Lecture II
Hydrological modeling requirements for Water Resources Applications – Data Requirement Issues

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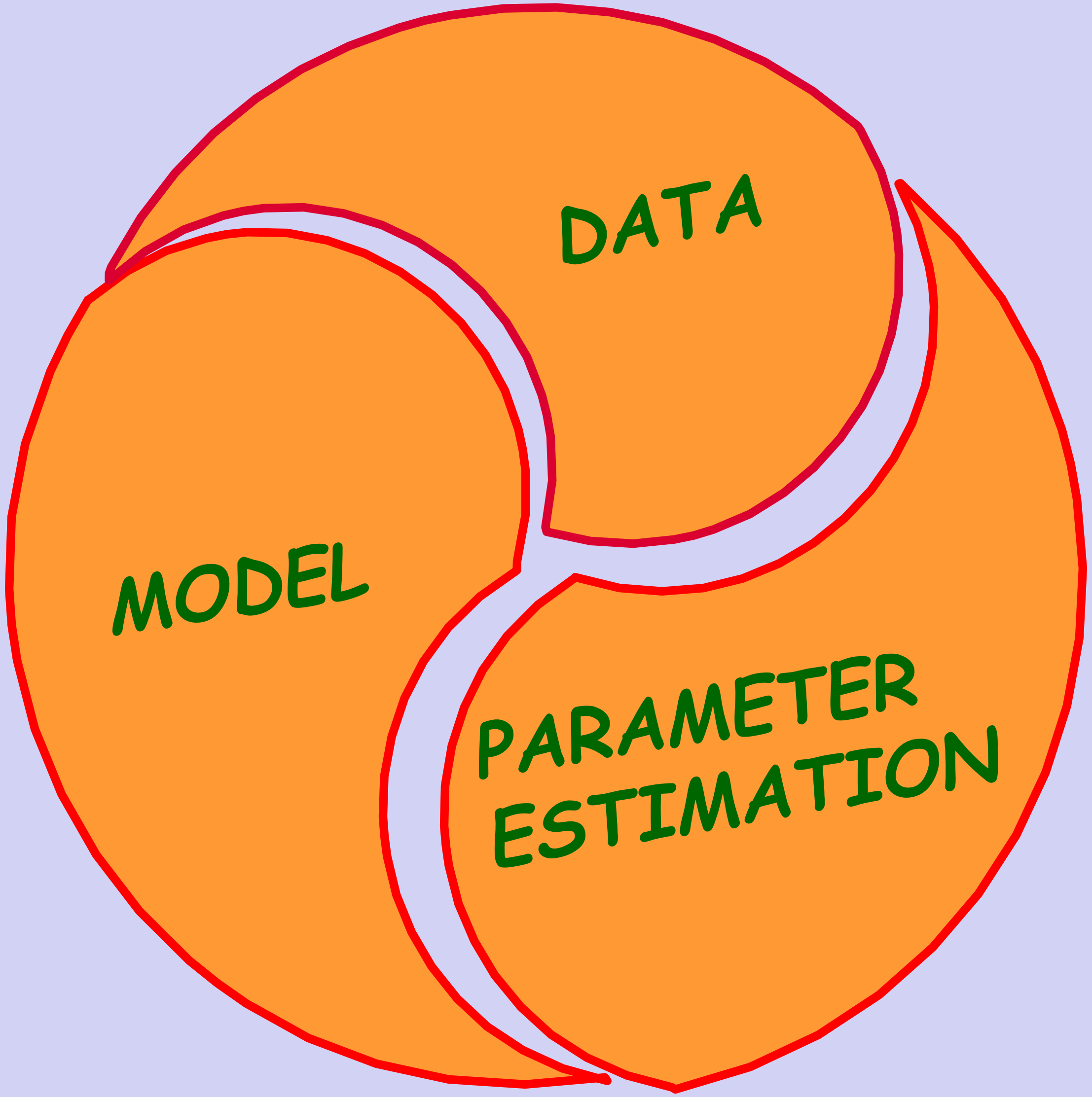
Center for Hydrometeorology and Remote Sensing

University of California Irvine

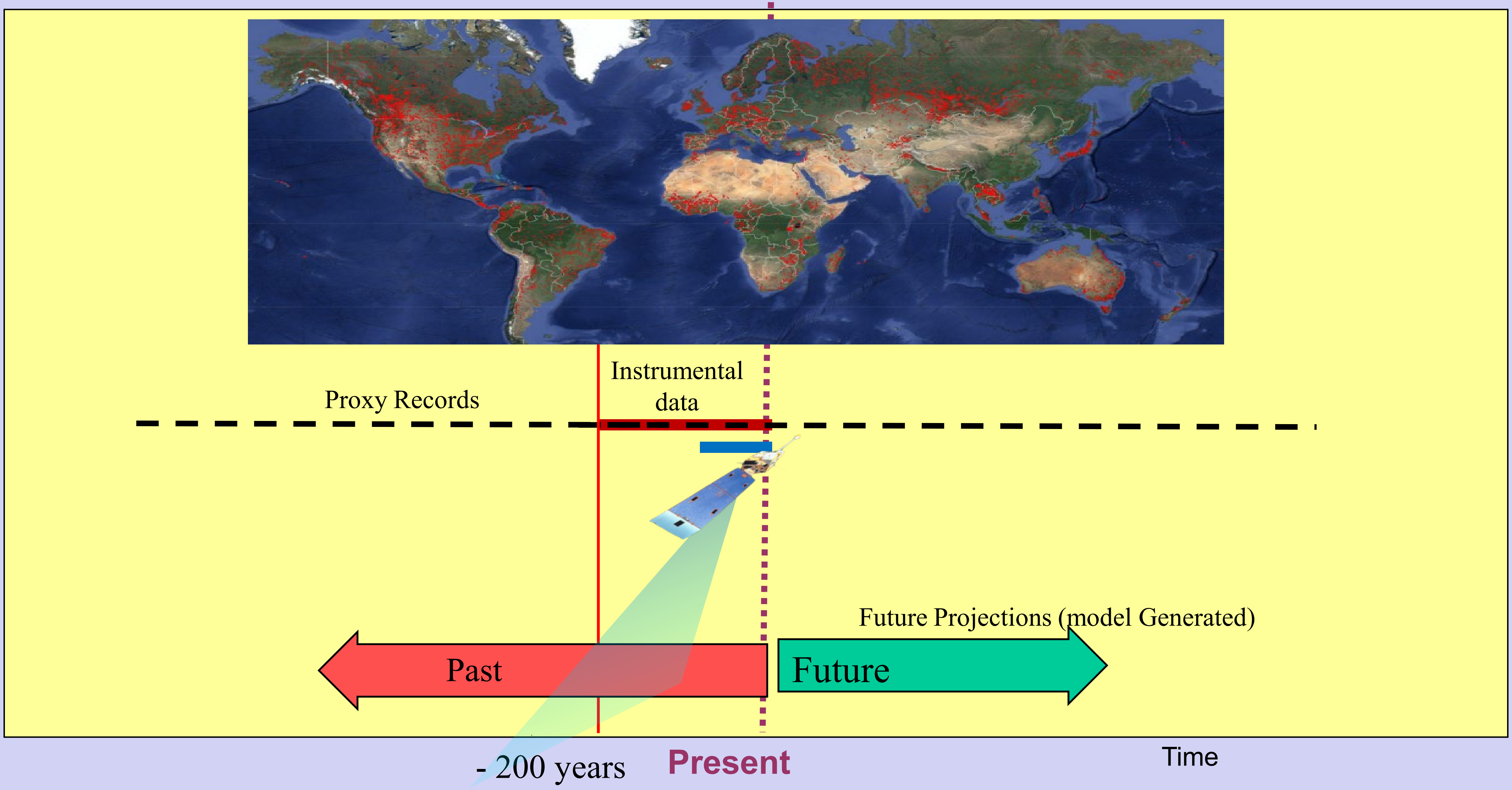
ICTP 6th Workshop on: *Water Resources in Developing Countries: Hydroclimate Modeling and Analysis Tools*

Trieste, Italy: May 20h – 31st 2024

Data



Hydroclimate of the Past and Future: Observation &Modeling



Information Relevant to Water Resources Planning

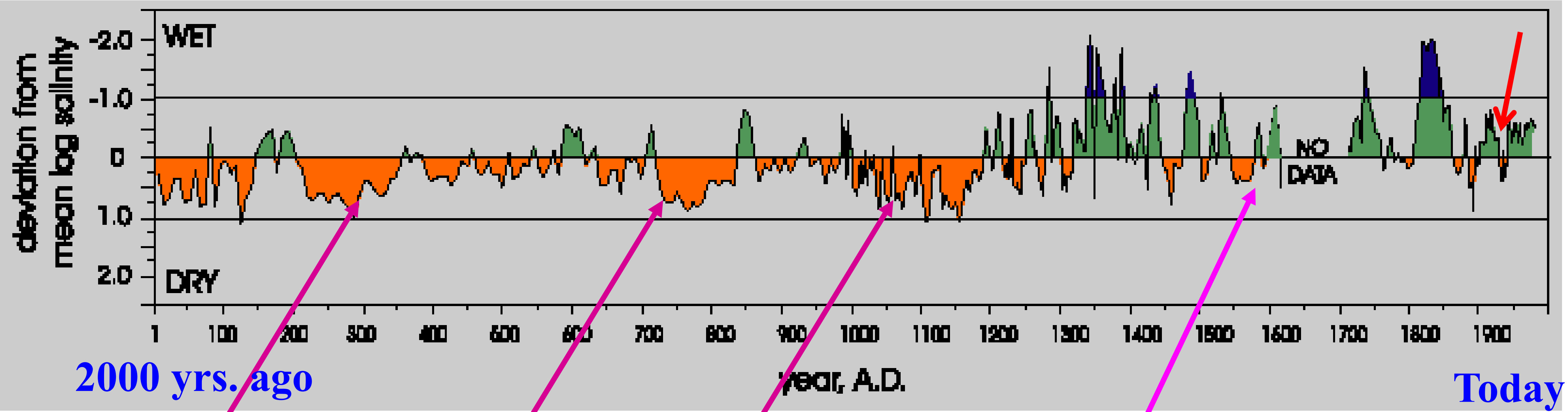
Observation (learning from data: Trends and Statistical Information useful for planning purposes)

Models (Future Projection)

2000-year HydroClimate history of central U.S.

The US Mid-West

1930's Dust bowl



2000 yrs. ago

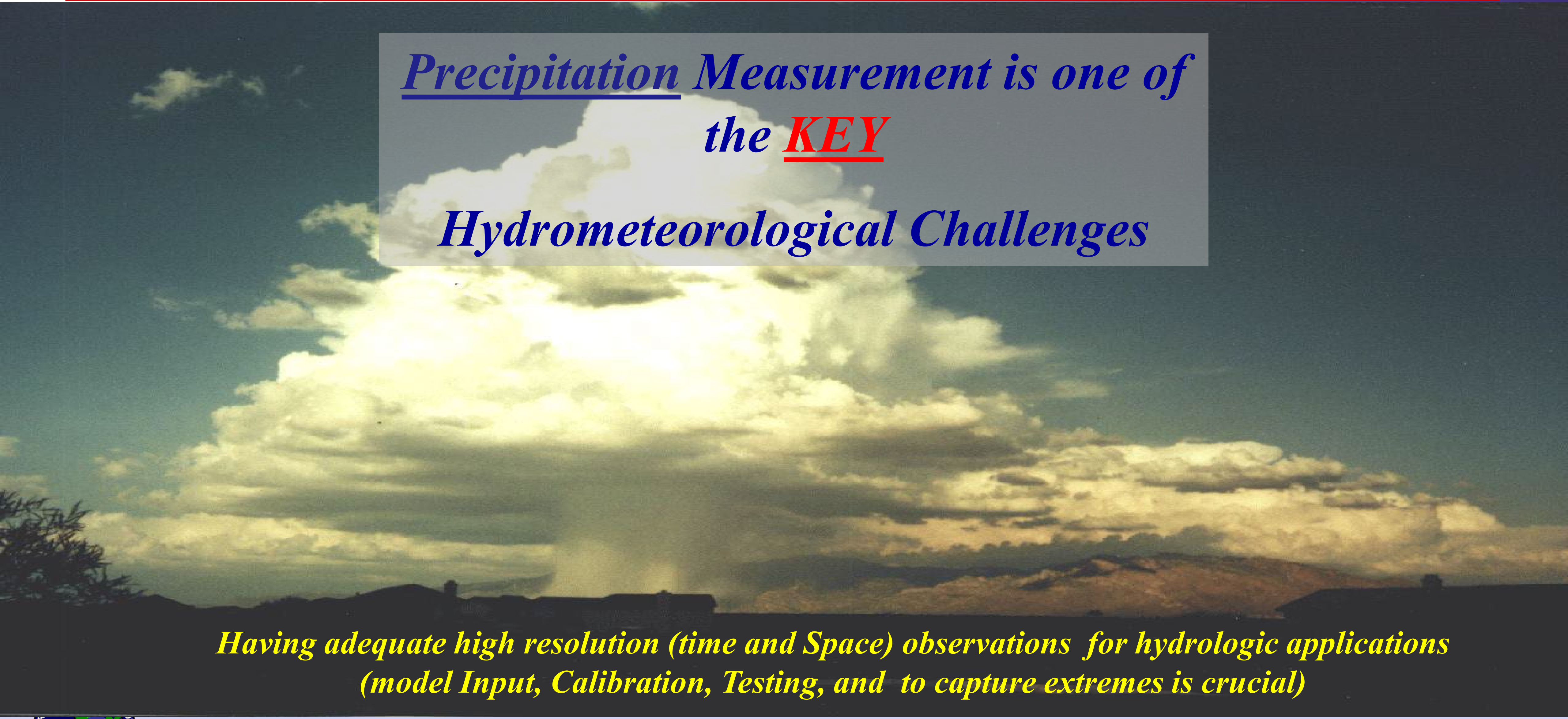
Today

- 100 year "megadroughts"

16th century "megadrought"

Source: Overpeck 2004

A Key Requirement!

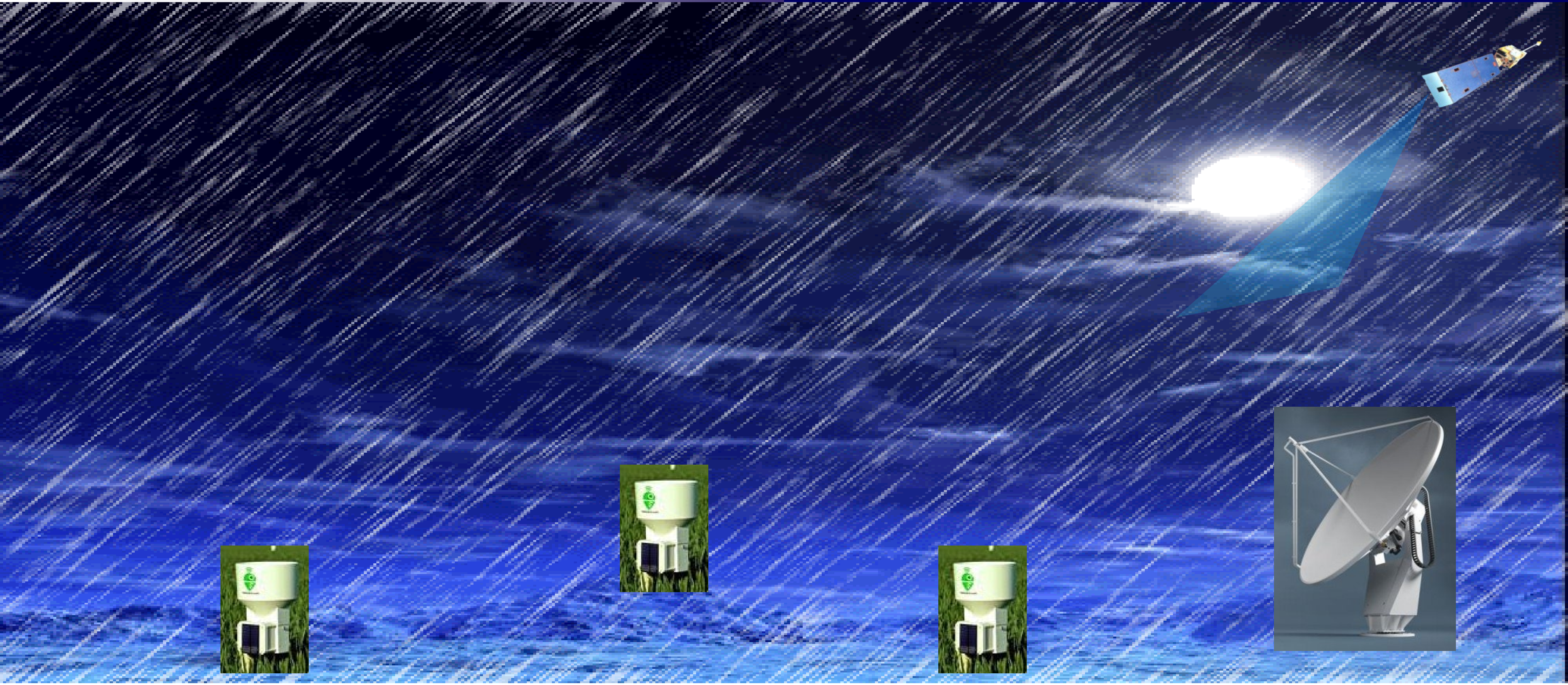


Precipitation Measurement is one of the KEY

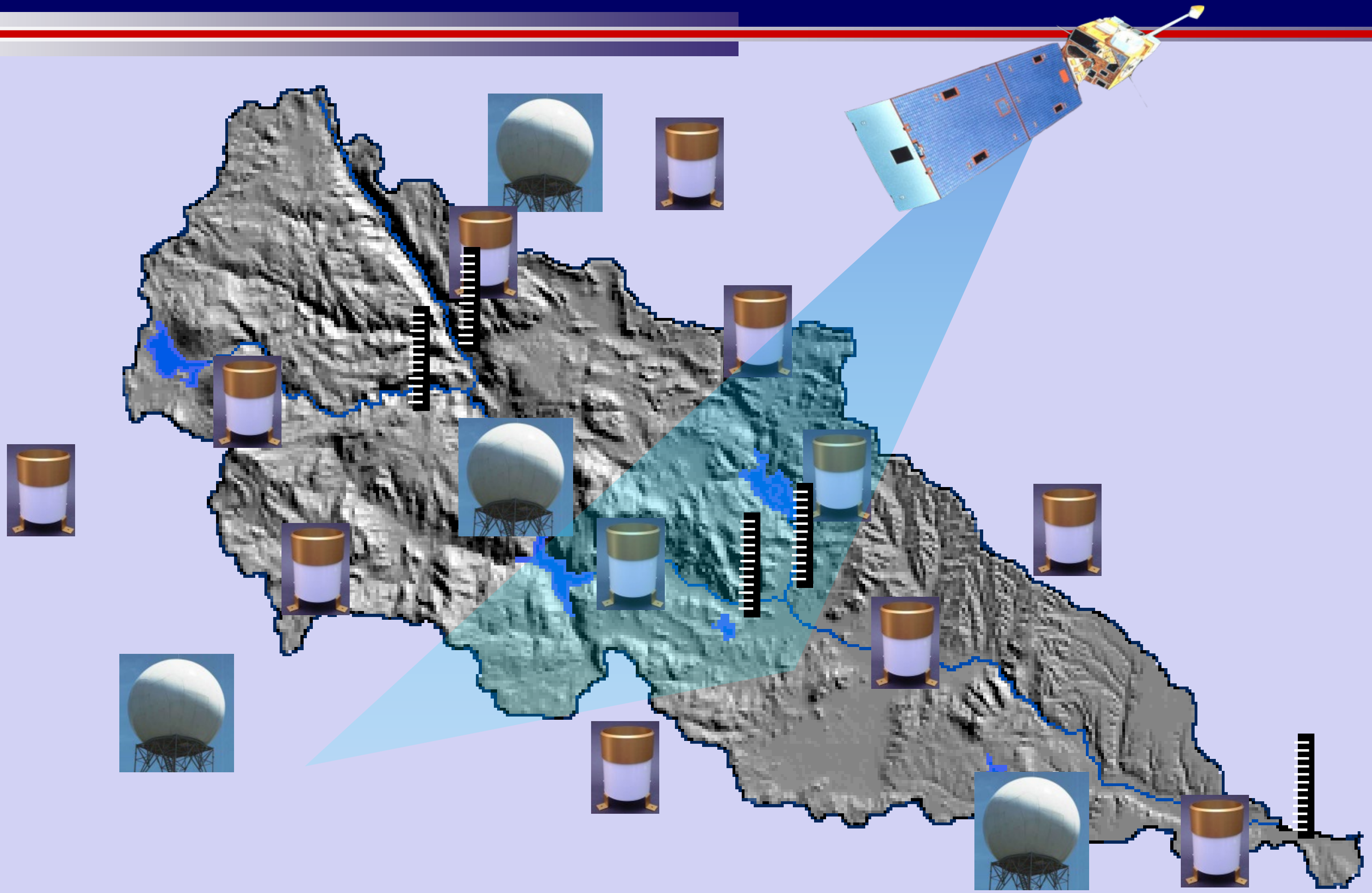
Hydrometeorological Challenges

Having adequate high resolution (time and Space) observations for hydrologic applications (model Input, Calibration, Testing, and to capture extremes is crucial)

Precipitation Measurement



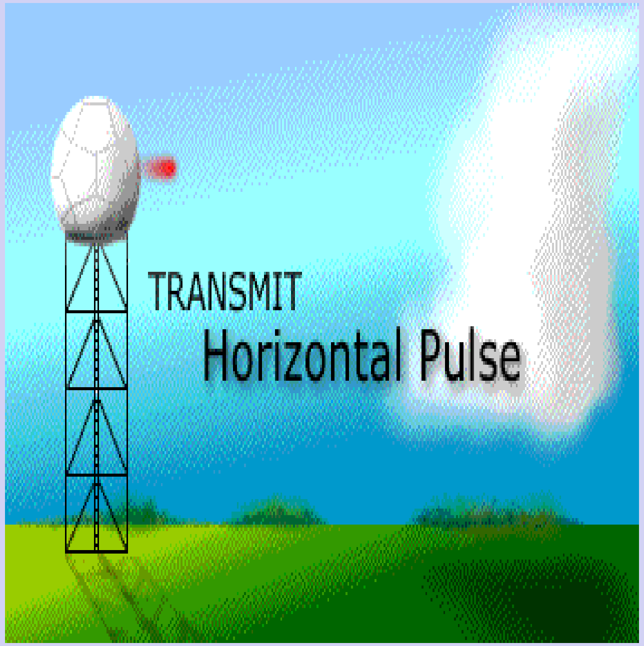
Data Requirements for Hydrologic Modeling

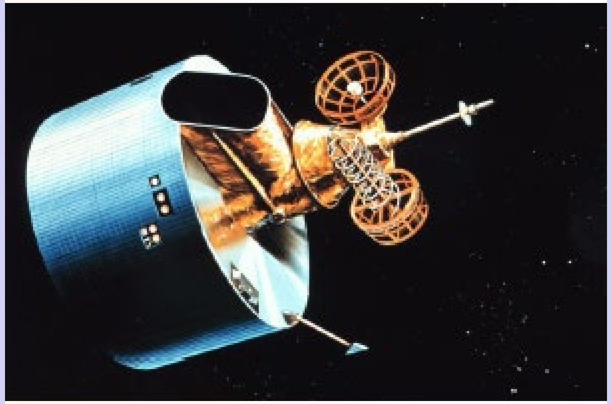


Data Limitation is an Important Factor in Success of Hydrologic Modeling

Precipitation Observations: Which to trust??

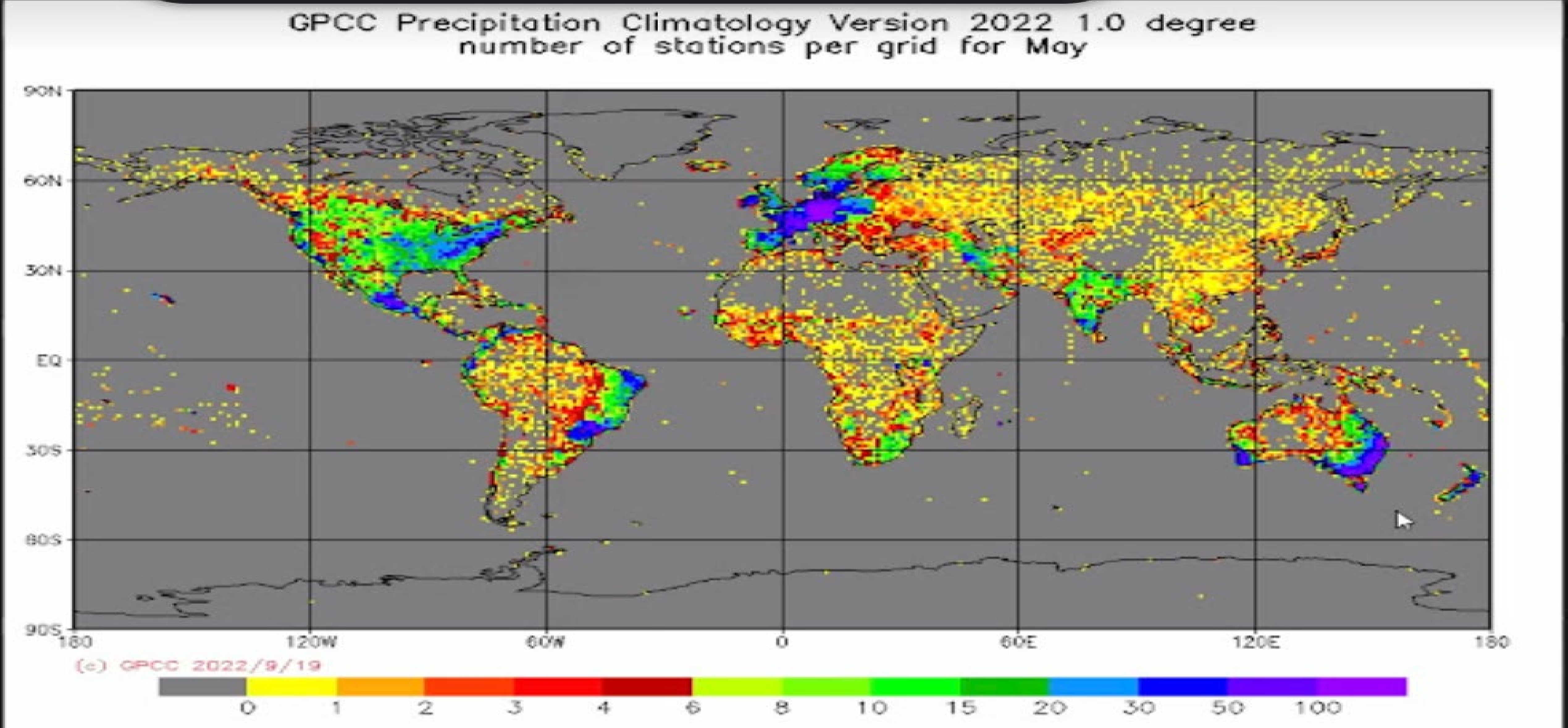
Rain Gauges



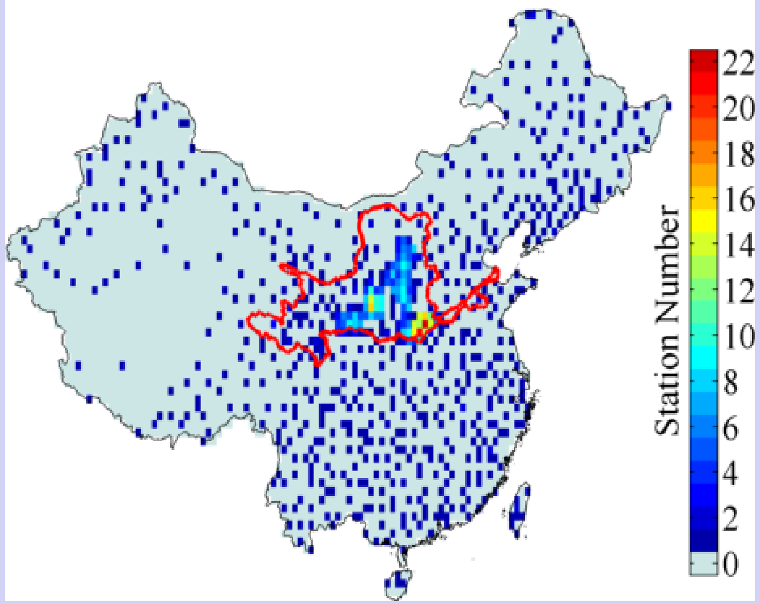


Satellite

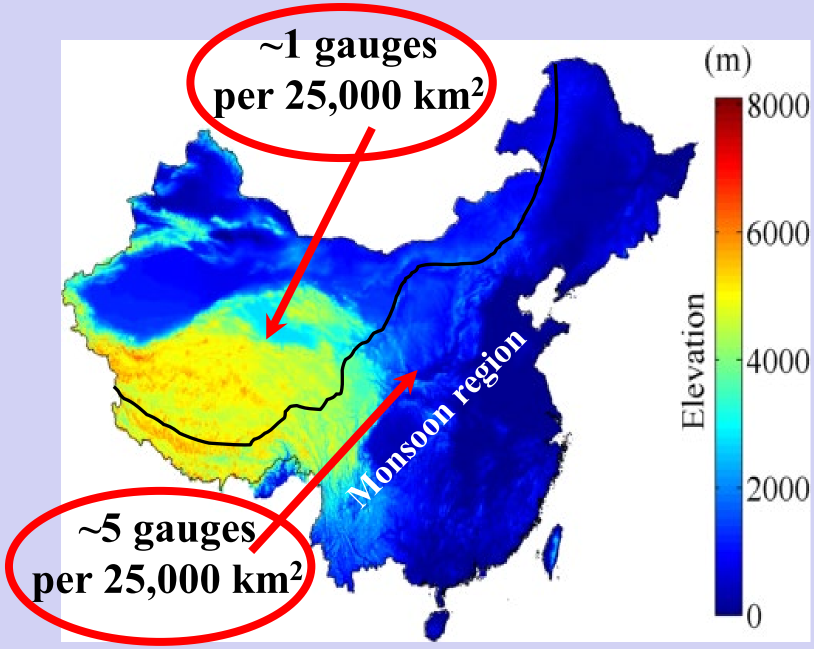
Spatial Resolution Challenges


GPCC Precipitation Climatology Version 2022 1.0 degree
number of stations per grid for May
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
(c) GPCC 2022/9/19
0
1
2
3
4
6
8
10
15
20
30
50
100

Rain Gauge Coverage over China

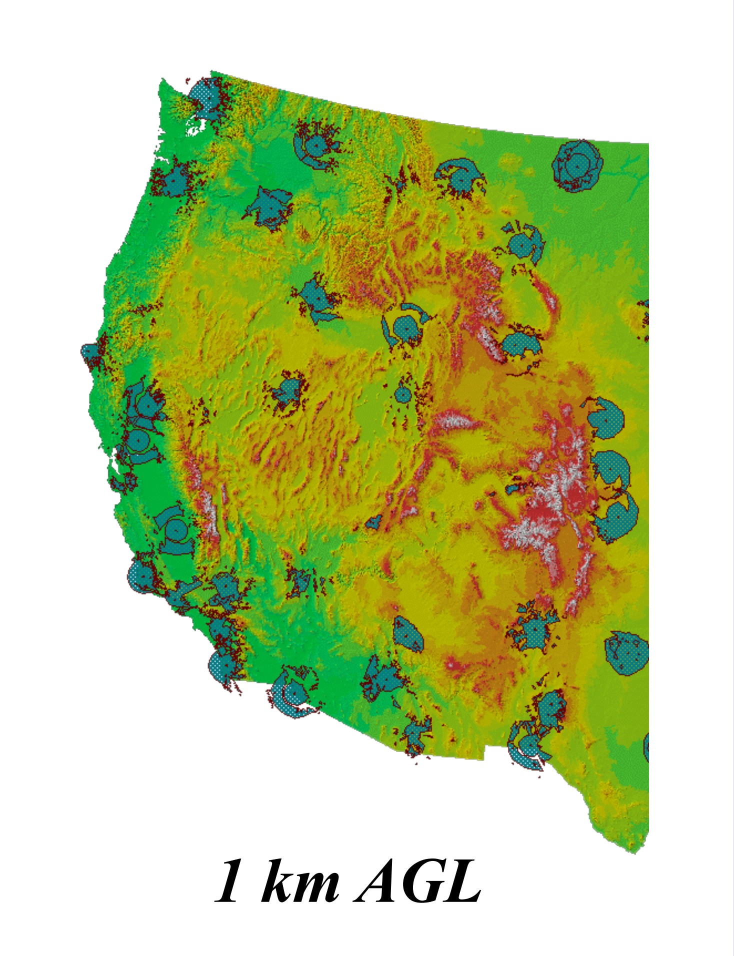


EA Rain Gauge Distribution

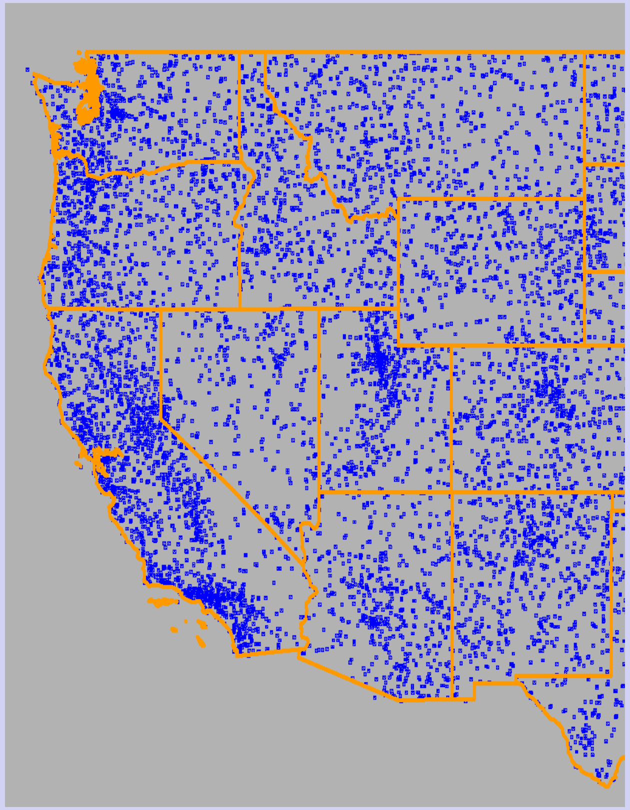


Elevation Map

Coverage of the WSR-88D and gauge networks



Maddox, et al., 2002

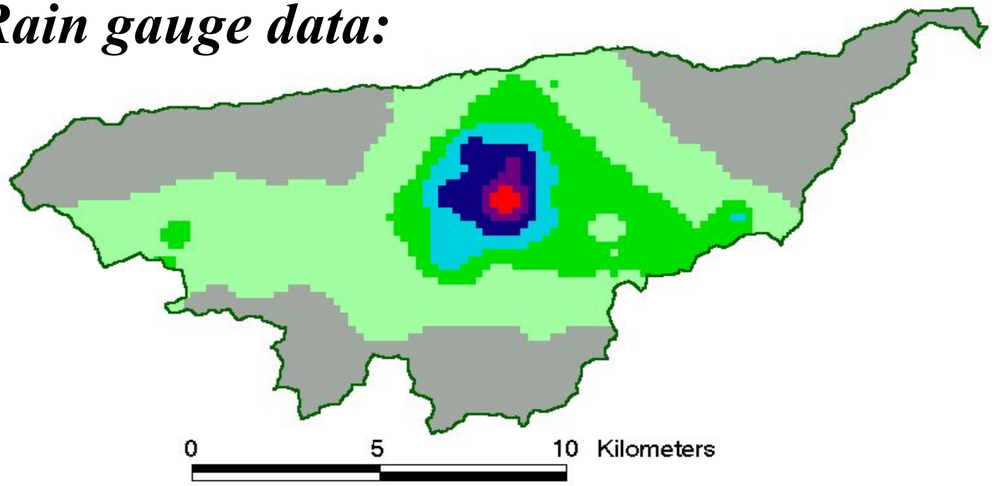


Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse

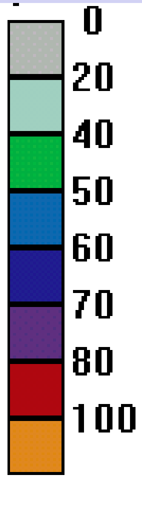
Radar-Gauge Comparison (Walnut Gulch, AZ)

Precipitation event: Aug. 11, 2000

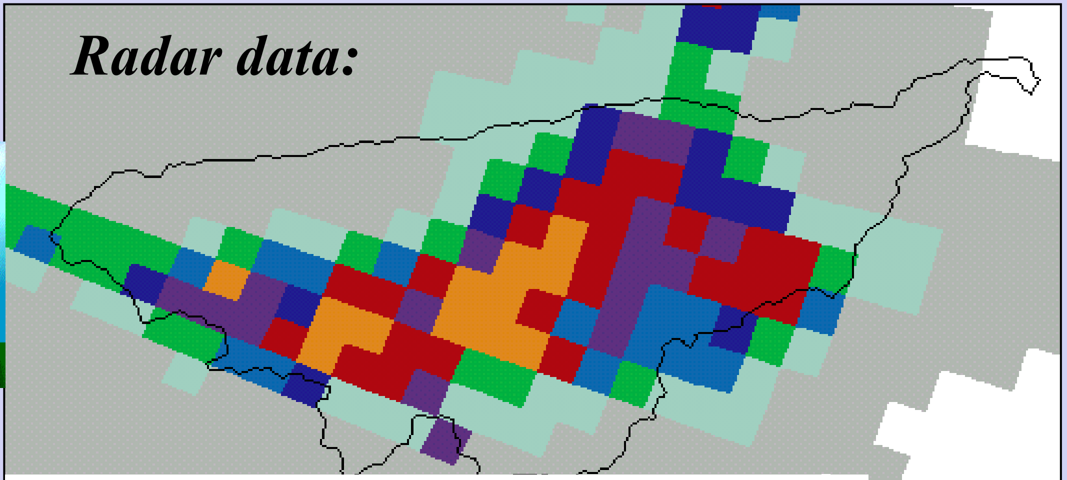
Rain gauge data:



Storm depth (mm)



Radar data:



$Z=300R^{1.4}$, 2.4^{o} elevation, HailThresh=56 dbz

70% overestimation by the radar!

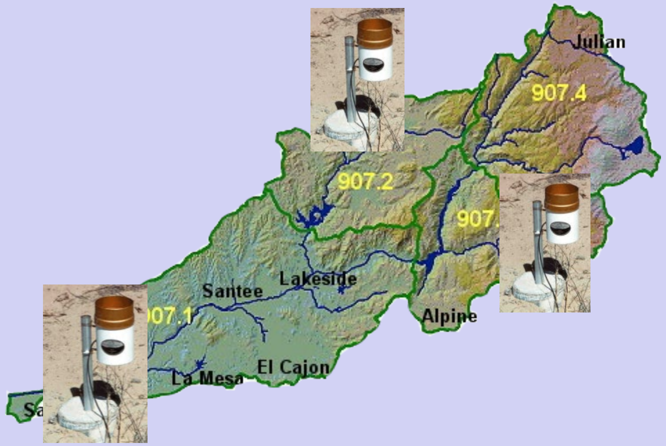
Morin et al ADWR 2005

Temporal Resolution Challenges

2 Precipitation Scenarios with different Temporal properties

Monthly Total

A



100 mm

Frequency 6.7%
Intensity 50.0 mm

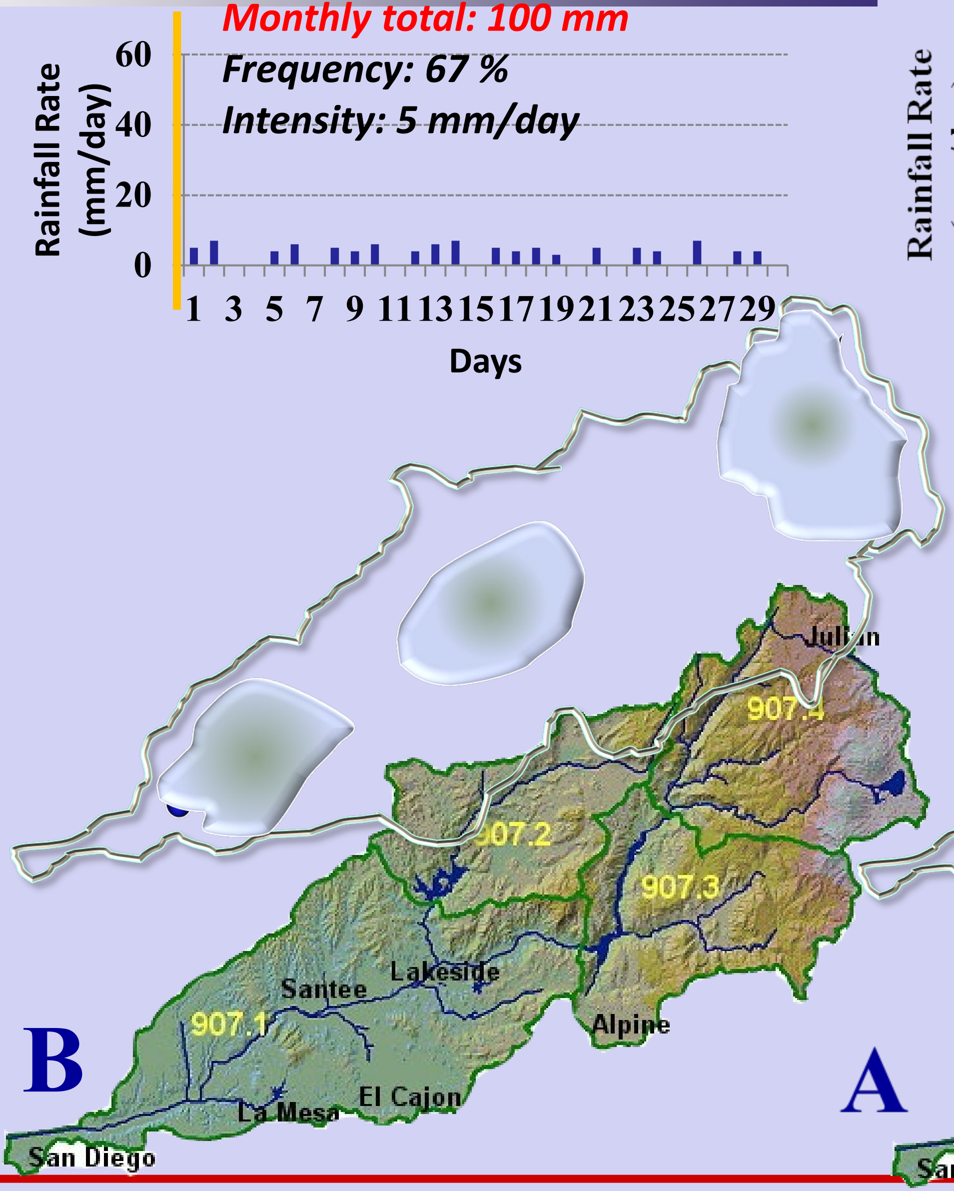
B

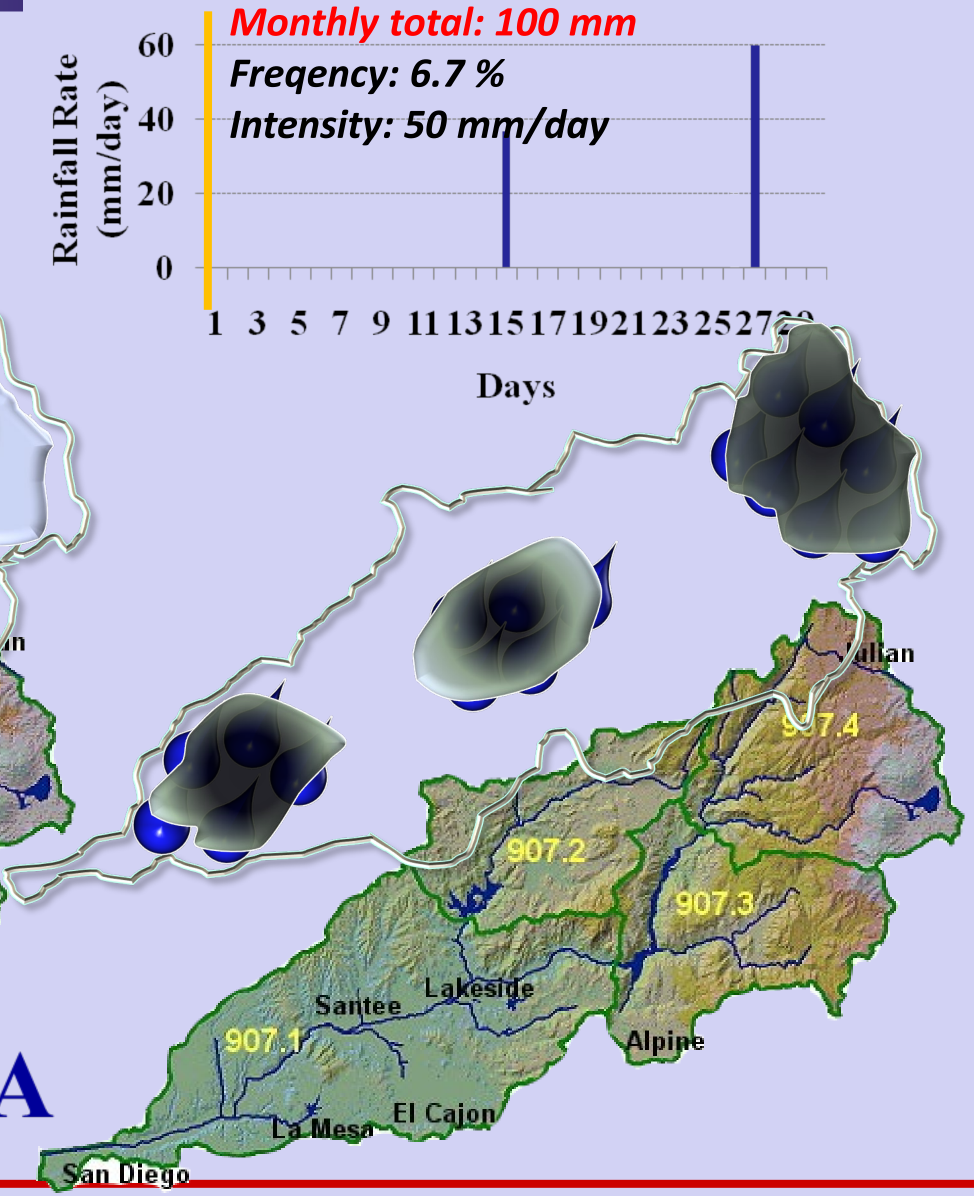
100 mm

Frequency 67%
Intensity 5.0 mm

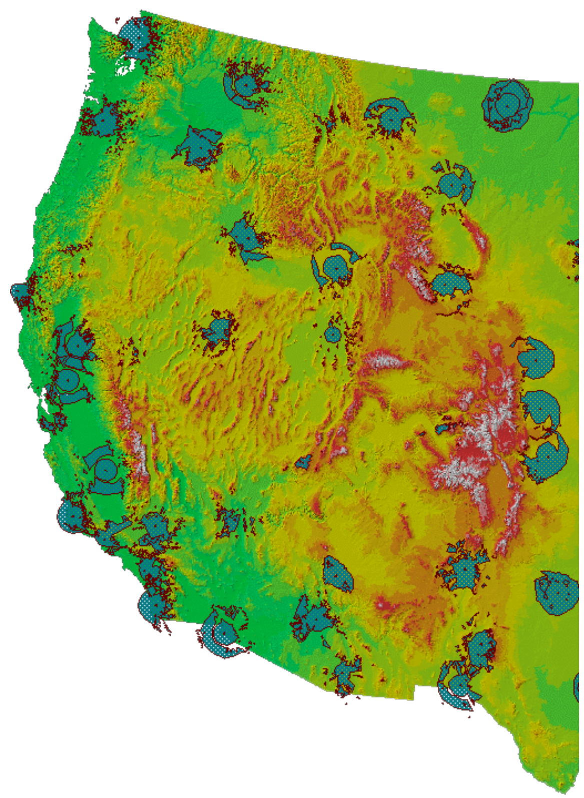
Idea from: K. Trenberth, NCAR

Temporal Scale Importance: Daily Precip. at 2 stations

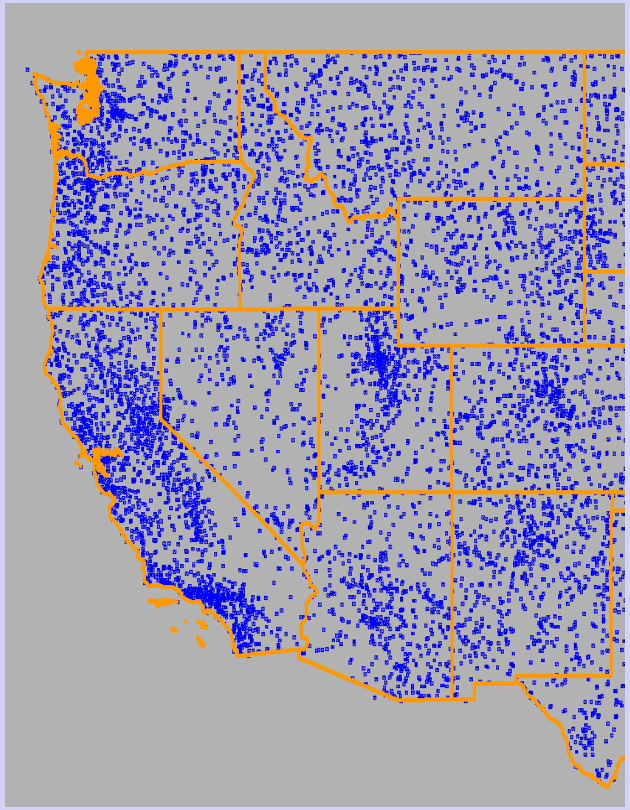




Coverage of the WSR-88D and gauge networks



Maddox, et al., 2002



Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse

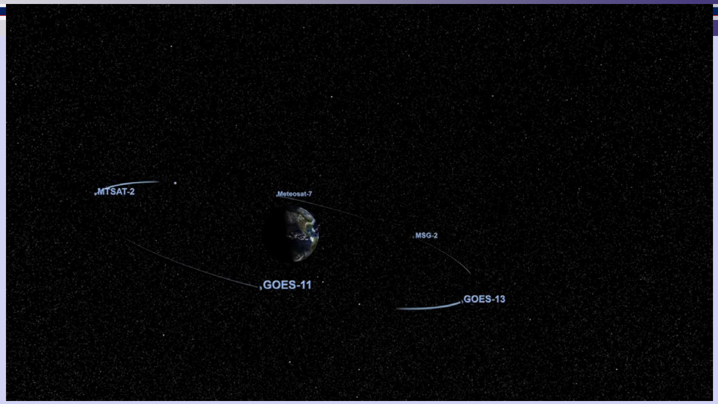
Observation of Primary Hydrologic Variables

Stream flow

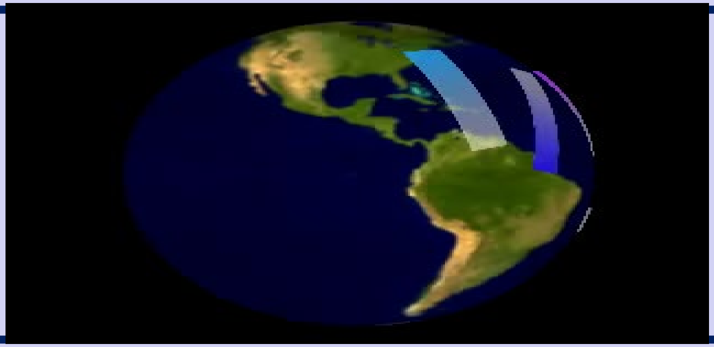
Precipitation

Space-Based Observations

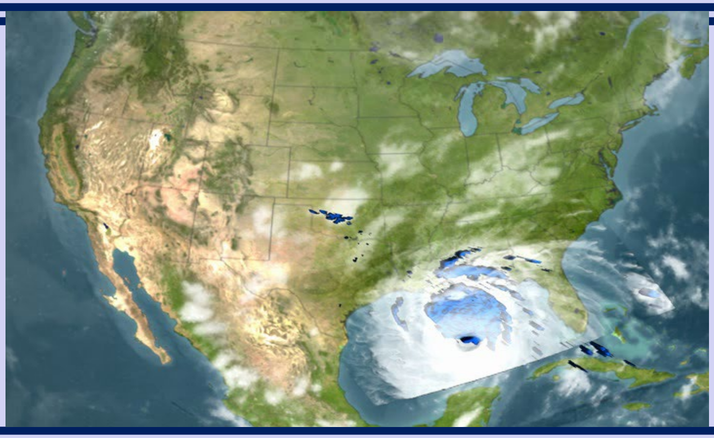
Satellite Data for Precipitation estimation



Geostationary IR
Cloud top data
15-30 minute temporal resolution

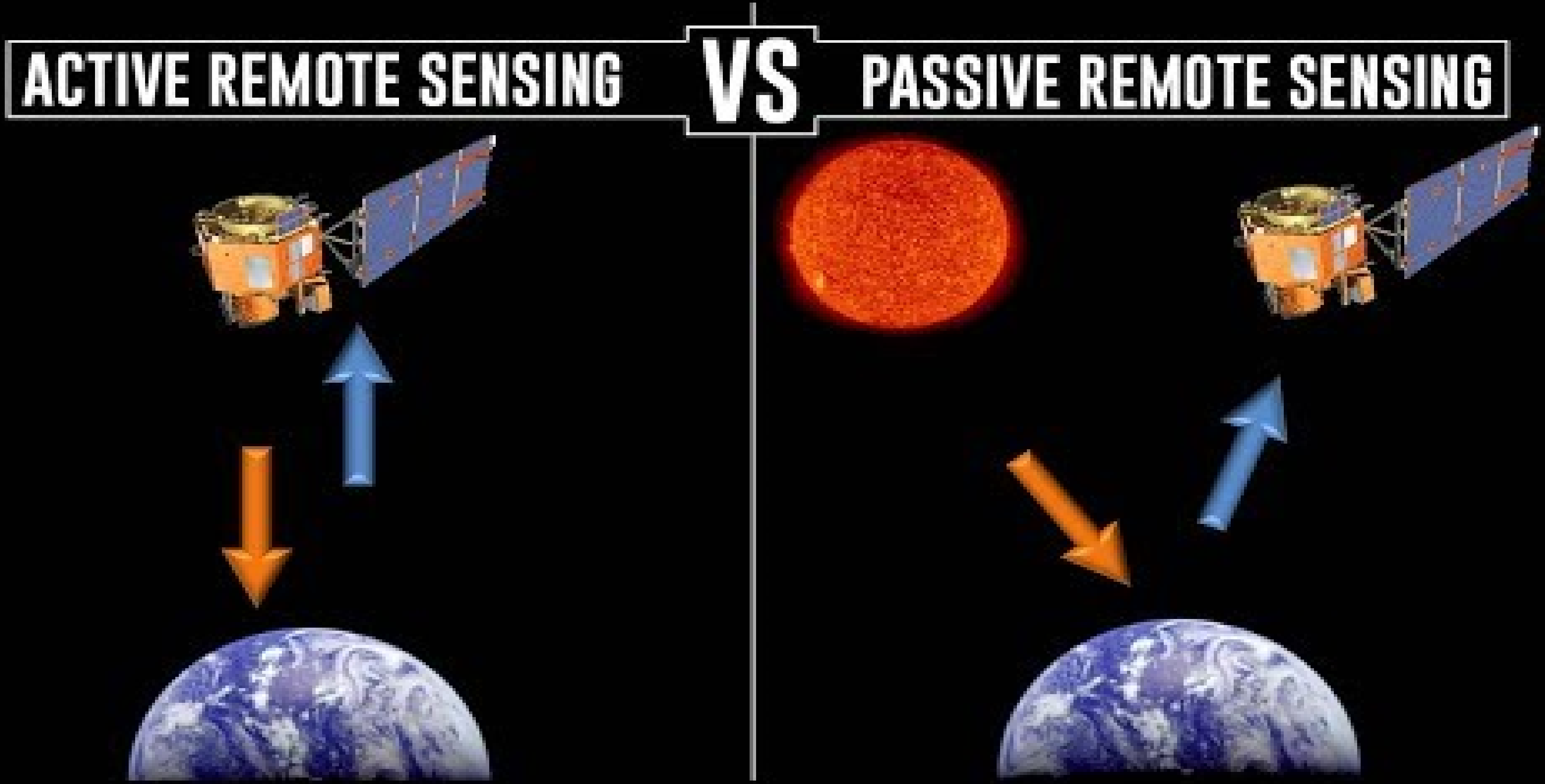


Passive Microwave (SSM/I)
Some characterisation of rainfall
~2 overpasses per day per
spacecraft, moving to 3-hour return time (GPM)

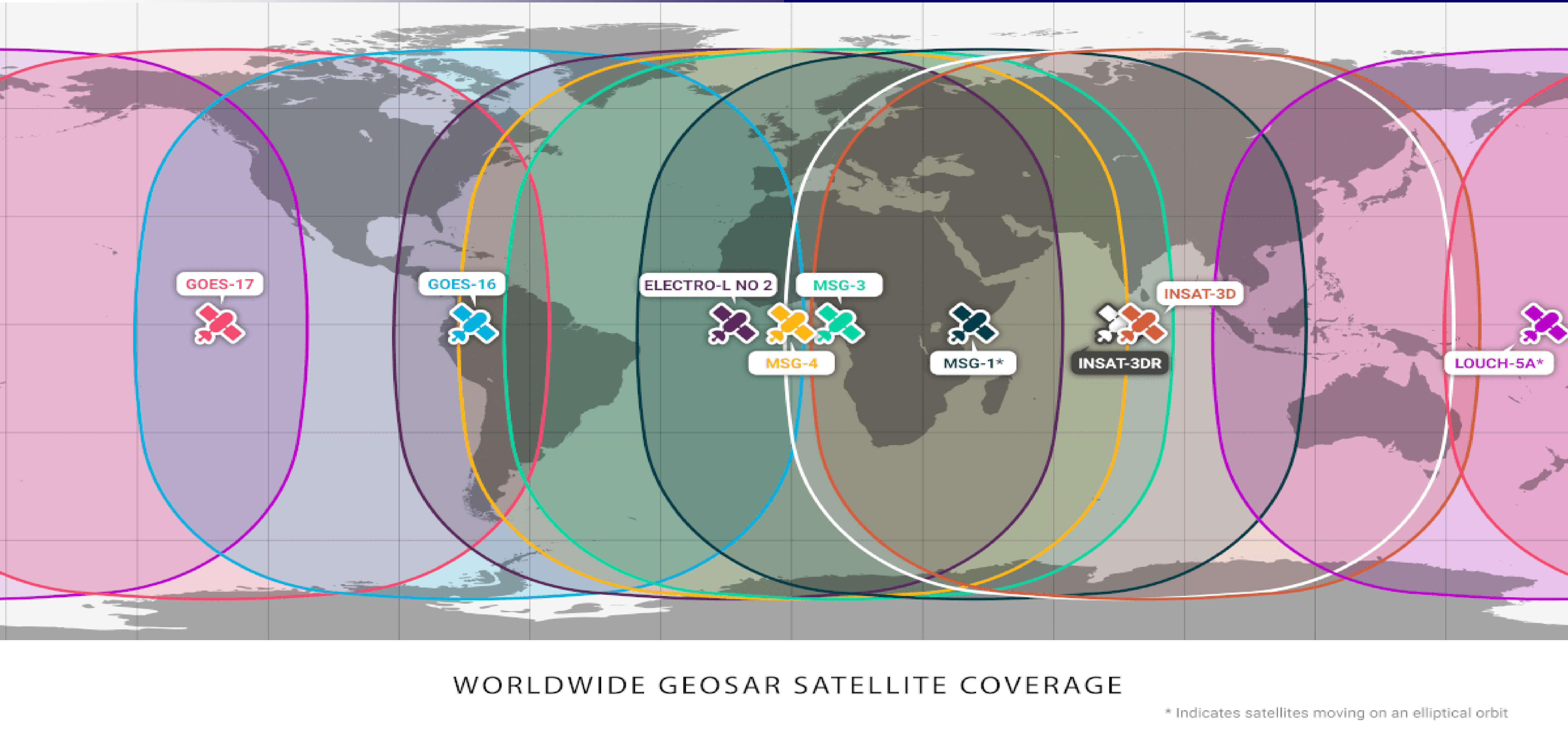


TRMM precipitation RADAR
3D imaging of rainfall
1-2 days between overpasses
(S-35°N-35 °)

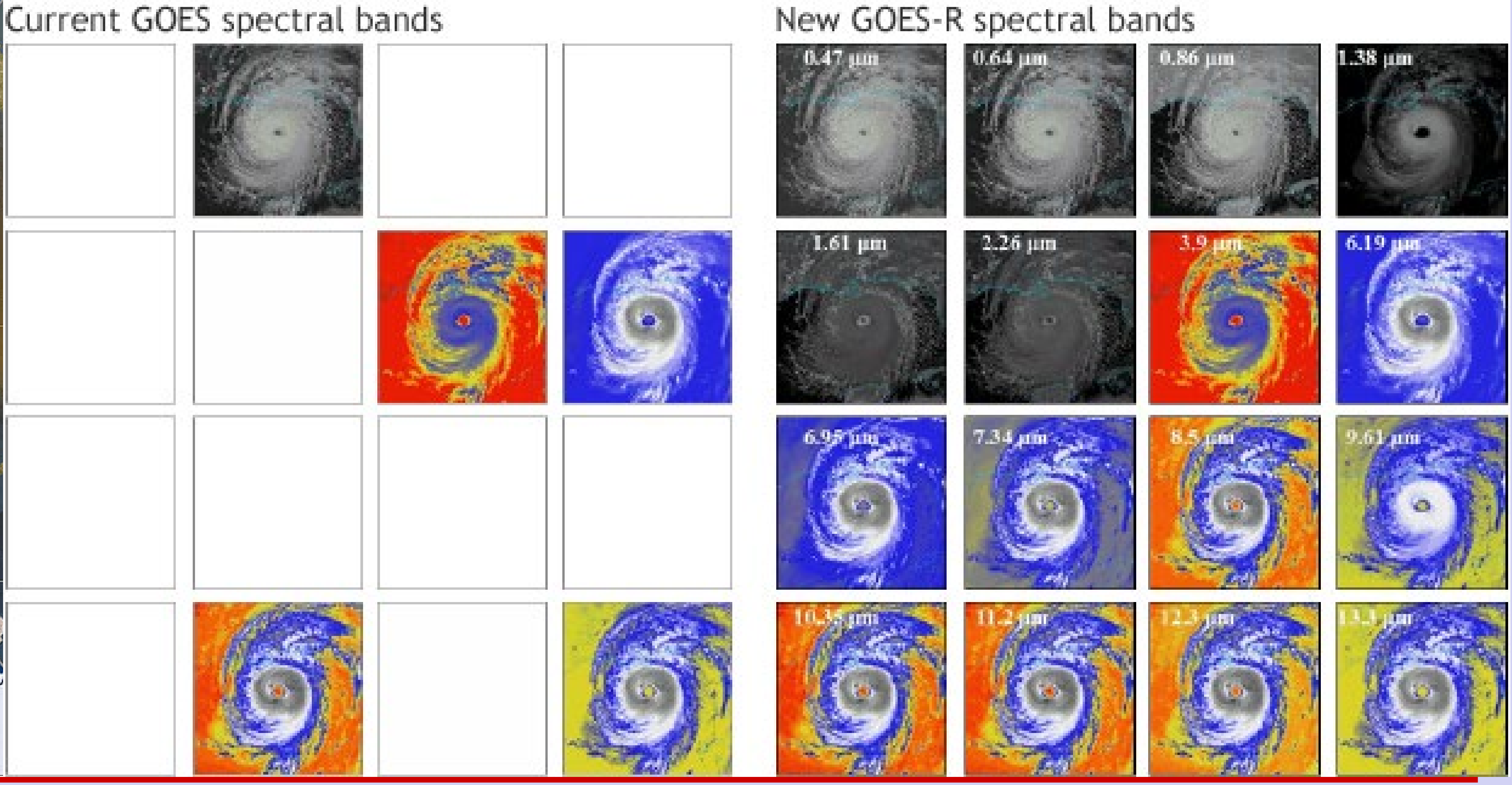
Active vs Passive Radar Sensors on Low Earth Orbiting Satellites



Typical Footprint of Geo-Stationary Satellites



Geostationary Satellites Covering the US - Recent Past and Future Generation



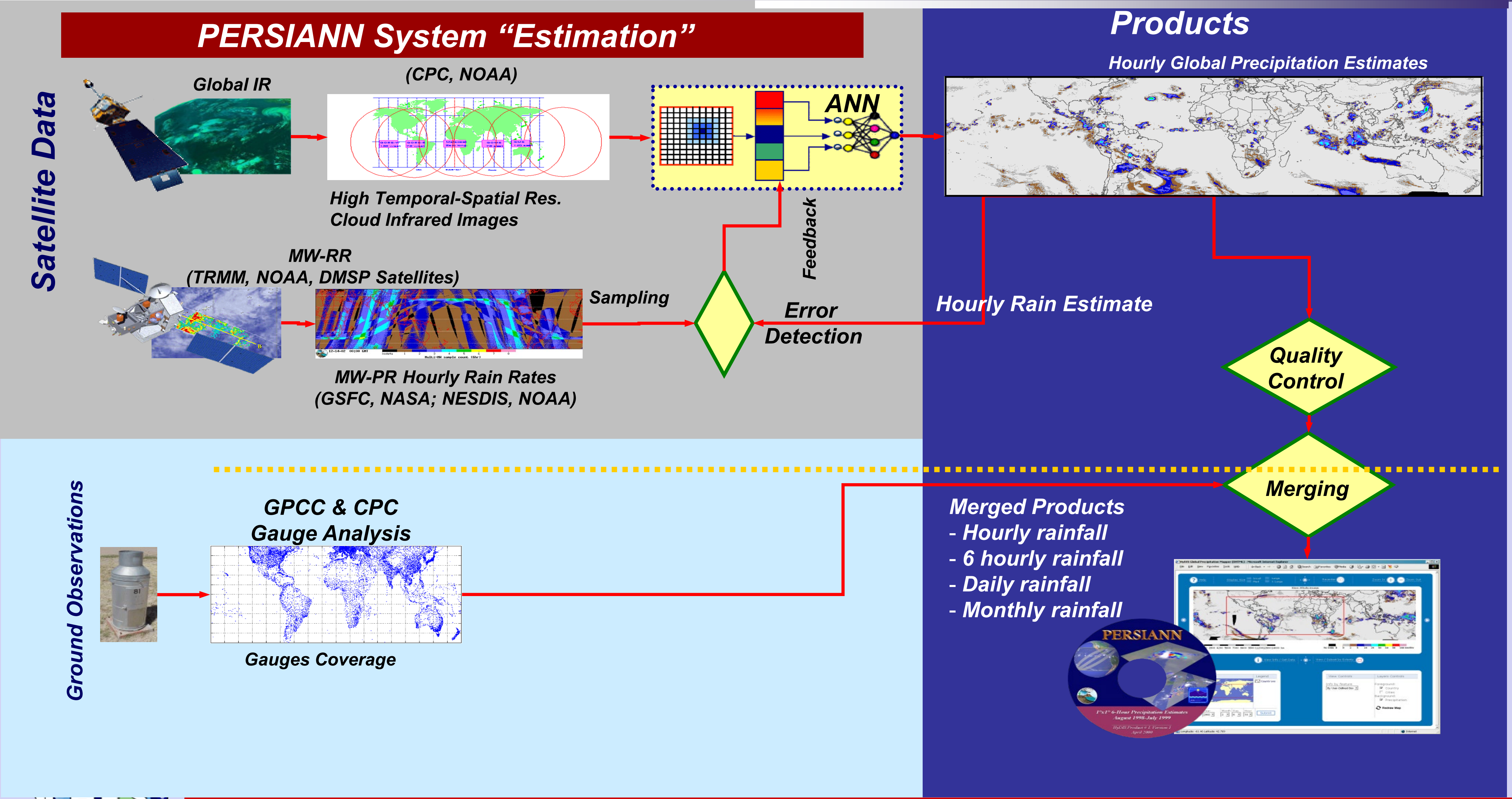
Slices of Earth - observational and modeling data

Courtesy: NASA's ESE

Integrated Multi-satellitE Retrievals for GPM (IMERG)

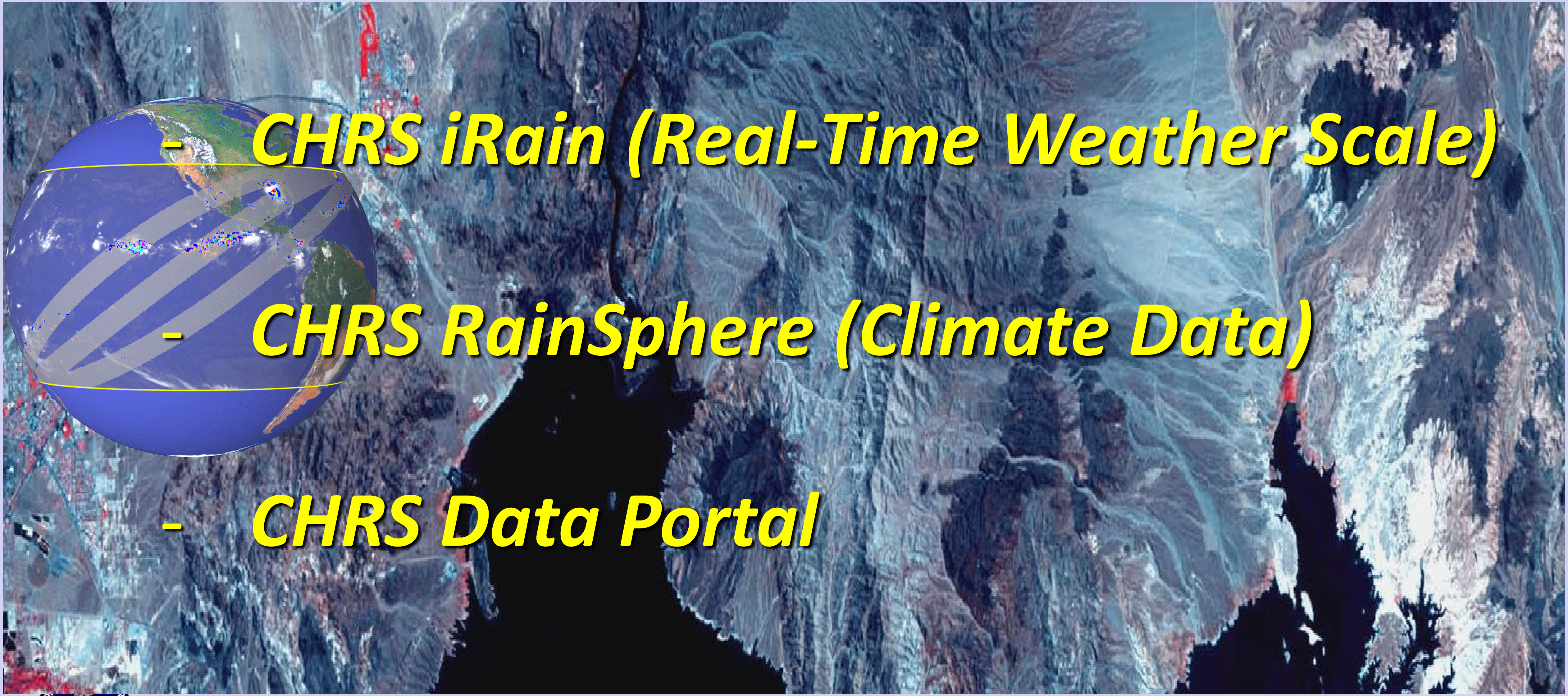
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)

Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)



Kuolin Hsu

PERSIANN Websites and Apps



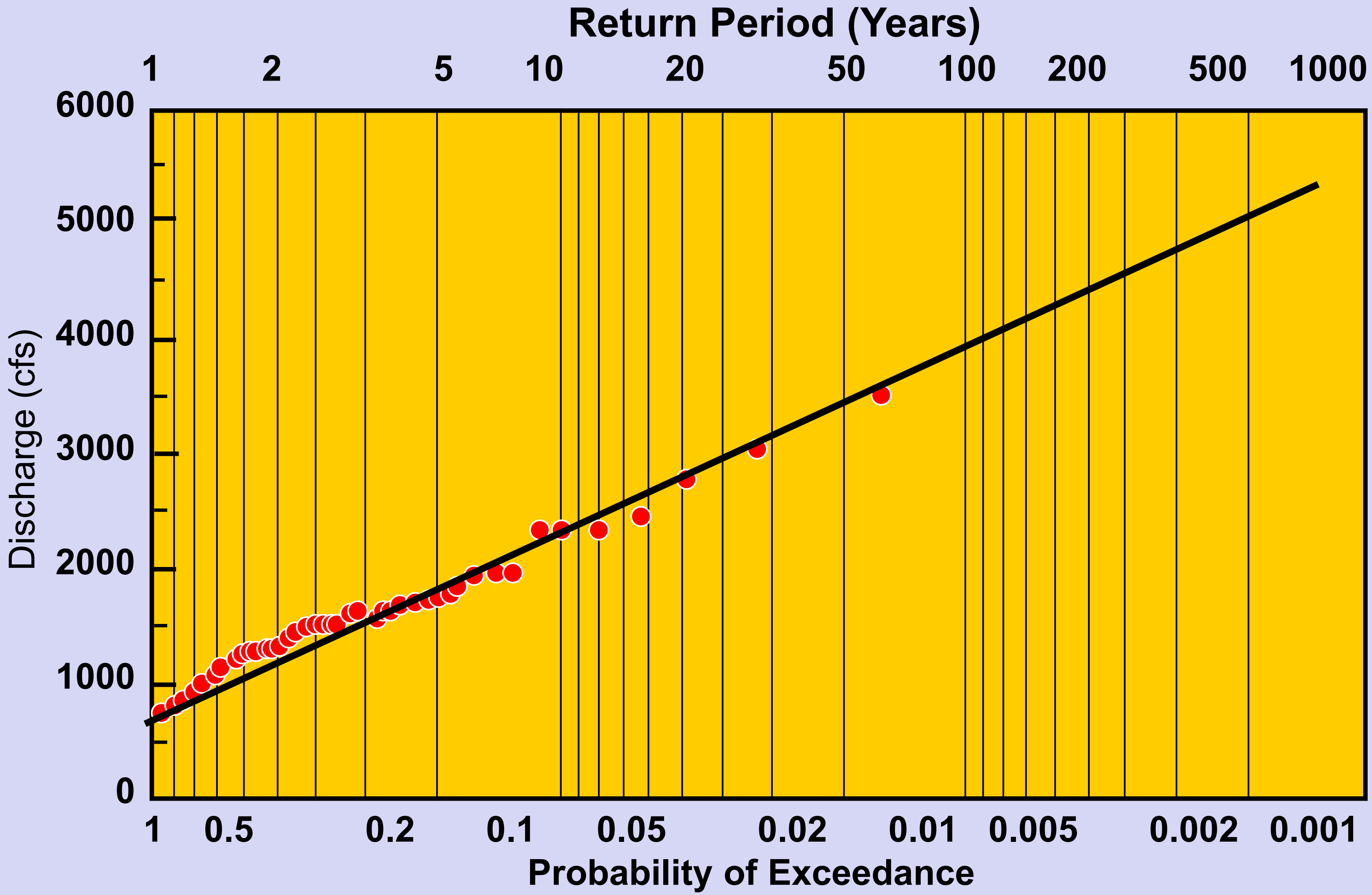
- CHRS iRain (Real-Time Weather Scale)
- CHRS RainSphere (Climate Data)
- CHRS Data Portal

Addressing "Extremes" in Water Resources Planning:

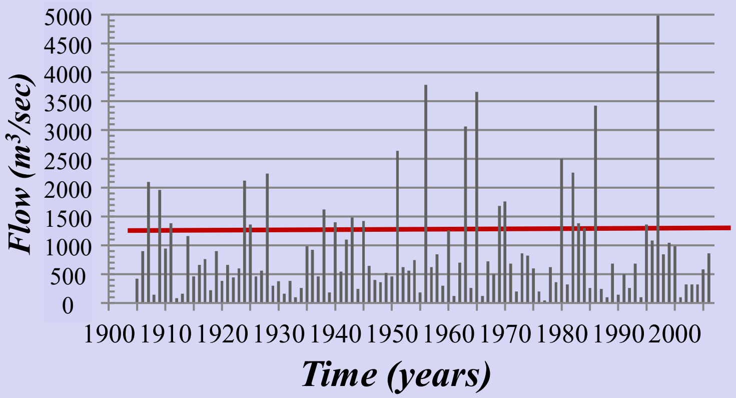
Stochastic Hydrology

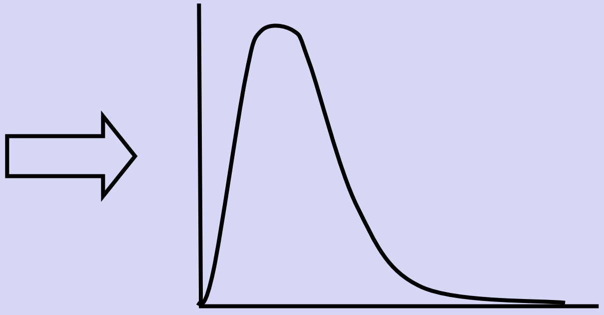
(Requirement- Observation Data)

Statistical Hydrology

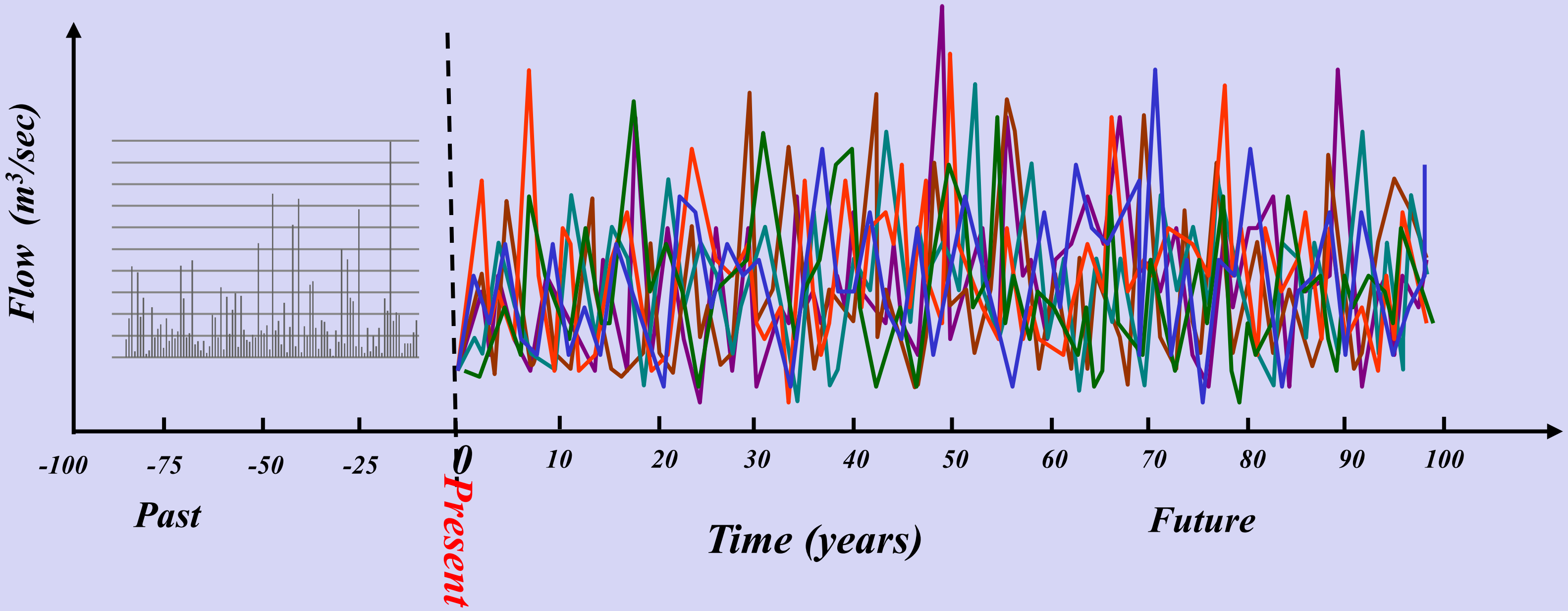


Statistical Hydrology: "synthetic" stream flow Generation

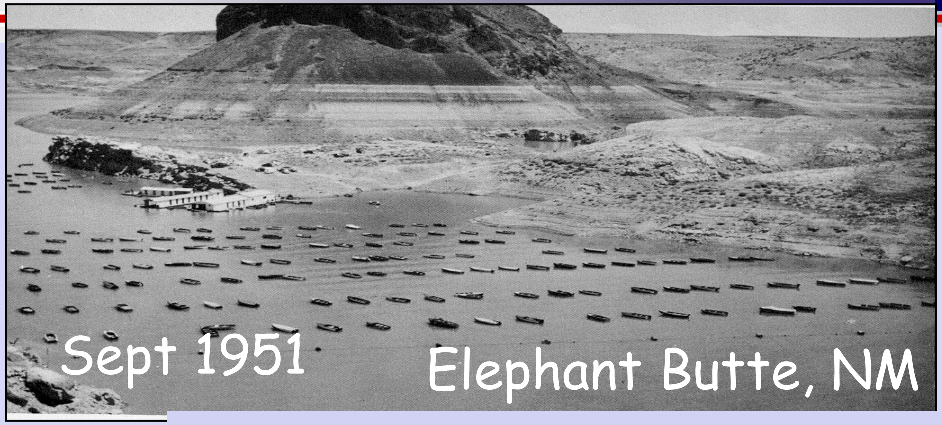




Probability density function

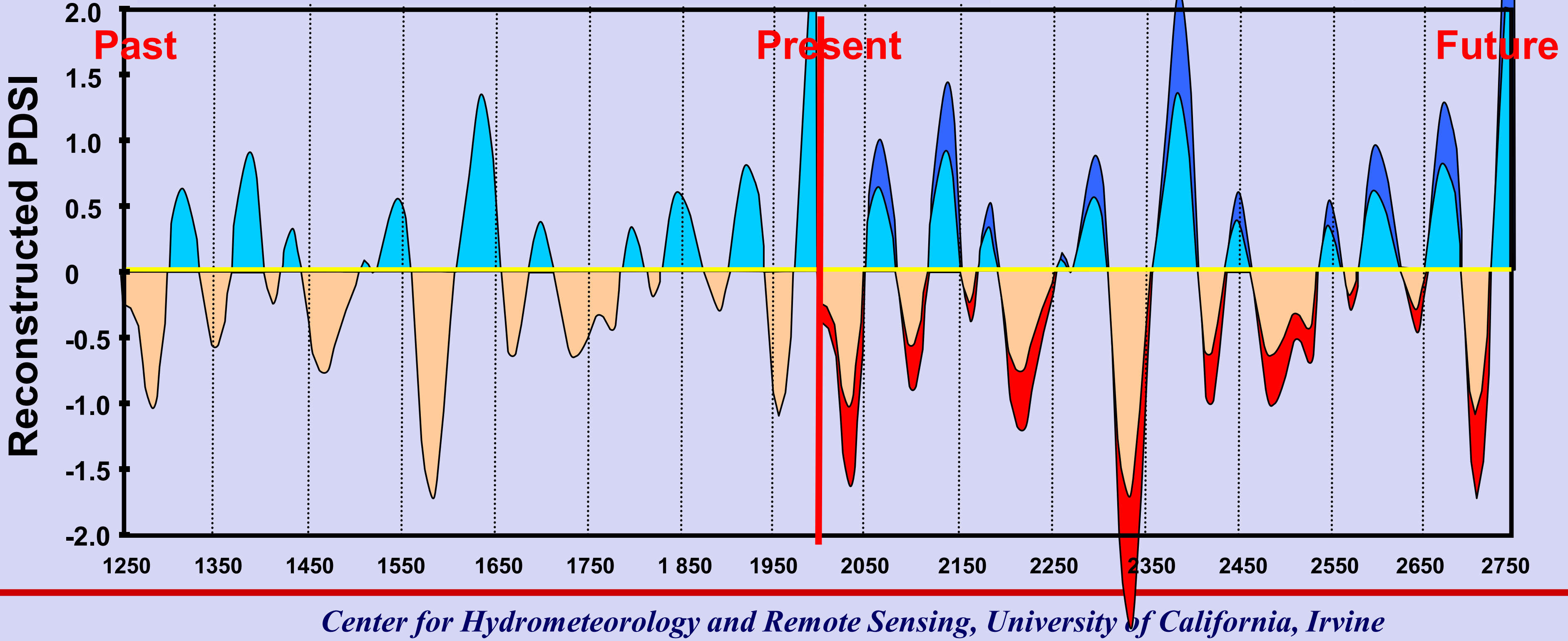


Statistical Hydrology Developed Based on Stationarity Assumption

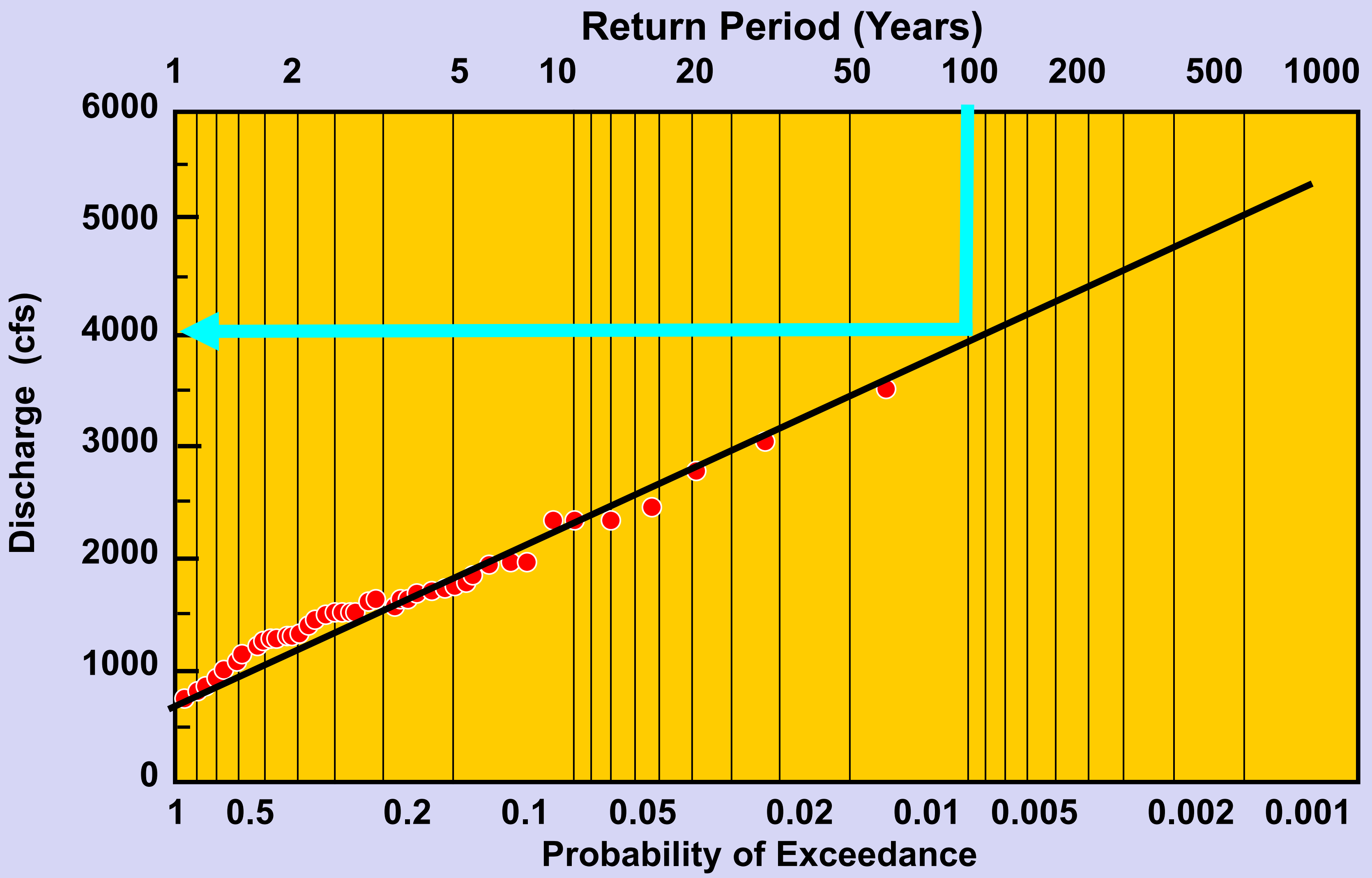


Middle Rio Grande Basin, NM AD

Grissino-Mayer, Baisan, Morino, & Swetnam, 2001



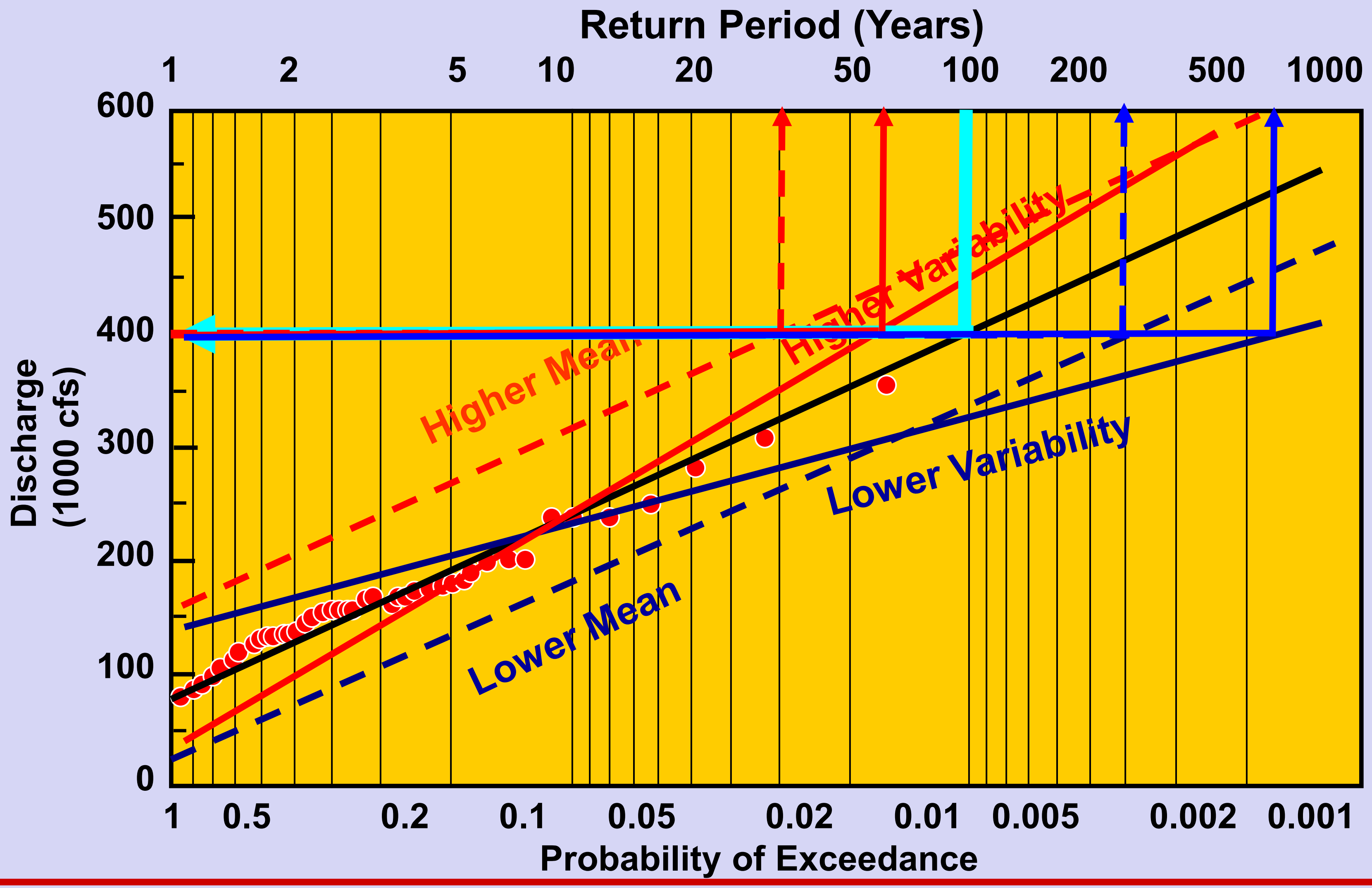
Flood Frequency Analysis: Stationarity!



Potential Hydrologic Scenarios

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

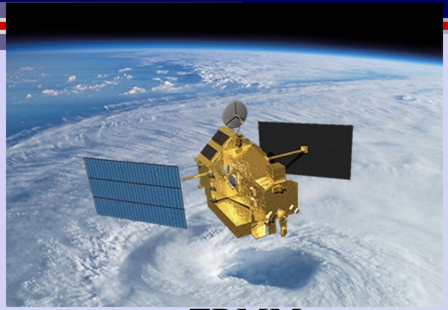
2. Hydrologic Variability
(e.g. magnitude/severity/duration)



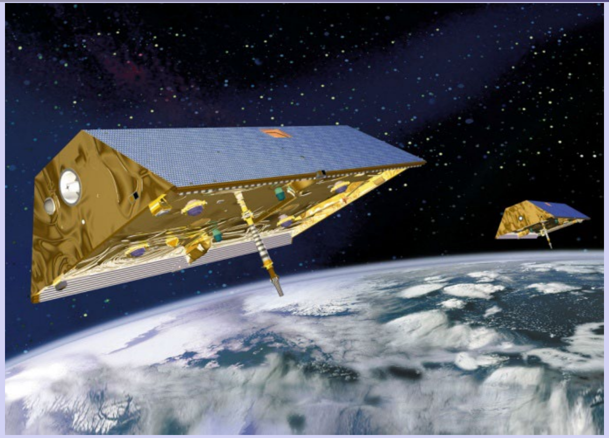
How Much Trust in Remote Sensing Observations??

Hydrologically - Relevant Remote Sensing Missions

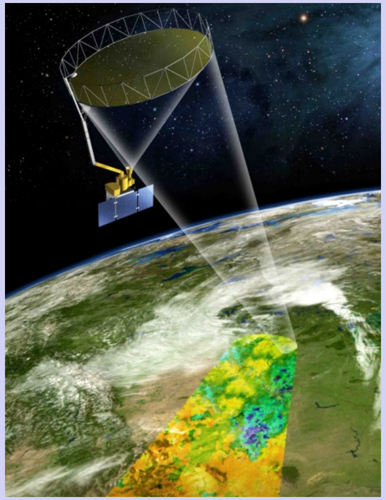
SMOS
ESA's Soil Moisture and Ocean Salinity (2009)



TRMM
The Tropical Rainfall Measuring Mission

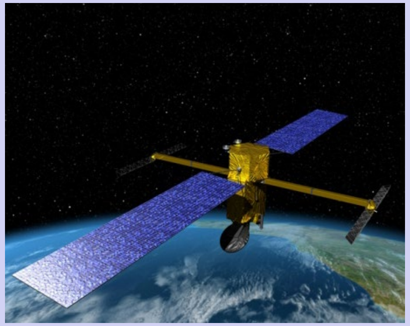


GRACE
Gravity Recovery and Climate Experiment (2002)

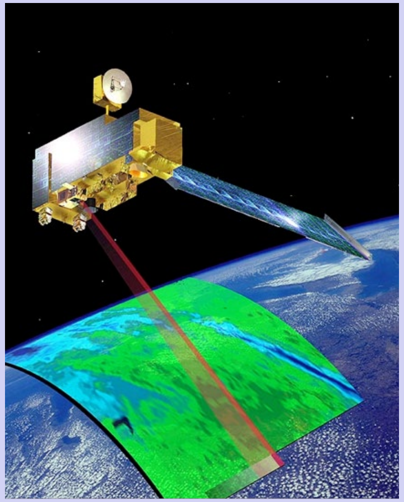


SMAP
Soil Moisture Active Passive Satellite(2014)

GPM
Global Precipitation Measurements (2014)



SWOT
Surface Water and Ocean Topography (2020)

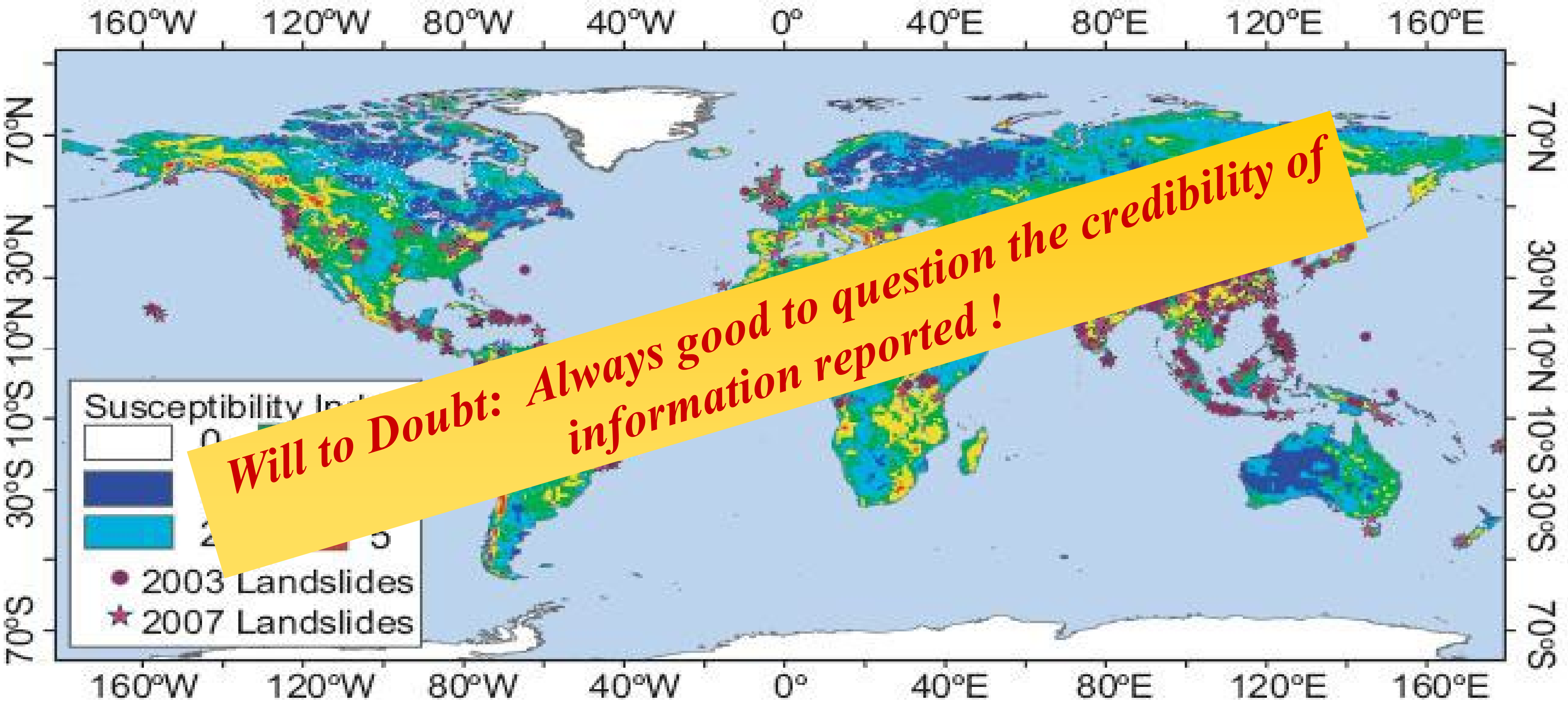


MODIS
Moderate Resolution Imaging Spectroradiometer
(1999) , (2002)

Problems with IR only algorithm

Assumption: higher cloud → colder → more precipitation

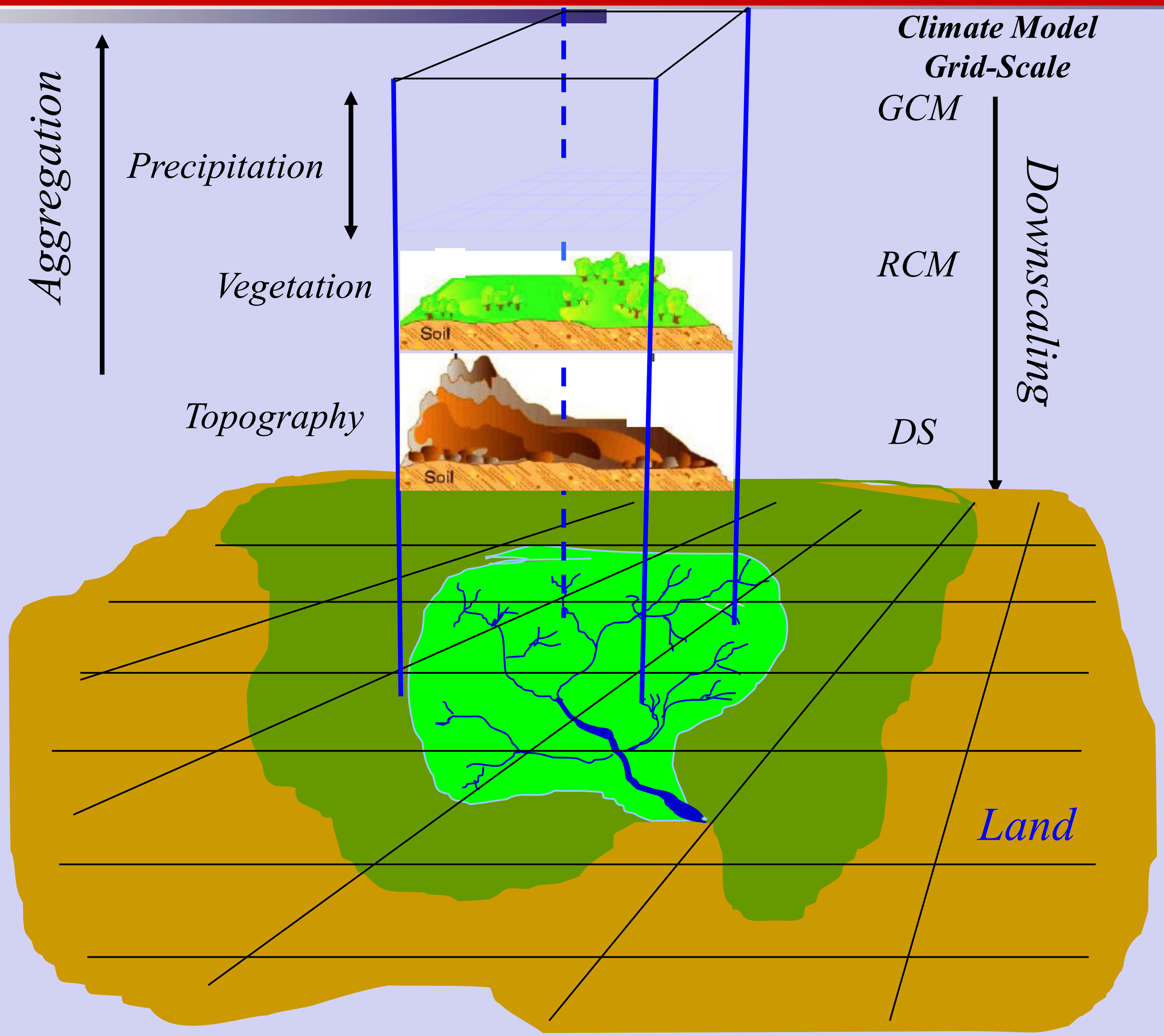
Landslide Risk map:



Will to Doubt: Always good to question the credibility of information reported !

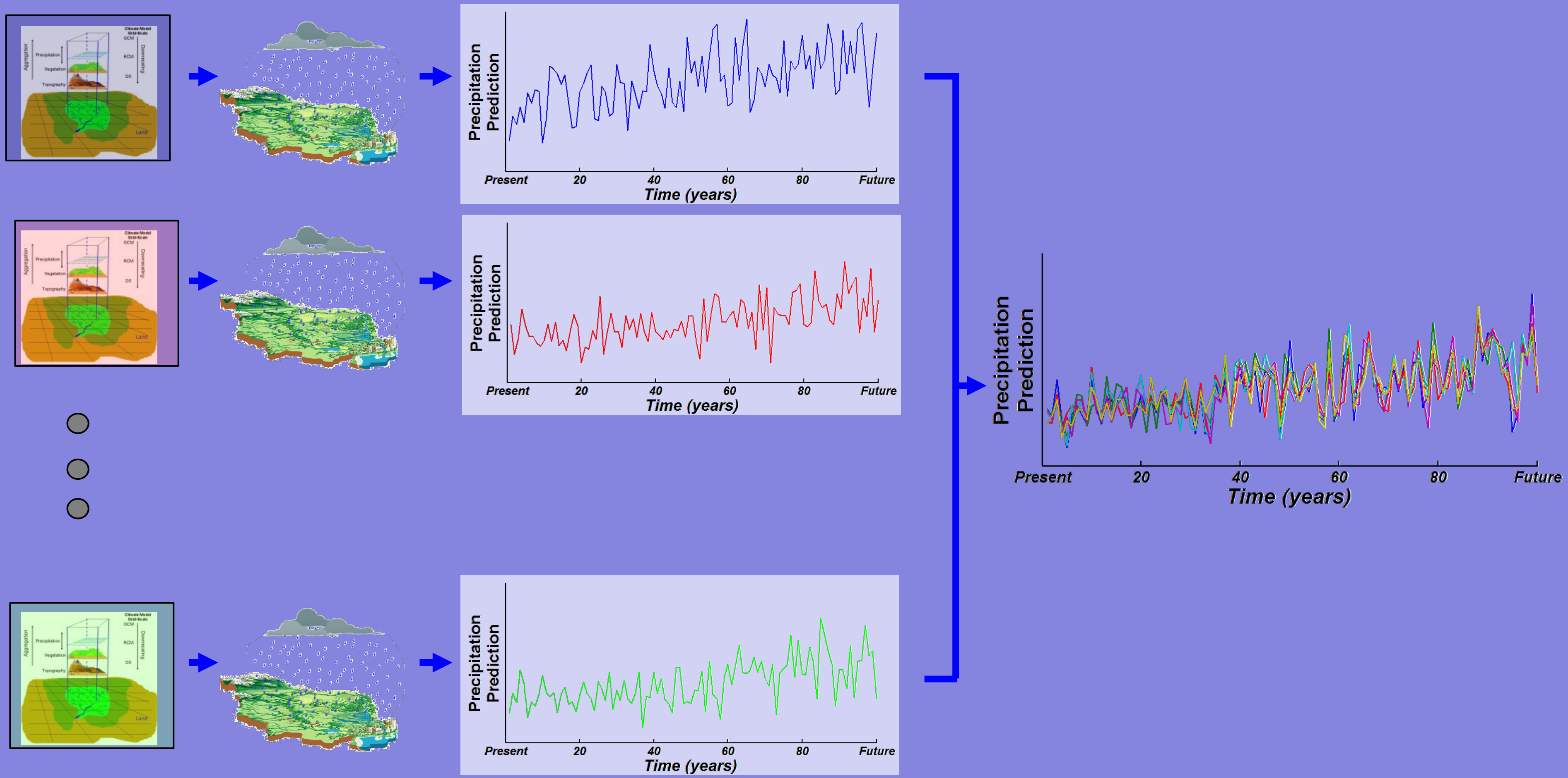
Climate Model Projections and their application in Water Resources

Climate Model Downscaling to regional/watershed Scale



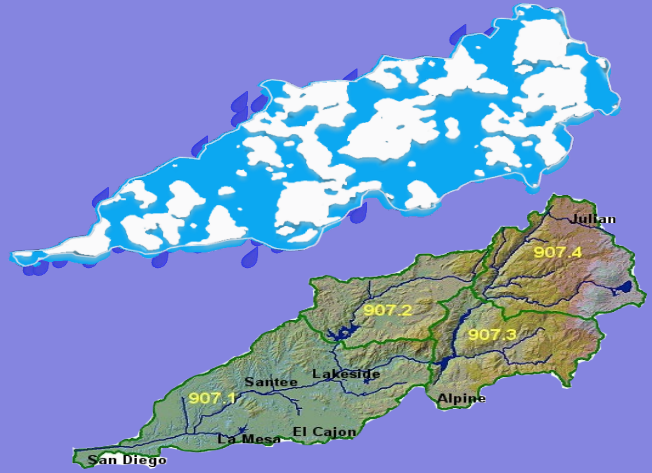
Ensemble Approach

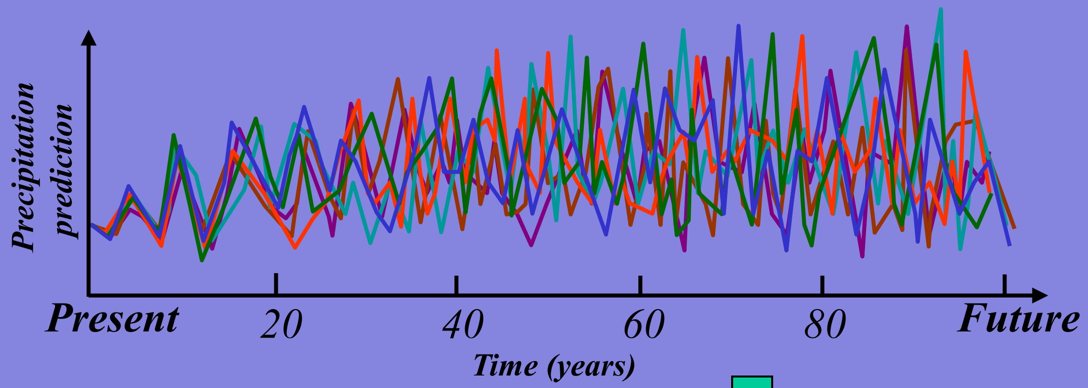
Generation of Future Precipitation Scenarios

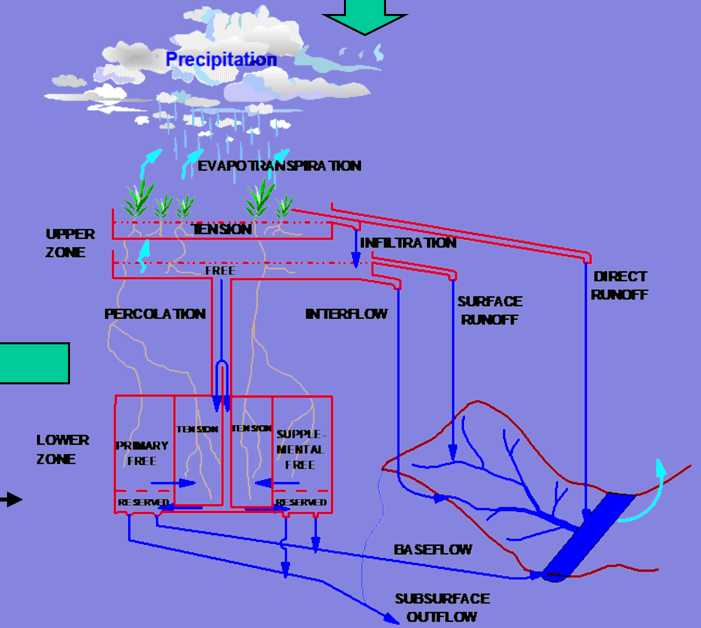


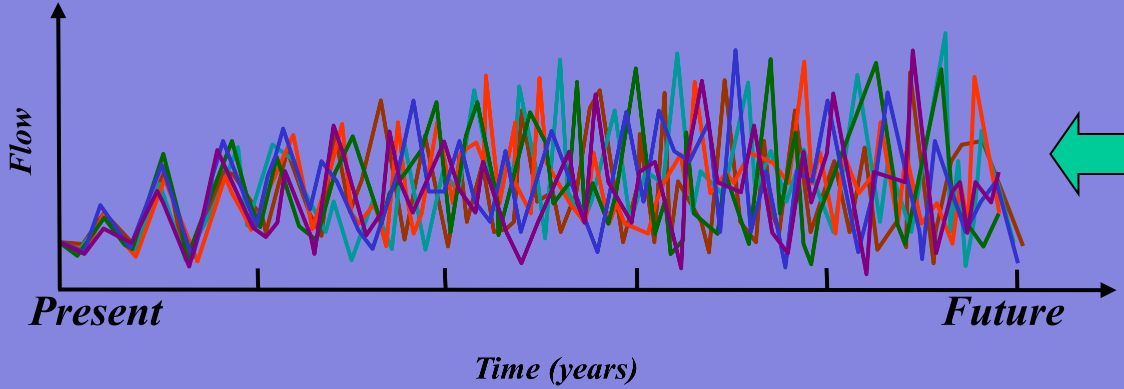
Downscaled Precipitation to Runoff Generation

Generation of Future Runoff Scenarios

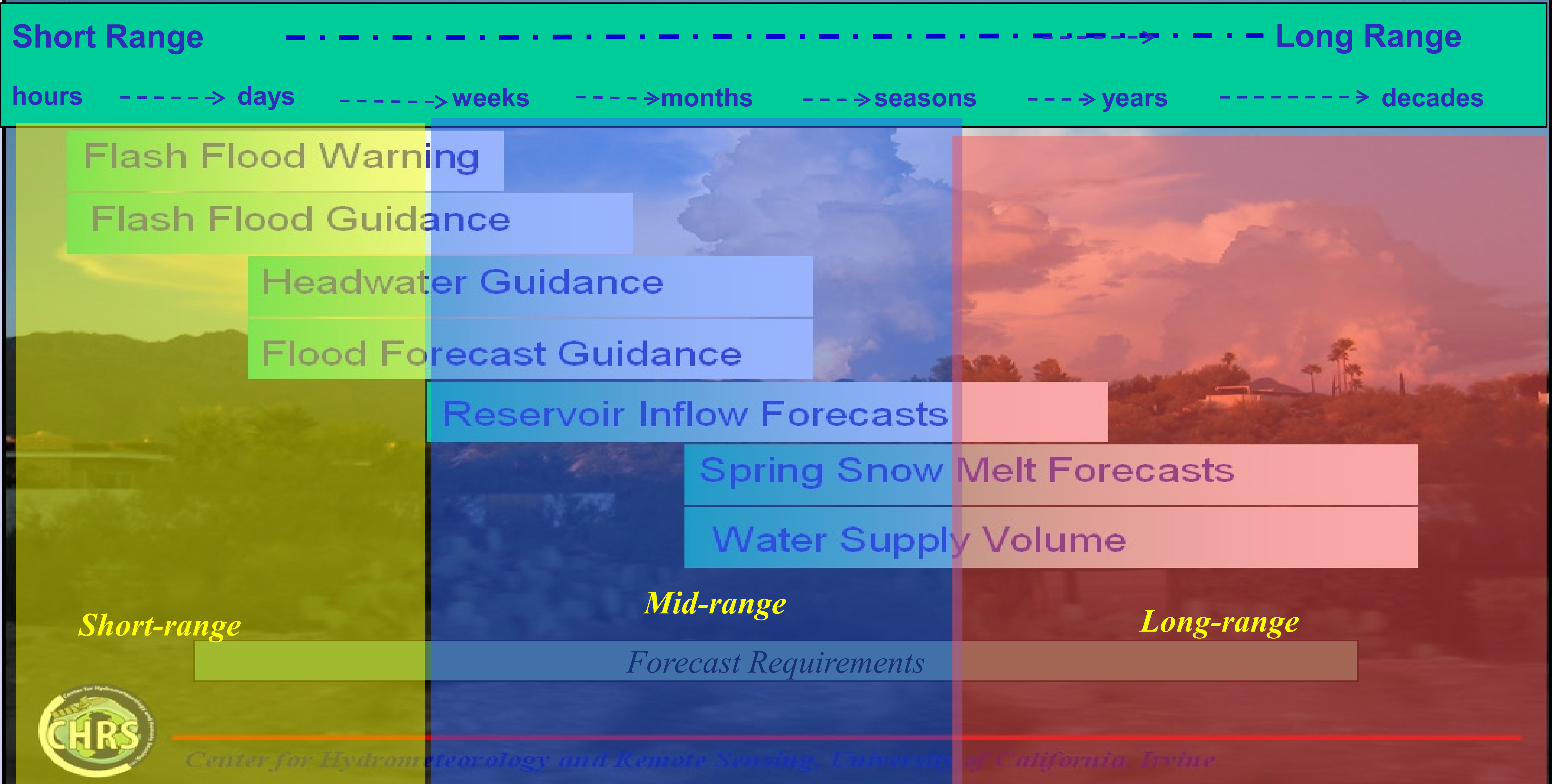








Required Hydrometeorologic Predictions



Seasonal-Scale Predictions

Short Range - - - - - - - - - - - - - - - - - - -> - - - Long Range

hours ------> days ------> weeks ------> months ---> seasons ---> years ---------> decades

Flash Flood Warning

Flash Flood Guidance

Headwater Guidance

Flood Forecast Guidance

Reservoir Inflow Forecasts

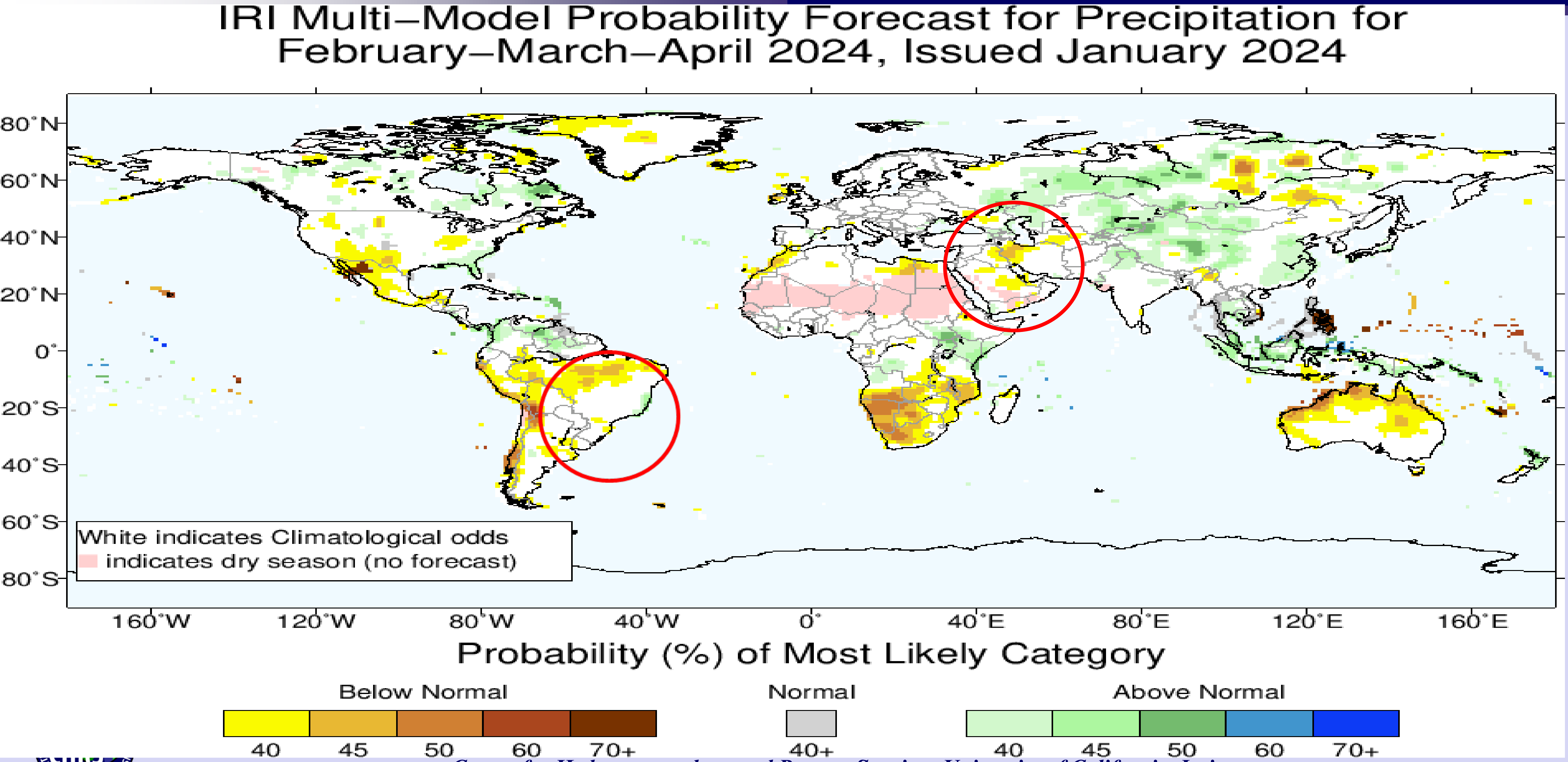
Spring Snow Melt Forecasts

Water Supply Volume

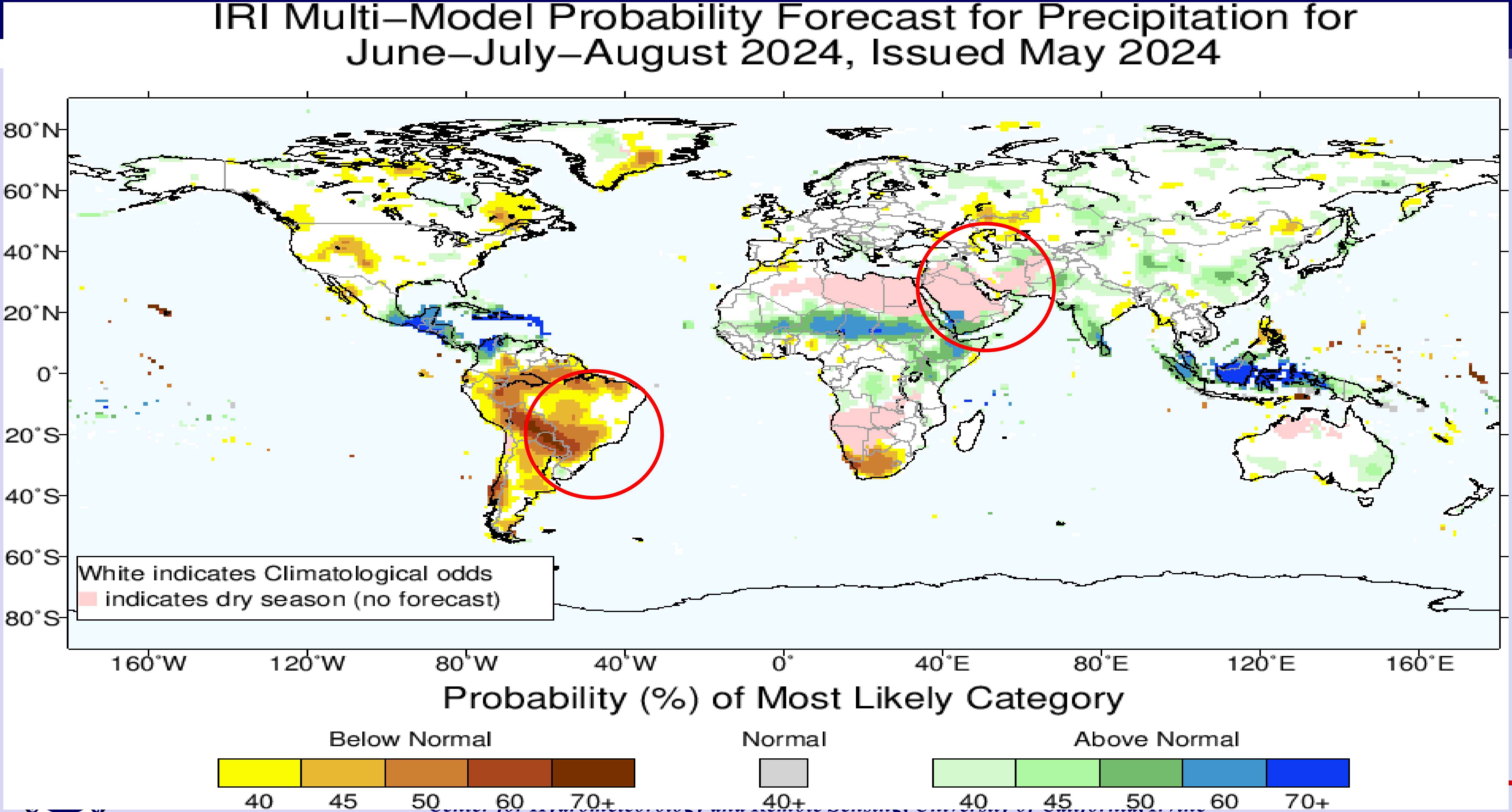
Mid-range

Forecast Requirements

IRI 3-Month Multi-Model Probability Precipitation Forecast



IRI 3-Month Multi-Model Probability Precipitation Forecast



Climate-Scale approaches to addressing hydrologic extremes

Short Range -> - - **Long Range**

hours ------> **days** ------> **weeks** ------> **months** ---> **seasons** ---> **years** ---------> **decades**

Flash Flood Warning

Flash Flood Guidance

Headwater Guidance

Flood Forecast Guidance

Reservoir Inflow Forecasts

Spring Snow Melt Forecasts

Water Supply Volume

Long-range

Forecast Requirements

Future Model Scenarios (2006-2099)

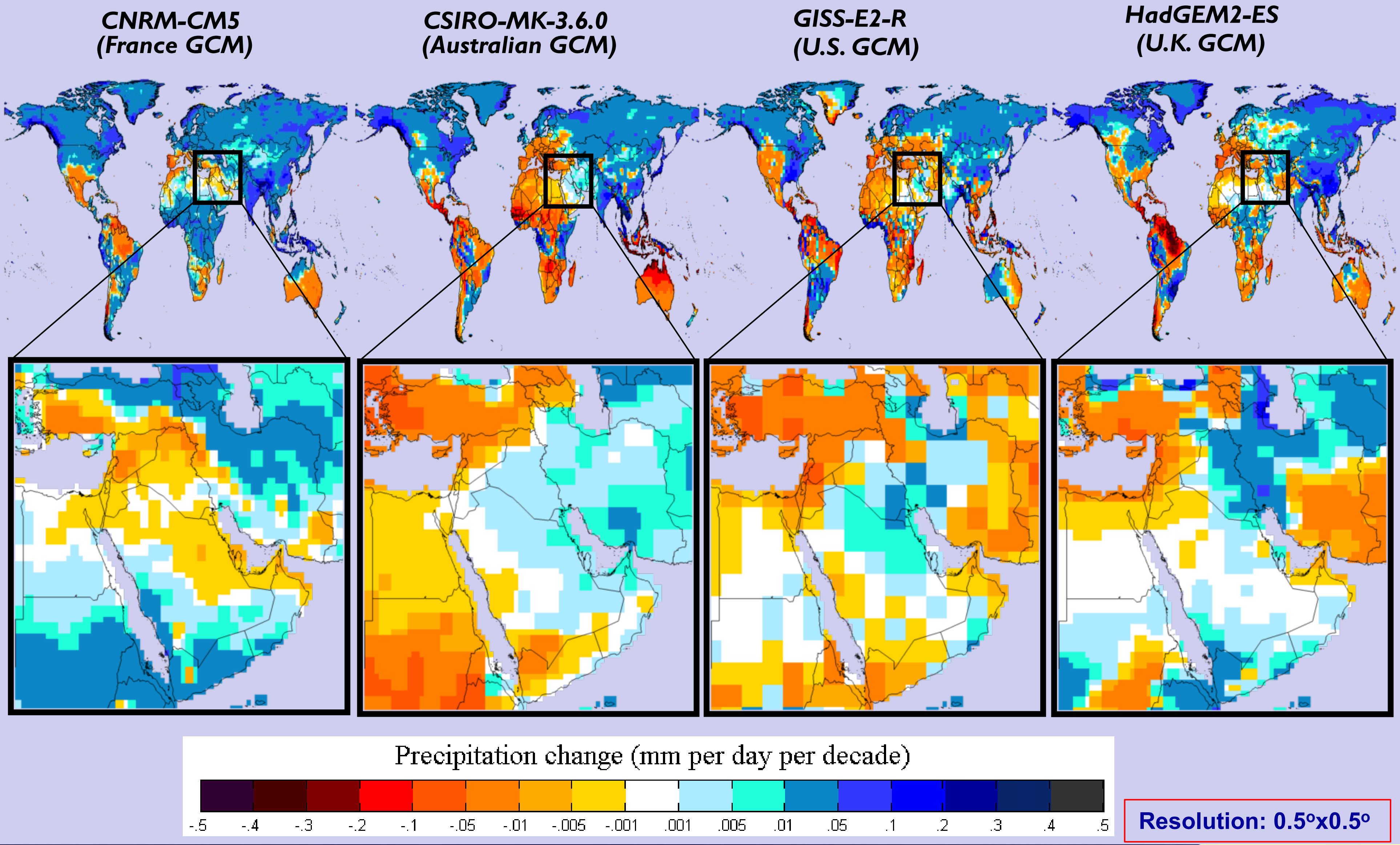
Middle East and North East Africa future model projections

Dr. Chiyuan Miao - BNU

IPCC AR5 Scenarios

Time period: 2006-2099

RCP8.5 (“High”: 8.5 W/m^2, Equivalent CO_2 conc. 936 ppm by 2100)

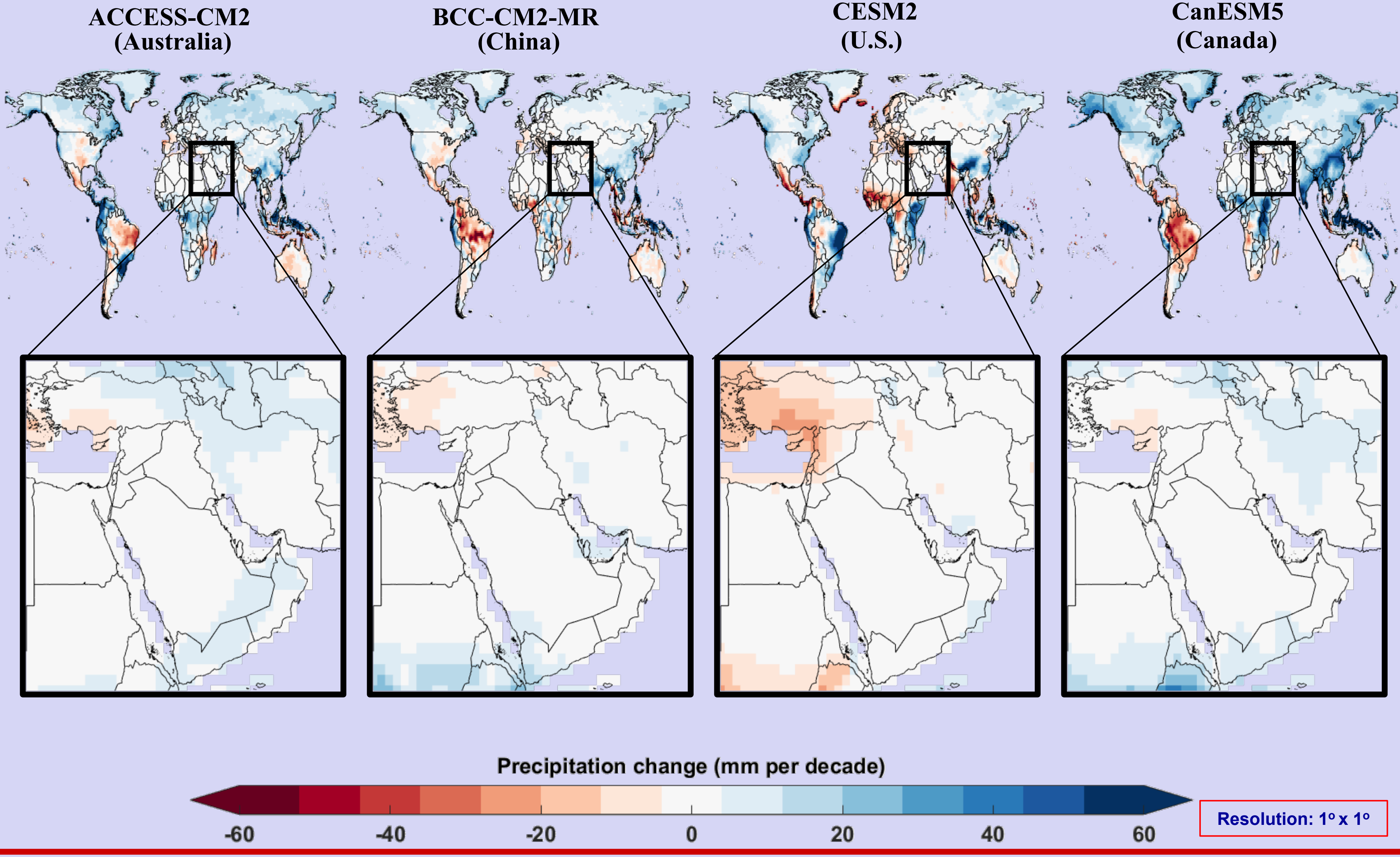


Resolution: 0.5°x0.5°

SSP2-4.5

IPCC AR6 Scenarios

Time period: 2015-2100



Resolution: 1° x 1°

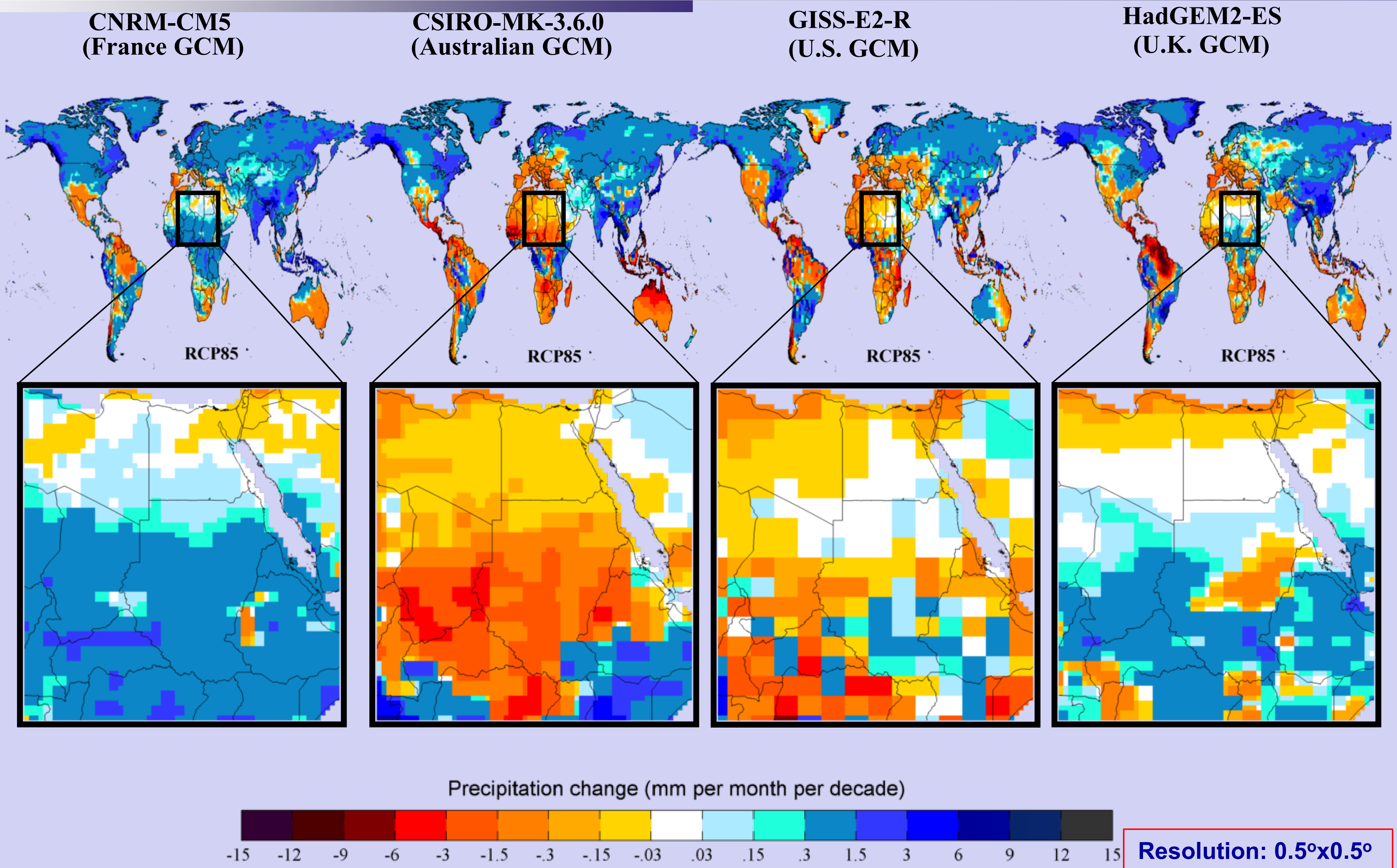
Future Modeling Scenarios

North East Africa

IPCC AR5 Scenarios

Time period: 2006-2099

RCP8.5 ("High": 8.5 W/m^2, Equivalent CO_2 conc. 936 ppm by 2100)



Resolution: 0.5°x0.5°

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

Take Home Message

- ***Despite advances to date, predicting the future Hydro-Climate variables will remain a major challenge:***

…d observing and modeling its nonlinear behavior is … will to doubt" the credibility of information "ge…

Factoring in Resiliency in water resources system's design and planning is still the safest approach!

- ***Long-term and sustained observation programs are critical, especially for model verification. Without some degree of verifiability, hard to expect their use***

Somewhere in New Mexico, USA - Photo: J. Sorooshian