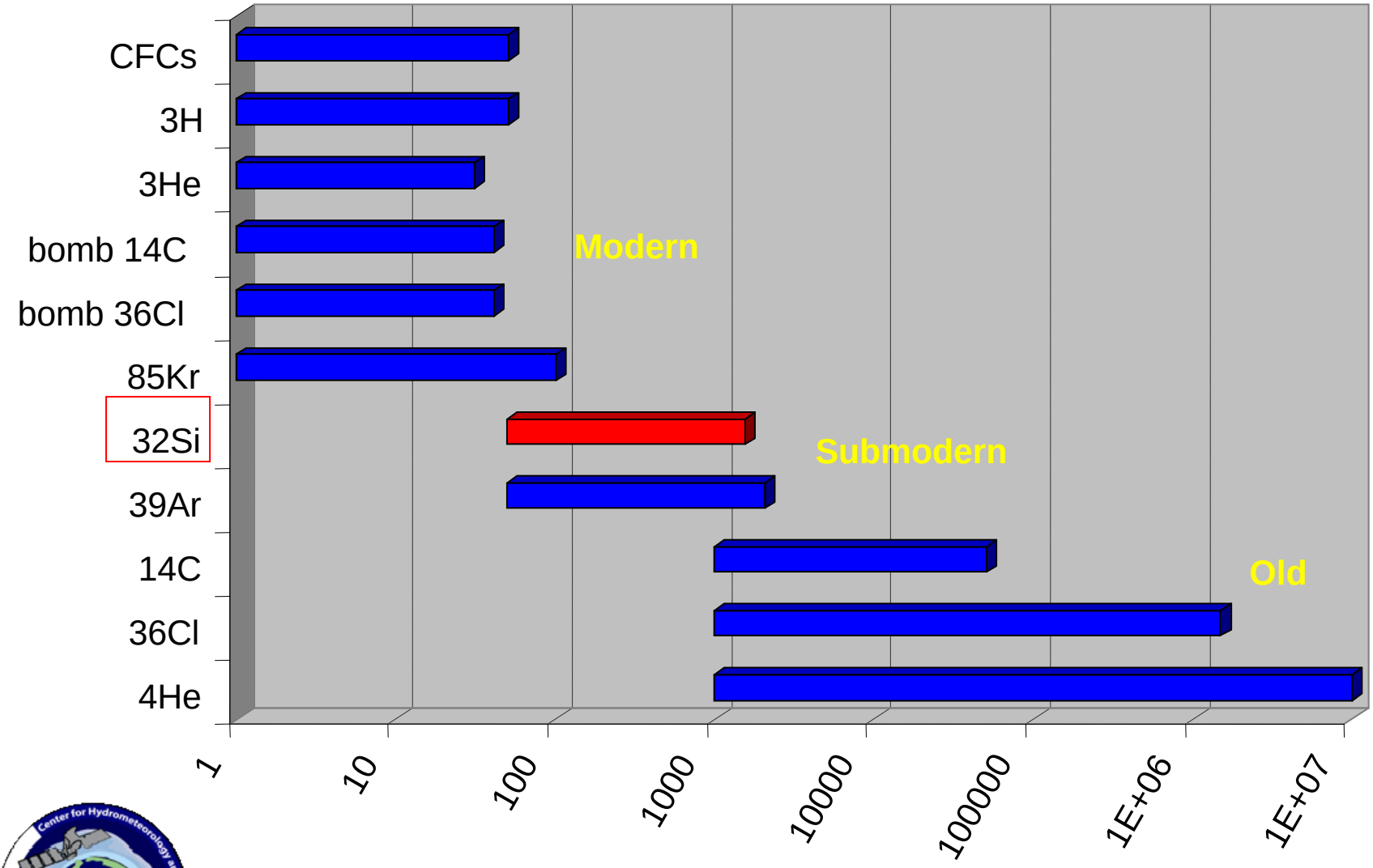


Tritium
$t_{1/2}$=12 yrs
Recent recharge



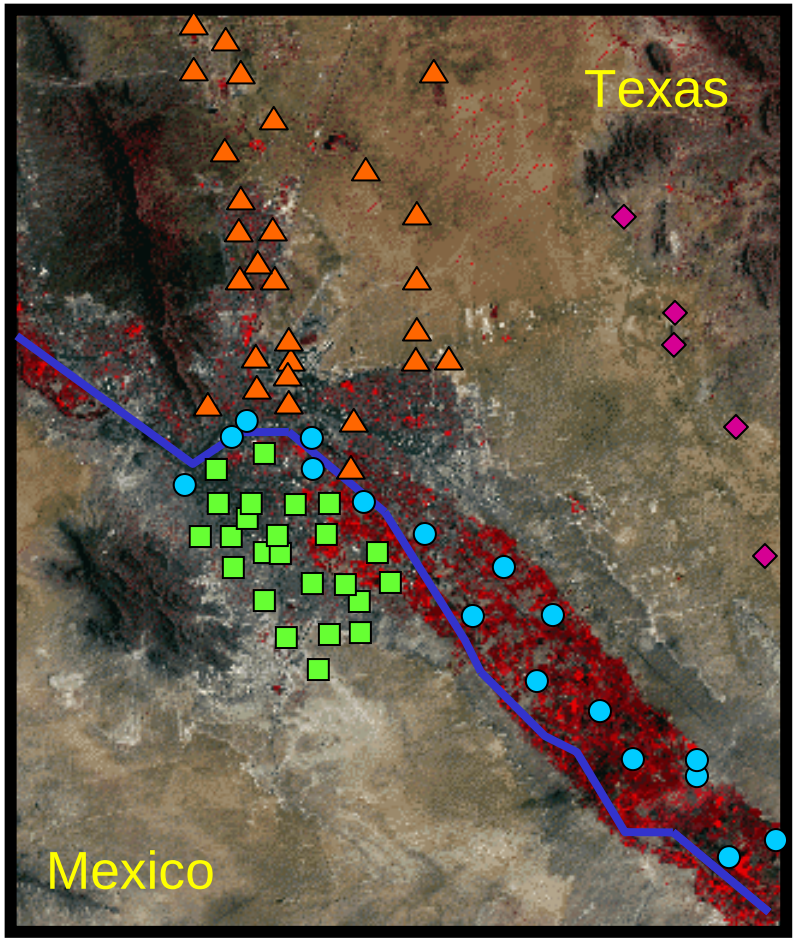
Carbon-14
$t_{1/2}$=5730 yrs
Long-term recharge

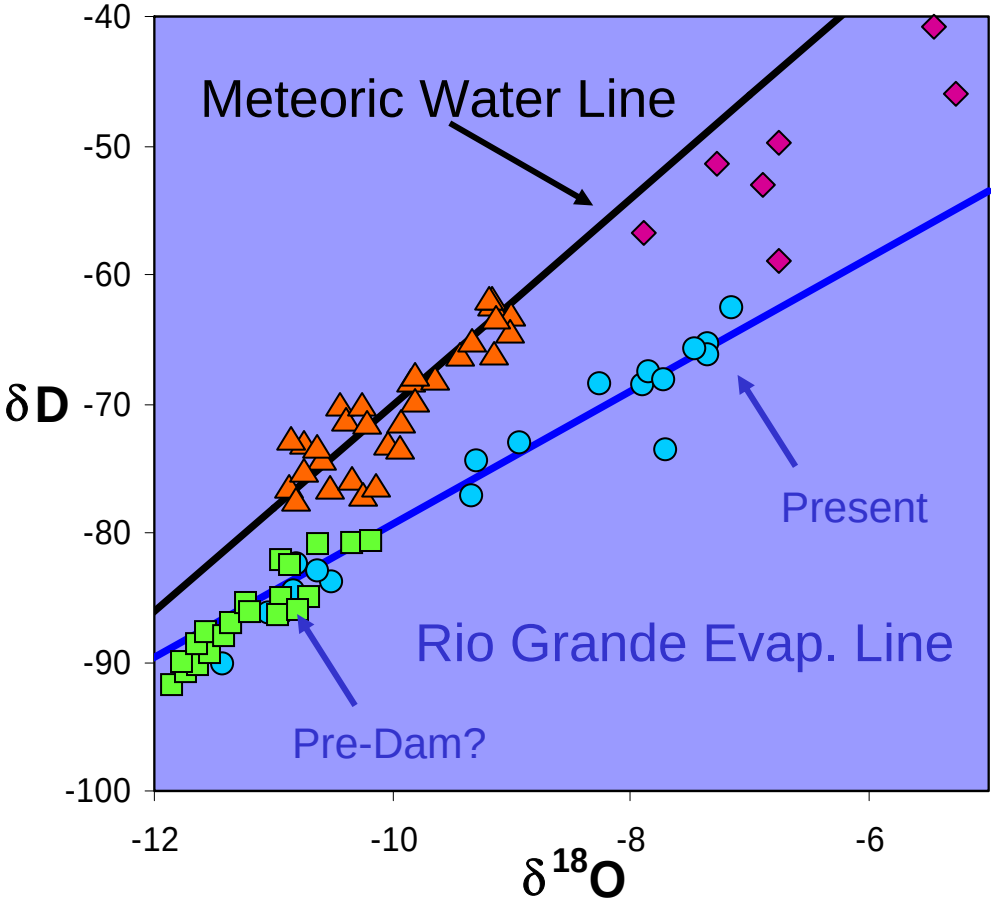
Ground Water Recharge can be studied over many time scales



Age Range of Tracer Applicability

Tracing Recharge Sources to Ground Water





→ River development may have greatly decreased recharge for Juárez

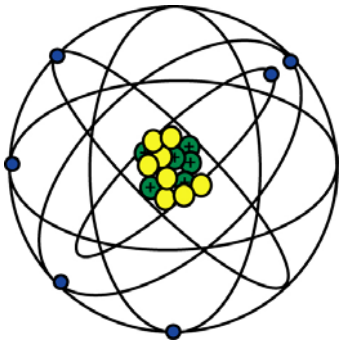
Slide content from Hibbs, Eastoe, Grandados, Dadakis & Hogan

The Role of the IAEA In Water Resources Development:

1. *Provide the "Know-How" For Water Resources Monitoring*
2. *Reconstruction of Past Climate History*
3. *Safe Disposal of "Wasted Fuel" From Nuclear Power Plants*

Reconstruction of Proxy Records of Droughts:

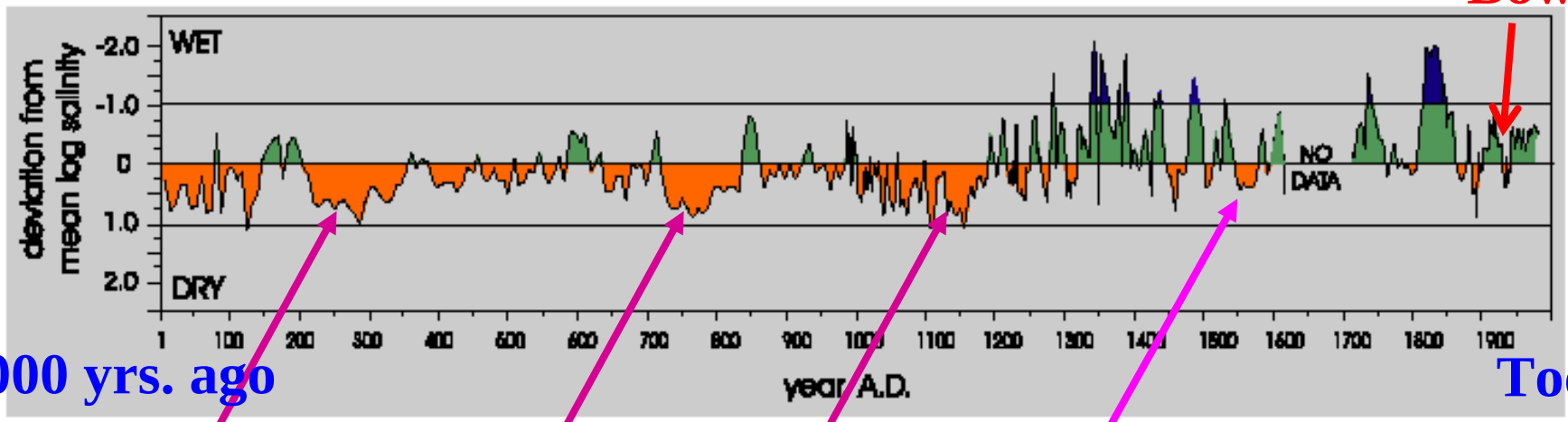
- Analysis of Salt Isotopes from Dry Lake Beds



2000-year Climate history of central U.S.

The US Breadbasket: The Mid-West

Dust Bowl



2000 yrs. ago

Today

16th century "megadrought"

100 year "megadroughts"

Source: Overpeck 2004

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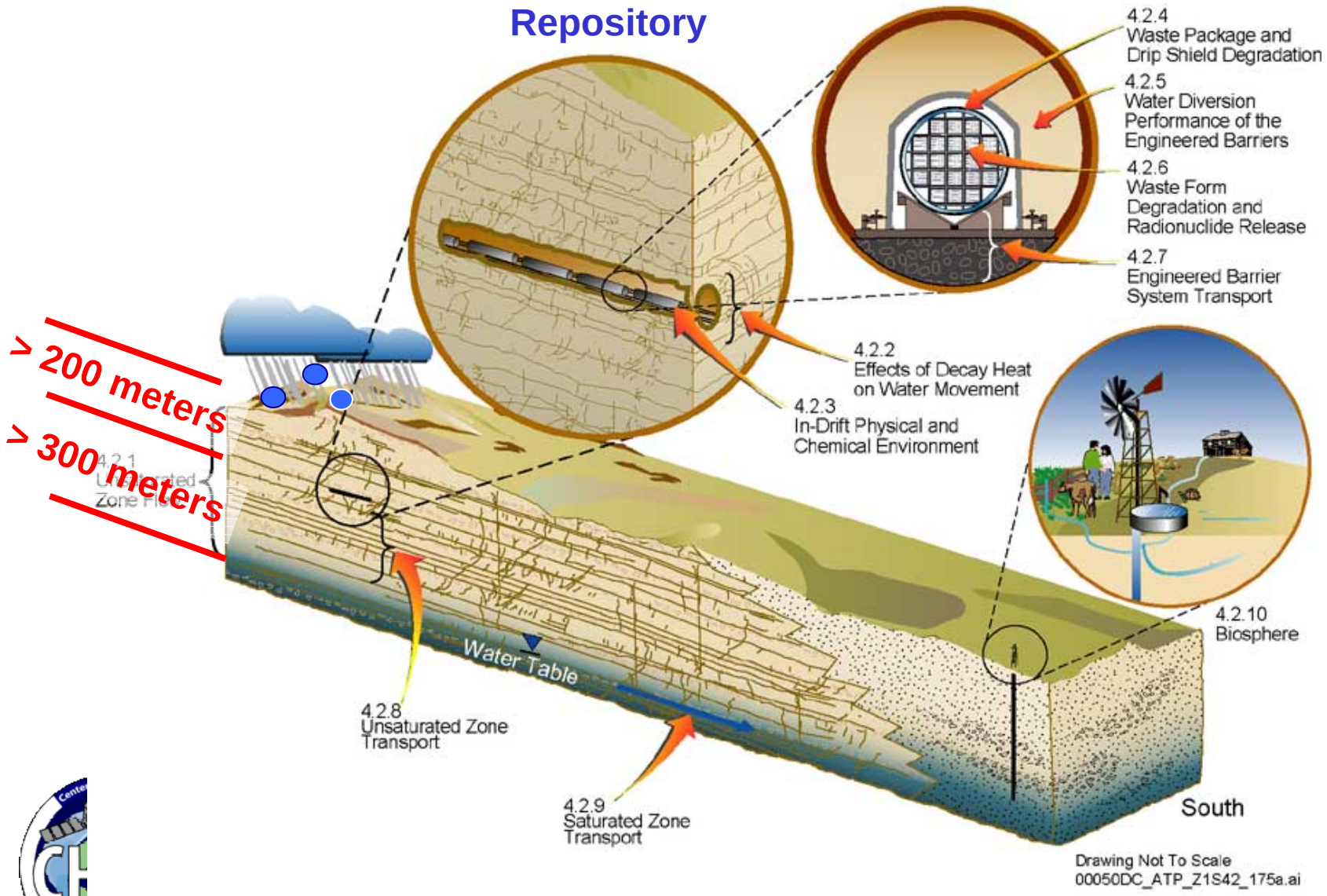
Climate Scenarios Used in Decision making: Yucca Mtn.

Simulation of Net Infiltration Over the Proposed Nuclear Waste Repository Site: Yucca Mountain, Nevada

(Time Horizon: 10,000 years)

Yucca Mountain: Nuclear Waste Repository



Thank You for Your Attention

A Birdseye View of The Earth: A Unique Planet!