"Sources of Climate Variation and the Importance of Monitoring"

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Iranian-U.S. Workshop on Water Management

National Academies Beckman Center, Irvine – California

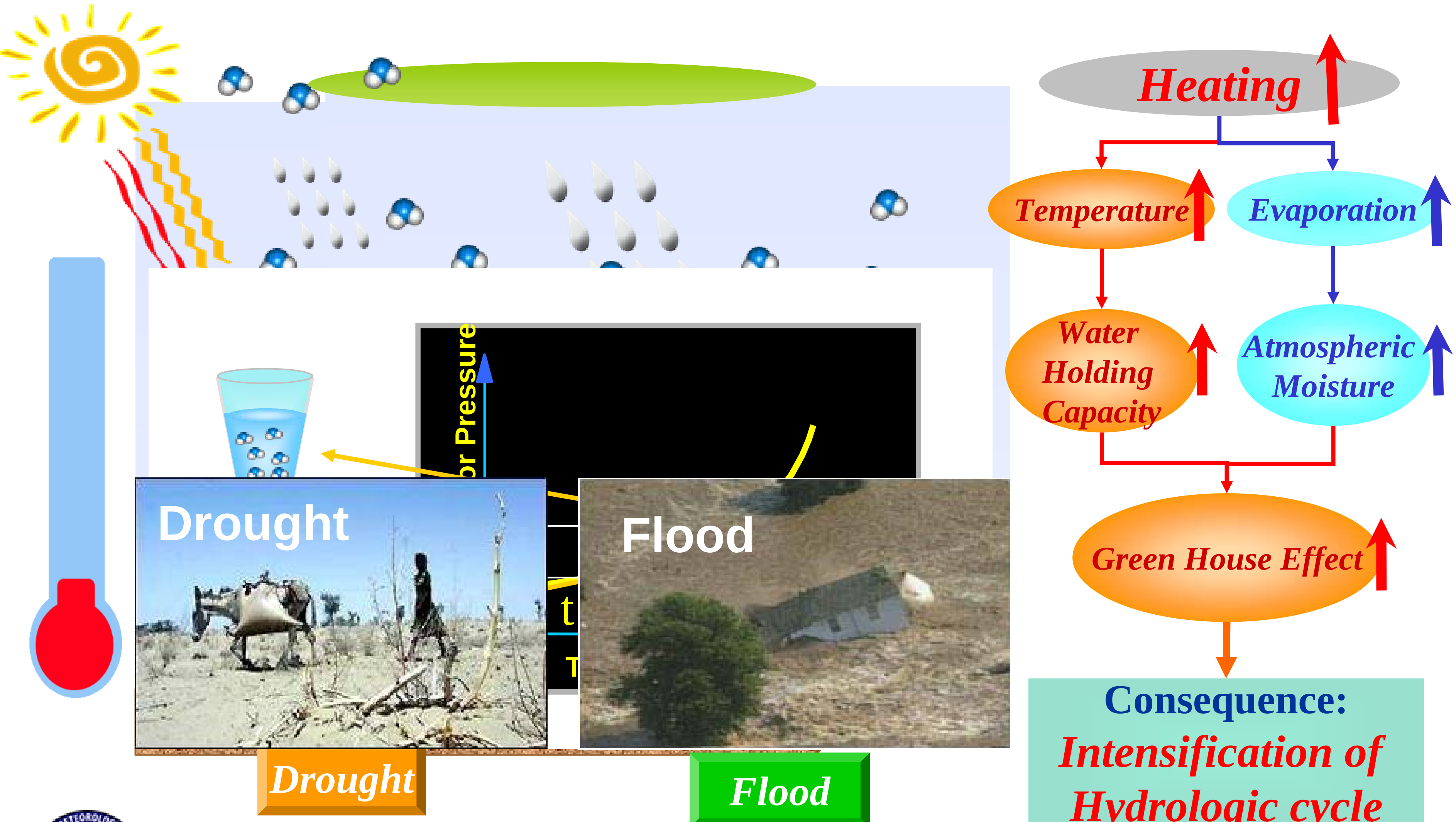
August 18- 20, 2008

CHRS & Affiliates: A truly International Team

University of California Irvine (UCI) and Arizona (UA)

May 2005 Drought Workshop - Iran

Climate And Hydrologic Cycle Connection



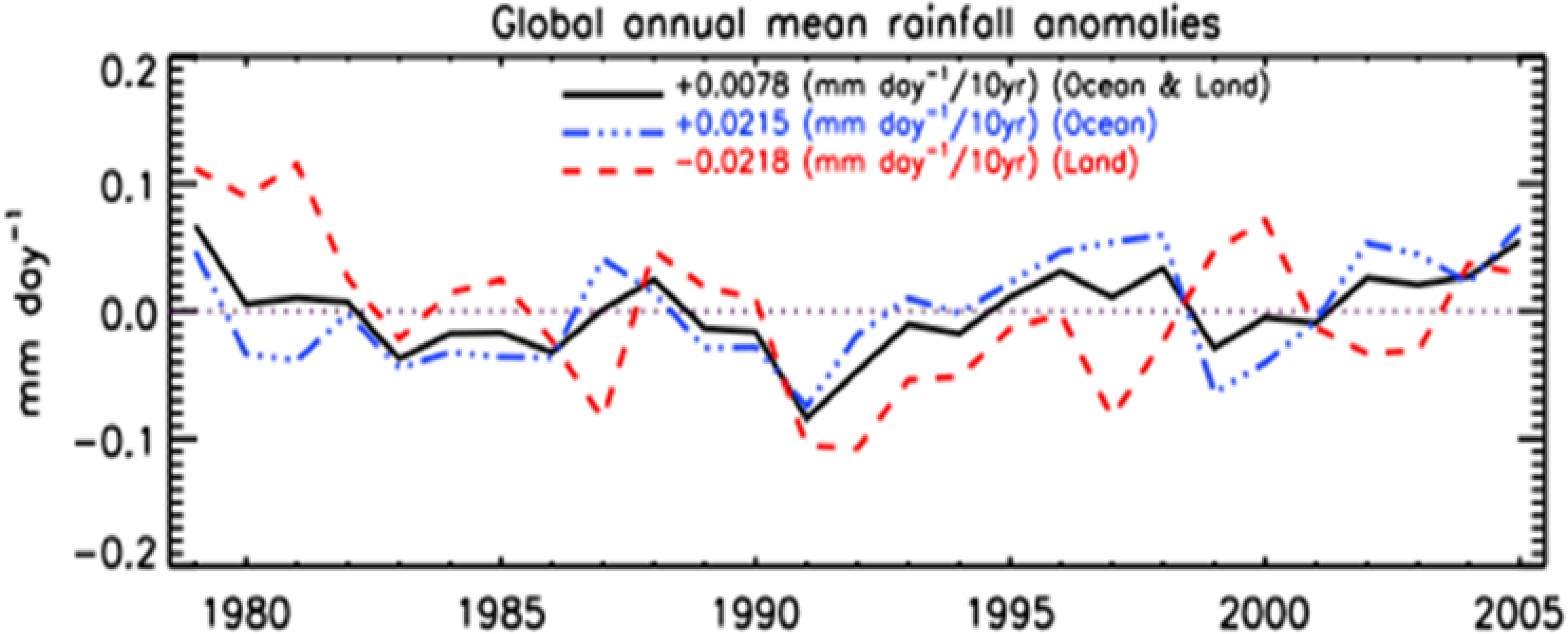
Consequence:

Intensification of Hydrologic cycle

Source: Gi-Hyeon Park

Global Variations in Precipitation (1979-2005) 90N-90S

Global mean = 2.6 mm/d *(Ocean [2.8 mm/d] Land[2.1 mm/d])*



- ***Little or no linear change during period [biggest change is +2% over ocean]***
- ***Ocean and land precipitation tend to compensate***

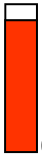
Adler et al. J. Hydromet.

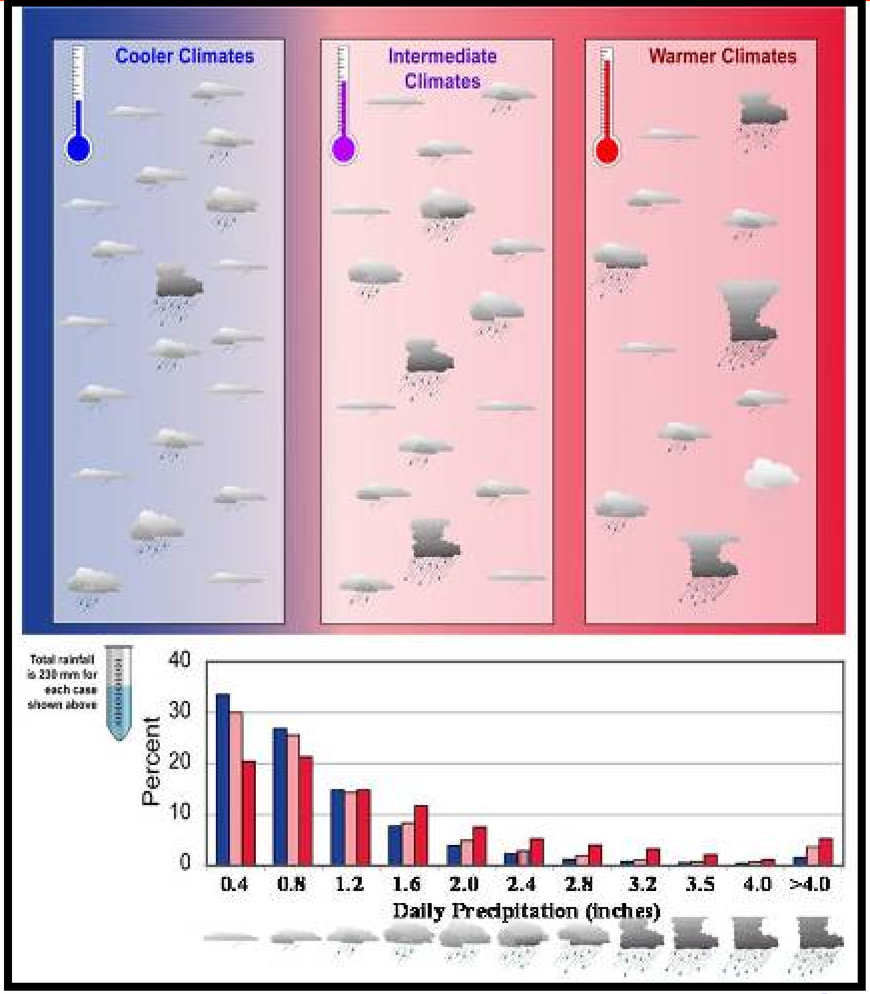
Observed changes: Heavy Precipitation

Facts from Observations

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

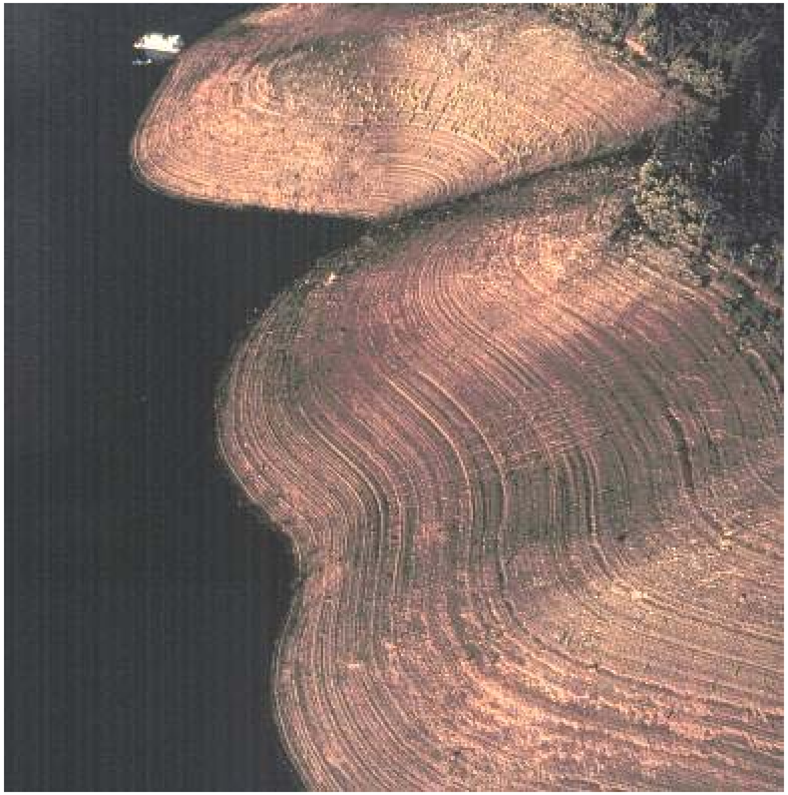
- Rainfall associated with warmer climates are more due to extreme events compared to colder climates





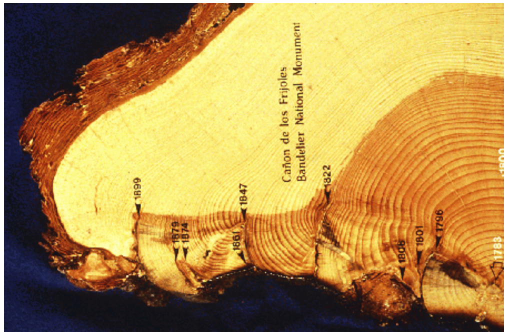
Source: Tom Karl NCDC-NOAA 2007

Droughts In Historical Context

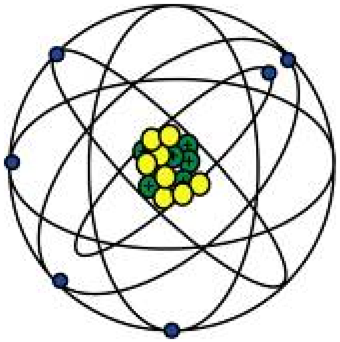


Reconstruction of Proxy Records:

- From Tree Rings



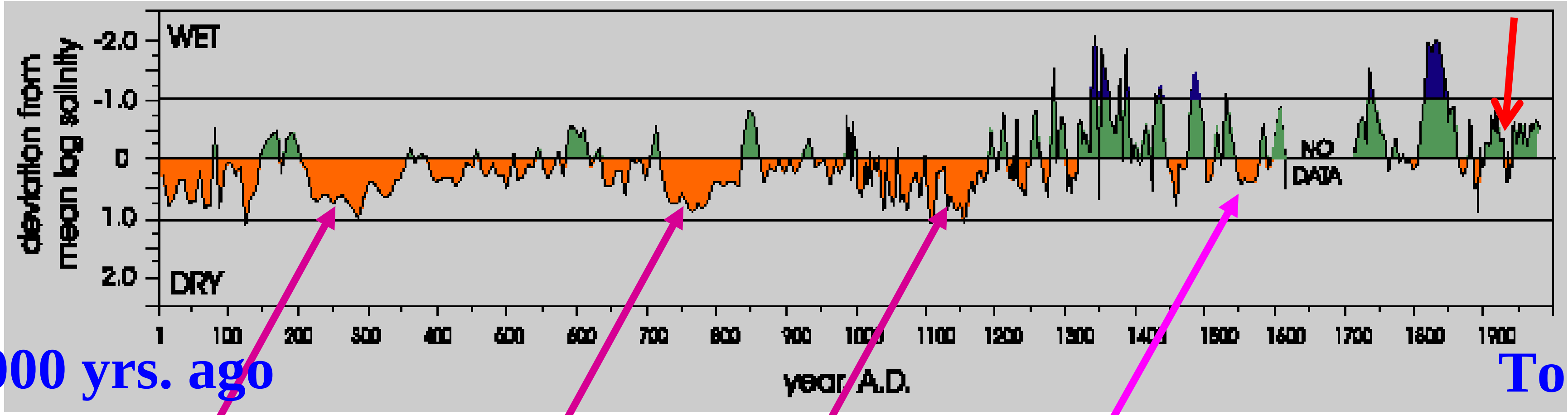
- Analysis of Salt Isotopes from Dry Lake Beds



2000-year Climate history of central U.S.

The US Breadbasket: The Mid-West

Dust Bowl



2000 yrs. ago

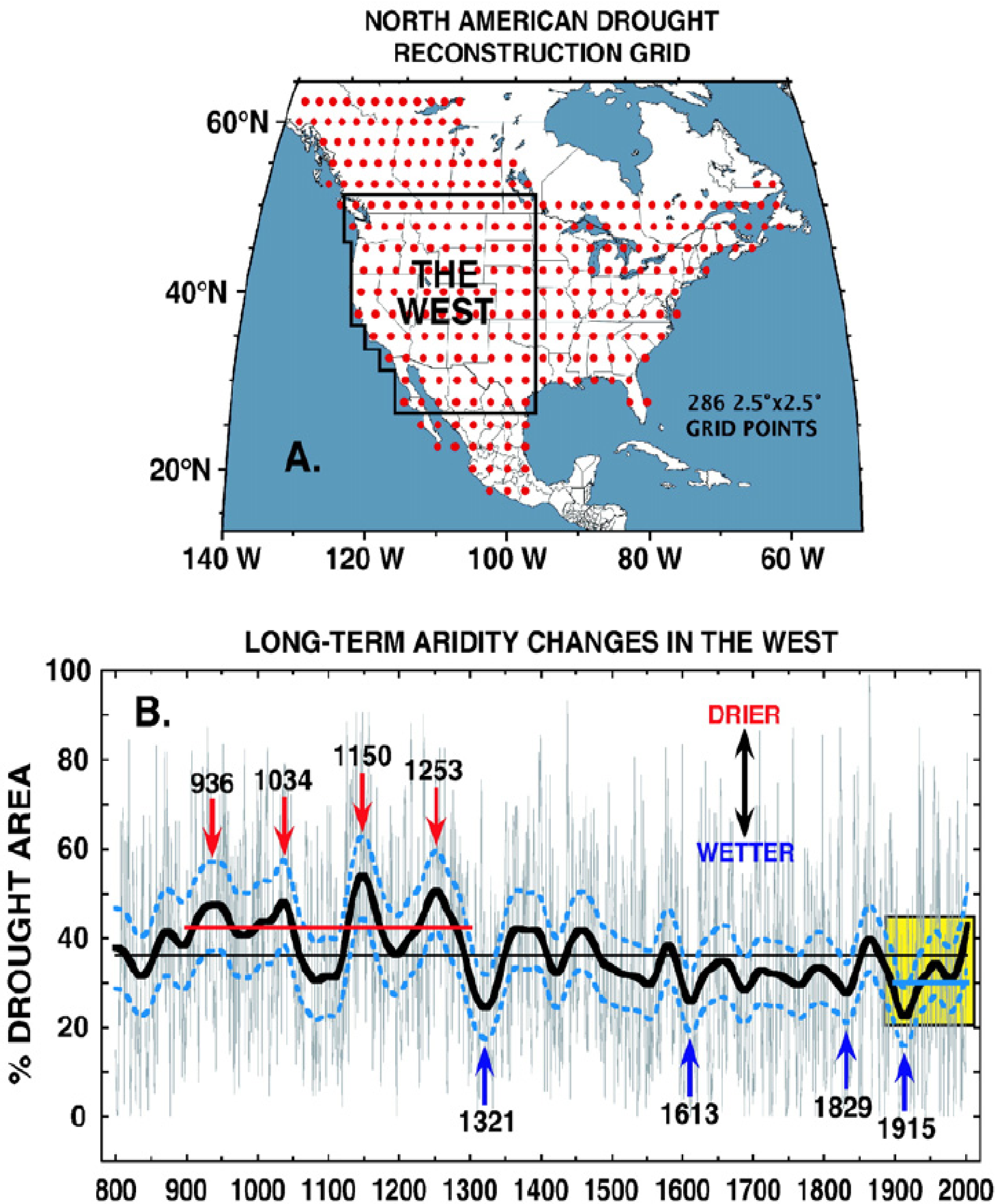
Today

16th century "megadrought"

100 year "megadroughts"

Source: Overpeck 2004

E.R. Cook et al. / Earth-Science Reviews 81 (2007) 93–134



Overall, the period from circa 900 to 1300 was a multi-century period of generally drier conditions throughout the West, including droughts of magnitude and duration not yet experienced in modern period.

Provided By Swetnam & Hughes
UA Tree Ring Lab

Practices in Factoring in Climate and Extreme Hydrologic Events in Water Resources:

Engineering Approach:

Control, Store, Use & Deliver for Multi-Purposes

CENTER FOR HYDROMETEOROLOGY & REMOTE SENSING
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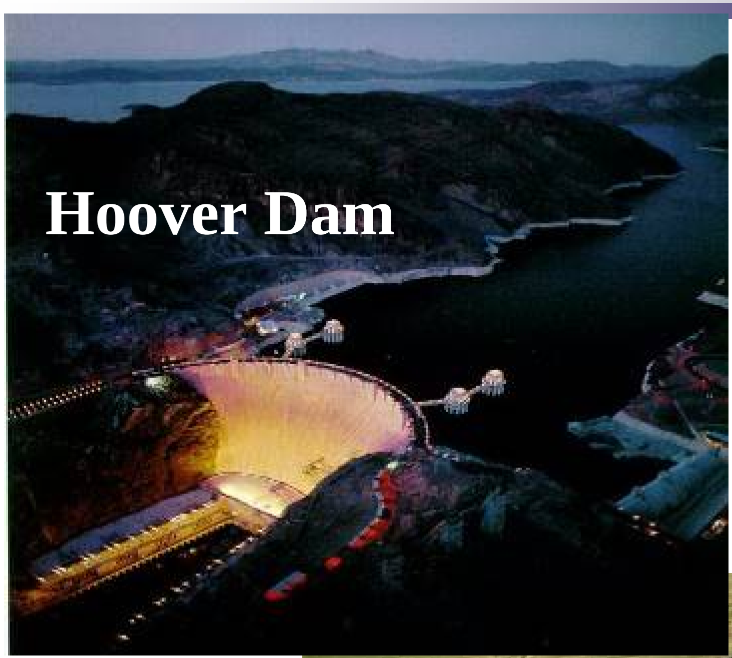
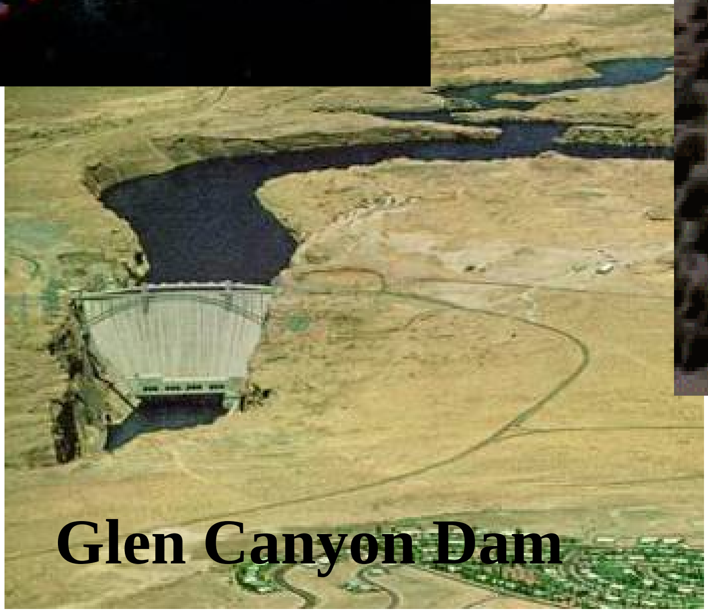
A Century of Water Resources Development: Engineering success!



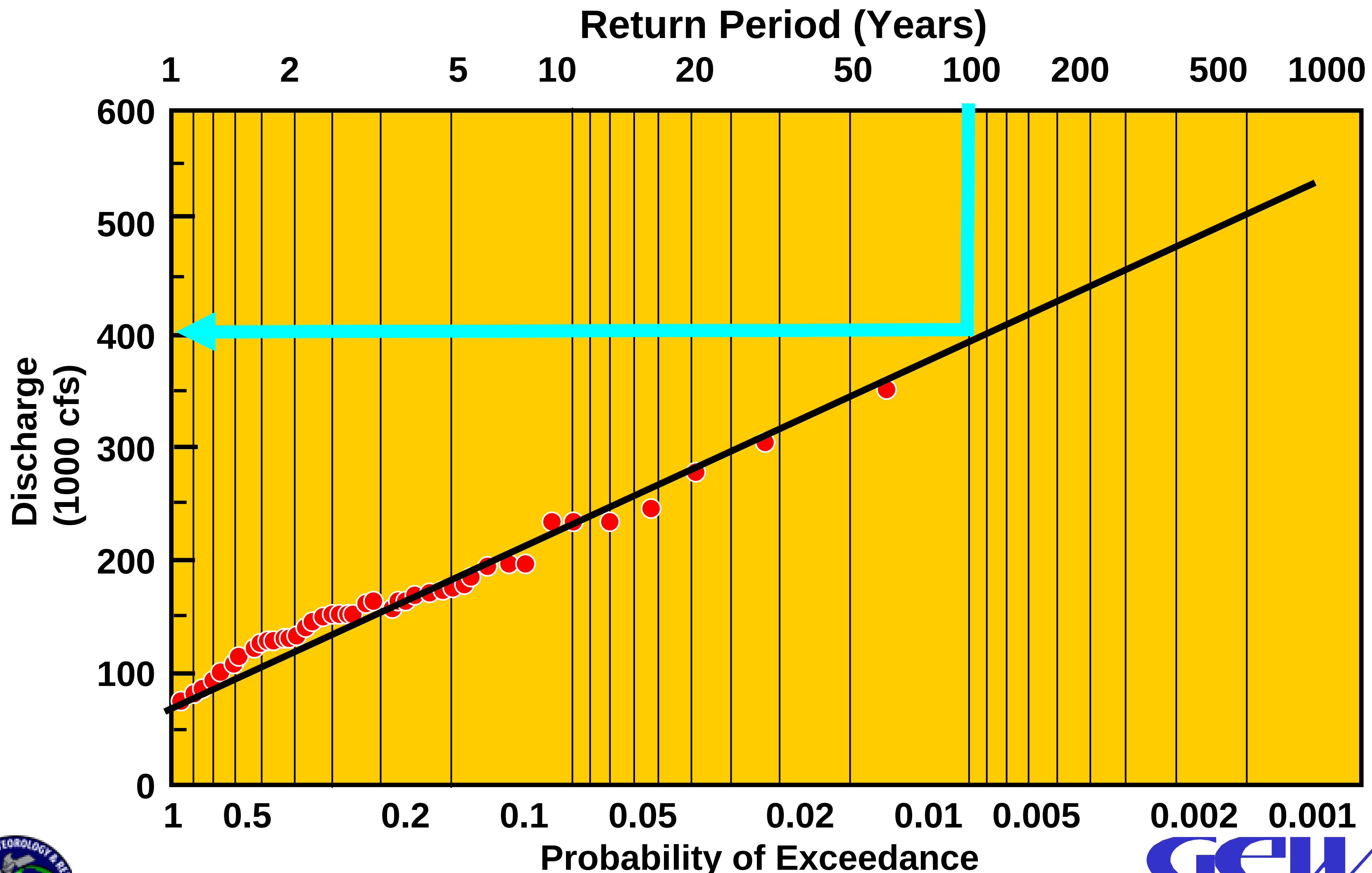


Central Arizona Project Aqueduct

Addressing " Climate Extremes" in Water Resources Planning:

Stochastic Hydrology

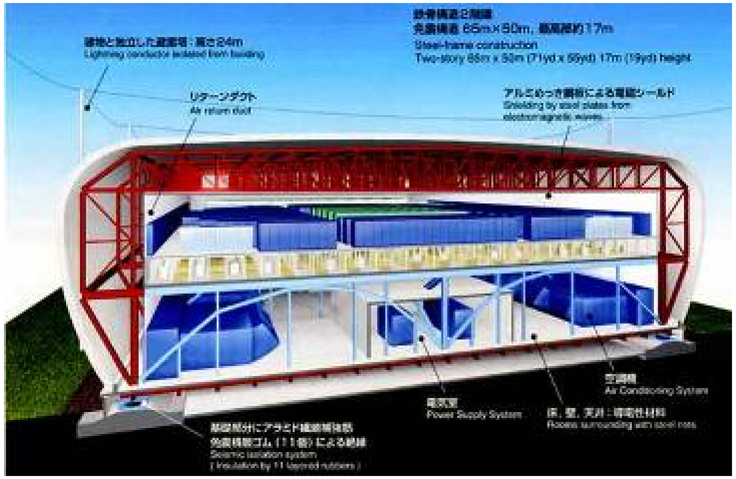
Potential Hydrologic Scenario: Stationarity!

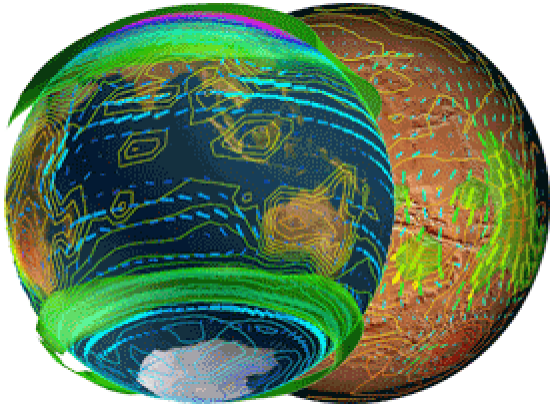


Big Challenge For "us":

Can we Offer Anything Better to Help Decision making?

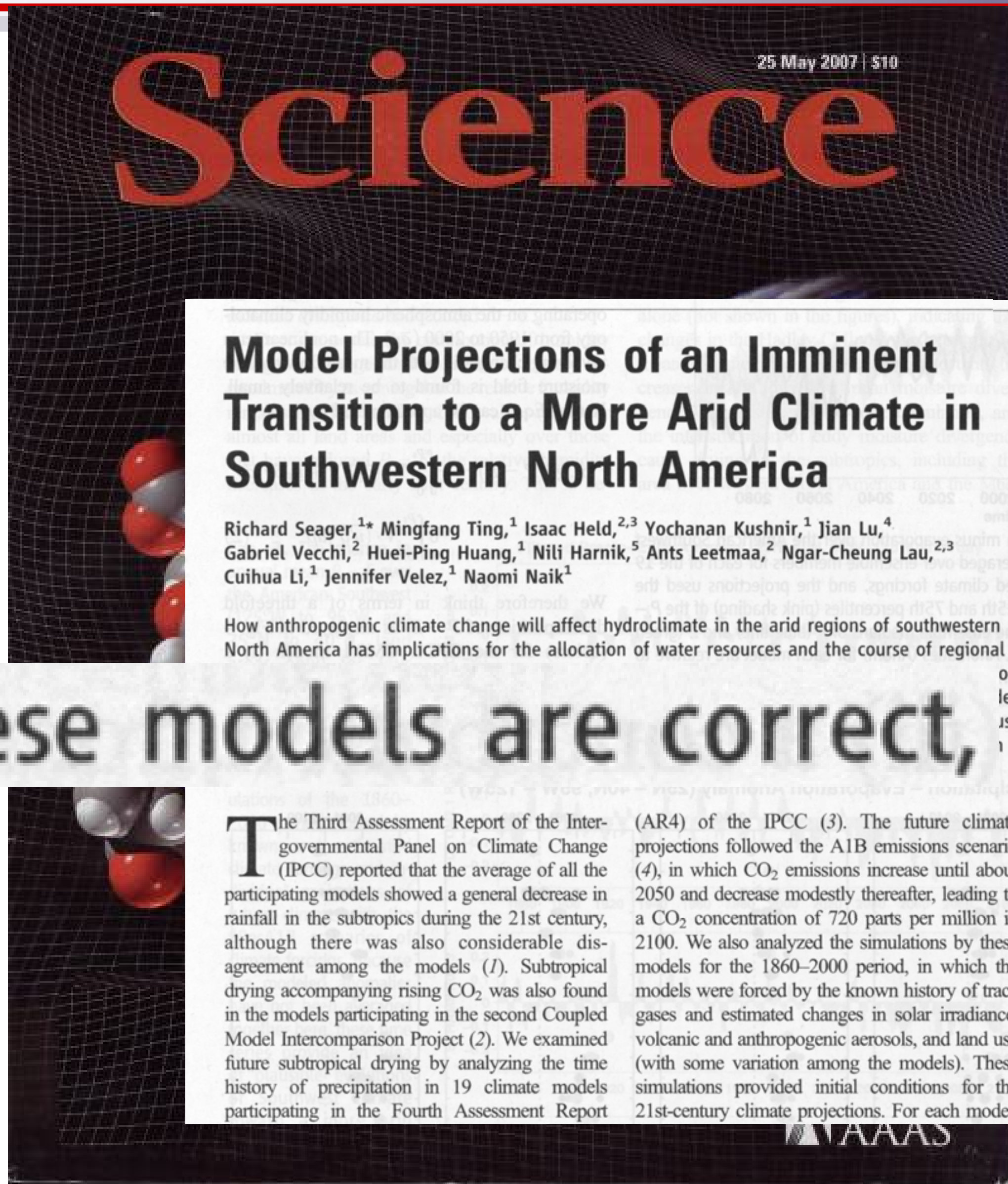
Climate Predictions into the Future!





Some Results from Long Time-Scales to Seasonal and Inter-Annual Time-Scales

A Dryer Future for Southwest US?



Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America

Richard Seager,[1*] Mingfang Ting,[1] Isaac Held,[2,3] Yochanan Kushnir,[1] Jian Lu,[4] Gabriel Vecchi,[2] Huei-Ping Huang,[1] Nili Harnik,[5] Ants Leetmaa,[2] Ngar-Cheung Lau,[2,3] Cuihua Li,[1] Jennifer Velez,[1] Naomi Naik[1]

How anthropogenic climate change will affect hydroclimate in the arid regions of southwestern North America has implications for the allocation of water resources and the course of regional

If these models are correct,

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reported that the average of all the participating models showed a general decrease in rainfall in the subtropics during the 21st century, although there was also considerable disagreement among the models (*1*). Subtropical drying accompanying rising CO_2 was also found in the models participating in the second Coupled Model Intercomparison Project (*2*). We examined future subtropical drying by analyzing the time history of precipitation in 19 climate models participating in the Fourth Assessment Report (AR4) of the IPCC (*3*). The future climate projections followed the A1B emissions scenario (*4*), in which CO_2 emissions increase until about 2050 and decrease modestly thereafter, leading to a CO_2 concentration of 720 parts per million in 2100. We also analyzed the simulations by these models for the 1860–2000 period, in which the models were forced by the known history of trace gases and estimated changes in solar irradiance, volcanic and anthropogenic aerosols, and land use (with some variation among the models). These simulations provided initial conditions for the 21st-century climate projections. For each model,

precipitation minus the evaporation ($P - E$), averaged over this region for the period common to all of the models (1900–2098). The median, 25th, and 75th percentiles of the model $P - E$ distribution and the median of P and E are shown. For cases in which there were multiple simulations with a single model, data from these simulations were averaged together before computing the distribution. $P - E$ equals the moisture convergence by the atmospheric flow and (over land) the amount of water that goes into runoff.

In the multimodel ensemble mean, there is a transition to a sustained drier climate that begins in the late 20th and early 21st centuries. In the ensemble mean, both P and E decrease, but the former decreases by a larger amount. $P - E$ is primarily reduced in winter, when P decreases and E is unchanged or modestly increased, whereas in summer, both P and E decrease. The annual mean reduction in P for this region, calculated from rain gauge data within the Global Historical Climatology Network, was 0.09 mm/day between 1932 and 1939 (the Dust Bowl drought) and 0.13 mm/day between 1948 and 1957 (the 1950s Southwest drought). The ensemble median reduction in P that drives the reduction in $P - E$ reaches 0.1 mm/day in midcentury, and one quarter of the models reach this amount in the early part of the current century.

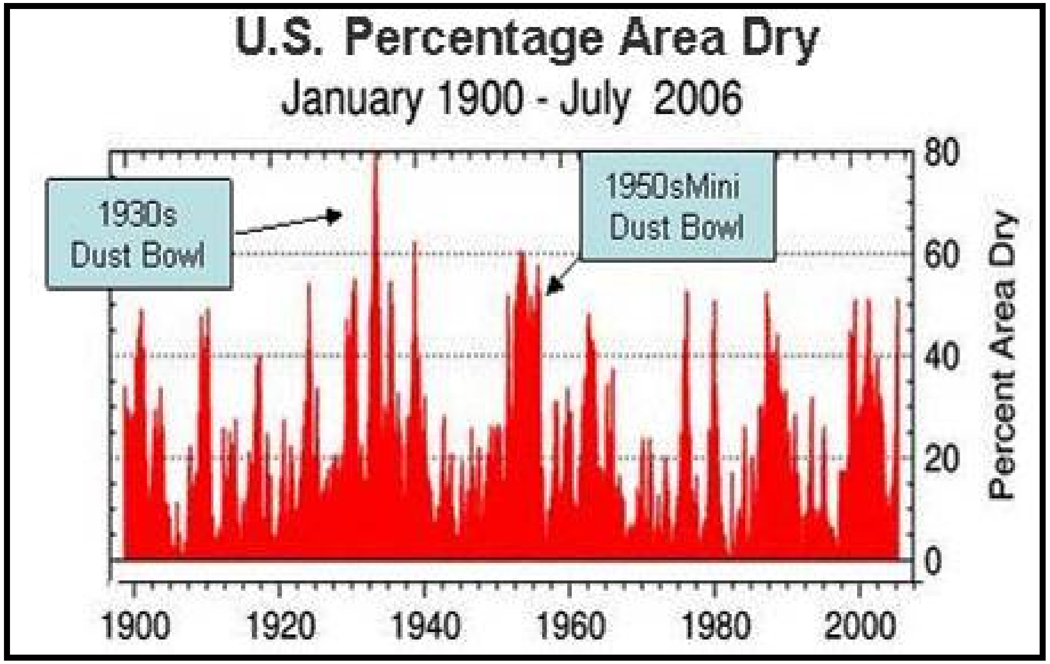
The annual mean $P - E$ difference between 20-year periods in the 21st century and the 1950–2000 climatology for the 19 models are shown in Fig. 2. Almost all models have a drying trend in the American Southwest and the con

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.**

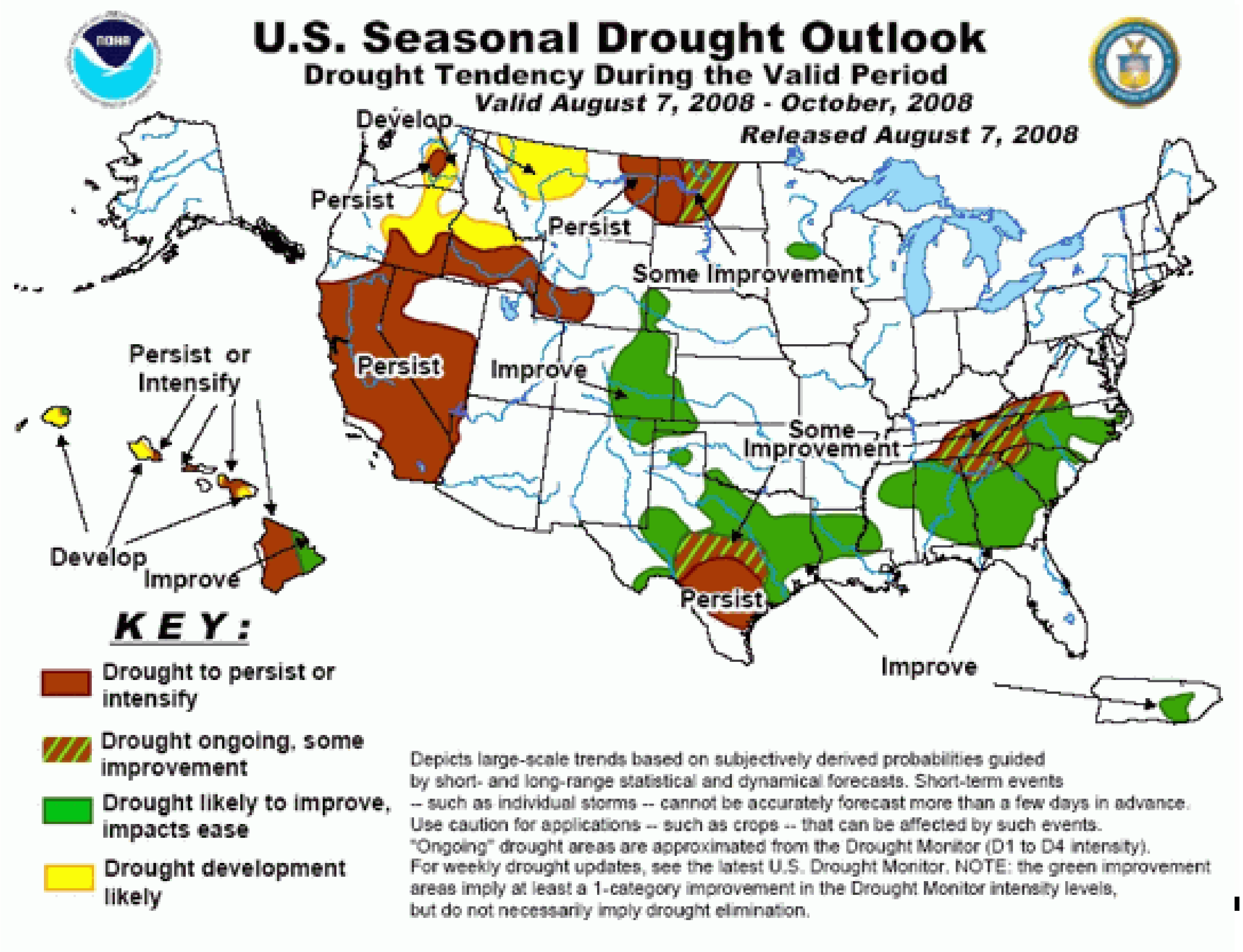
10
5
0
Confidence Index



Based on Palmer Drought Index
Moderate to Extreme Drought

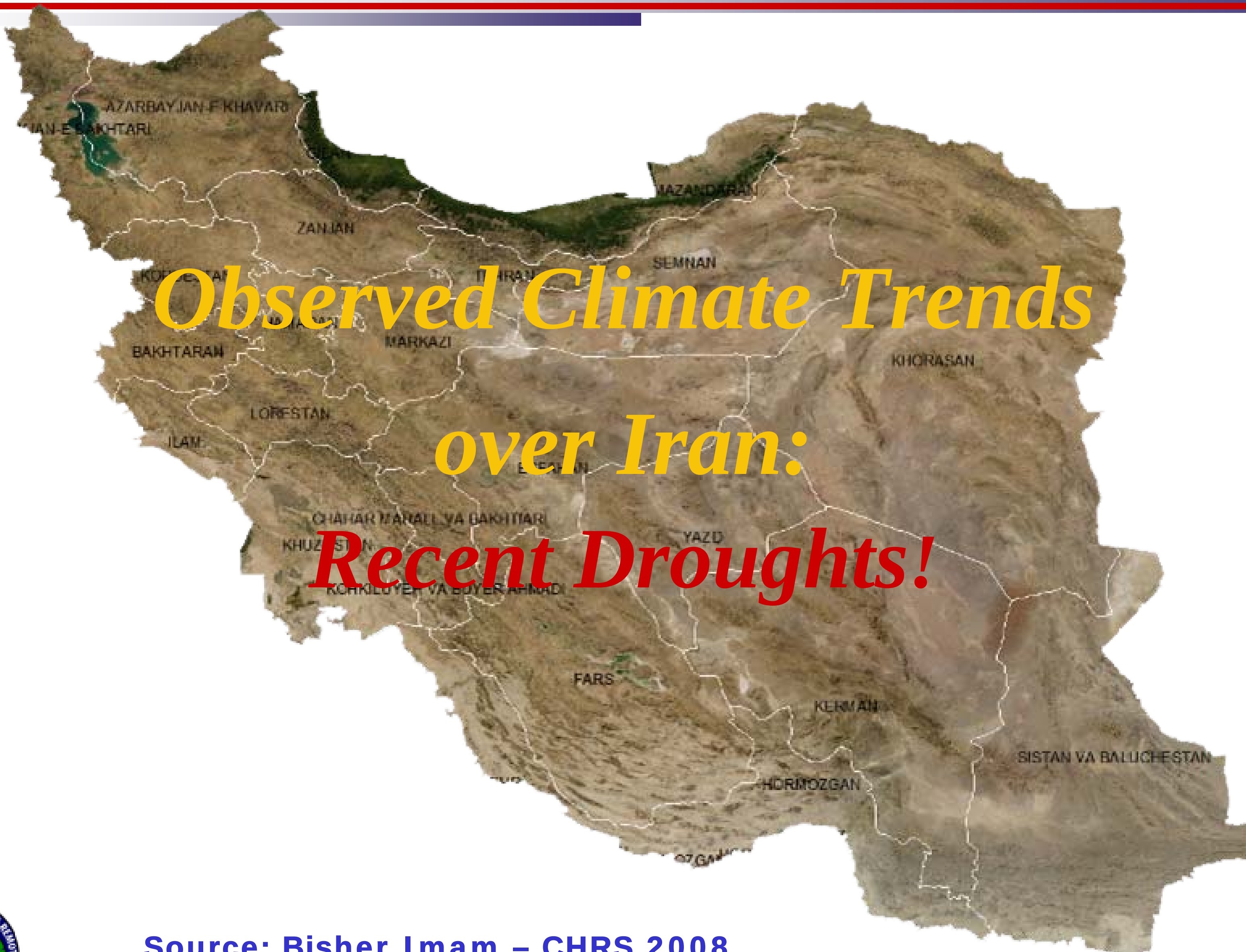
Source: Tom Karl NCDC-NOAA 2007

Seasonal Drought Outlook for U.S.



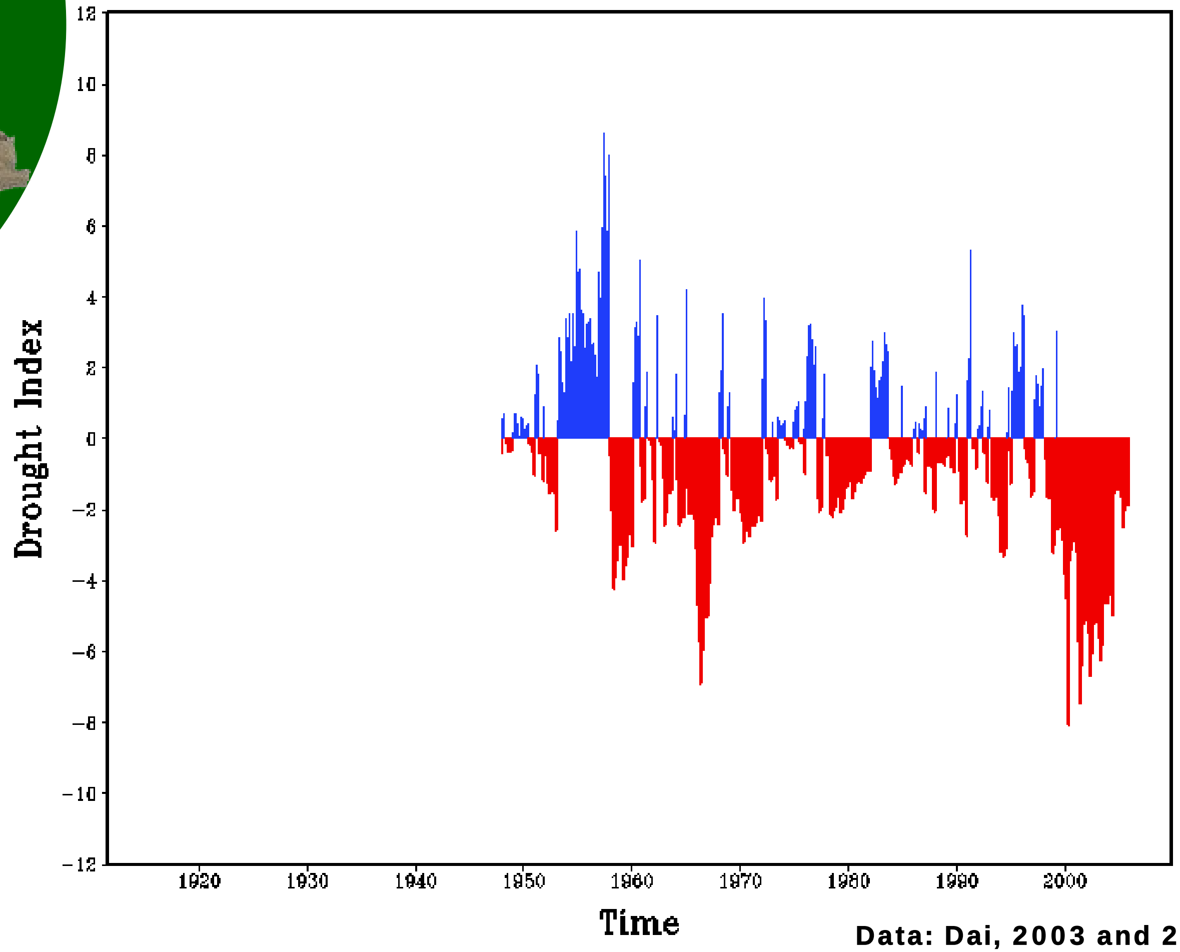
Observed Climate Trends over Iran:

Recent Droughts!



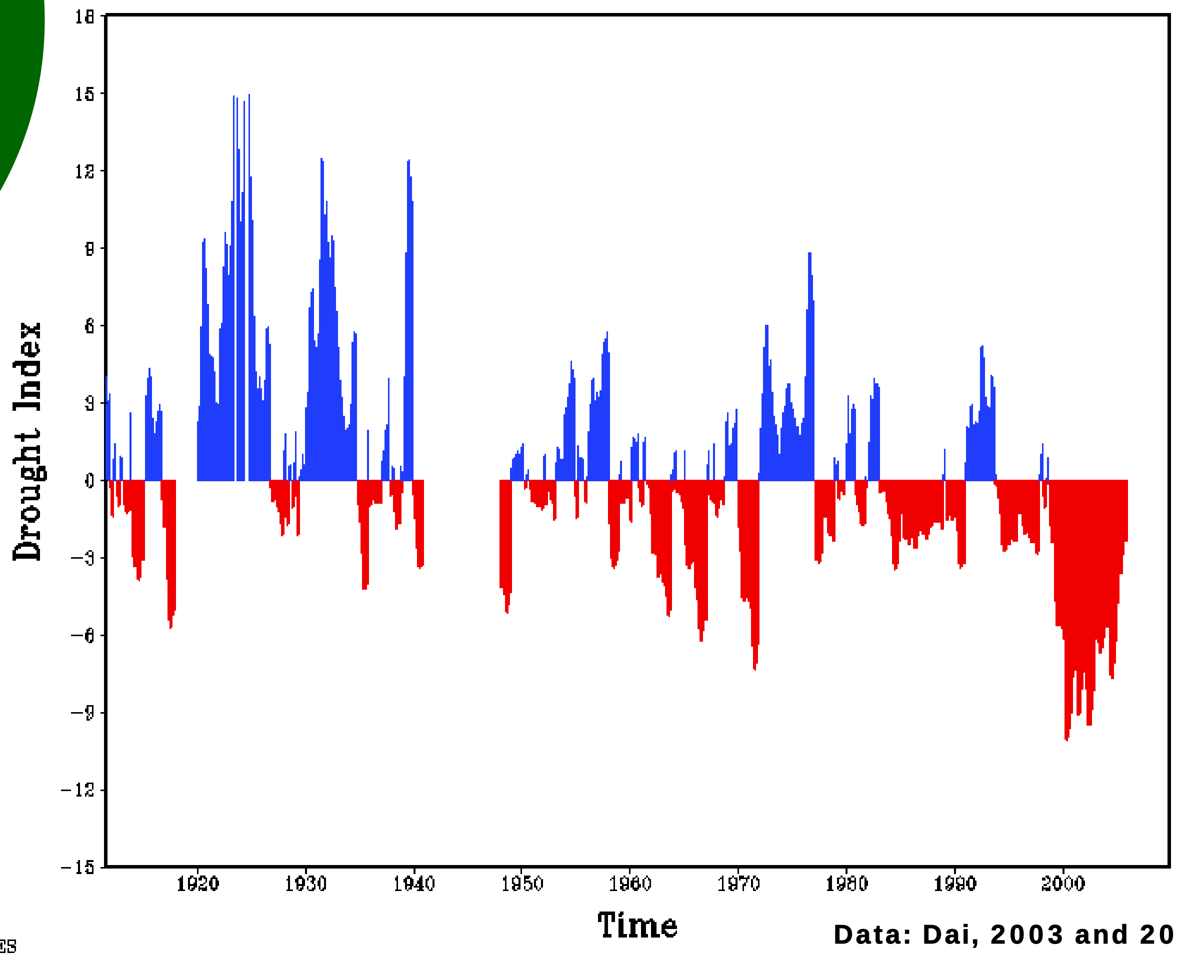
Source: Bisher Imam – CHRS 2008

KERMAN



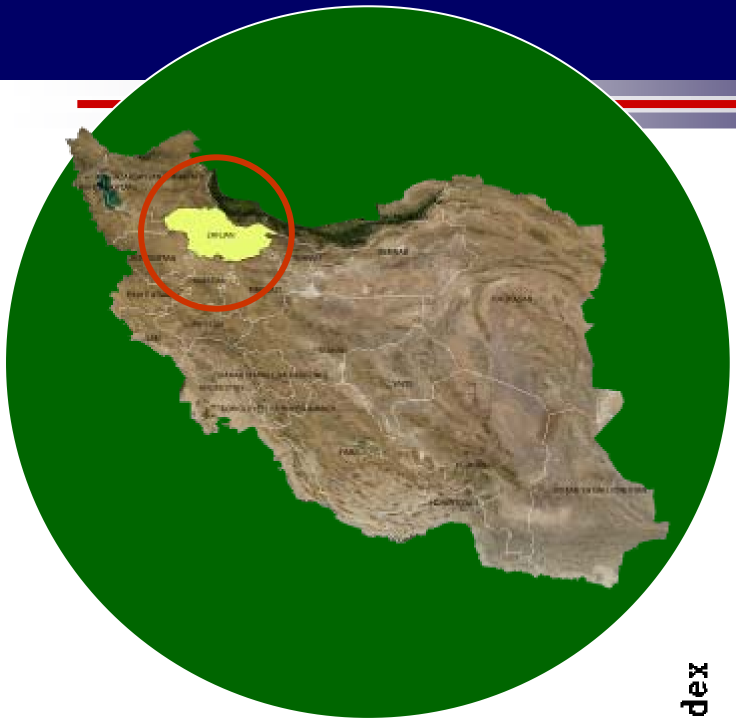
Data: Dai, 2003 and 2007

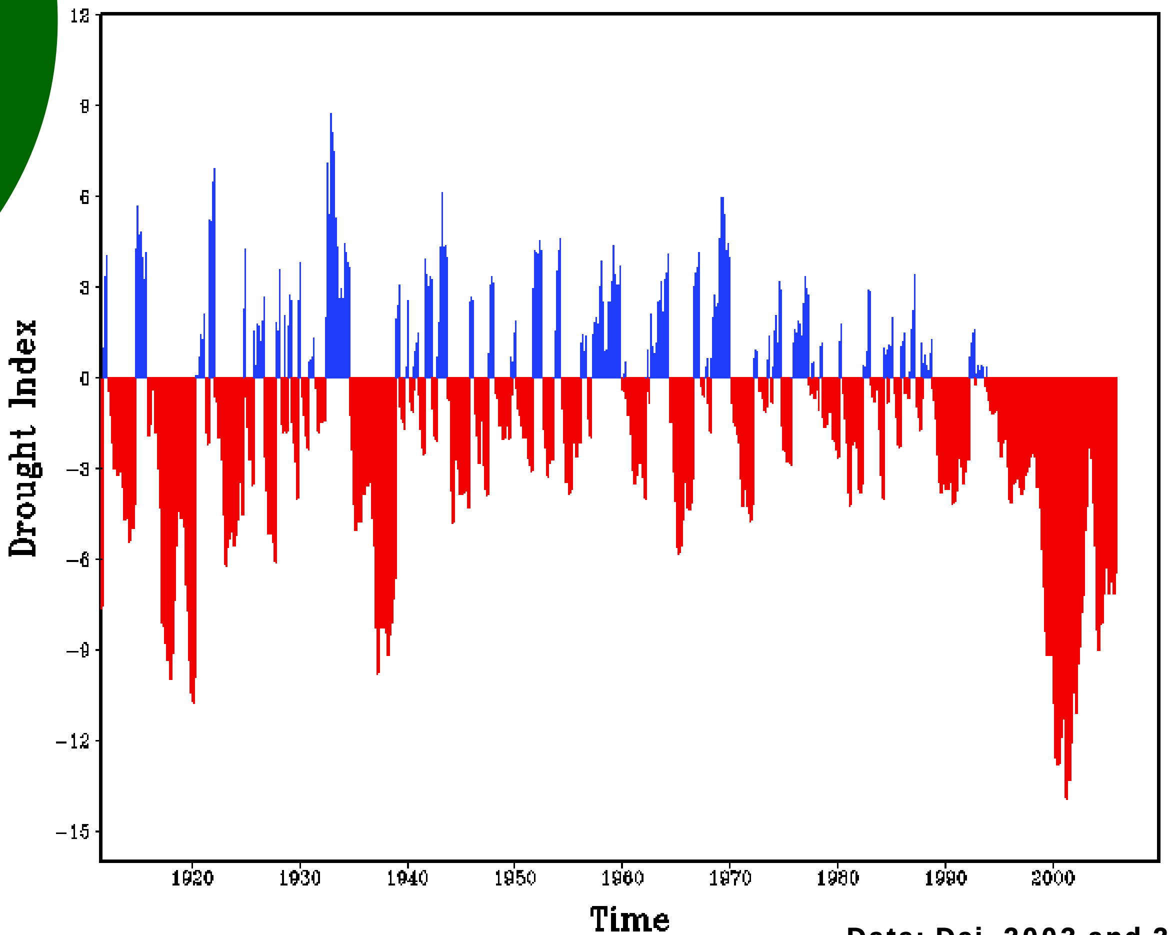
KHORASAN



Data: Dai, 2003 and 2007

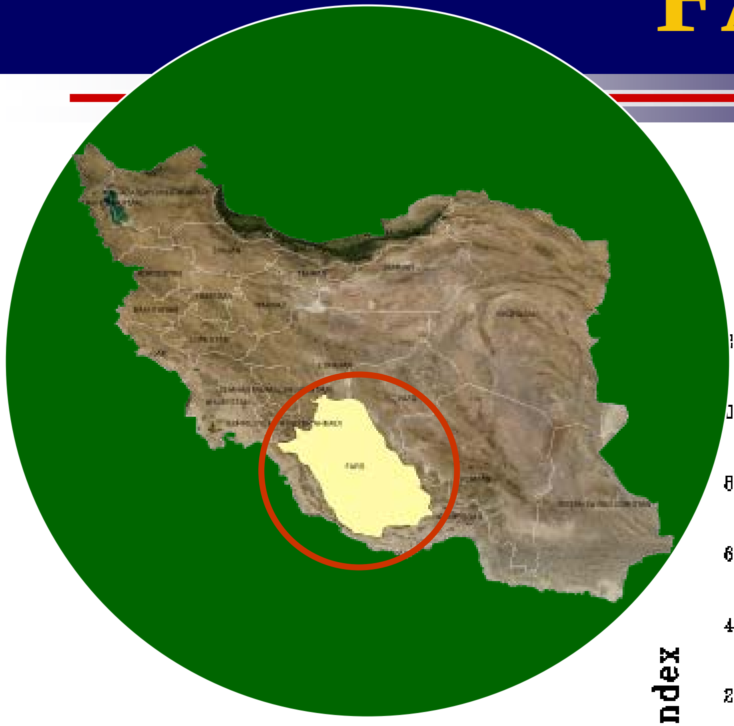
ZANJAN

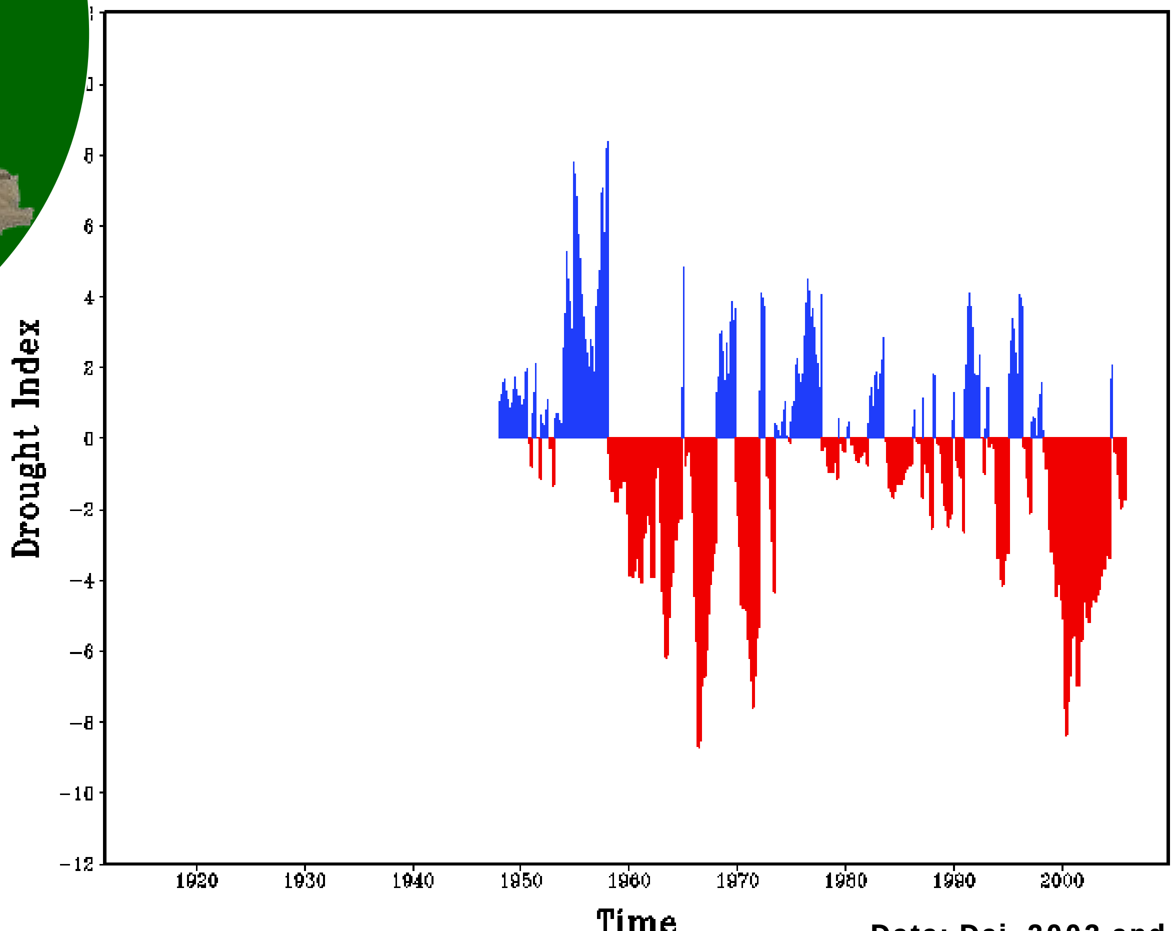




Data: Dai, 2003 and 2007

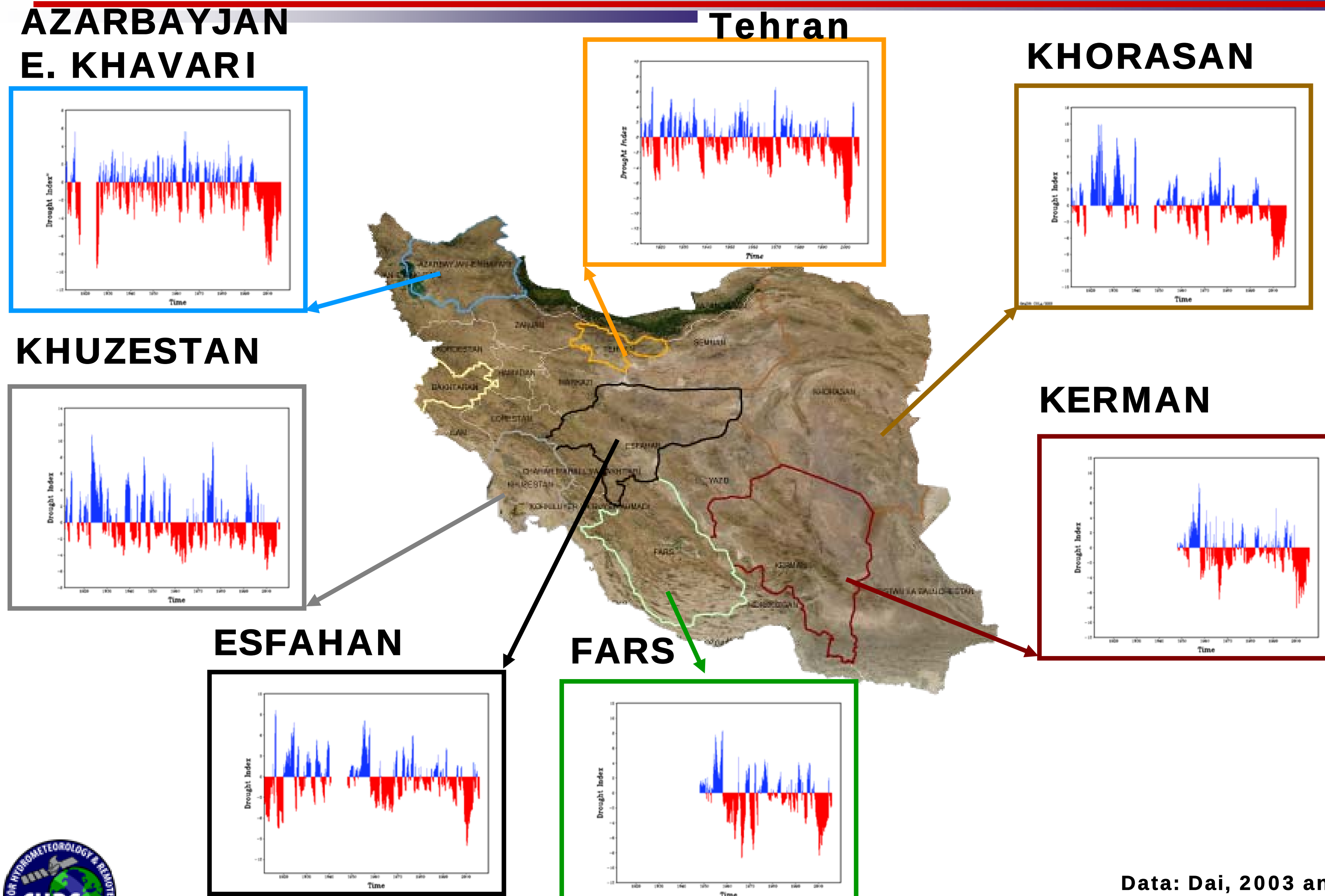
FARS





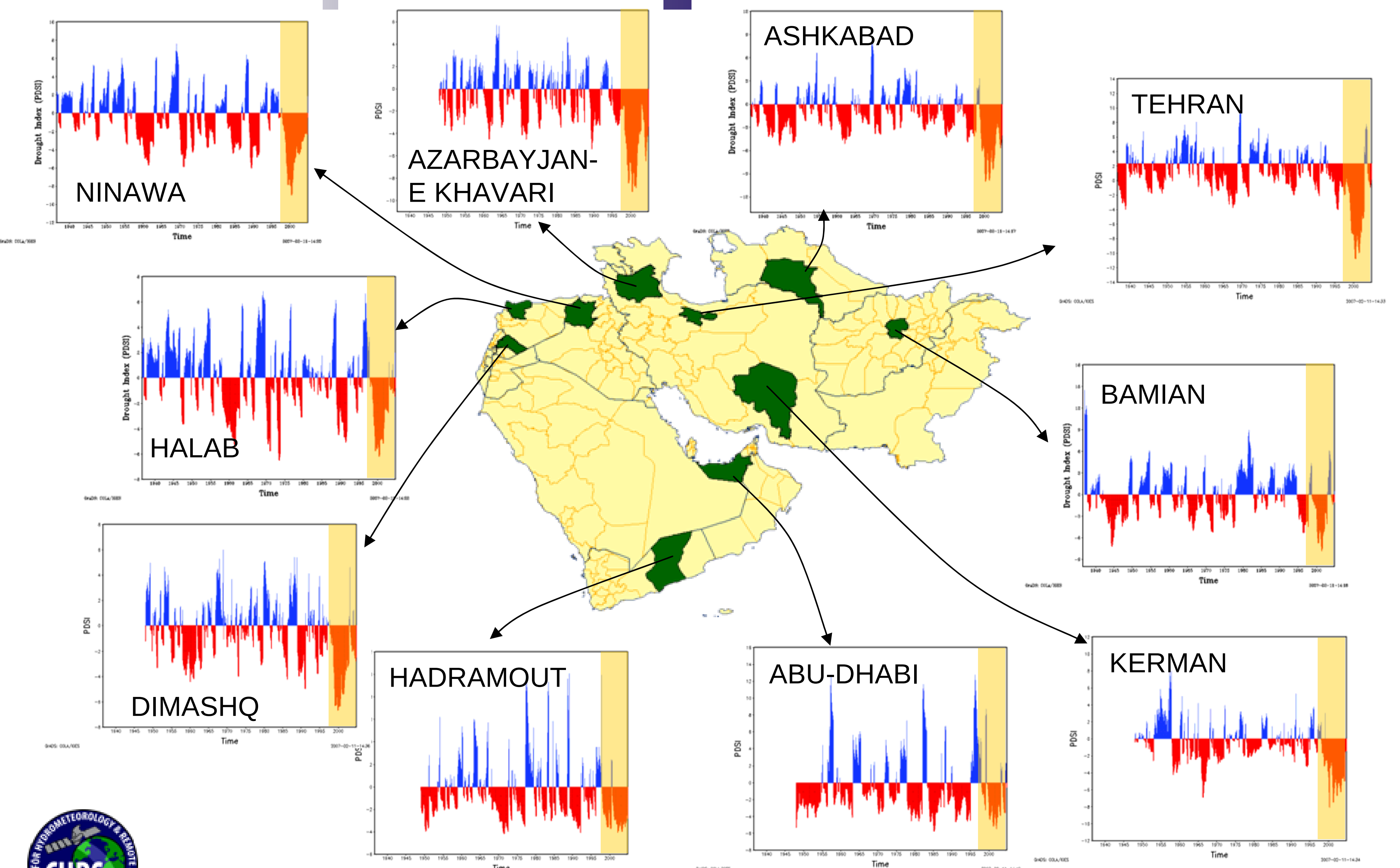
Data: Dai, 2003 and 2007

Clear Large-Scale Drought Since Late 90s

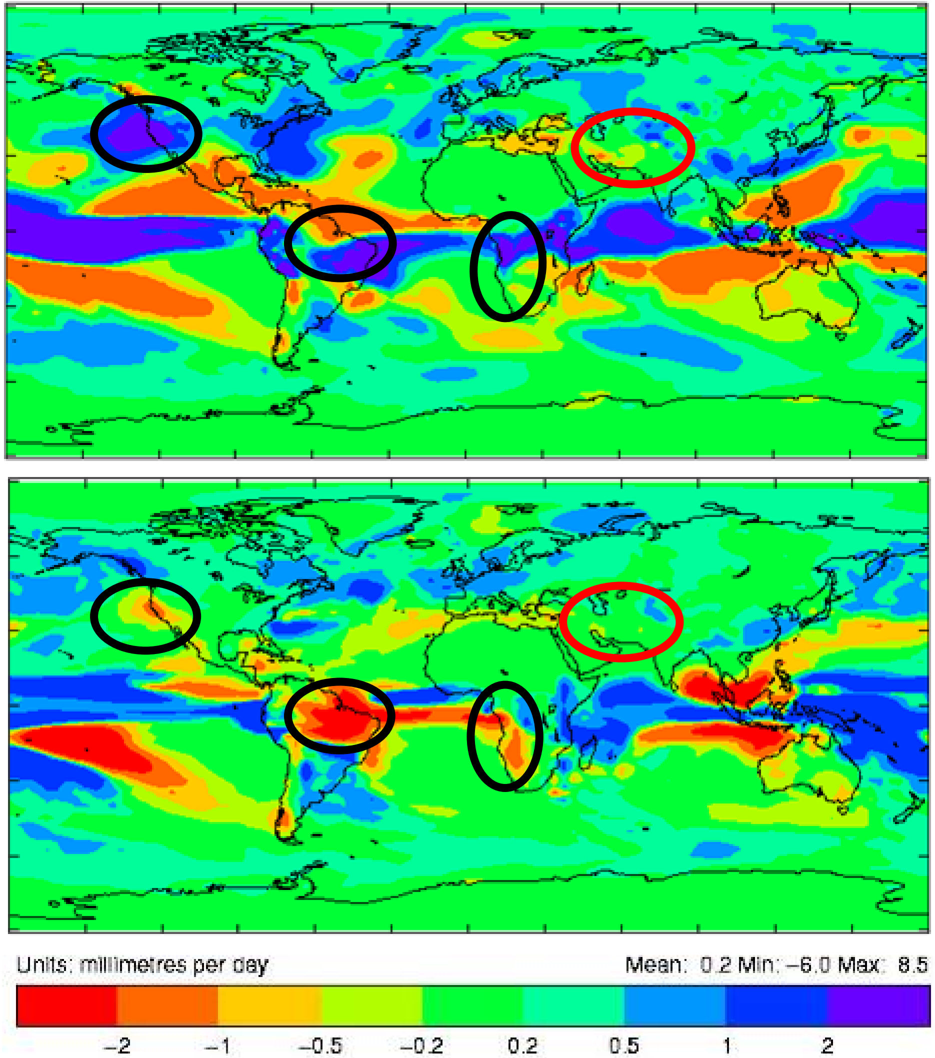


Data: Dai, 2003 and 2007

1998-2003 Drought: Largest since 1936 in most of the region



Climate model Predictions about the future? → globally



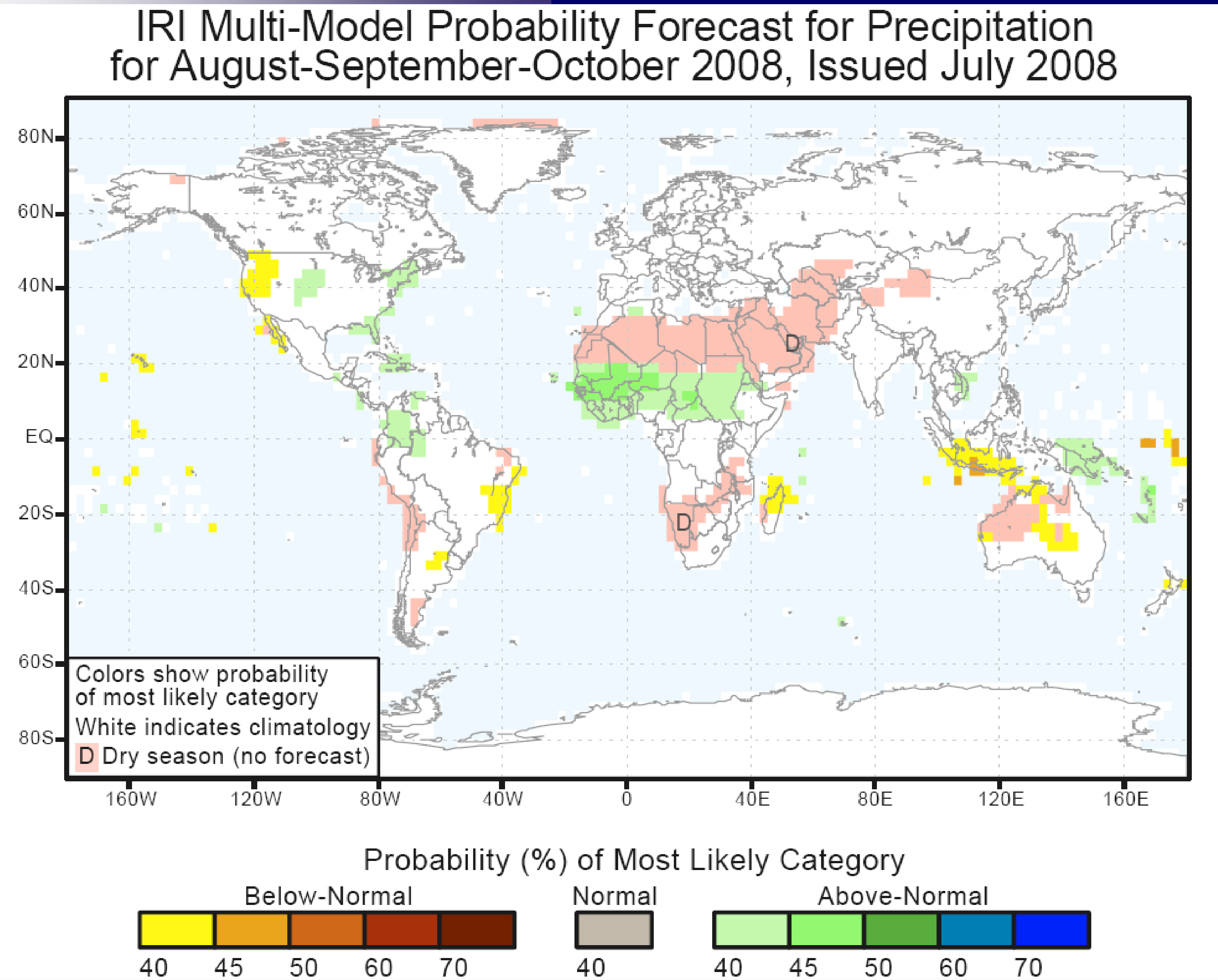
DJF Precipitation Changes
CM2 - Old model

CM3 - Updated model

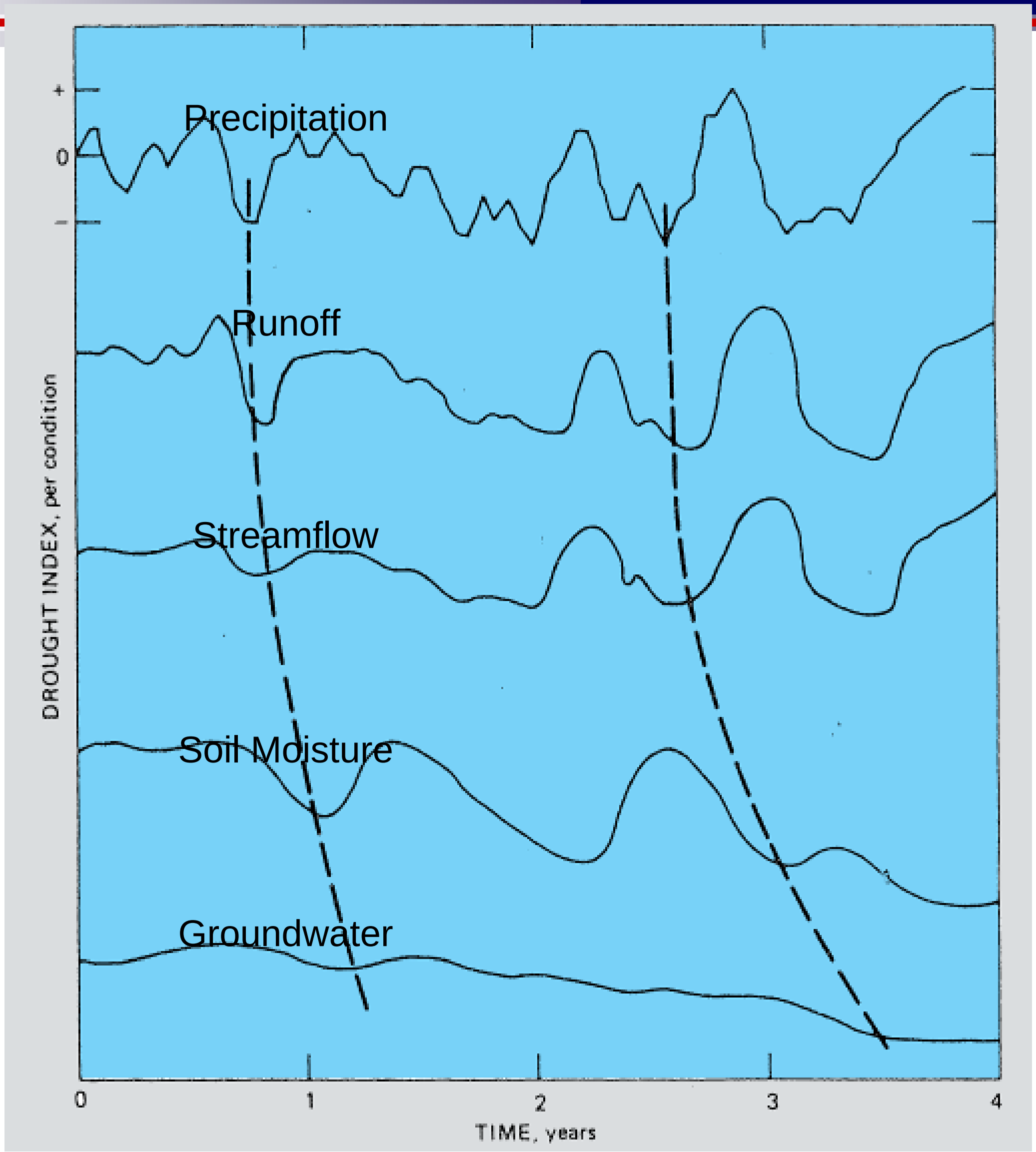
Significant differences in regional outcomes!

Source: Hadley Center (Climate Change Projections)

Seasonal Climate Predictions: Global by IRI



Progression of Droughts



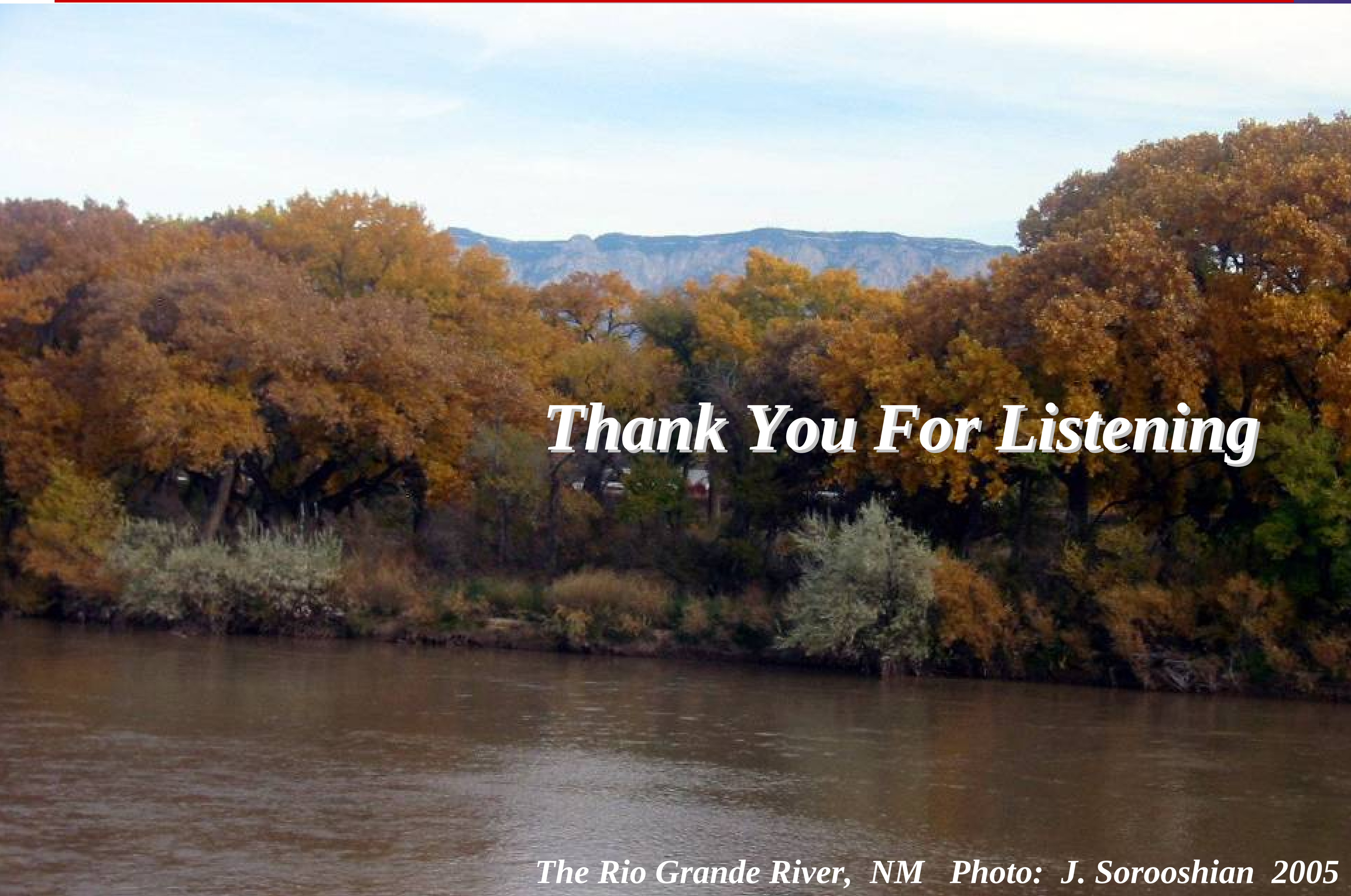
Changnon, 1987

Summary:

- ***Presently, the reliability of regional-scale climate model predictions fall short of meeting the requirements of water resources planning.***

Factoring in Resiliency in water resources systems design and planning is still the safest approach!

May 2005 Drought Workshop - Iran



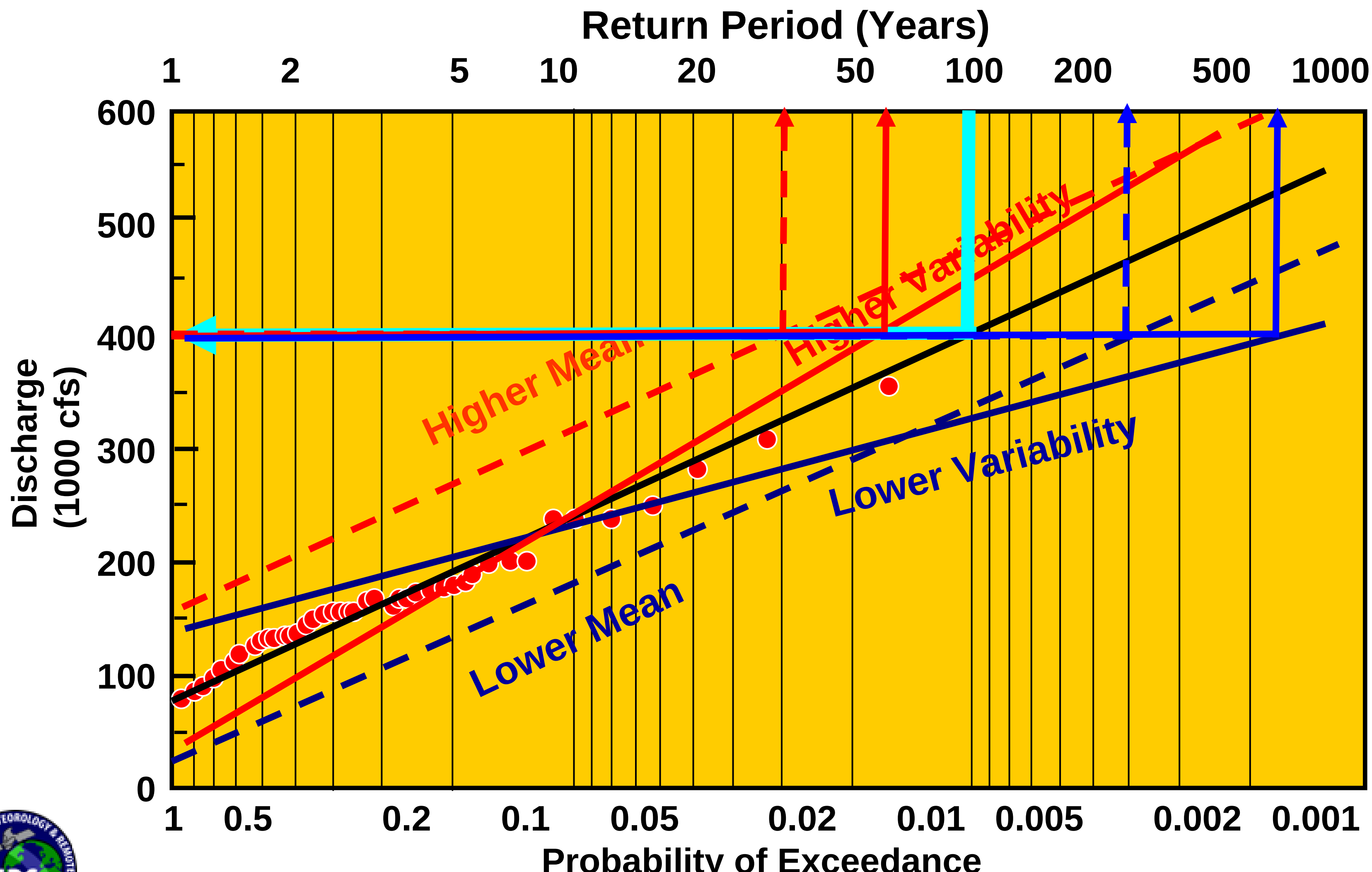
The Rio Grande River, NM Photo: J. Sorooshian 2005

Back up slides

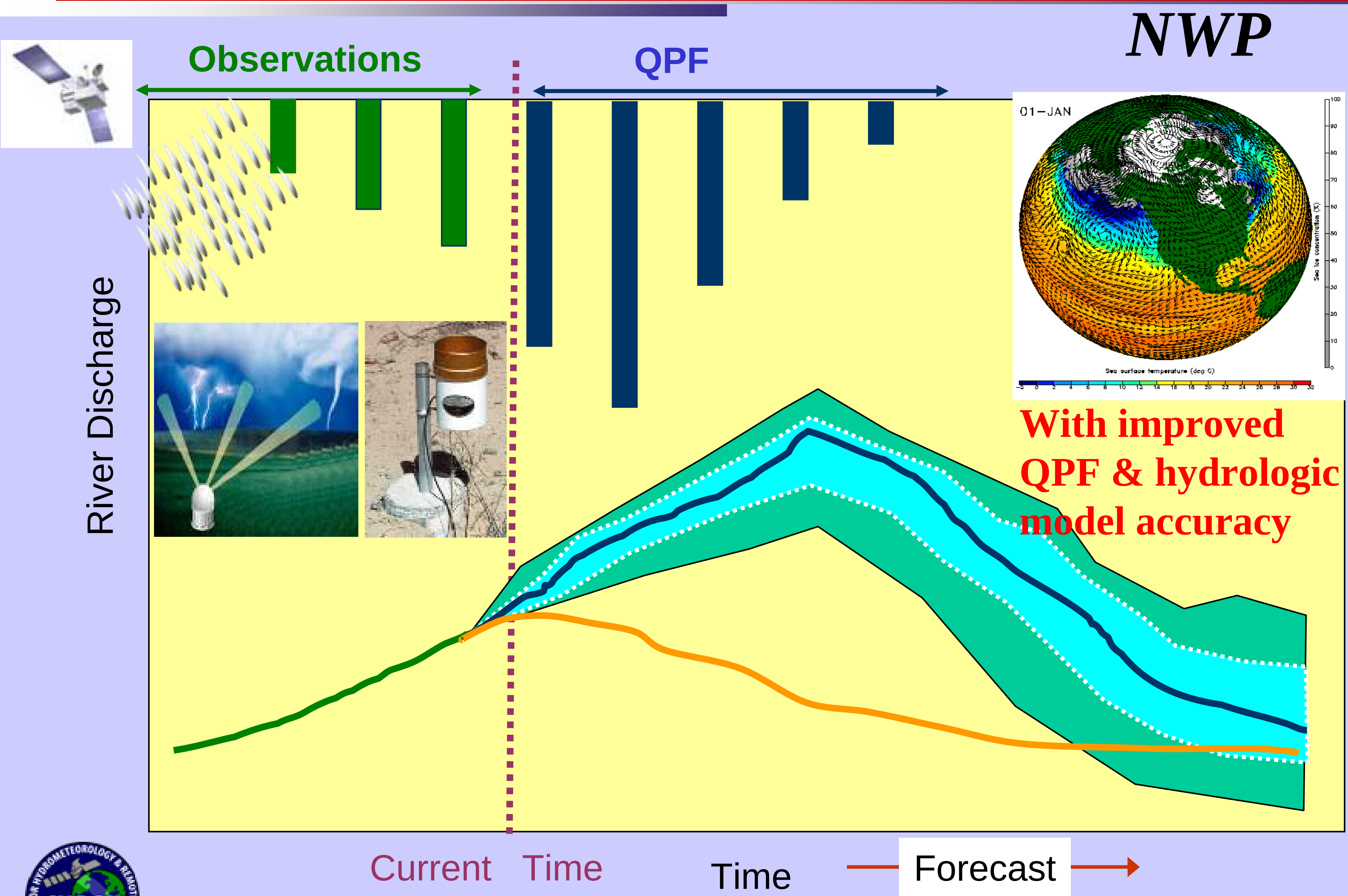
Potential Hydrologic Scenarios

1. Precipitation and Runoff Trends
   (e.g. increase/decrease)

2. Hydrologic Variability
   (e.g. magnitude/severity/duration)

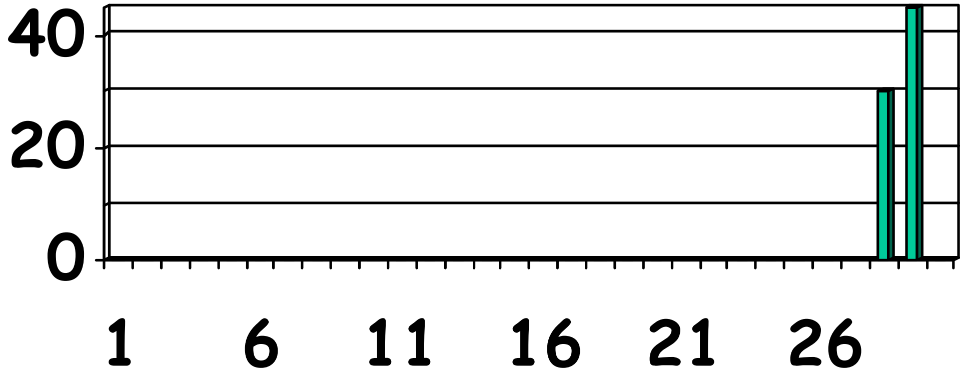


Shorter Time scale: Extending the Forecast Lead time



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

A

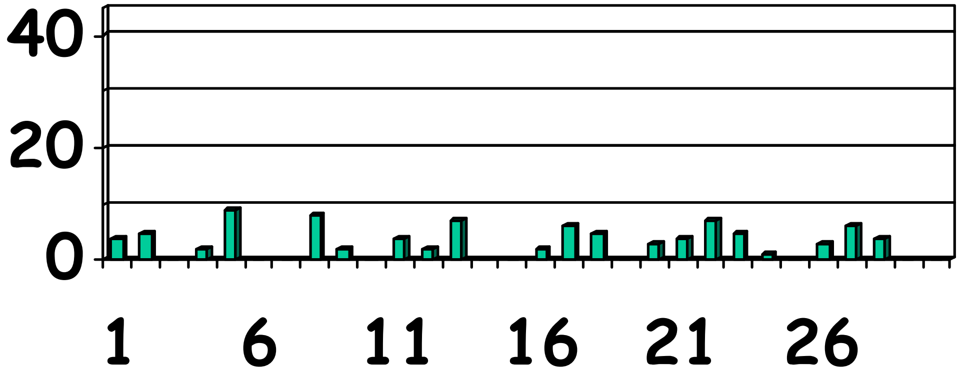


Monthly
Amount 75 mm

Frequency 6.7%
Intensity 37.5 mm

local Floods
Stream bed Recharge

B



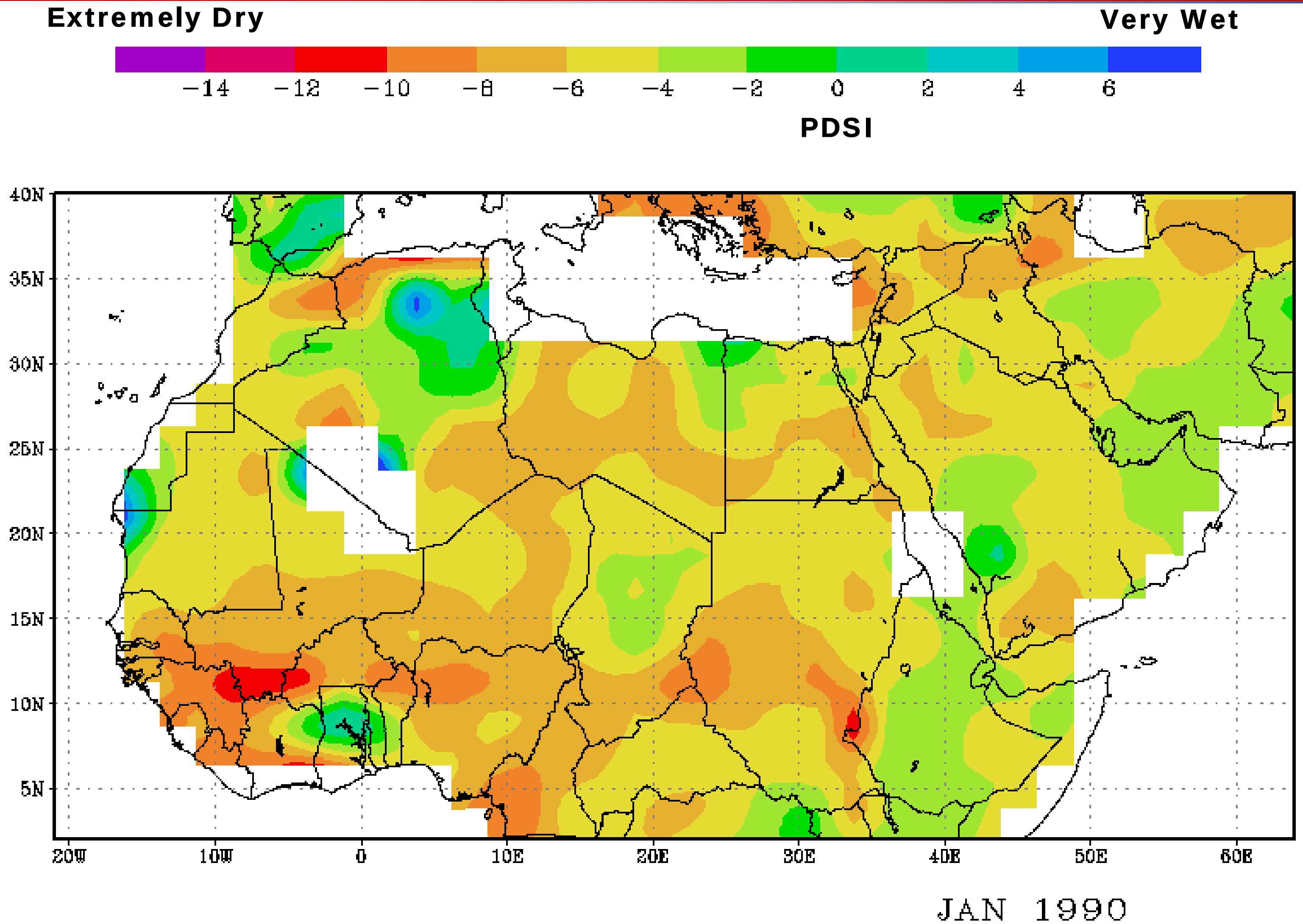
Amount 75 mm

Frequency 67%
Intensity 3.75 mm

soil moisture replenished
virtually no runoff

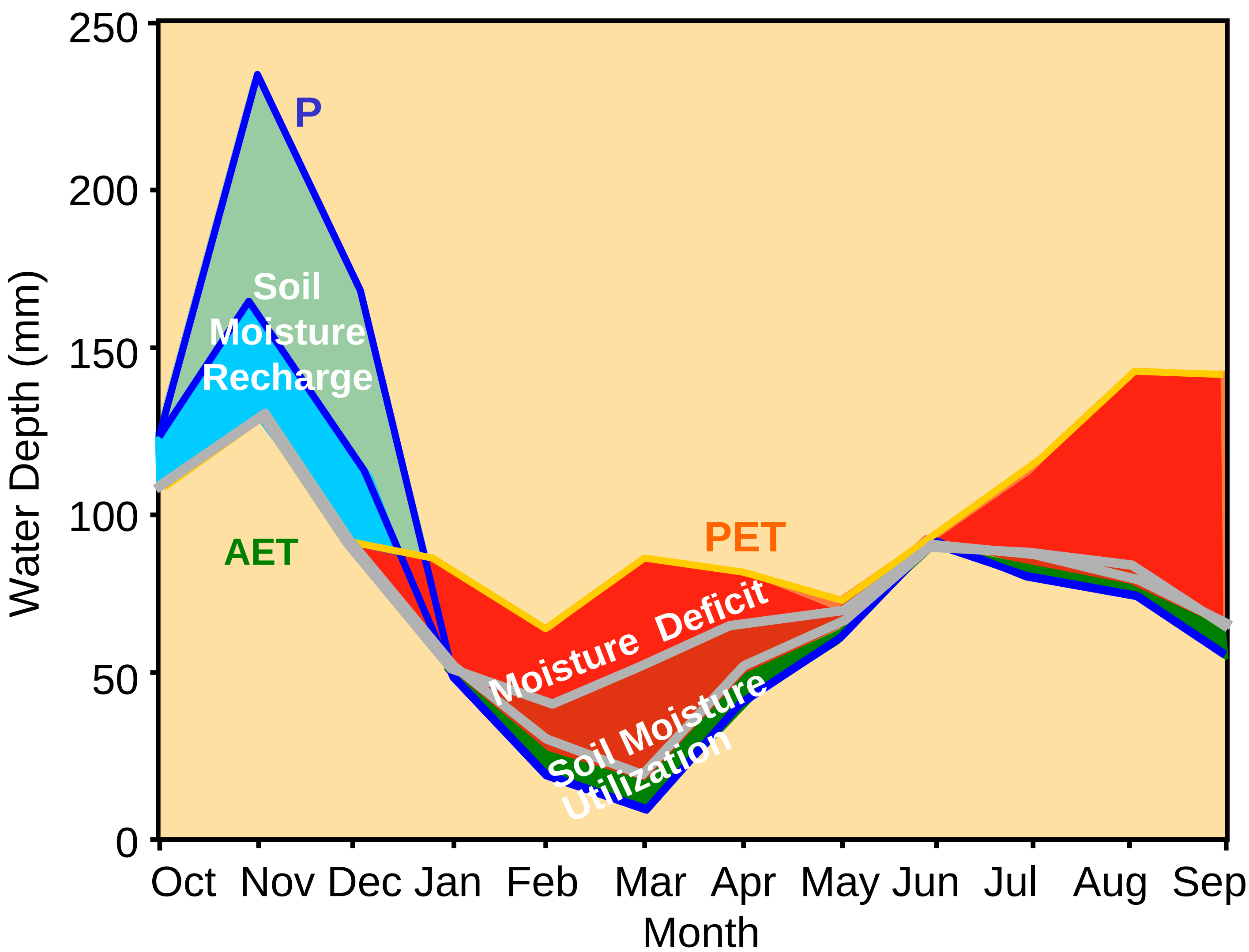
Source: K. Trenberth, NCAR

Recent Drought Episodes in the Middle East Region



Data Source: Dai 2006
Animation: CHRS

Monthly water balance deficit propagation: Some Scenarios



Changnon, 1987

Wide-Range of Impacts on Infrastructure Design