



*Review of CHRS Satellite Datasets:  
The Challenges in Their Development for Application in  
Hydrometeorology*

*Soroosh Sorooshian*

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



*29<sup>th</sup> GEWEX-SSG Meeting*

*Sanya Bay, China*

*February 5-10 2017*





# Research Team: Present and Recent Past



*and many more ...*

# *Some Definitions and Scope of this Presentation*

---

## *Definitions*

*“Tools” : Models*

*“Data” : - In-situ and RS Observations  
- Model-Generated*

*Scope: Focus on Precipitation*

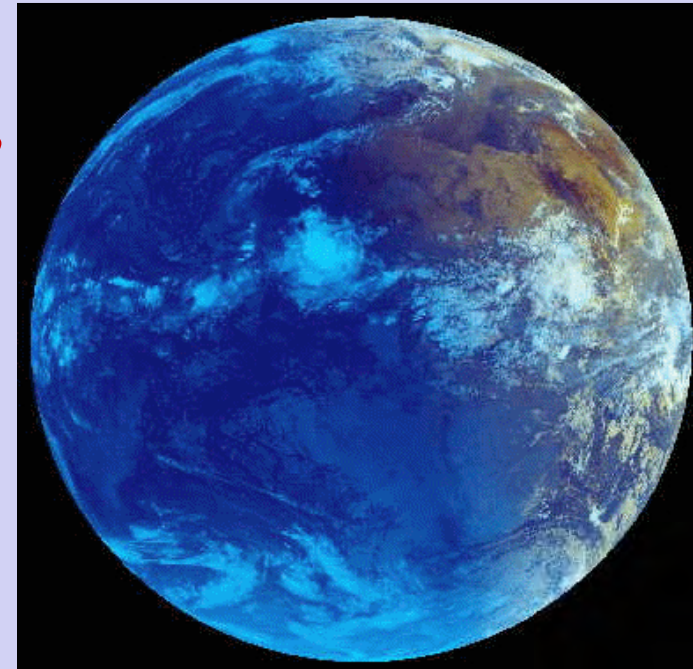




# *Climate, Hydrology and Water Resources*

---

- *How will Climate effect water Availability?*
- *Can we predict the future changes **which are responsive to “user” needs?***



# Prediction Requirements for Water Resources

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

*Short-range*

*Mid-range*

*Long-range*

*Forecast Requirements*



# Prediction Requirements for Water Resources

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*

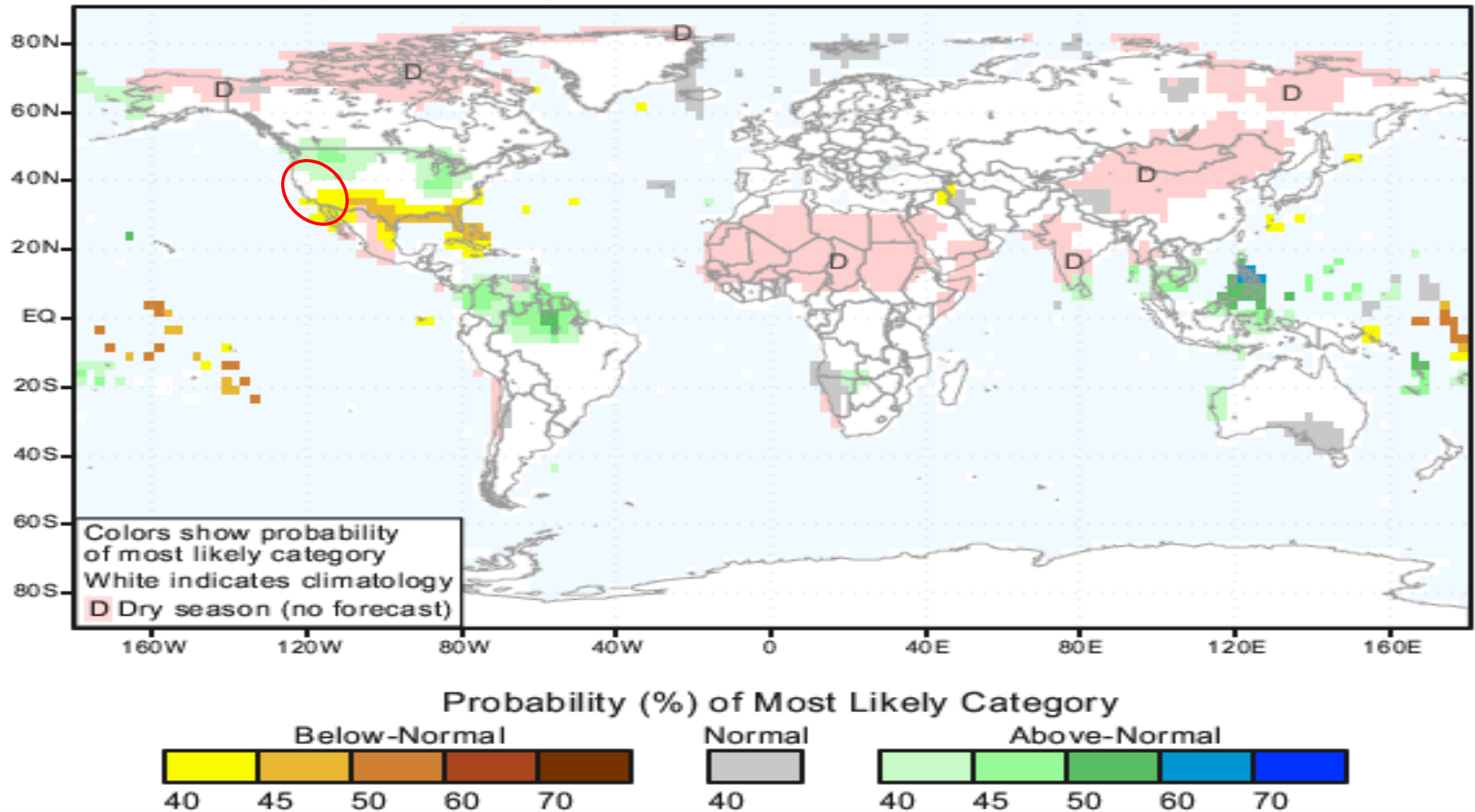
*Forecast Requirements*





# IRI 3-Month Multi-Model Probability Precipitation Forecast

IRI Multi-Model Probability Forecast for Precipitation for January-February-March 2017, Issued December 2016



# 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*





*Western U.S. future  
model projections*



*Dr. Chiyuan Miao - BNU*



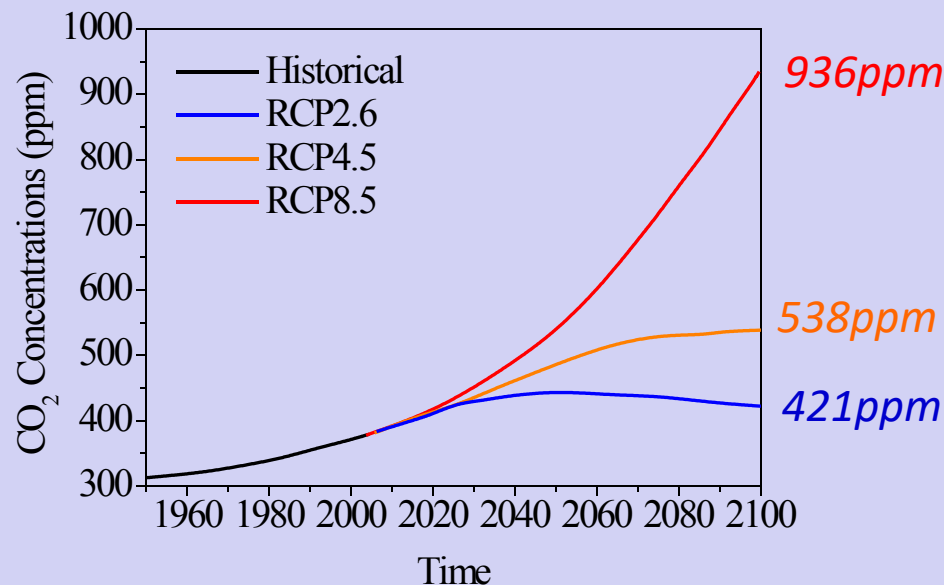
# Future Modeling Scenarios – IPCC AR5

## Representative Concentration Pathways (RCP) Scenarios:

**RCP2.6:** represent 'low' scenarios featured by the radiative forcing of  $2.6 \text{ W/m}^2$  by 2100, the resulting  $\text{CO}_2$ -equivalent concentrations is 421 ppm in the year 2100.

**RCP4.5:** represent 'medium' scenarios featured by the radiative forcing of  $4.5 \text{ W/m}^2$  by 2100, the resulting  $\text{CO}_2$ -equivalent concentrations is 538 ppm in the year 2100.

**RCP8.5:** represent 'high' scenarios featured by the radiative forcing of  $8.5 \text{ W/m}^2$  by 2100, the resulting  $\text{CO}_2$ -equivalent concentrations is 936 ppm in the year 2100.

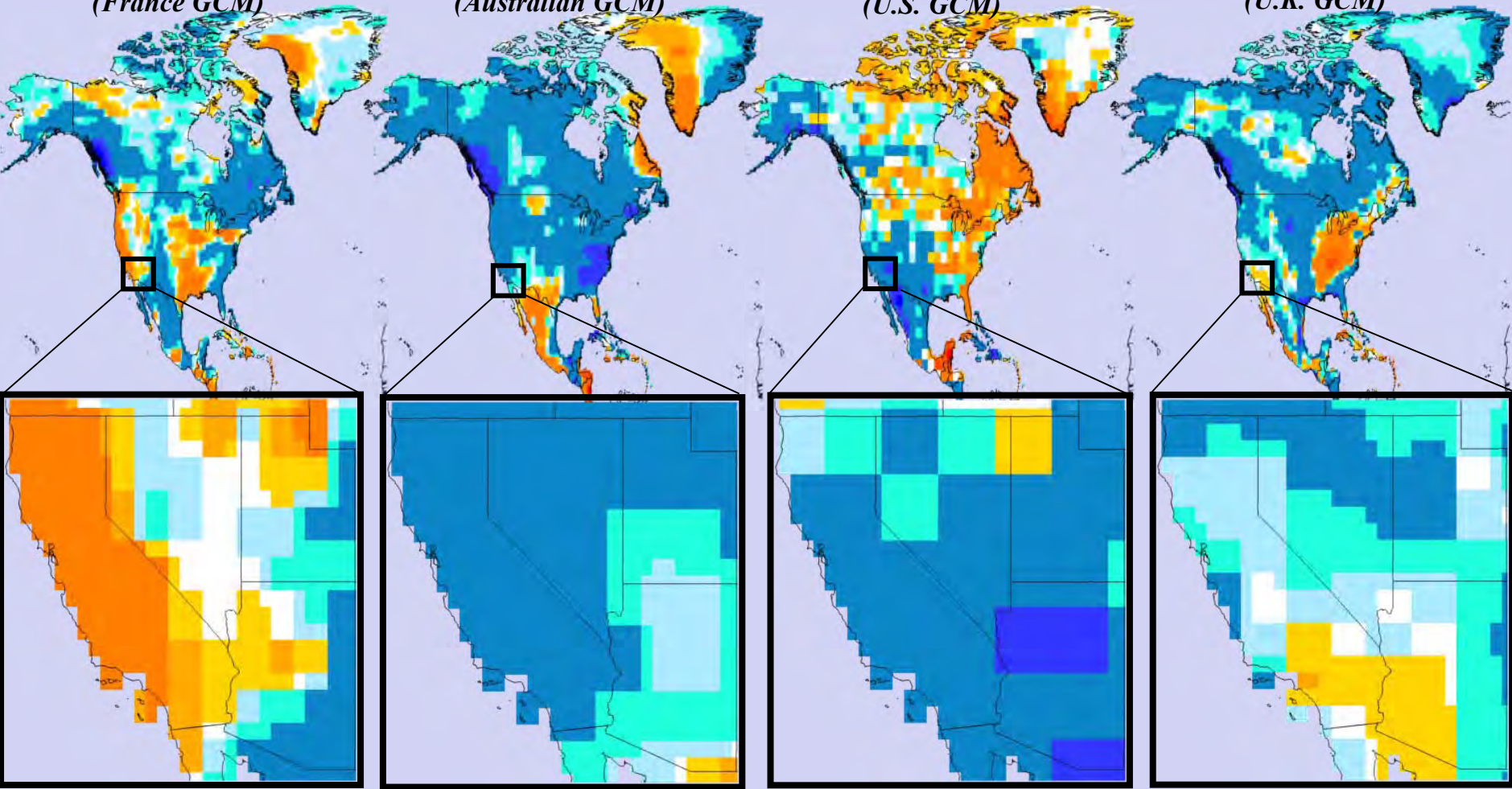


**CNRM-CM5**  
(France GCM)

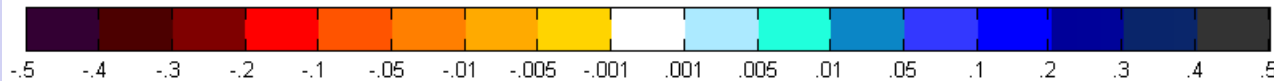
**CSIRO-MK-3.6.0**  
(Australian GCM)

**GISS-E2-R**  
(U.S. GCM)

**HadGEM2-ES**  
(U.K. GCM)



Precipitation change (mm per day per decade)



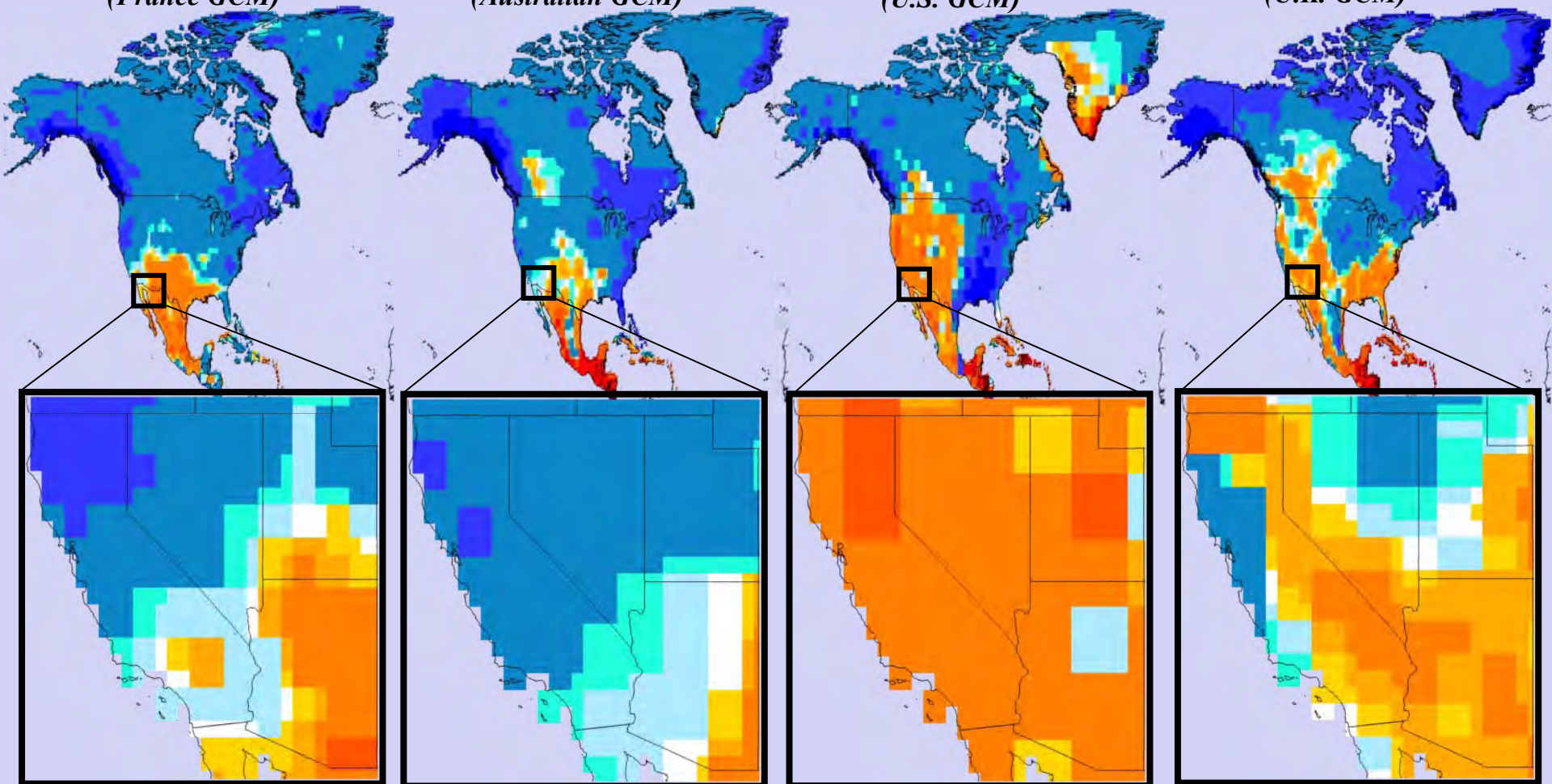


**CNRM-CM5**  
(France GCM)

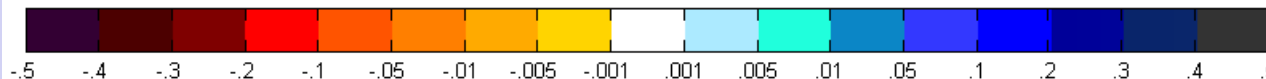
**CSIRO-MK-3.6.0**  
(Australian GCM)

**GISS-E2-R**  
(U.S. GCM)

**HadGEM2-ES**  
(U.K. GCM)



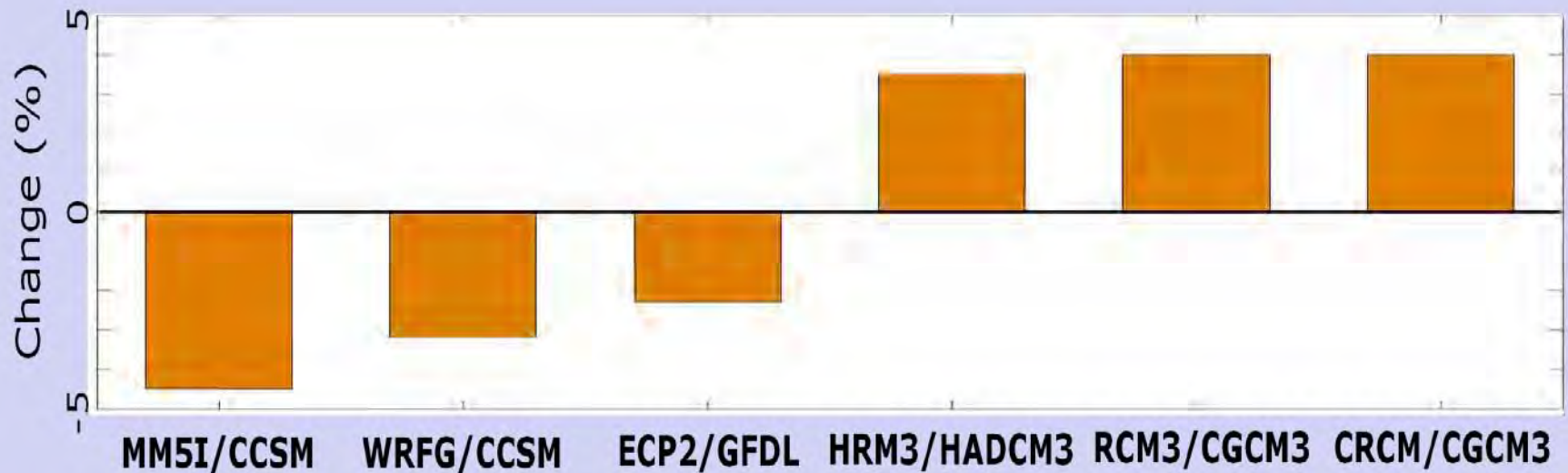
Precipitation change (mm per day per decade)



# Recent Evaluation of RCM/GCM over Western U.S.



Models indicate different signs and magnitudes of changes in the mean precipitation over the Western U.S. under the SRES A2 emissions scenario.



Trend of area-average precipitation (comparing 2040-2070 with 1970-2000)



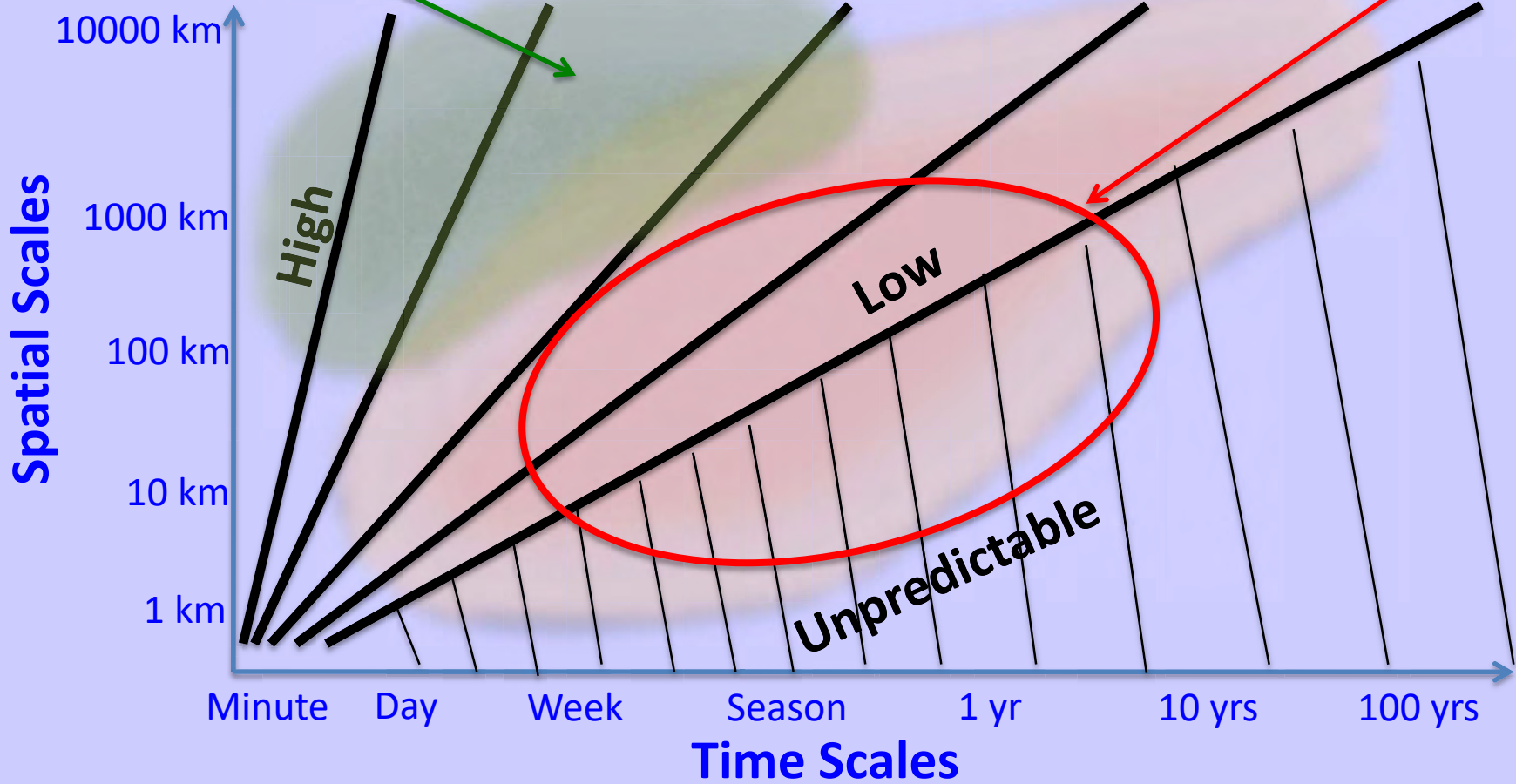
Wei Chu 2011



# Drought Predictability

Current Skill

User Needs





# *Information Relevant to Water Resources Planning*

- Models Projections*
- Observations*



A wide-angle photograph of a desert landscape under a hazy sky. A road curves through the foreground, and sparse vegetation is scattered across the flat terrain.

*For a user of model  
information about future, the  
question maybe:*

*Which model (or groups of models) should  
be “trusted” for their “Accuracy”*

*Answer is partly related to how well should we trust observations used as both input and reference to test the models:*





# *How Much Trust in Remote Sensing Observations??*

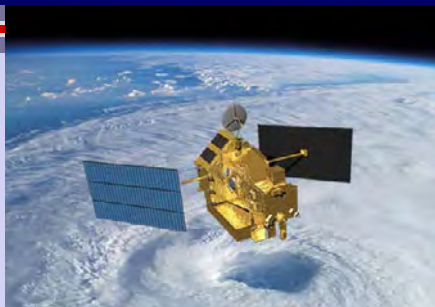


# Hydrologically - Relevant Remote Sensing Missions



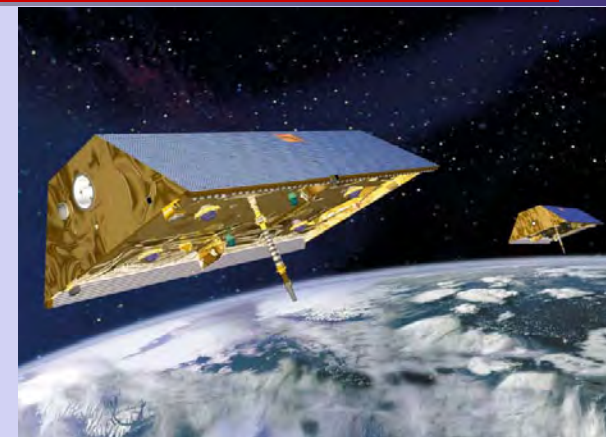
**SMOS**

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



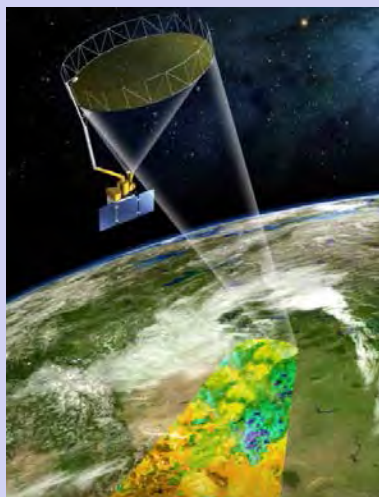
**TRMM**

*The Tropical Rainfall Measuring Mission*



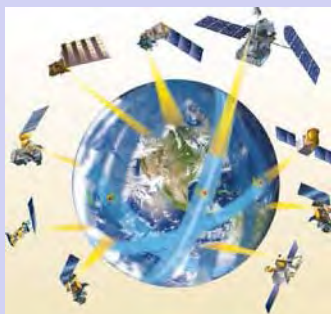
**GRACE**

*Gravity Recovery and Climate Experiment (2002)*



**SMAP**

*Soil Moisture Active Passive Satellite(2014)*



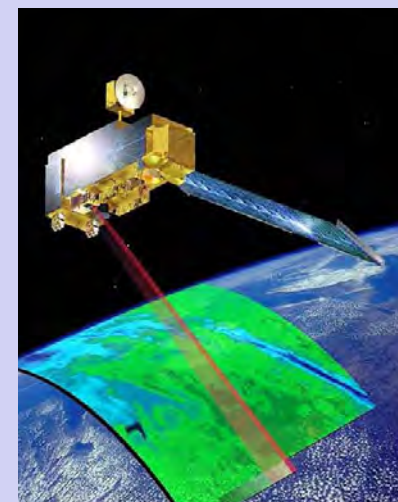
**GPM**

*Global Precipitation Measurements (2014)*



**SWOT**

*Surface Water and Ocean Topography (2020)*



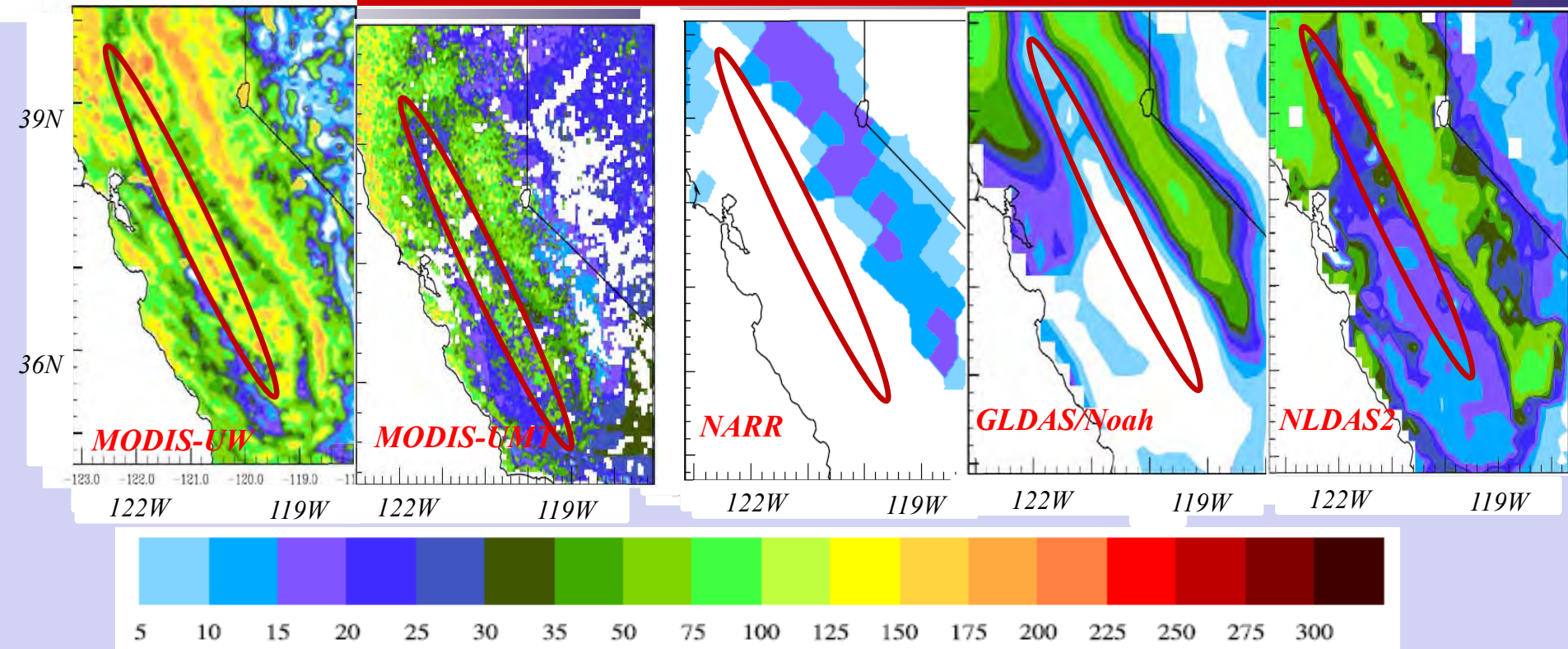
**MODIS**

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





# Actual ET Estimates From Different Data sets— JJA 2007



## 2007 JJA Monthly ET (mm)

An Important Dilemma for the modeling application community will be:  
**Which Remotely Sensed ET Product should be used for model testing and validation??**

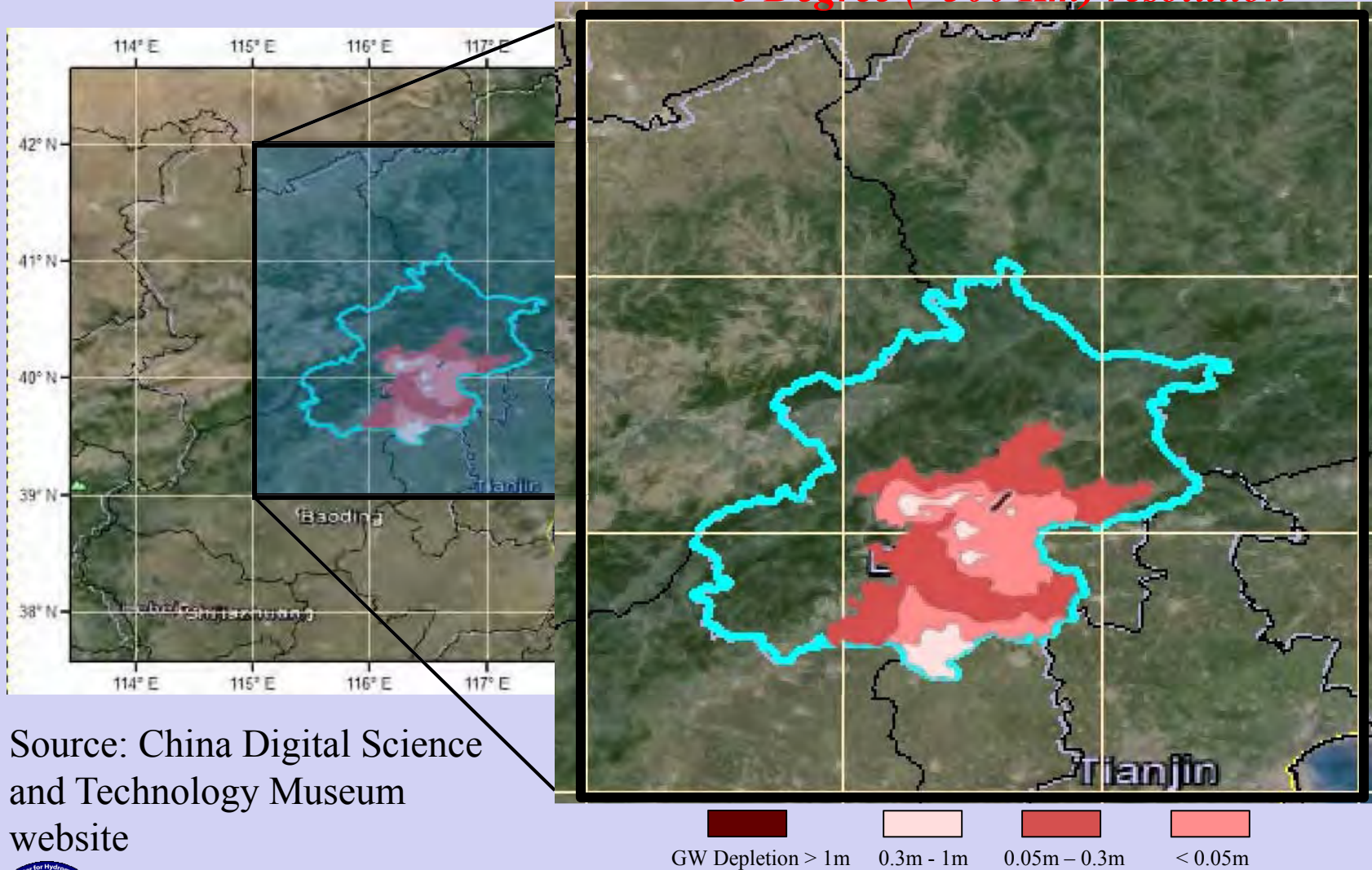


*Sorooshian et al. 2011, 2012 & 2014*



# GRACE Satellite Footprint

3 Degree (~300 Km) resolution



*Created by: N. Nasrollahi. Tiantian Yang & S. Sarachi*

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

# Finally: Recent Reaction to Overblown Stories About Ground Water Detection by Remote Sensing

## Groundwater

Technical Commentary/

## Bringing GRACE Down to Earth

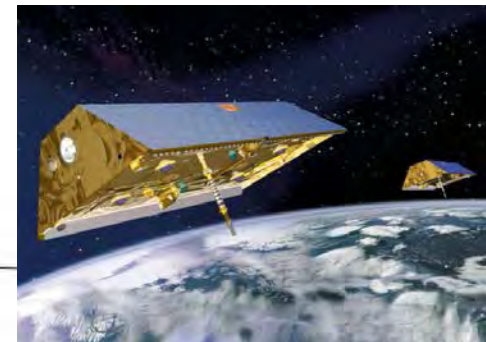
by William M. Alley<sup>1</sup> and Leonard F. Konikow<sup>2</sup>

### Introduction

NASA's Gravity Recovery and Climate Experiment (GRACE), which is a joint mission of the United States and Germany, uses a pair of coupled satellites to measure spatial and temporal changes in the Earth's gravity field. From these data, estimates of changes (time-variable anomalies) in mass are derived. In turn, the mass changes are attributed primarily to changes in water content (Tapley et al. 2004; Tiwari et al. 2009; Rodell et al. 2009; Famiglietti and Rodell 2013). Changes in water mass can arise from several hydrologic components, including soil

### GRACE Provides a One-Dimensional Indicator of the Status of a Large Three-Dimensional Groundwater Body: It Is Not a Management Tool

GRACE data provide precise monthly estimates of total change in water storage (accuracy of 1.5 cm equivalent water height) over a large footprint—a resolution on the order of 200,000 km<sup>2</sup> (Famiglietti and Rodell 2013). Many aquifers that play a critical role in meeting human needs, however, occur at scales of 100s or 1000s of km<sup>2</sup>, much smaller than the GRACE footprint.



**GRACE**  
*Gravity Recovery and Climate Experiment*  
(2002)





# *A Key Requirement!*

*Precipitation Measurement is one of  
the KEY  
hydrometeorologic Challenges*

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

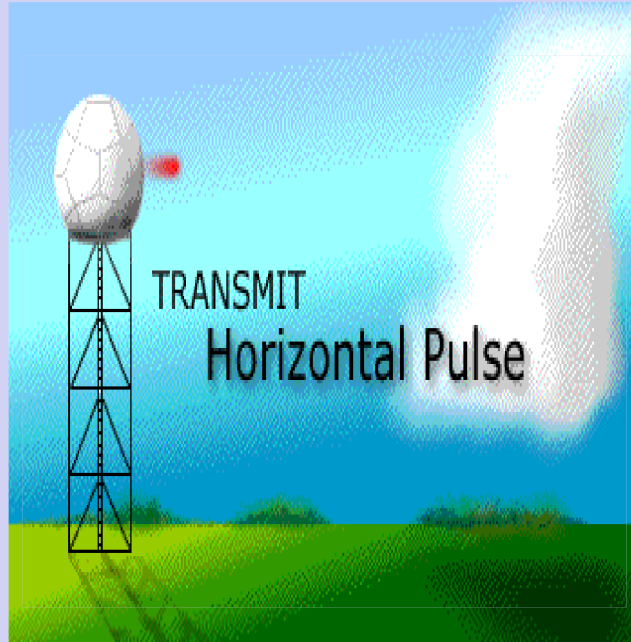




# Precipitation Observations: Which to trust??



Rain Gauges

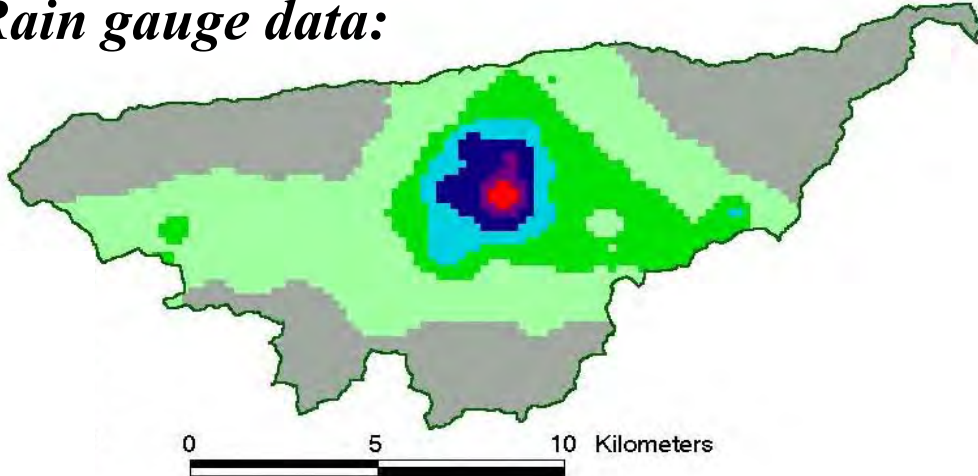


Satellite



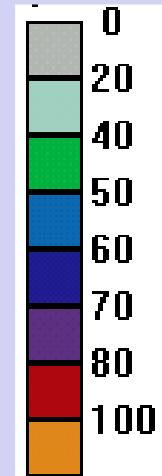
# Radar-Gauge Comparison (Walnut Gulch, AZ)

*Rain gauge data:*

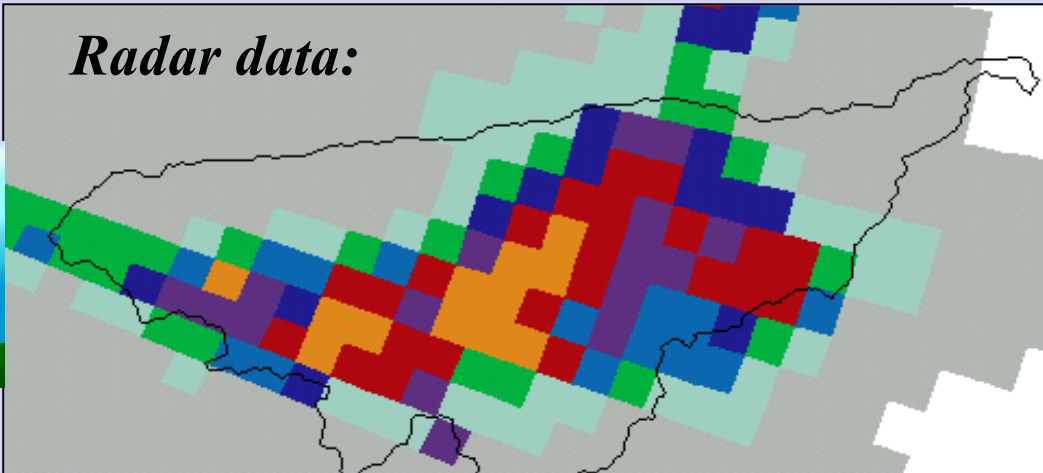


*Precipitation event:  
Aug. 11, 2000*

*Storm depth (mm)*



*Radar data:*



*70% overestimation  
by the radar!*

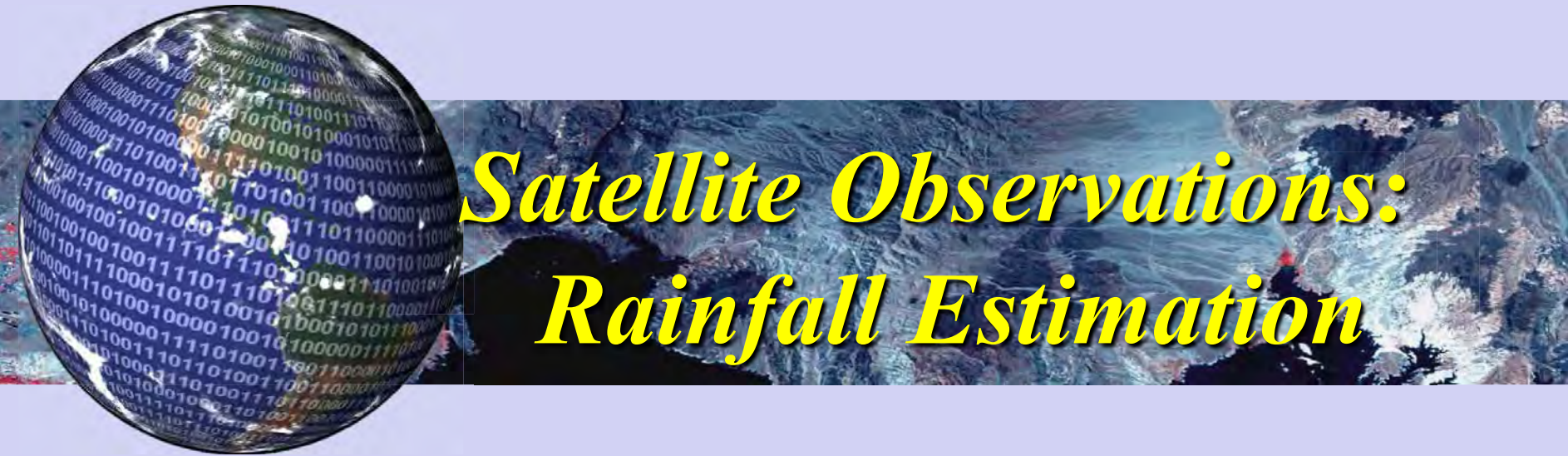
$Z=300R^{1.4}$ , 2.4° elevation, HailThresh=56 dbz

*Morin et al ADWR 2005*



# *Space-Based Observations for Model Testing*

---



## *Satellite Observations: Rainfall Estimation*





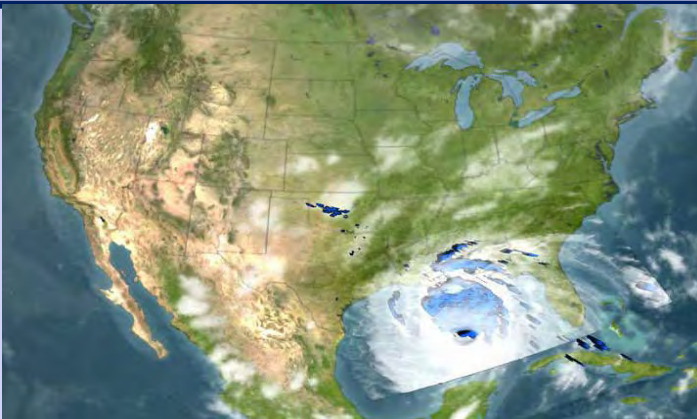
# Satellite Data for Precipitation estimation



*Geostationary IR  
Cloud top data  
15-30 minute temporal  
resolution*



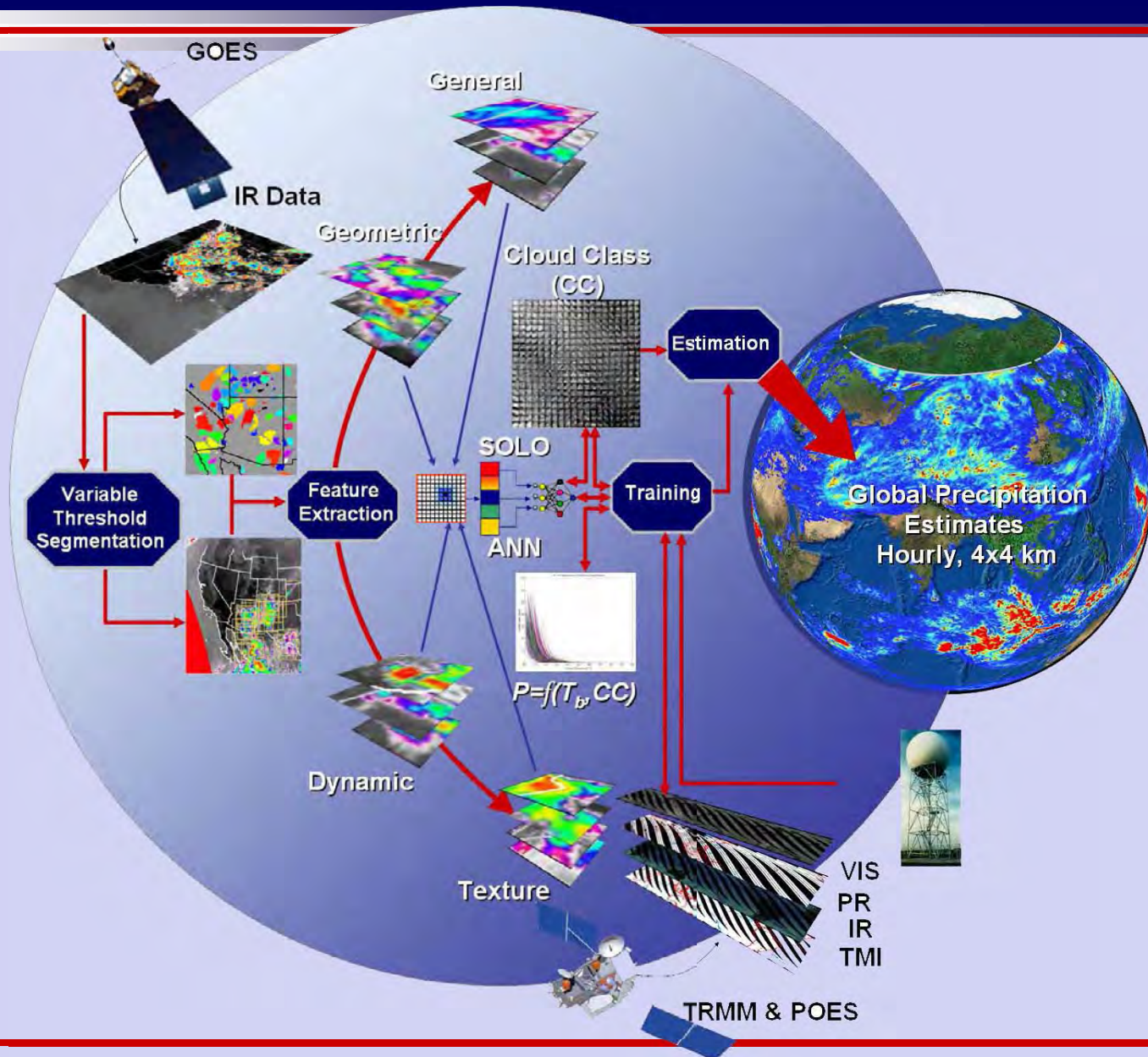
*Passive Microwave (SSM/I)  
Some characterisation of rainfall  
~2 overpasses per day per  
spacecraft, moving to 3-hour  
return time (GPM)*



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



# PERSIANN-CCS (Real-time 4 km)





## CHRS RainSphere

**An Integrated System for Global Satellite Precipitation  
Data and Information**

*<http://rainsphere.eng.uci.edu>*





# ***PERSIANN Extensions: Climate-Related***

---



## ***- PERSIANN- CDR (Climate Data Record)***





# PERSIANN -CDR

<http://www.ncdc.noaa.gov/cdr/operationalcdrs.html>

NOAA'S NATIONAL CLIMATIC DATA CENTER

## NOAA's Climate Data Record (CDR) Program

PRECIPITATION ESTIMATION FROM REMOTE SENSING INFORMATION USING ARTIFICIAL NEURAL NETWORK

# PERSIANN



**PERSIANN CLIMATE DATA RECORD SPECIFICATIONS**

- 0.25-deg \* 0.25-deg (60°S~60°N latitude and 0°~360° longitude)
- Daily Product
- 1980~present
- Updated Monthly

**INPUTS TO THE PERSIANN CLIMATE DATA RECORD**

- GridSat-B1 CDR (IRWIN)
- GPCP 2.5-deg Monthly Data

**SOME USES OF THE PERSIANN CLIMATE DATA RECORD**

- Climatologists can perform long-term climate studies at a finer resolution than previously possible.
- Hydrologists can use PERSIANN-CDR for rainfall-runoff modeling in regional and global scale, particularly in remote regions.
- Performing extreme Event Analysis (intensity, frequencies, and duration of floods and droughts).
- Water Resources Systems Planning and Management

**PERSIANN CLIMATE DATA RECORD**  
<http://www.ncdc.noaa.gov/cdr/operationalcdrs.html>

**CLIMATE DATA RECORD PROGRAM INFORMATION**  
<http://www.ncdc.noaa.gov/cdr/index.html>

www.climate.gov  
www.ncdc.noaa.gov

Center for Hydrometeorology & Remote Sensing, University of California, Irvine  
September 2013

- **Daily Precipitation Data**
- **Data Period: 1983~2014**
- **Coverage: 60°S ~ 60°N**
- **Spatial Resolution: 0.25°x0.25°**

Volume 96 Issue 1  
(January 2015)

< Previous



**BAMS**

**PERSIANN-CDR**

A 50+ Year Global Daily Precipitation Dataset

Ashouri, Hsu et al., BAMS, 2015.





# Sierra-Nevada Mountain Region

Area: 63,100 square kilometers (24,370 sq mi)

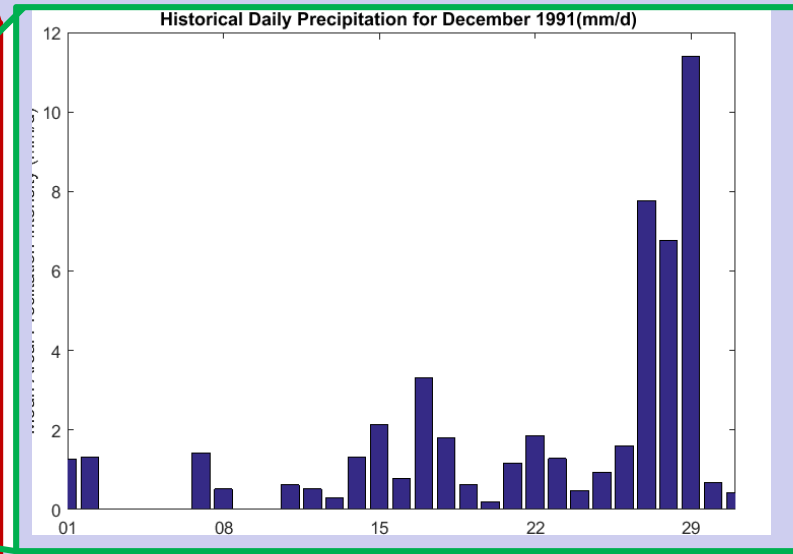
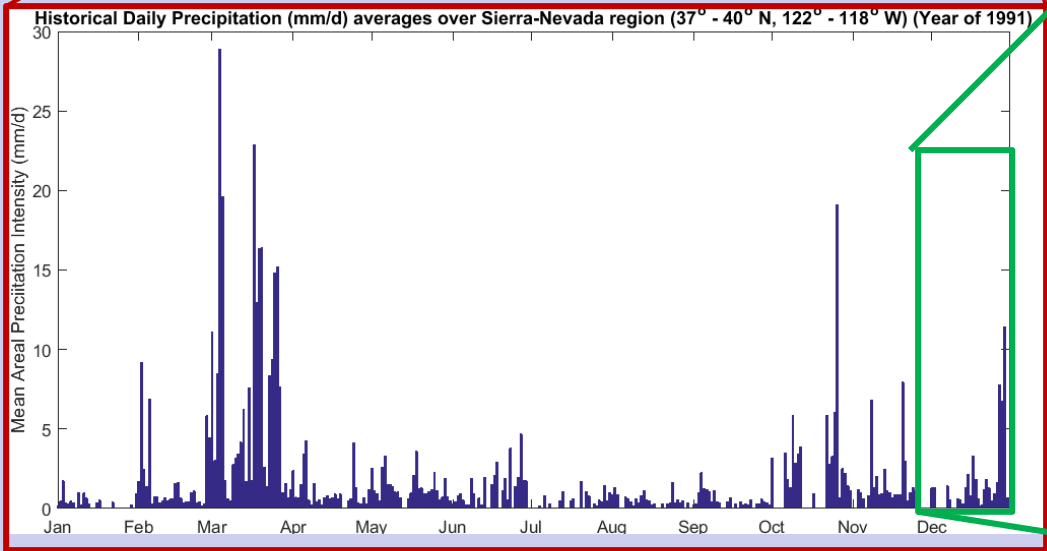
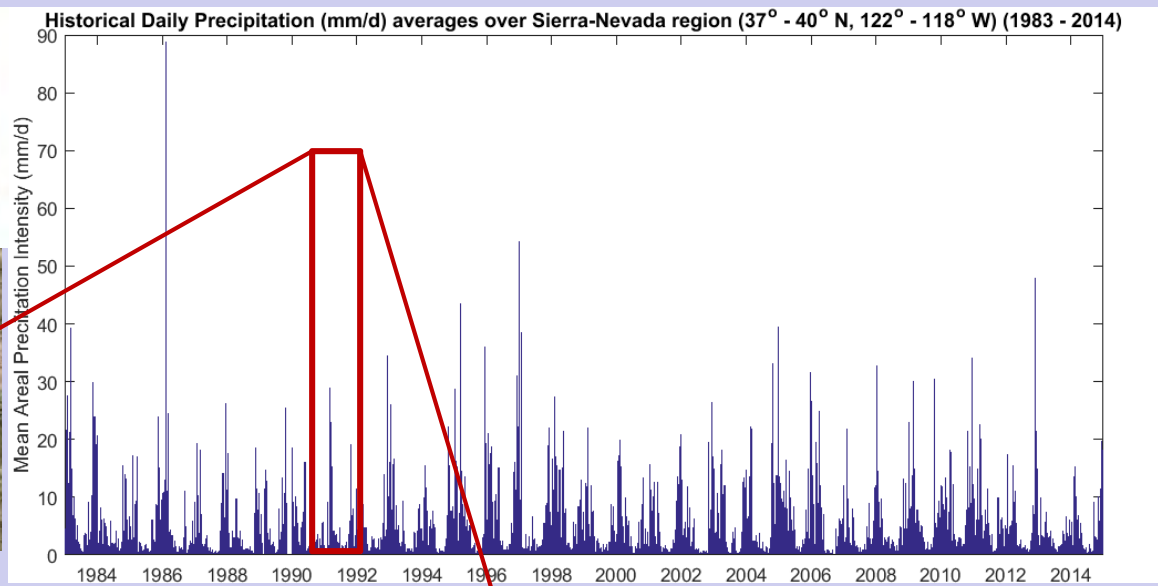
Length: 400 mile, Width: 64 mile.



Map Source: Google Earth

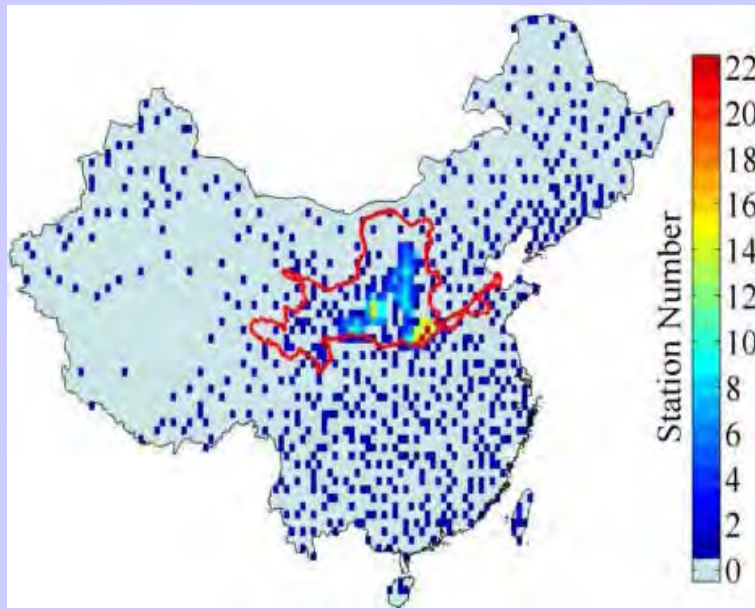


# Sierra-Nevada Mountain (California and Nevada)

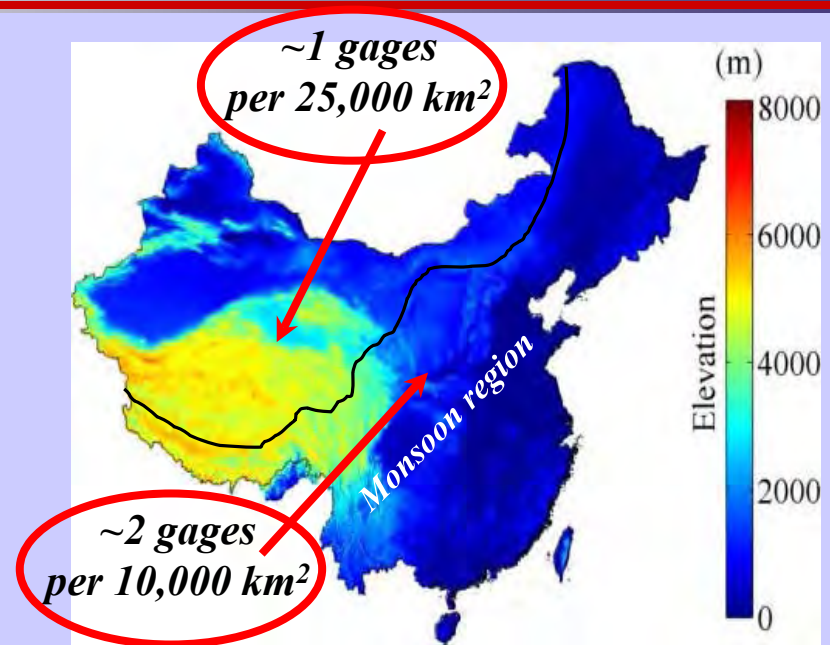


*Many Regional Evaluation  
of PERSIANN CDR Are  
Being Reported:*

# PERSIANN-CDR Evaluation over China



*EA Rain Gauge Distribution*



*Elevation Map*



*Dr. Chiyuan Miao - BNU*

*Gauge data: daily precipitation over East Asia (EA) (Xie et al., 2007)*

- More than 2200 ground-based stations across China*
- 0.5° resolution*
- Period 1983-2006*

*PERSIANN-CDR: up scaled into the same resolution as EA (0.5°)*





# Results: Entire China

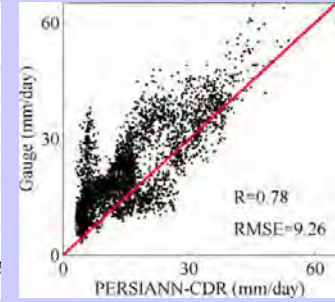
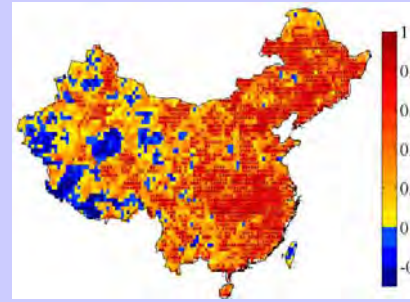
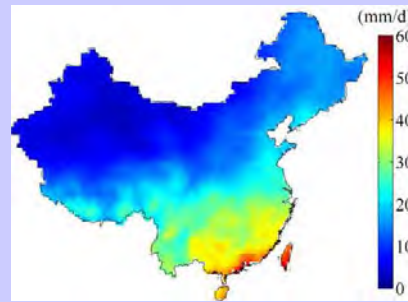
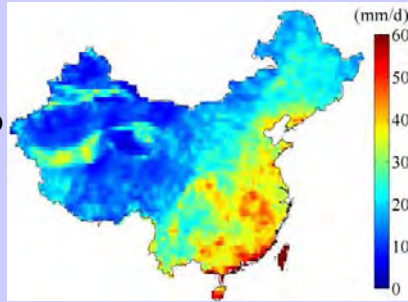
EA

PERSIANN-CDR

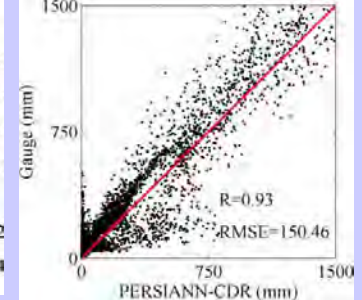
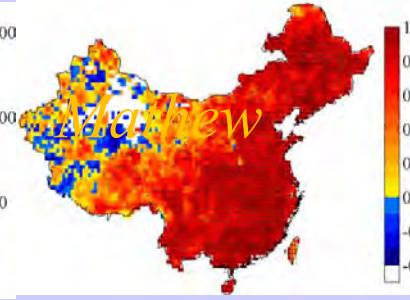
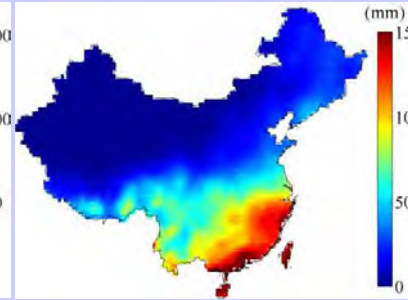
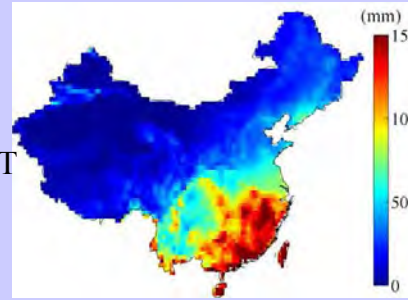
Pixel correlation

Scatterplot of mean

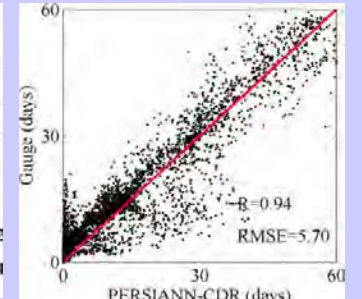
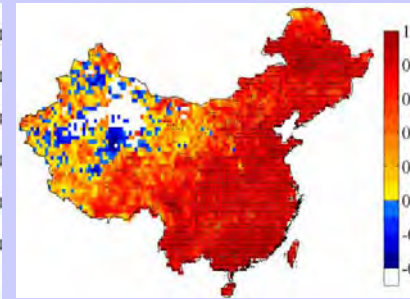
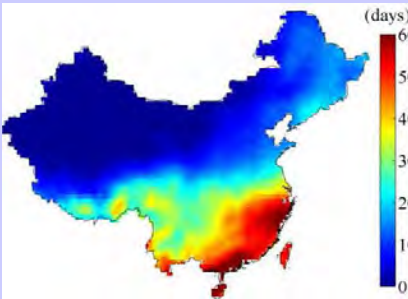
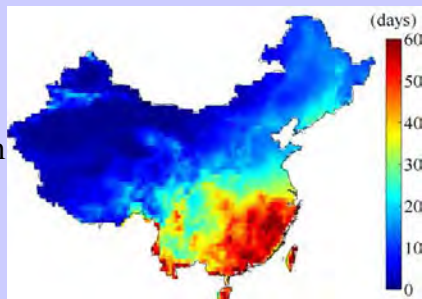
RR95p



R10mmTOT



R10mm



Miao et al., JHM 2015

# *Hydrologically-Relevant Data*

*What is the value of this  
data set to application and  
Modeling communities?*



# Model historical simulation (1983-2005)

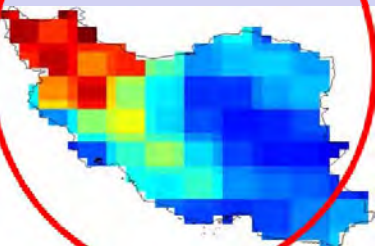
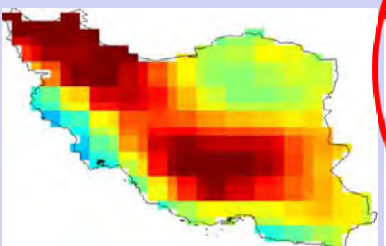
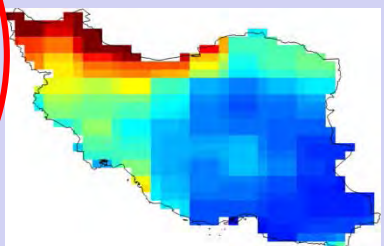
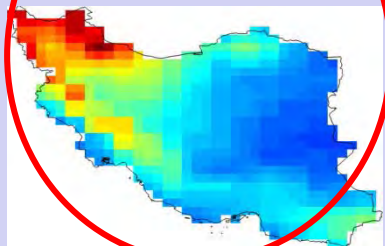
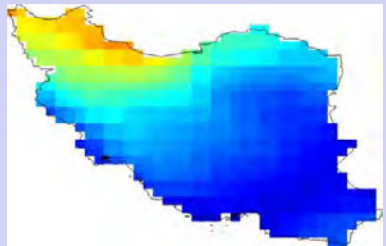
*bcc\_csm1\_1\_m*  
(Chinese GCM)

*CCSM4*  
(NCAR, USA GCM)

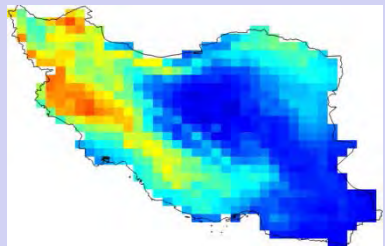
*HadGEM2-ES*  
(U.K GCM)

*MIROC5*  
(Japan GCM)

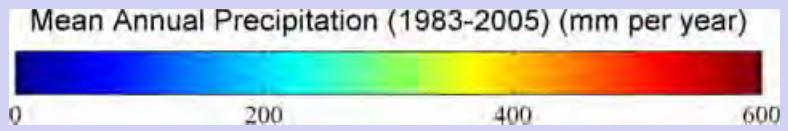
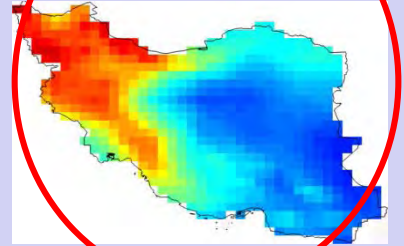
*MPI-ESM-MR*  
(Germany GCM)



*Observation*  
(CRU Dataset)



*Remotely Sensed Estimates*  
(PERSIANN-CDR)

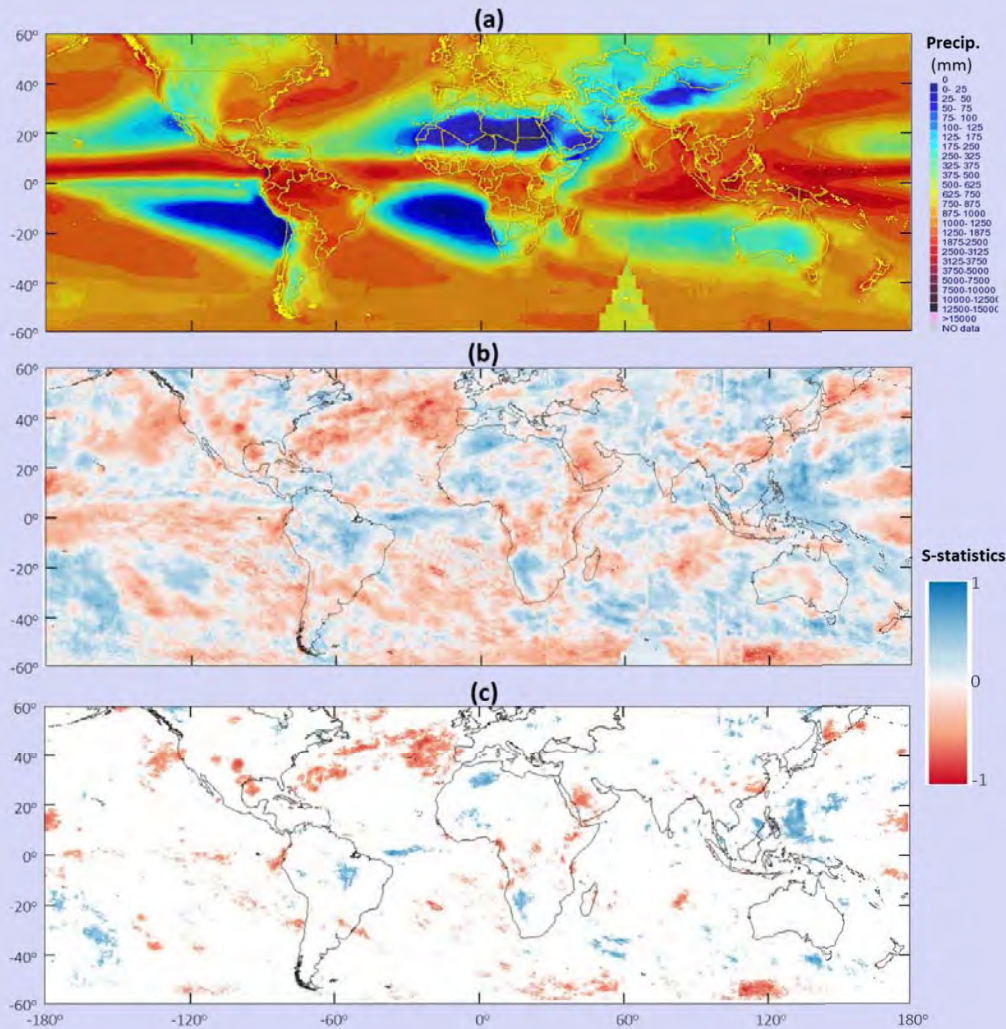




## **PERSIANN-CDR Application:**

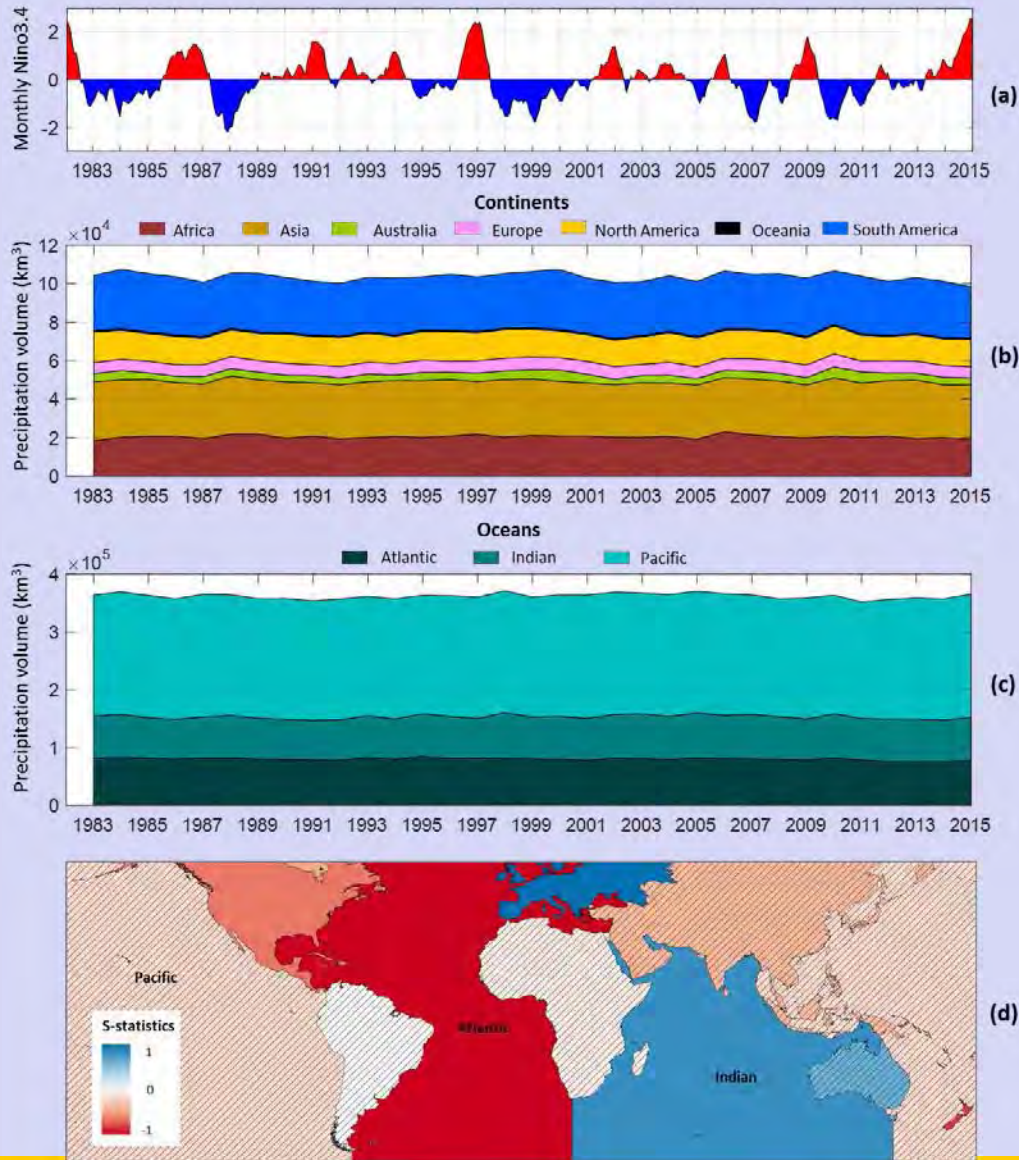
**Global precipitation trends across spatial  
scales**

# Rainfall Trend Analysis: Pixel-based



Annual mean  
precipitation in mm  
(a) and pixel-based  
precipitation trends  
(b, c) from 1983 to  
2015 from  
PERSIANN-CDR

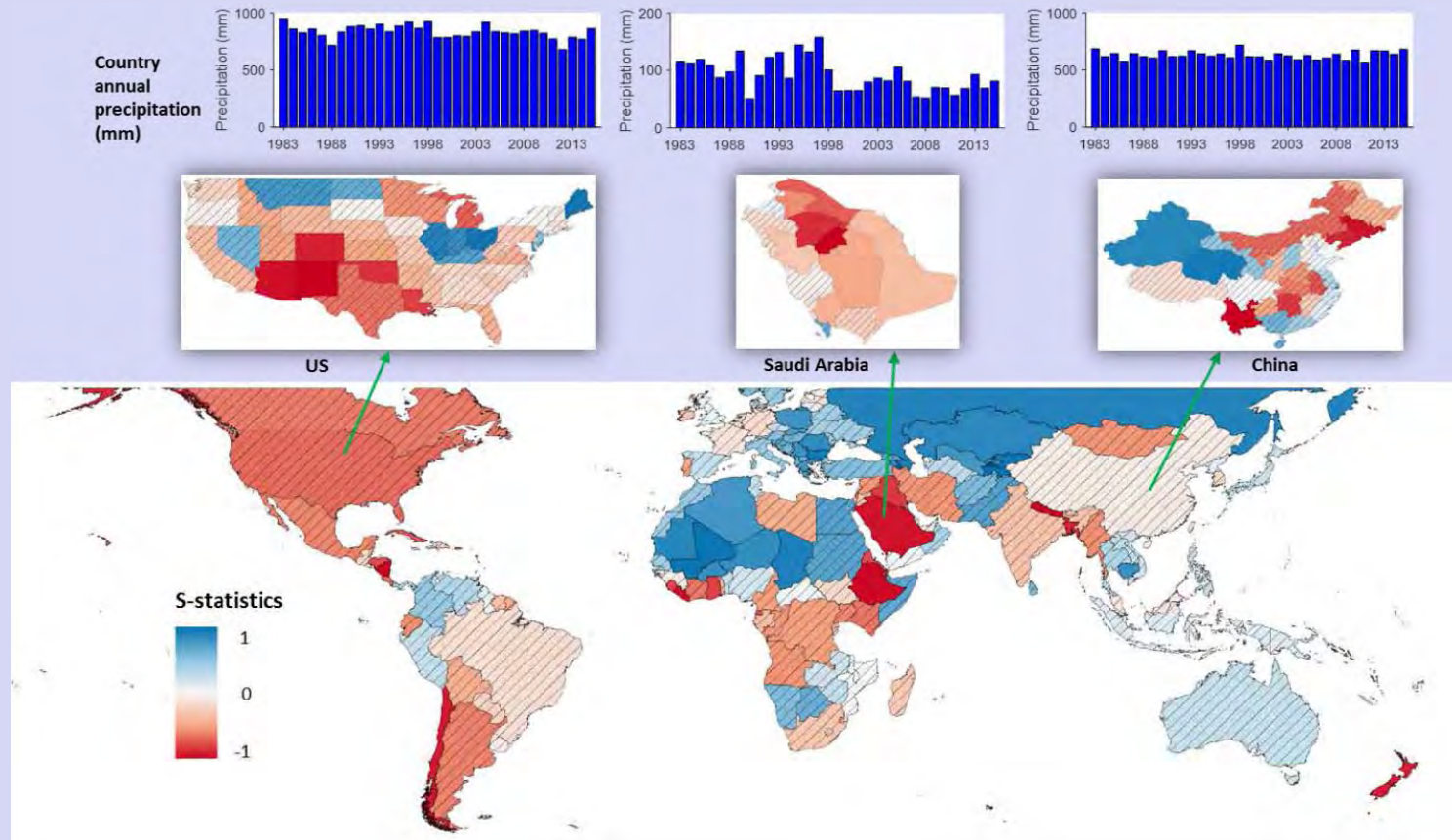
# Rainfall Trend Analysis: Continents and Oceans



Monthly Niño3.4 (a)  
Changes in precipitation volume (b, c) and precipitation volume trends (d) over continents and oceans.

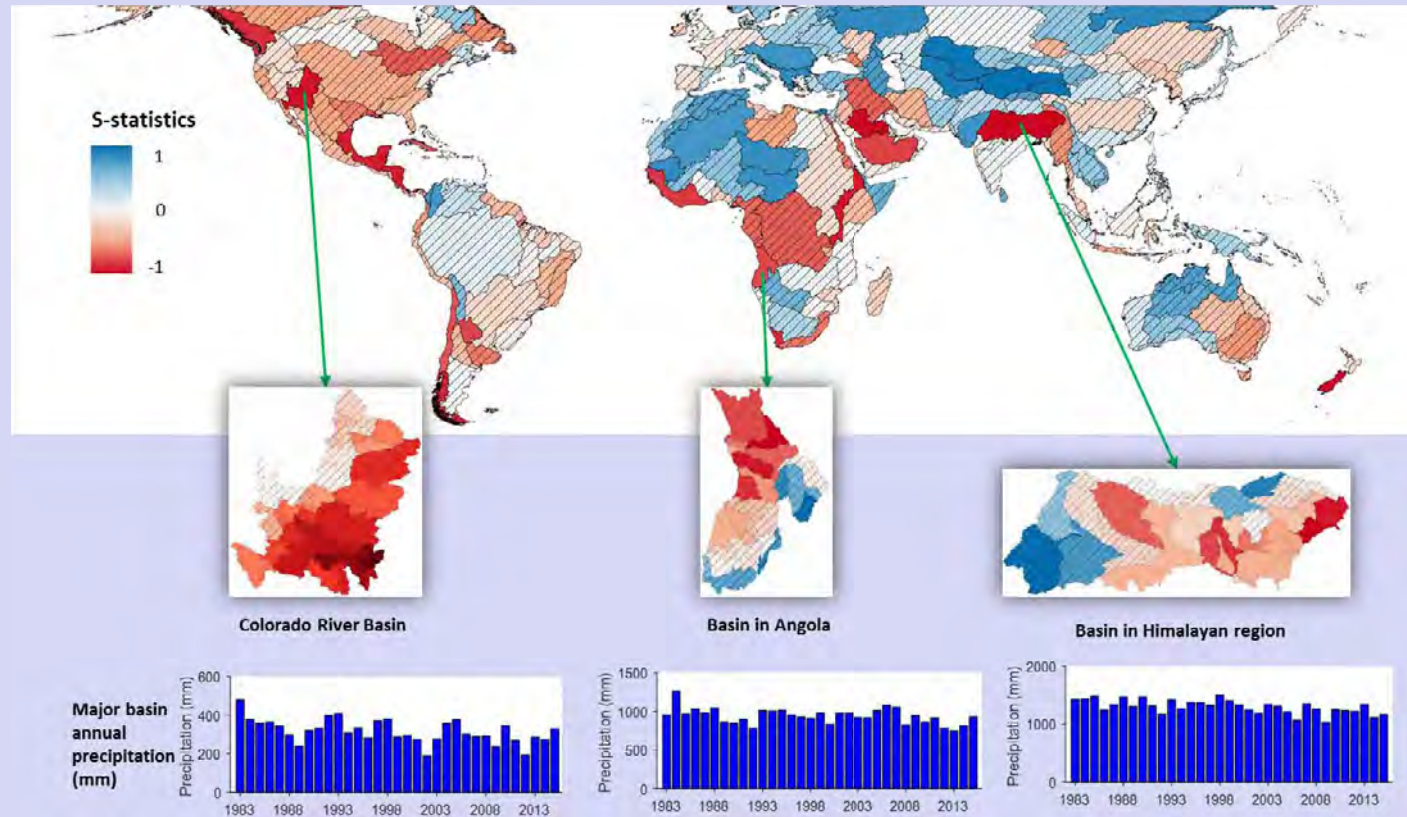


# Rainfall Trend Analysis: Countries and Political Divisions



Precipitation trends from 1983 to 2015 over 201 countries (60°N - 60°S) and state/province political divisions of US, Saudi Arabia and China

# Rainfall Trend Analysis: Basins and Watersheds



Precipitation trends from 1983 to 2015 over 237 global major basins



# *PERSIANN Websites and Apps*

---

- 
- *CHRS RainSphere*
  - *CHRS iRain*
  - *CHRS Data Portal*
  - *PERSIANN-CONNECT*





# RainSphere Interface

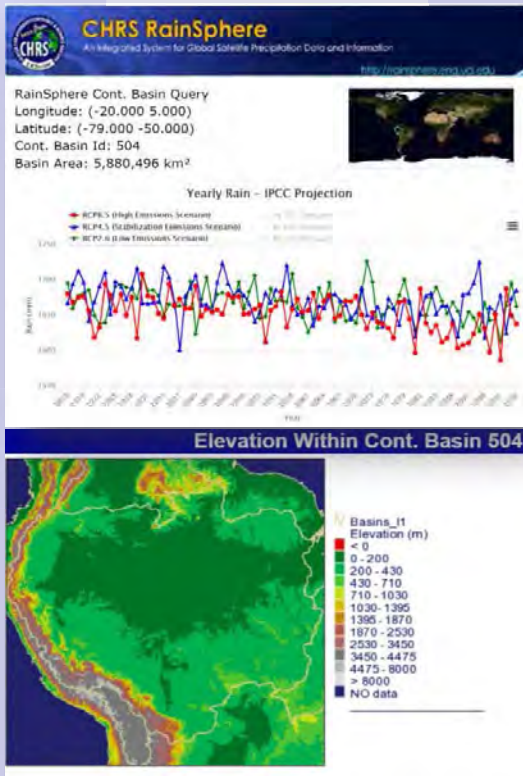
<http://rainsphere.eng.uci.edu>



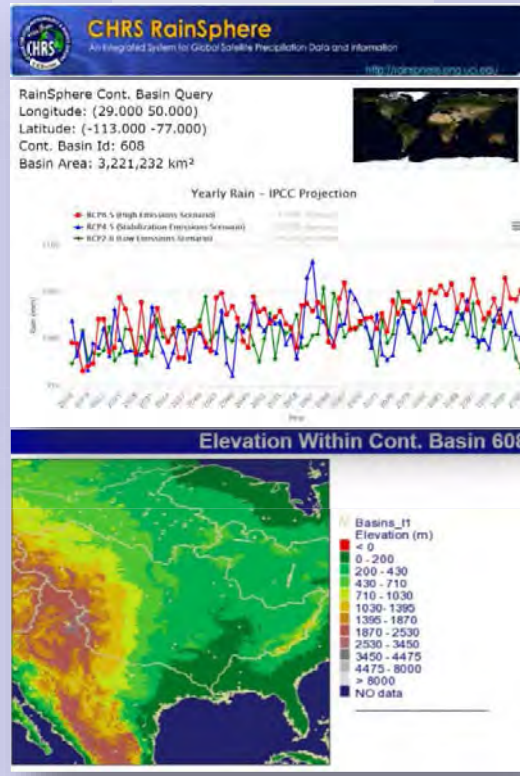
# RainSphere

## Future Projection

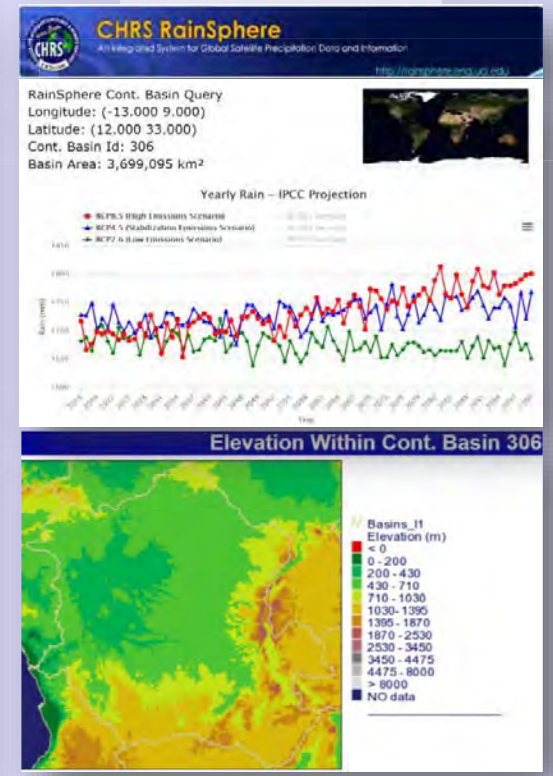
### Amazon



### Mississippi



### Congo





## CHRS iRain

# An Integrated System for Global Real-time Precipitation Observation

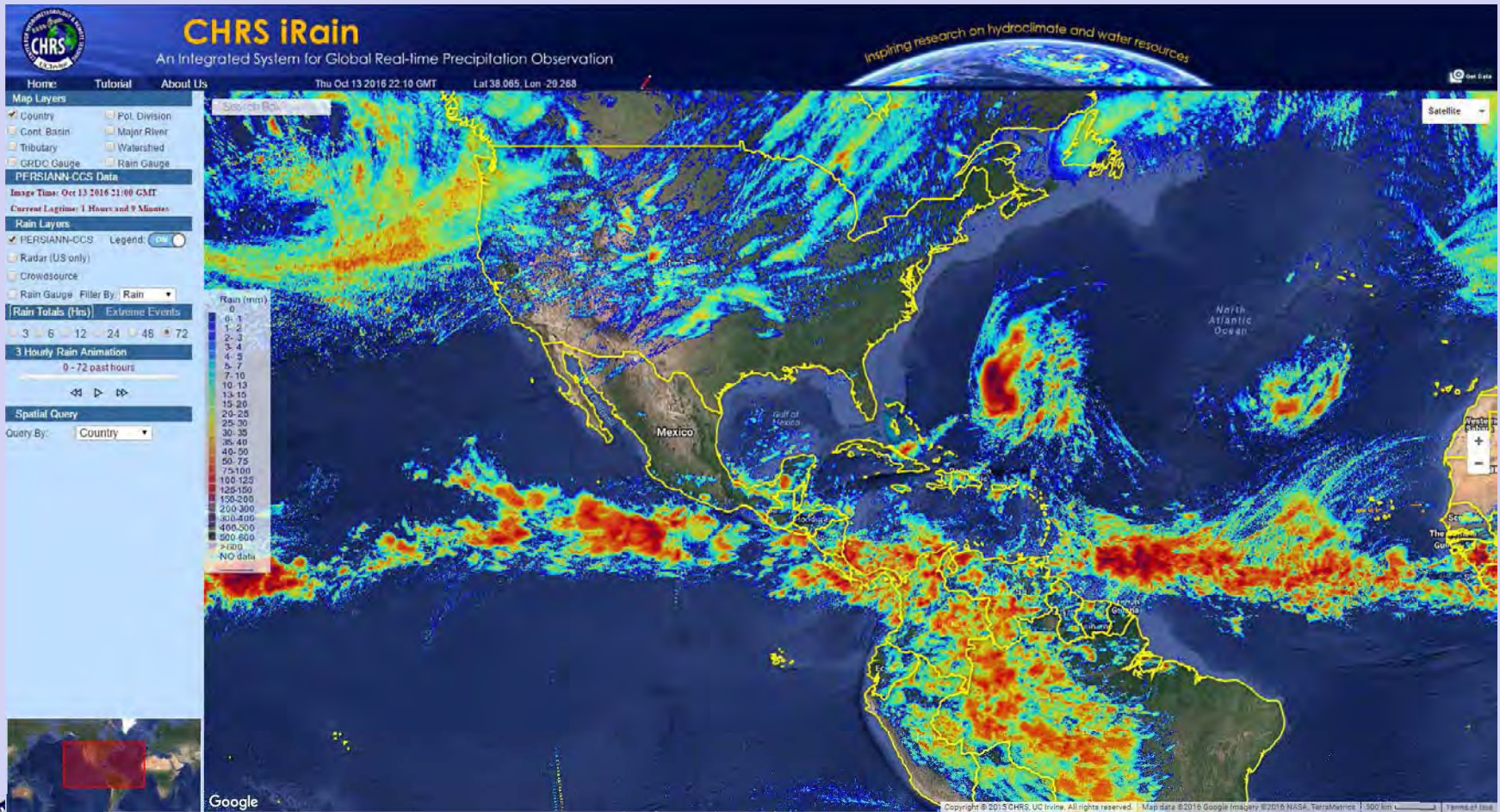
*<http://irain.eng.uci.edu>*





# iRain Interface

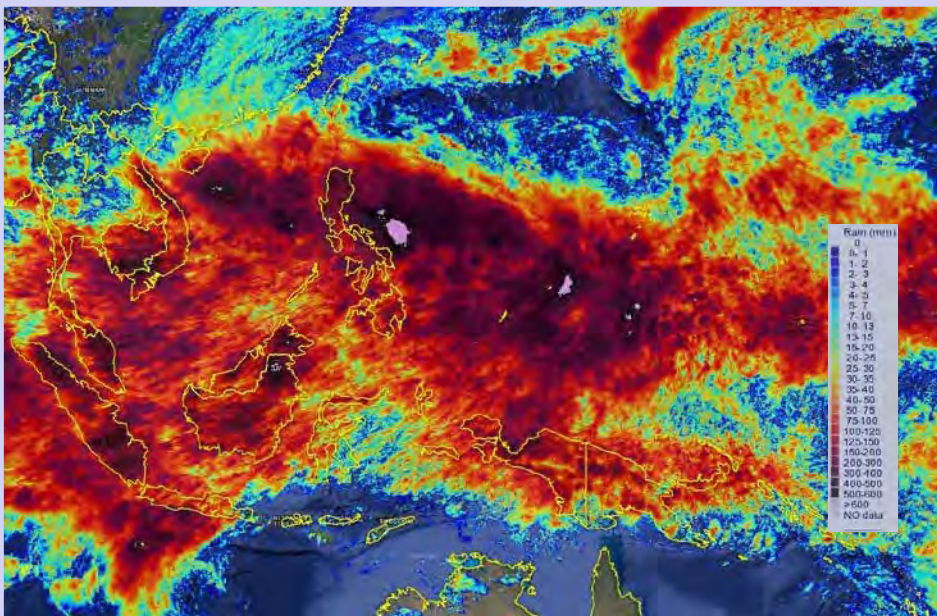
<http://irain.eng.uci.edu>



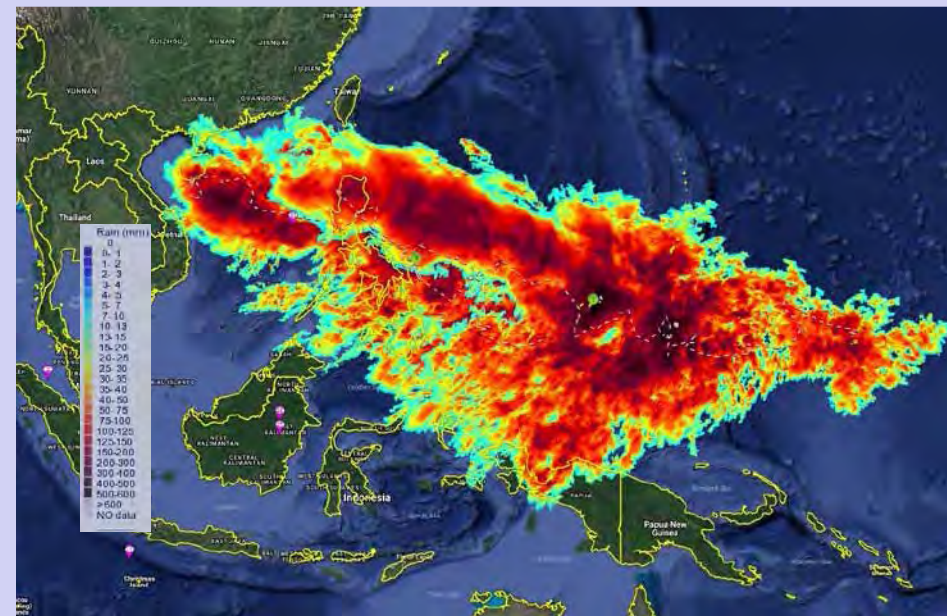


# *Typhoons Sarika and Haima October 2016*

Monitoring Typhoons Sarika and Haima on CHRS iRain System ([iRain.eng.uci.edu](http://iRain.eng.uci.edu))  
Using Real-time Global High Resolution (4km) Satellite Precipitation PERSIANN-CCS Data



Rain Accumulation October 10 – 20, 2016



Rain totals of Typhoons Sarika and Haima extracted using CHRS CONNECT Algorithm





**PERSIANN System**  
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks

CHRS  
CENTER FOR HYDROMETEOROLOGY & REMOTE SENSING  
U.C.Irvine



Rain!





# CHRS Data Portal

<http://chrsdata.eng.uci.edu>



## Data Portal

UNDER DEVELOPMENT

Home Info Tutorial Products About Us Lat: 0.352, Lon: 160.170

INSPIRING RESEARCH ON HYDROCLIMATE AND WATER RESOURCES

PERSIANN PERSIANN-CCS PERSIANN-CDR

The current operational PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) system developed by the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine (UCI) uses neural network function classification approximation procedures to compute an estimate of rainfall rate at each  $0.25^\circ \times 0.25^\circ$  pixel of the infrared brightness temperature image provided by geostationary satellites. An adaptive training feature facilitates updating of the network parameters whenever independent estimates of rainfall are available. The PERSIANN system was based on geostationary infrared imagery and later extended to include the use of both infrared and daytime visible imagery. The PERSIANN algorithm used here is based on the geostationary longwave infrared imagery to generate global rainfall. Rainfall product covers  $60^\circ\text{S}$  to  $60^\circ\text{N}$  globally. [Further reading](#).

**Data Period:** March 2000 - Present

**Coverage:**  $60^\circ\text{S}$  to  $60^\circ\text{N}$

**Resolutions:**  $0.25^\circ \times 0.25^\circ$

**Timesteps:** 1, 3, 6 hourly, daily

**FTP Download (full):** [1 hourly](#), [3 hourly](#), [6 hourly](#), [Daily](#), [Monthly](#), [Yearly](#)

**Latest Update:** Near real time with 2 day delay

**Selected References:**  
Sorooshian, S., P. Nguyen, S. Seillars, D. Braithwaite, A. AghaKouchak, and K. Hsu. 2014. Satellite-based remote sensing estimation of precipitation for early warning systems. *Extreme Natural Hazards, Disaster Risks and Societal Implications*, A. Ismail-Zadeh, J.U. Fucugauchi, A. Kijko, K. Takeuchi, and I. Zaliapin.



Google

Copyright © 2015 CHRS, UC Irvine. All rights reserved. | Map data © 2015 Imagery © 2015 | 100°W | 100°E | Terms of Use | Report a problem

Dataset: PERSIANN-CCS | Time Step: Daily | Domain: Whole Globe

Visualization | Download | Comparison

DateTime: 2016-10-12 | Visualize | Clear Image | Legend:

Precipitation Stats:  
Max: 162.00 mm  
Min: 0.00 mm  
Mean: 2.43 mm  
Median: 0.00 mm

News FAQ

[Houston Flooding Rainfall](#)  
[Hurricane Patricia](#)  
[RainMapper](#)  
Check out our [RainSphere](#)  
[Super Typhoon Haiyan](#)  
[PERSIANN-CDR Dataset](#)

## News & Recent Events

### Houston Flooding Rainfall

#### The second most severe rainfall in Houston since 1888

Houston flooding rainfall on 18th of April 2016 was the second wettest calendar day on record for official reporting stations in Houston, since 1888, with 9.92 inches of rain measured at Bush Intercontinental Airport. The storm hit the area in two major waves: the first wave stopped over the area by the high pressure system late on 17 April. Fed by the moisture originating from the Gulf of Mexico and moving north, the second and more intense wave was triggered early on 18 April.



# Who Uses CHRS Products



## CHRS User Statistics



Overall CHRS Homepage G-WADI iRain RainSphere Data Portal CONNECT

Total Visits: 570,957 since 01-Jan-2010  
Countries: 195 countries registered

| # | Country                   | Total Visits |
|---|---------------------------|--------------|
| 1 | United States             | 372,328      |
| 2 | China                     | 39,859       |
| 3 | France                    | 20,766       |
| 4 | Thailand                  | 16,494       |
| 5 | Japan                     | 15,766       |
| 6 | Germany                   | 12,903       |
| 7 | Ukraine                   | 7,745        |
| 8 | Iran, Islamic Republic Of | 7,104        |
| 9 | Canada                    | 5,859        |





# *CHRS iRain and Rainsphere Development Team*



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





# UNIVERSITY OF CALIFORNIA, IRVINE



*Thank you for Listening*

Center for Hydrometeorology & Remote Sensing  
Engineering Hall, Suite #5300 (Building #308) Irvine, CA 92617

SOROOSH SOROOSHIAN, Distinguished Professor, Director  
Civil and Environmental Engineering, & Earth System Science  
University of California, Irvine  
Phone: (949) 824-8825

Fax: (949) 824-8831

SOROOSH@UCI.EDU