"Application of Machine Learning in Global Precipitation Estimation": The PERSIANN System

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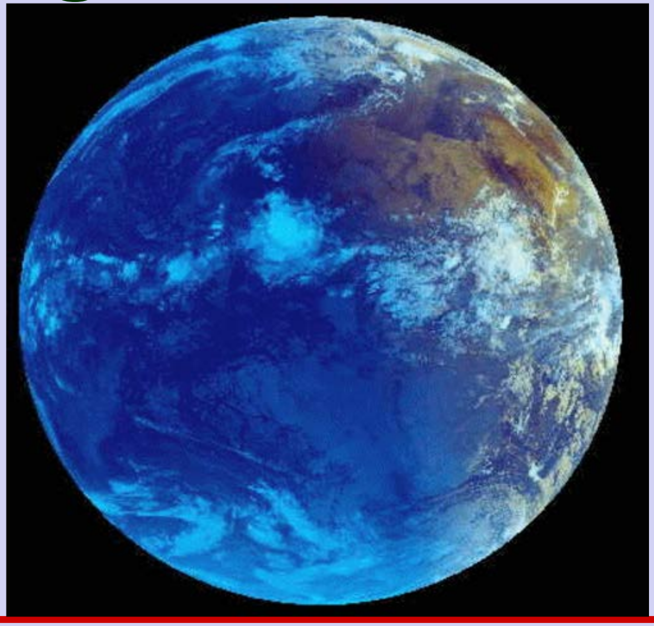
2019 US CLIVAR Summit
Long Beach, California
August 6th 2019

University of California Irvine (UCI)

- ***How will Climate change affect precipitation variability and water Availability?***

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

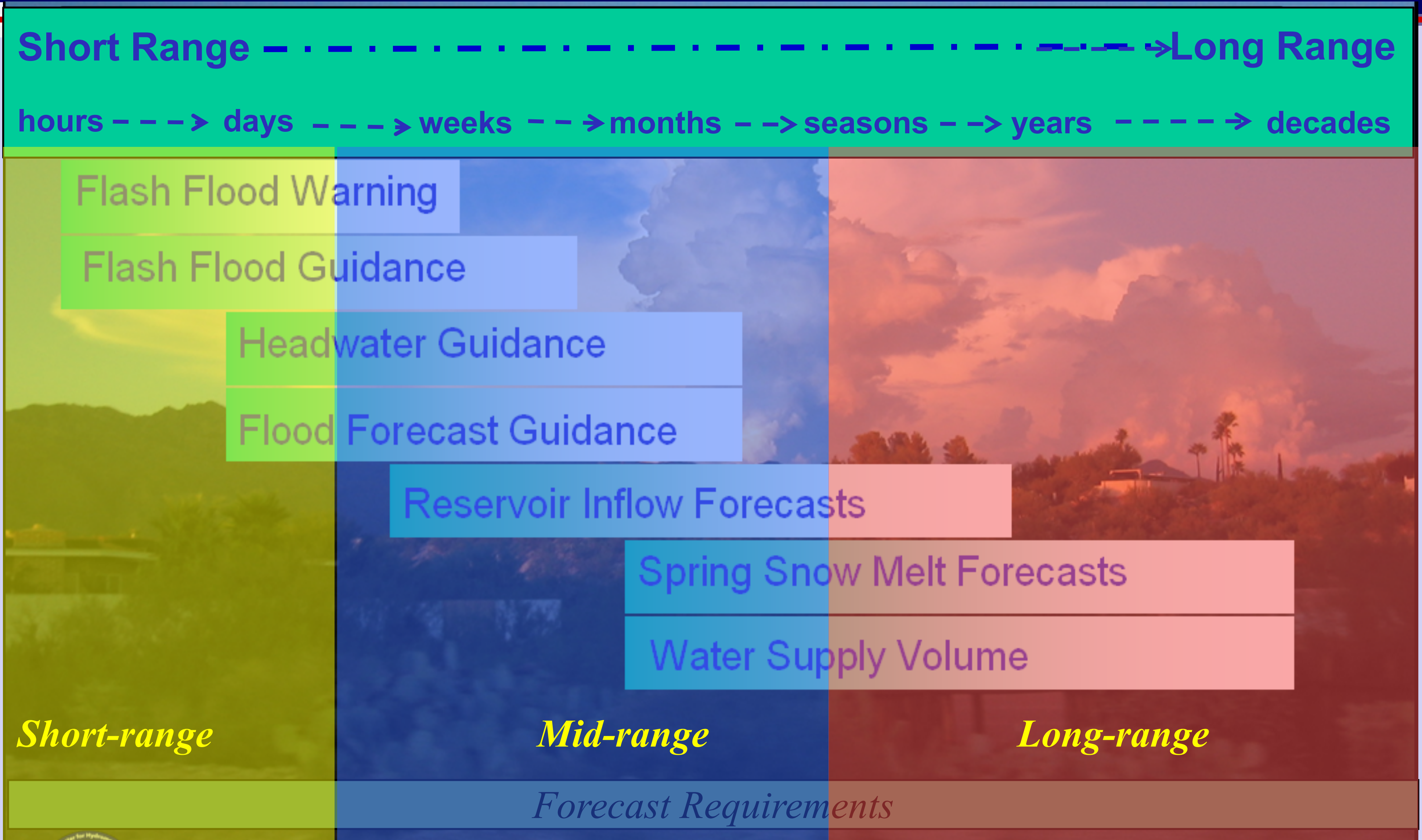


Information Relevant to Water Resources Planning

- Models Projections

- Observations

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

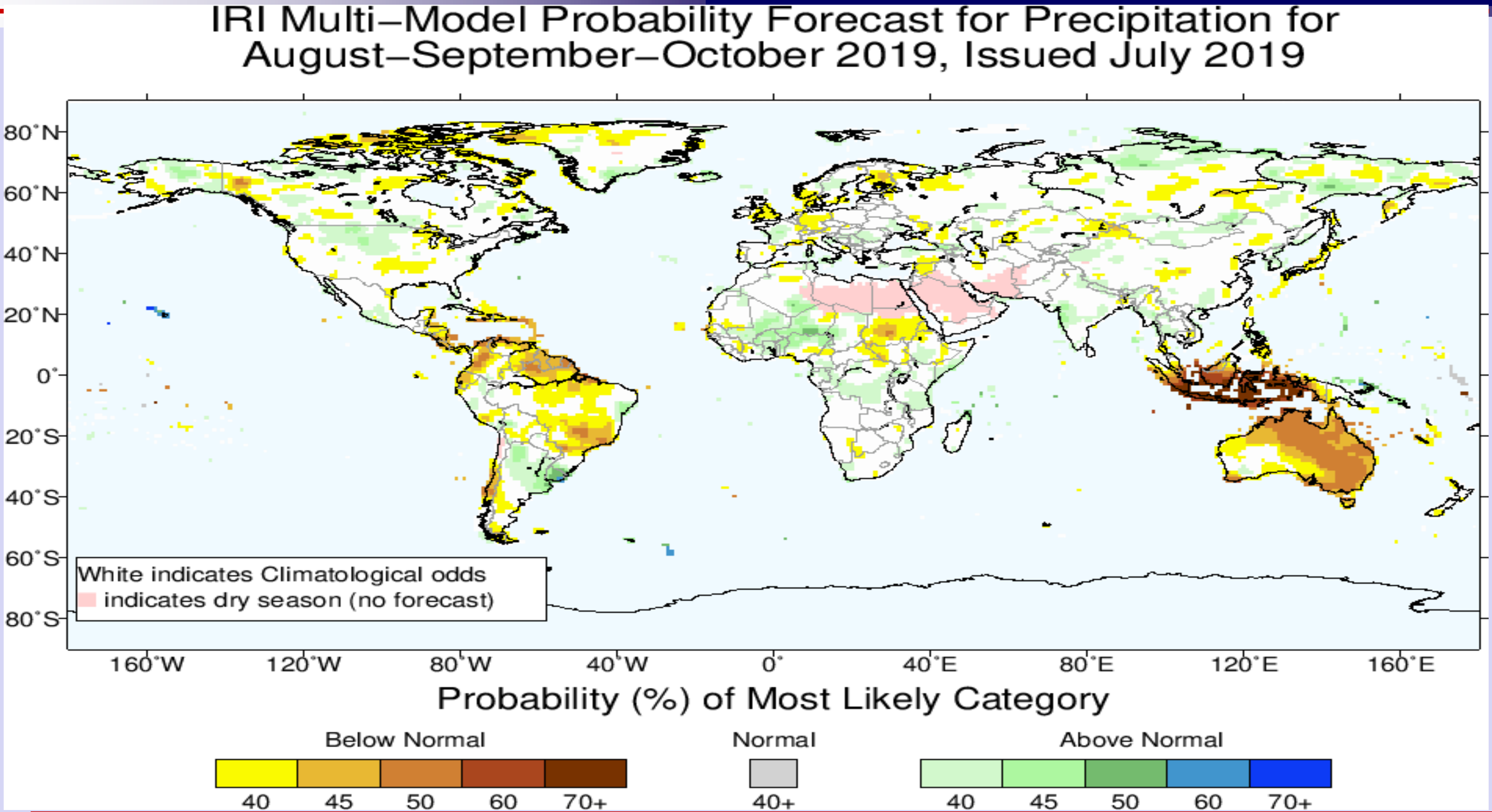
Spring Snow Melt Forecasts

Water Supply Volume

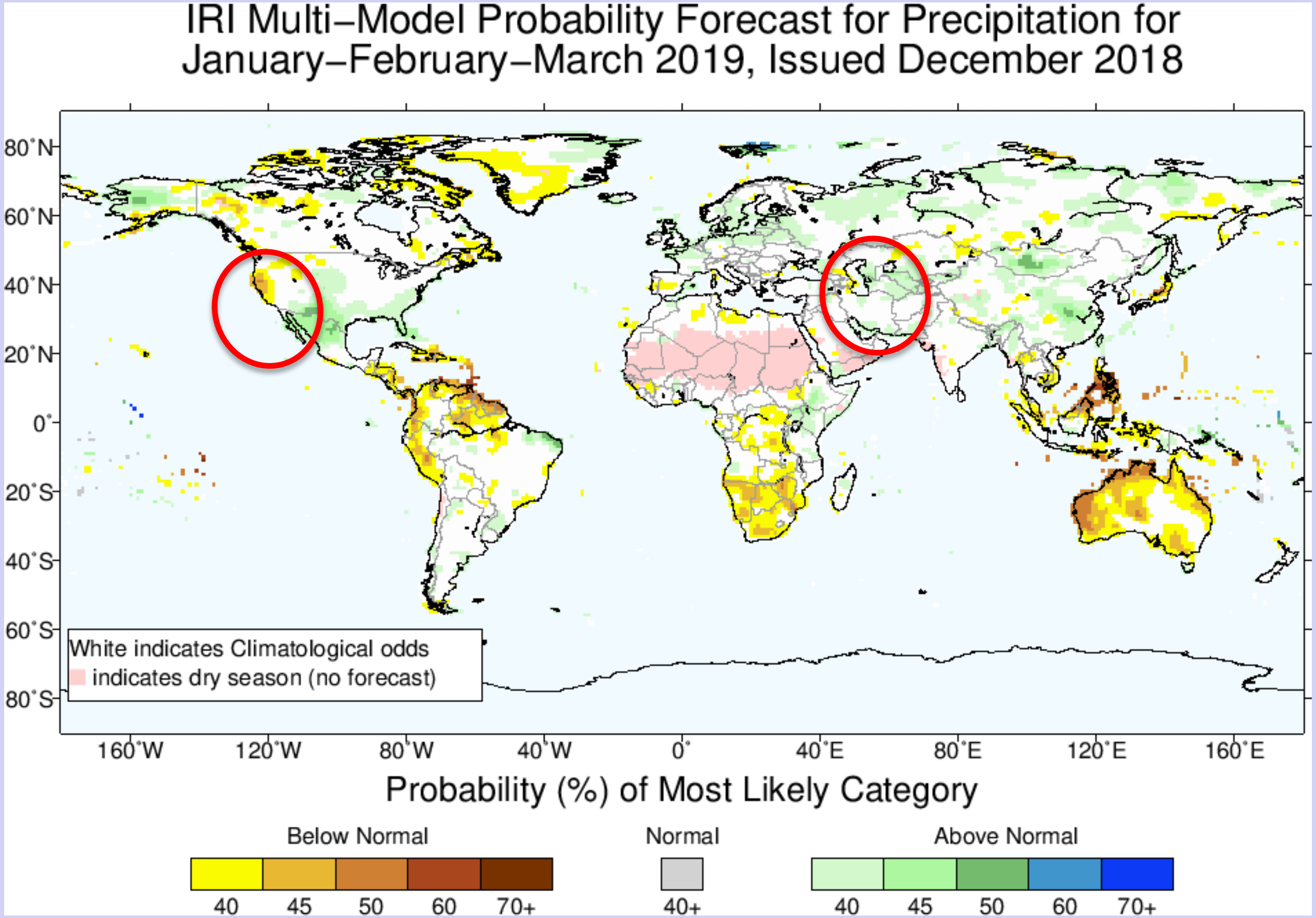
Mid-range

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

Western U.S. future model projections

Dr. Chiyuan Miao - BNU

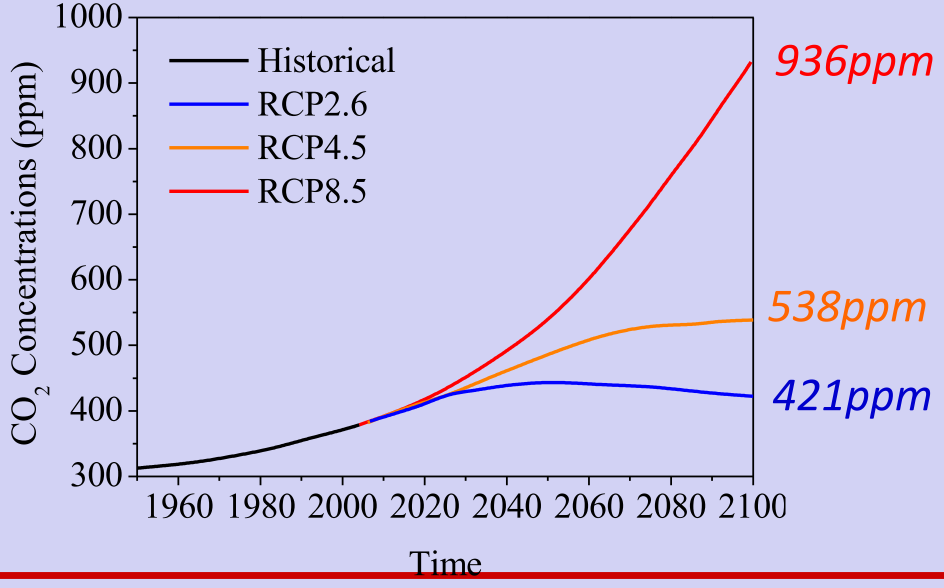
Future Modeling Scenarios – IPCC AR5

Representative Concentration Pathways (RCP) Scenarios:

RCP2.6: represent 'low' scenarios featured by the radiative forcing of 2.6 W/m^2 by 2100, the resulting CO_2-equivalent concentrations is 421 ppm in the year 2100 .

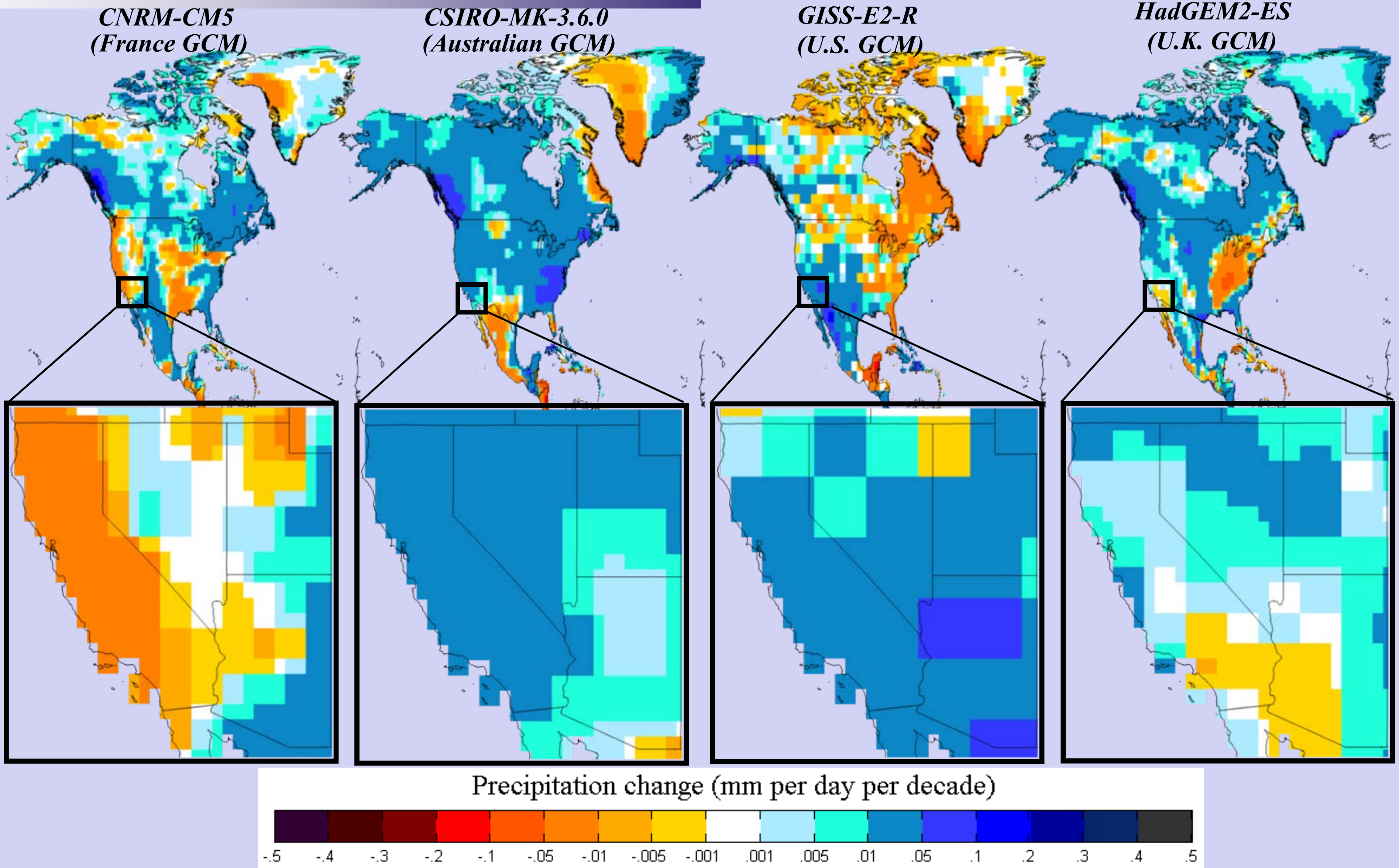
RCP4.5: represent 'medium' scenarios featured by the radiative forcing of 4.5 W/m^2 by 2100, the resulting CO_2-equivalent concentrations is 538 ppm in the year 2100 .

RCP8.5: represent 'high' scenarios featured by the radiative forcing of 8.5 W/m^2 by 2100, the resulting CO_2-equivalent concentrations is 936 ppm in the year 2100 .

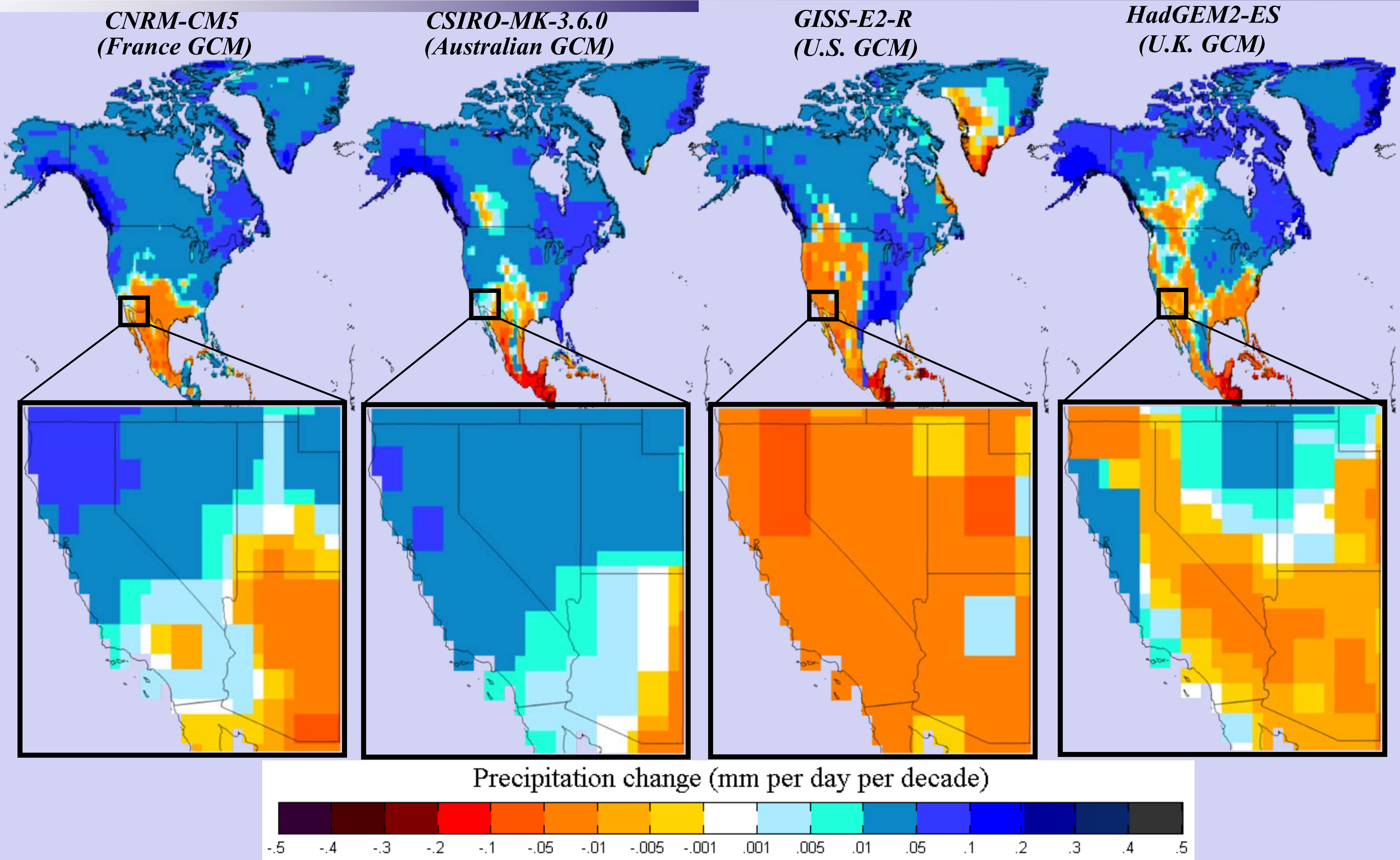


RCP2.6

Time period: 2006-2099

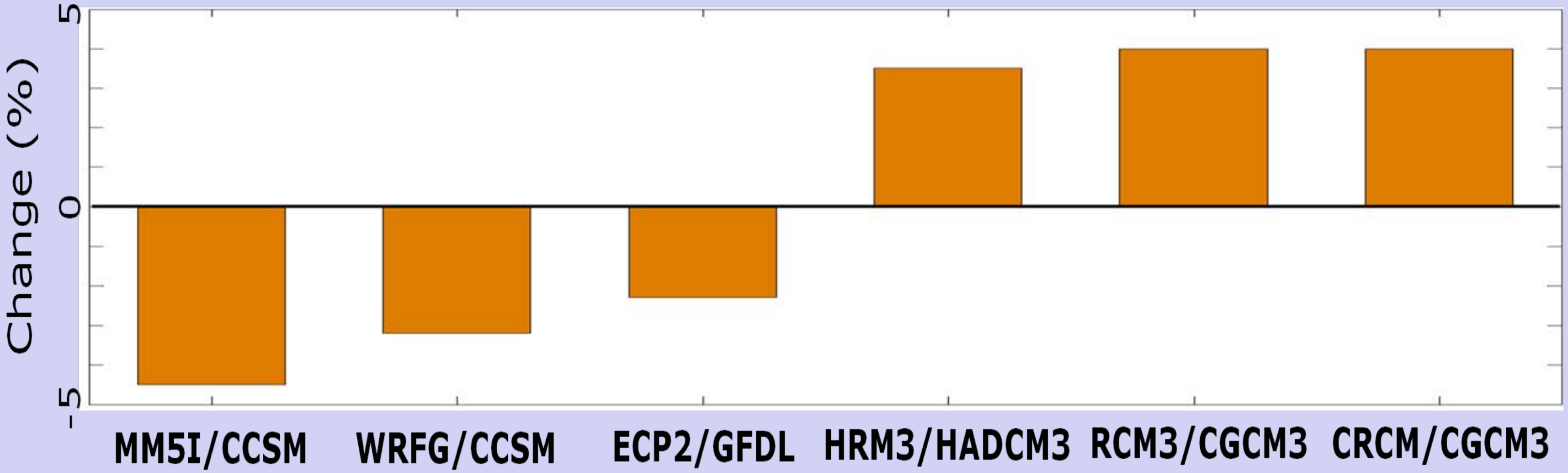


RCP8.5 Time period: 2006-2099



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

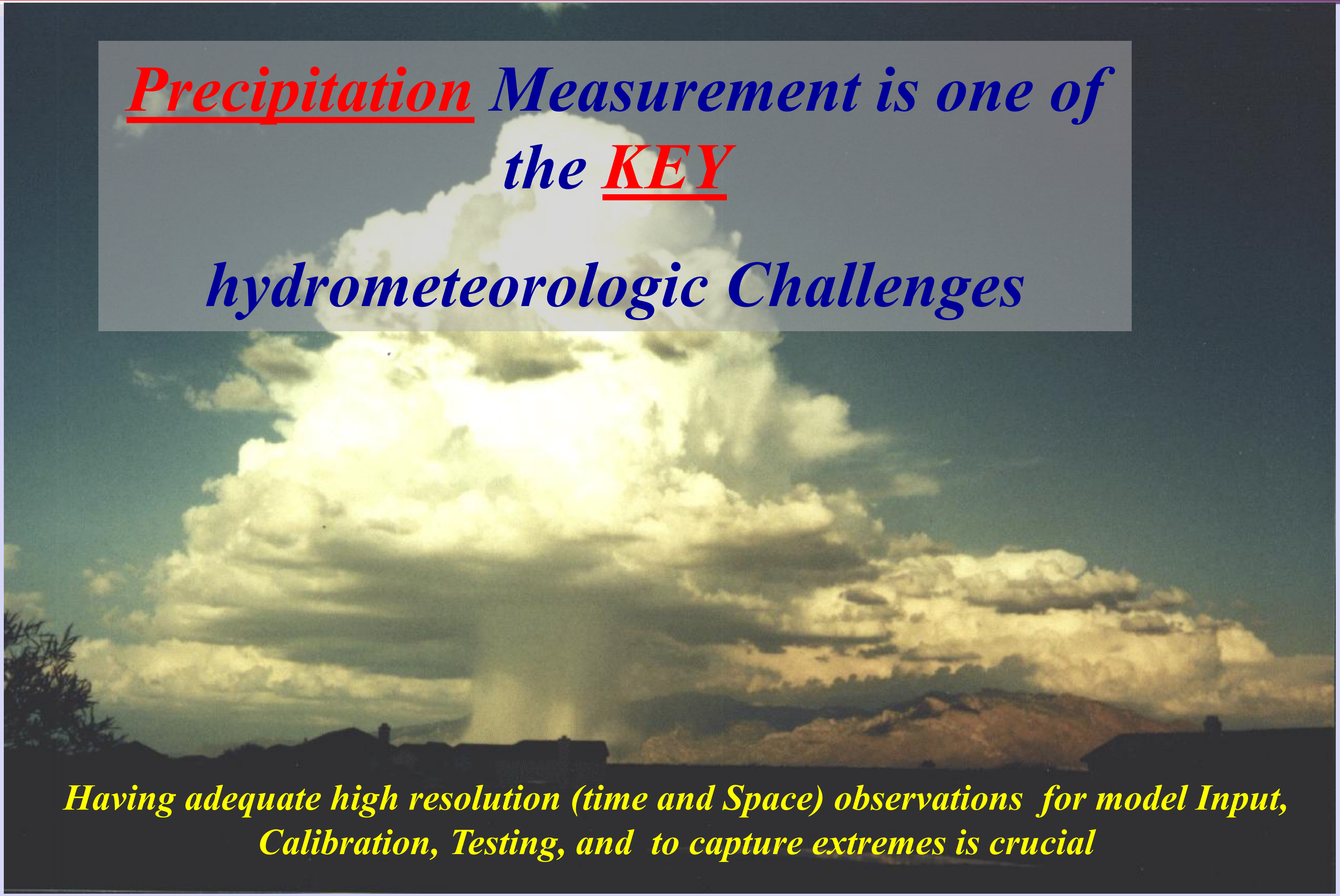
For users of model information the question is:

Which model (or groups of models) should be "trusted" for their "Accuracy"

Answer is partly related:

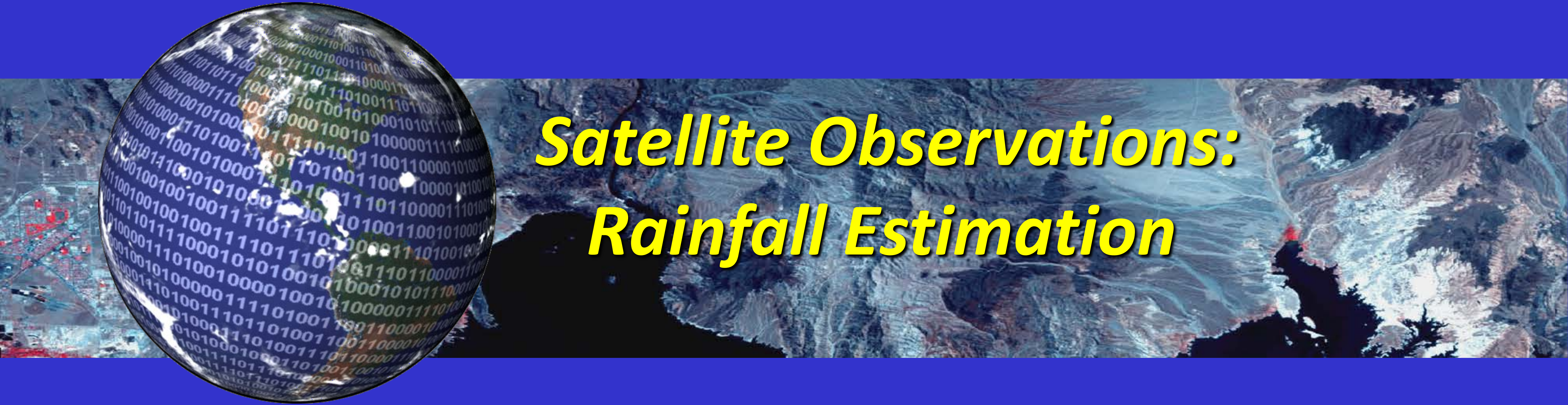
To what degree should we trust observations used as both input and reference to test the models

A Key Requirement!



Precipitation Measurement is one of the KEY hydrometeorologic Challenges

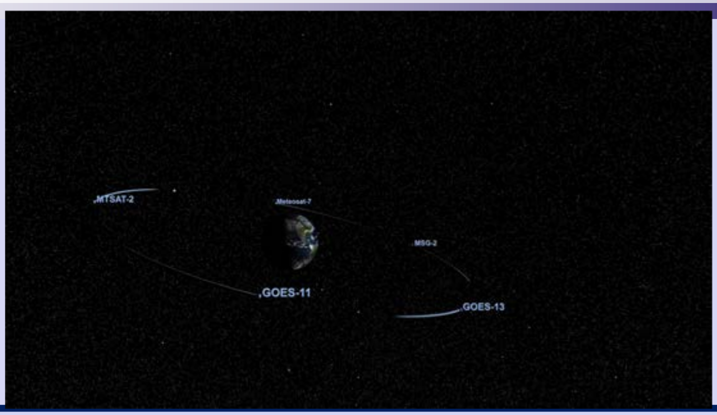
Having adequate high resolution (time and Space) observations for model Input, Calibration, Testing, and to capture extremes is crucial



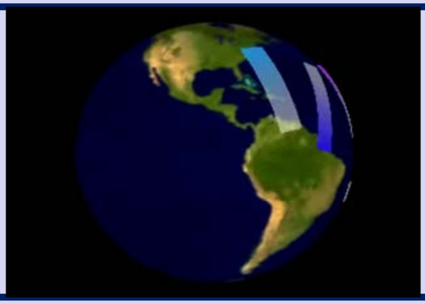
Satellite Observations: Rainfall Estimation

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

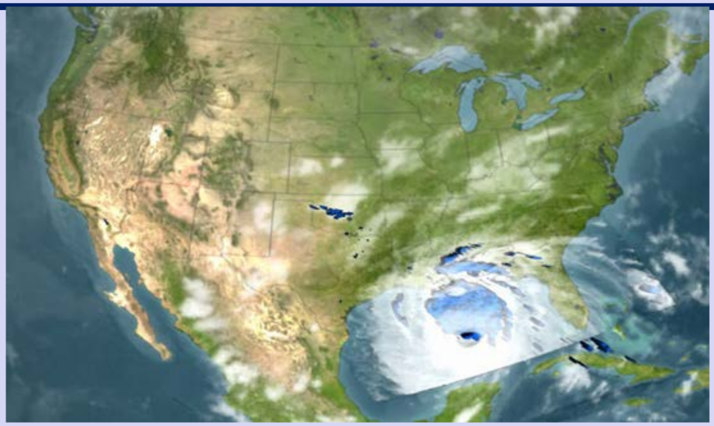
Satellite Data for Precipitation estimation



Geostationary IR
Cloud top data
15-30 minute temporal resolution

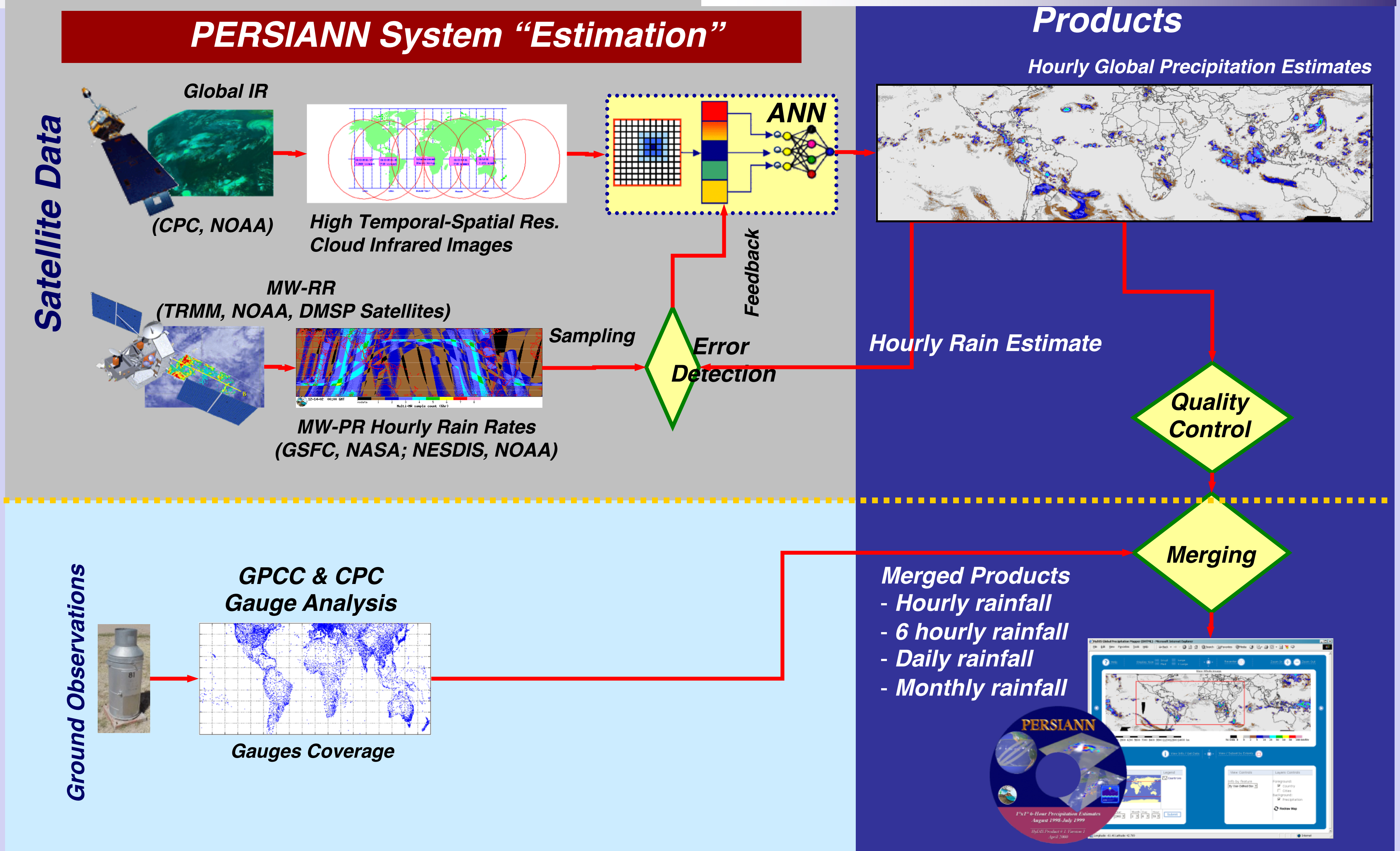


Passive Microwave (SSM/I)
Some characterisation of rainfall
~2 overpasses per day per spacecraft, moving to 3-hour return time (GPM)

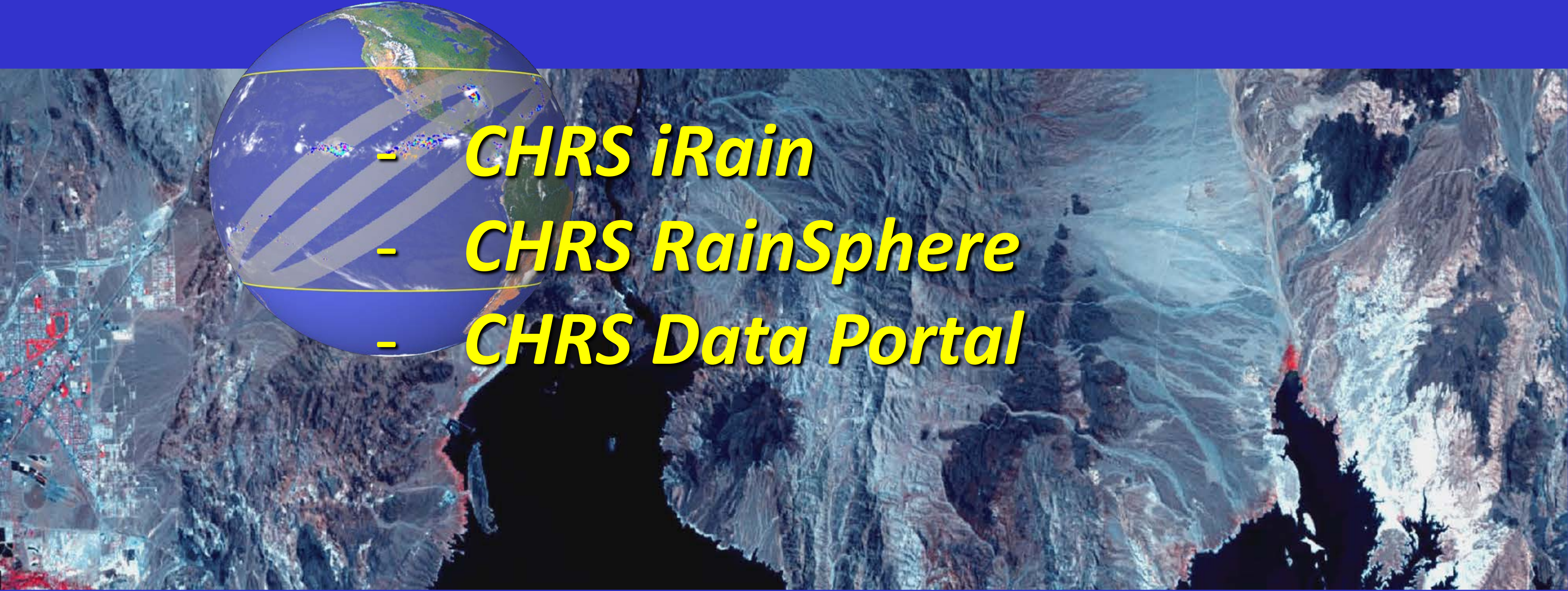


TRMM precipitation RADAR
3D imaging of rainfall
1-2 days between overpasses
(S-35°N-35 °)

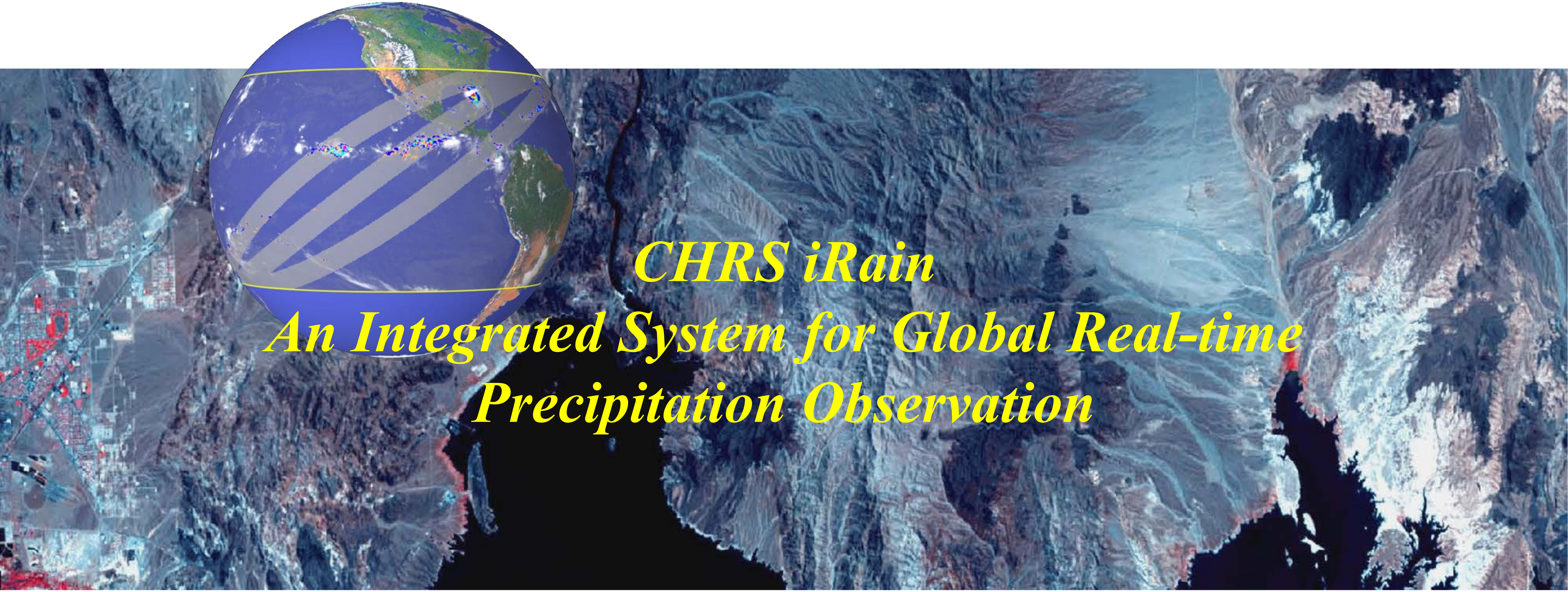
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)



PERSIANN Websites and Apps



- CHRS iRain
- CHRS RainSphere
- CHRS Data Portal



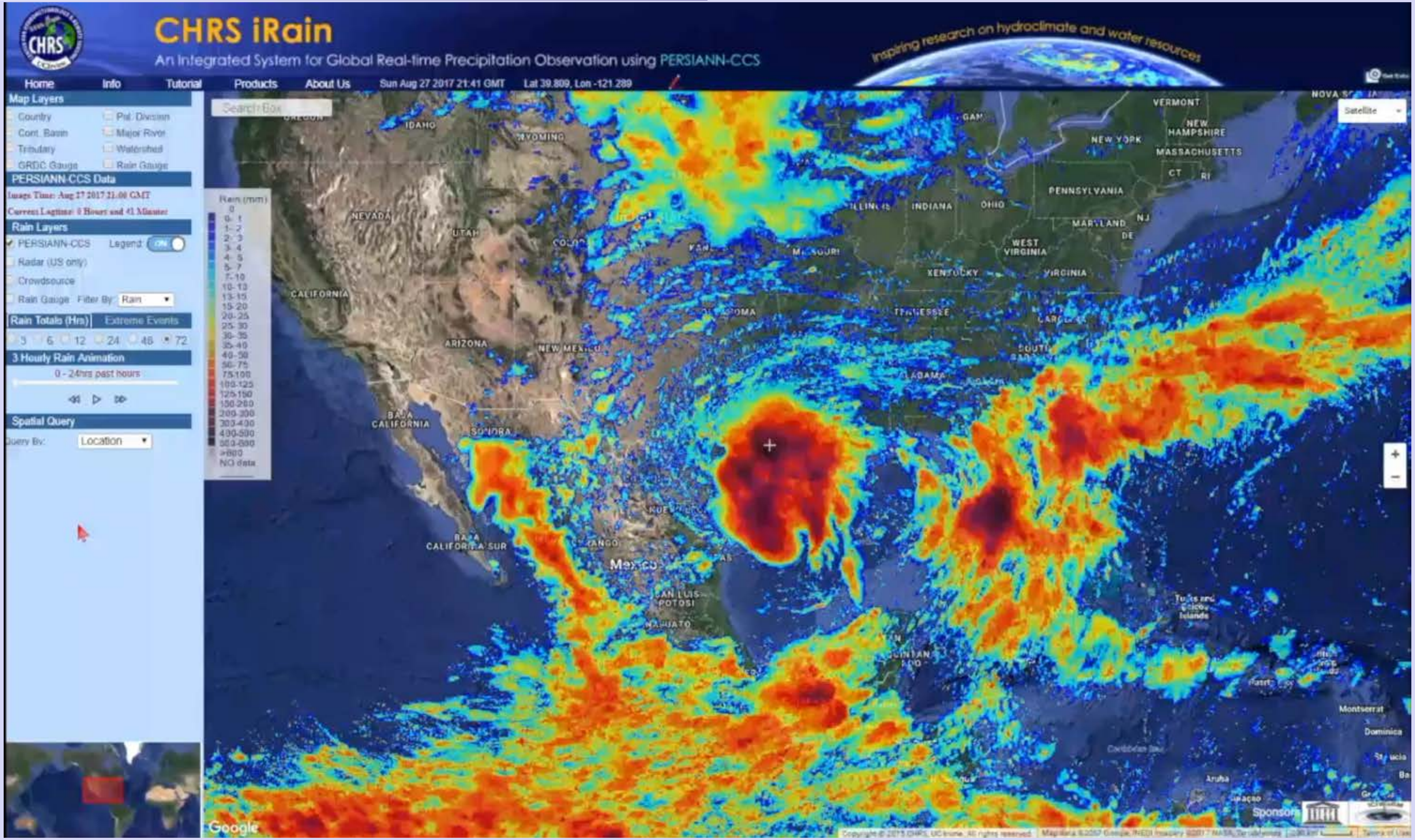
CHRS iRain

An Integrated System for Global Real-time Precipitation Observation

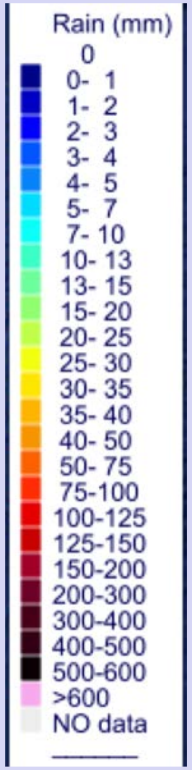
http://irain.eng.uci.edu

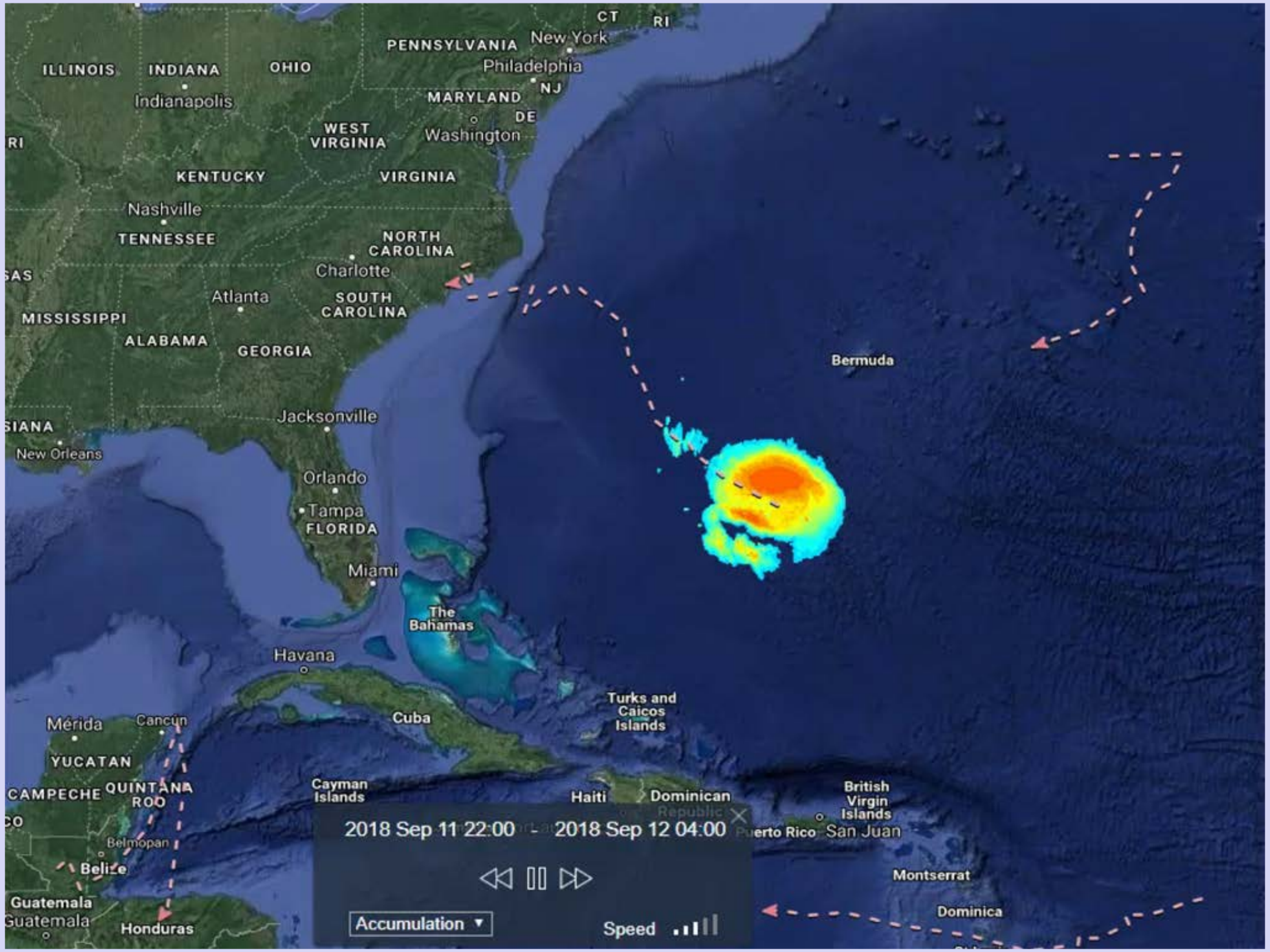
CHRS iRain capturing Tropical Storm Harvey - August 2017

irain.eng.uci.edu



Tracking Hurricane Florence (CONNECT Algorithm)

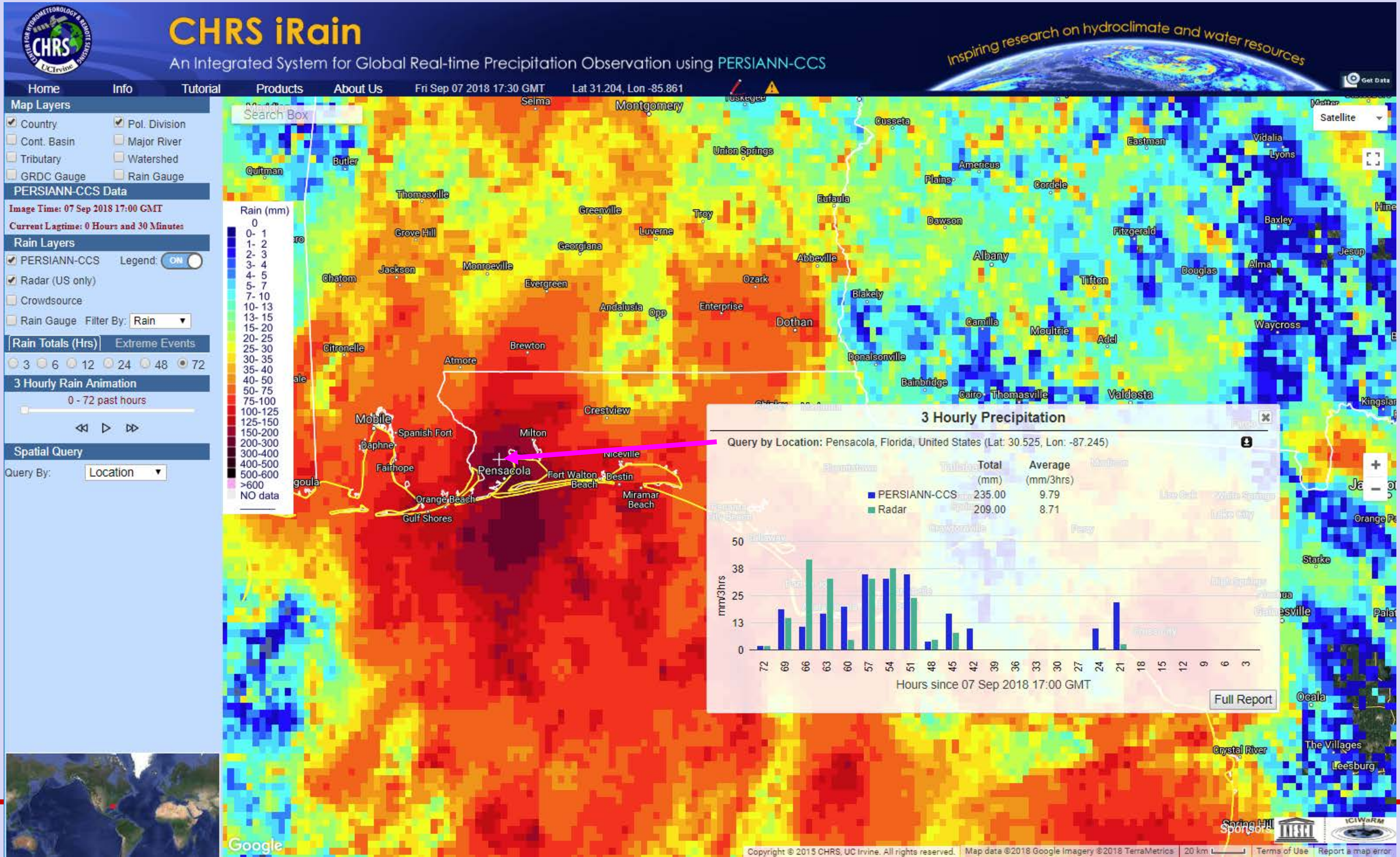




Storm Statistics	
Storm ID	10
Max Rain Intensity	94 mm/3hrs
Avg Rain Intensity	15 mm/3hrs
Max Point Accum	282 mm
Storm Coverage Area	7.97e+5 km^2
Total Rain Volume	47.41 km^3
Storm Duration	72 hrs
From	2018 Sep 11 22:00
To	2018 Sep 14 22:00
Storm Status	Active

Storm Statistics

Extreme rainfall event in Alabama (09-07-2018)
Location query

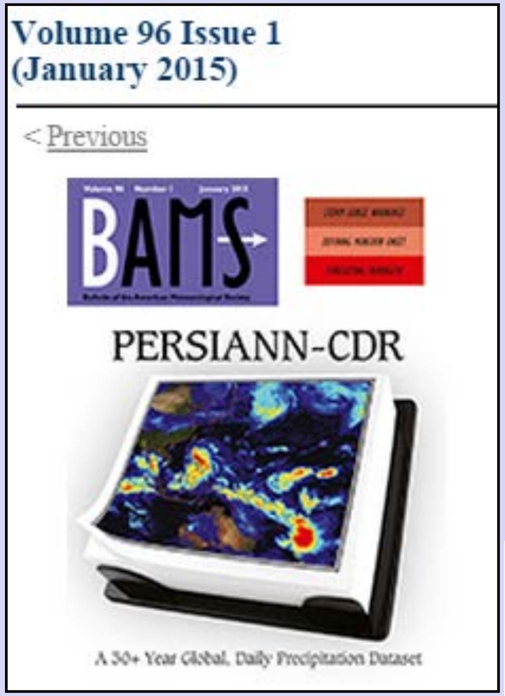


PERSIANN Extensions: Climate-Related

PERSIANN-CDR

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

- *Daily Precipitation Data*
- *Data Period: 1983~2019*
- *Coverage: 60°S ~ 60°N*
- *Spatial Resolution: 0.25°x0.25°*

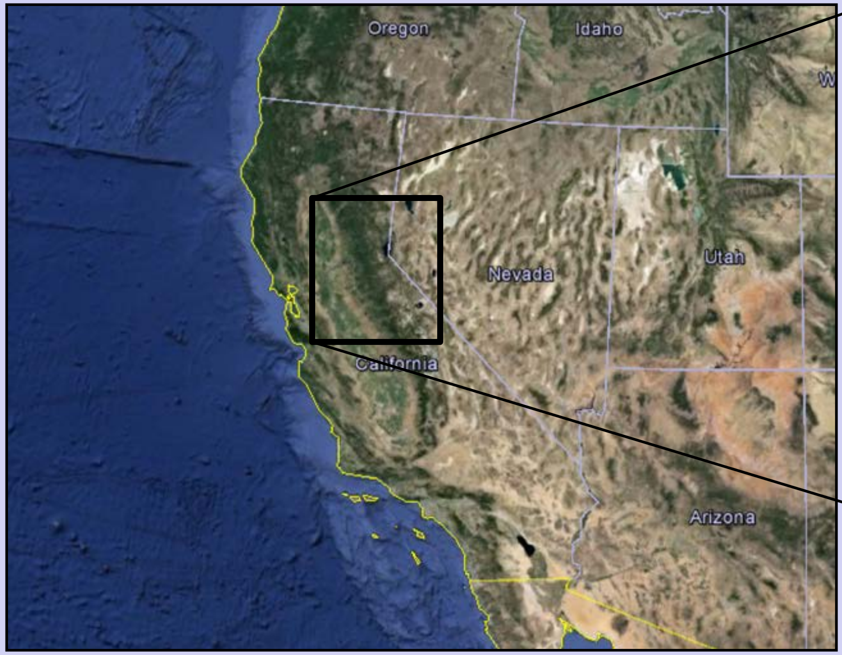


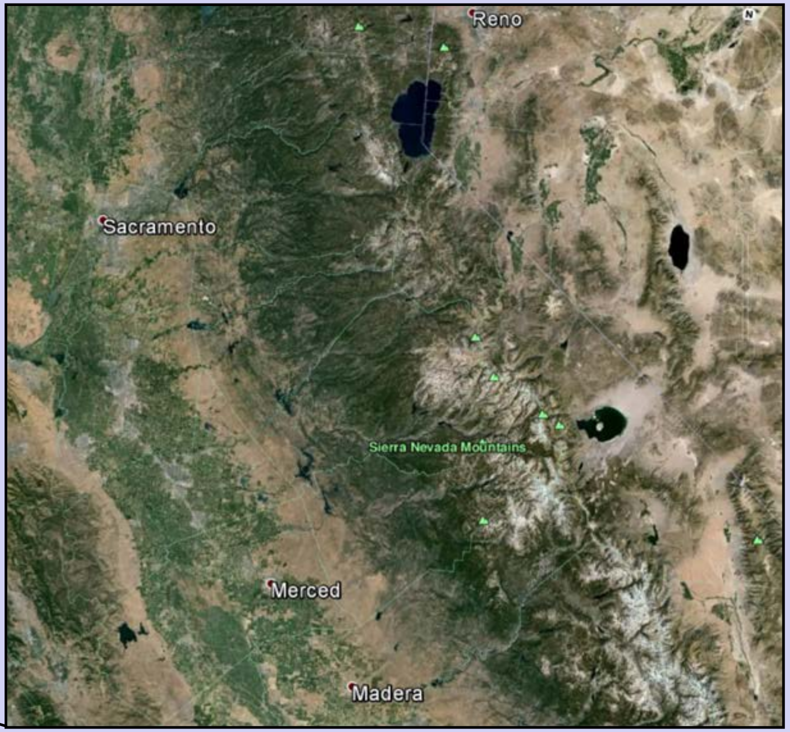
Ashouri, Hsu et al., BAMS, 2015.

Sierra-Nevada Mountain Region

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

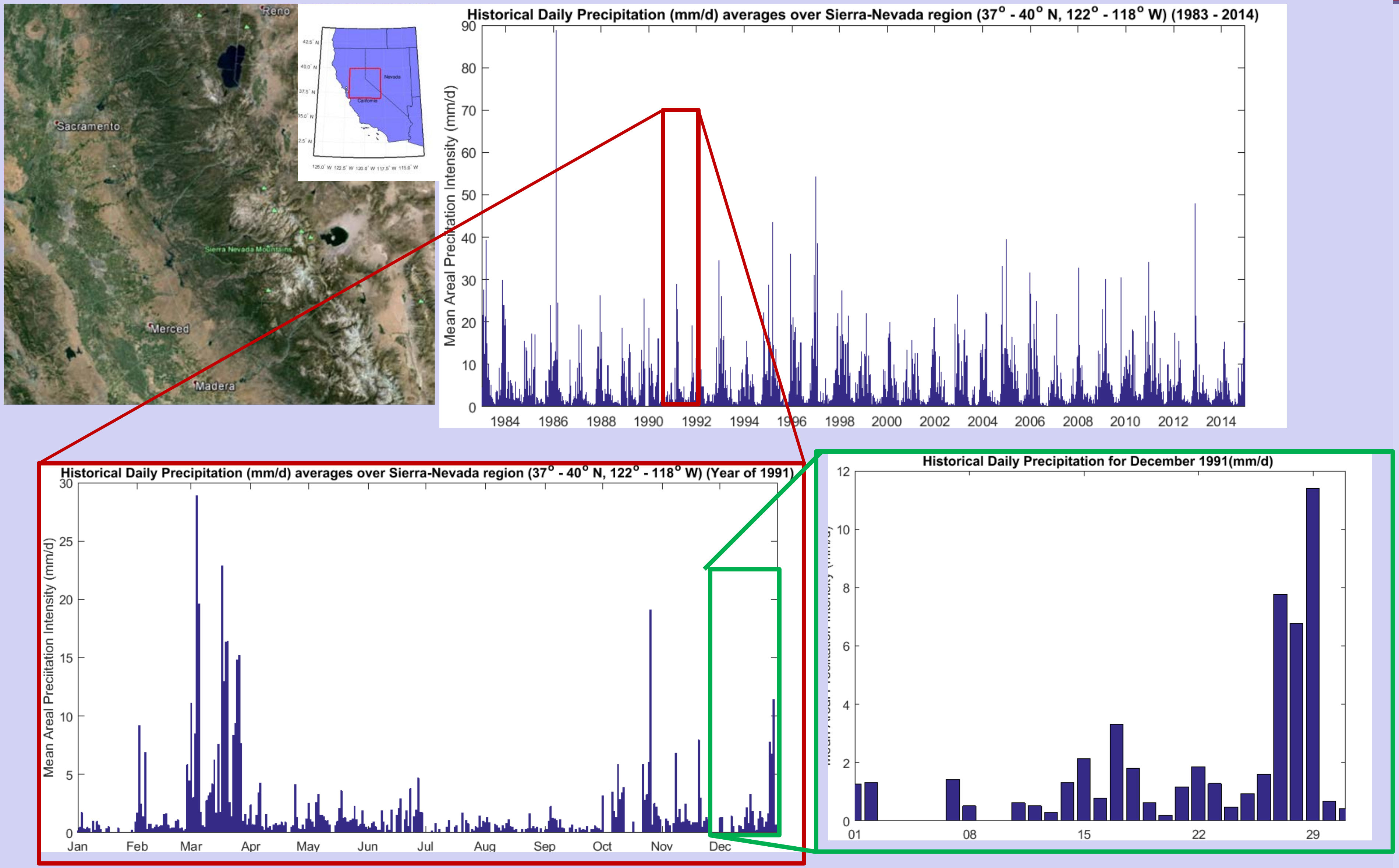
Length: 400 mile, Width: 64 mile.



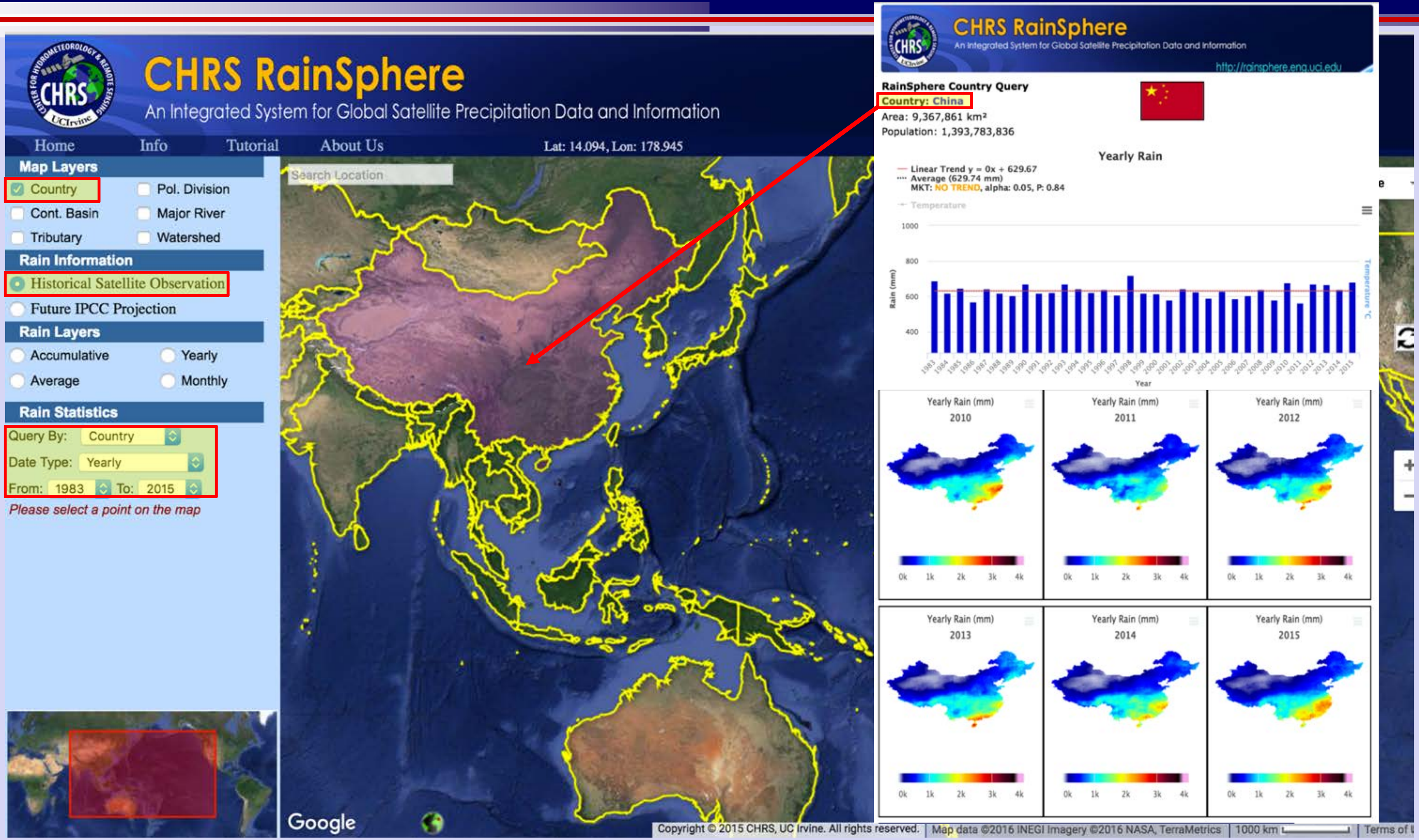


Map Source: Google Earth

Sierra-Nevada Mountain (California and Nevada)



CHRS RainSphere



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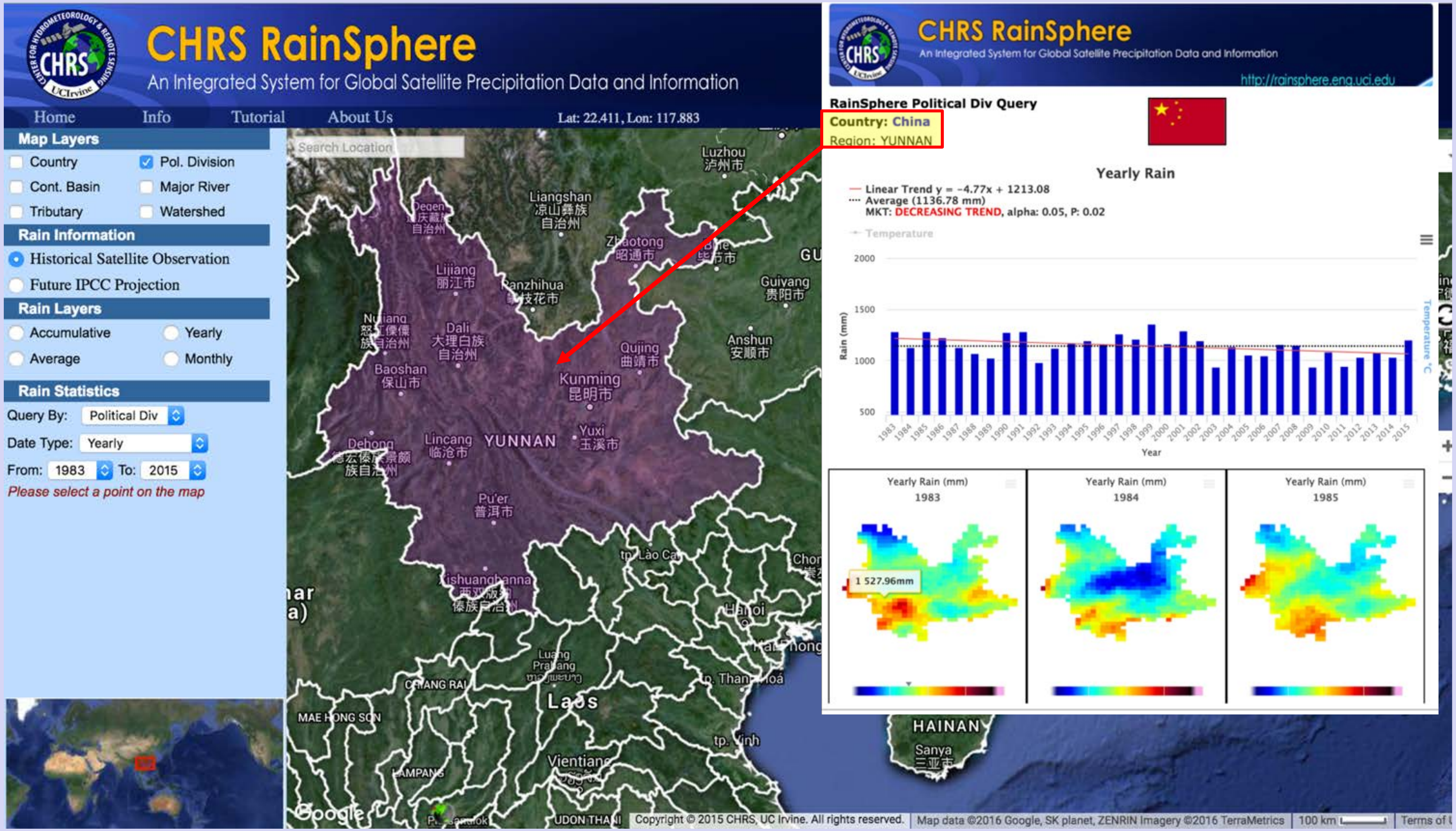
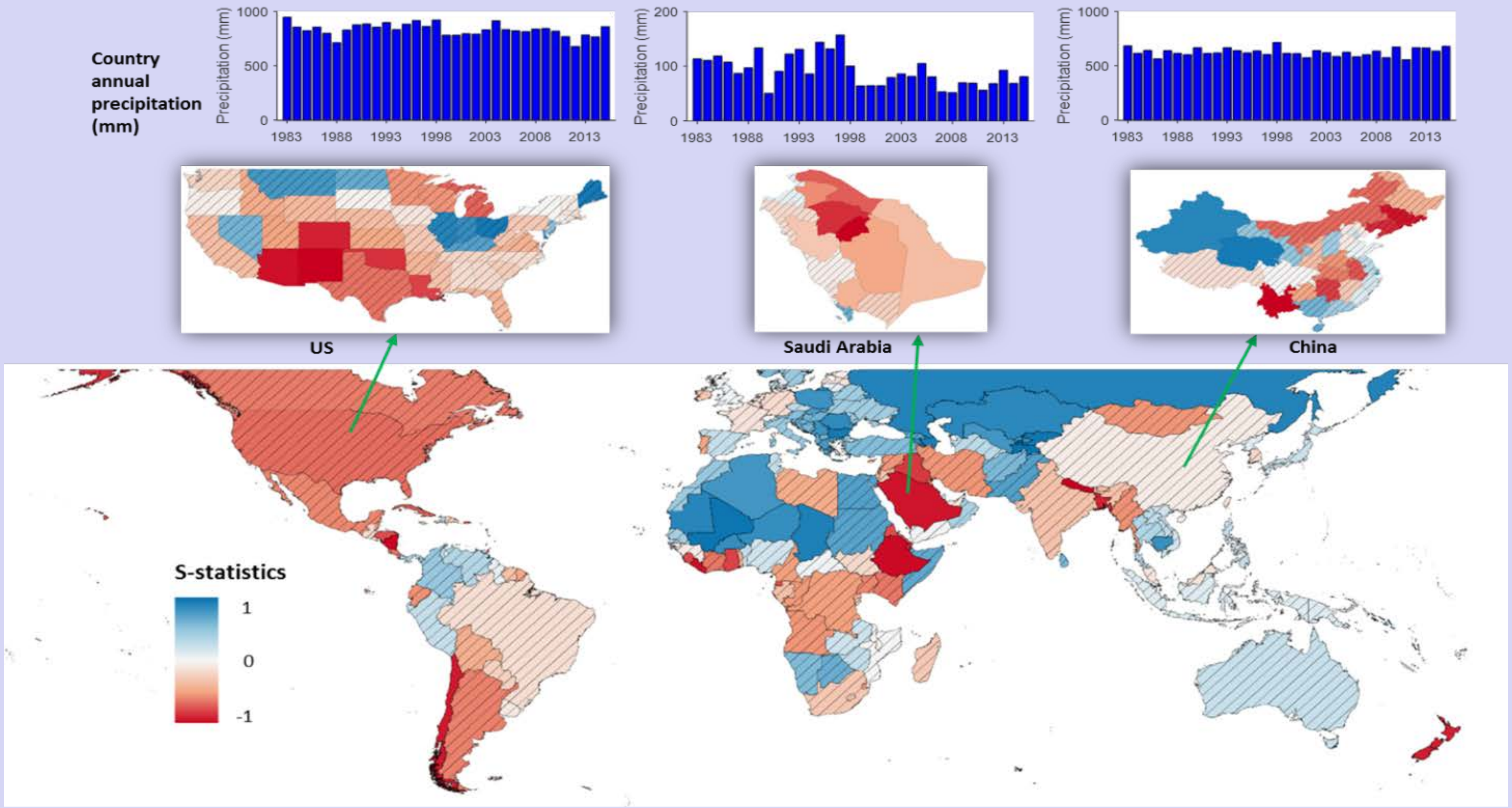


Rainfall Trend Analysis: Countries and Political Divisions



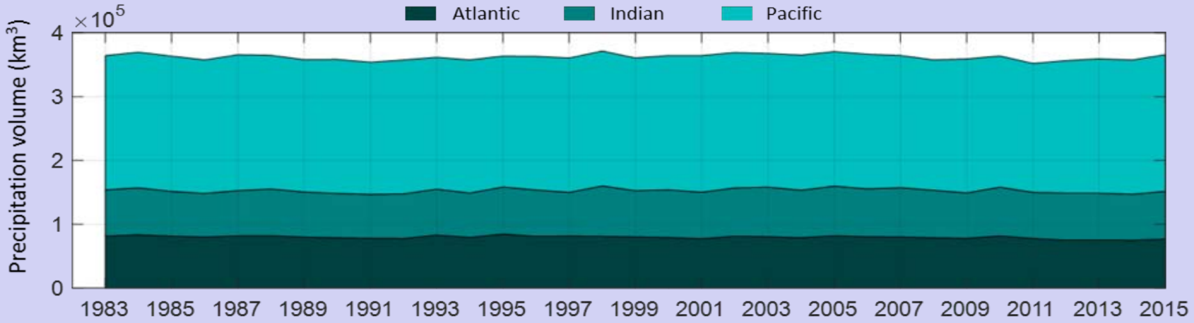
Precipitation trends from 1983 to 2015 over 201 countries (60°N - 60°S) and state/province political divisions of US, Saudi Arabia and China

Nguyen et al. BAMS (2018)

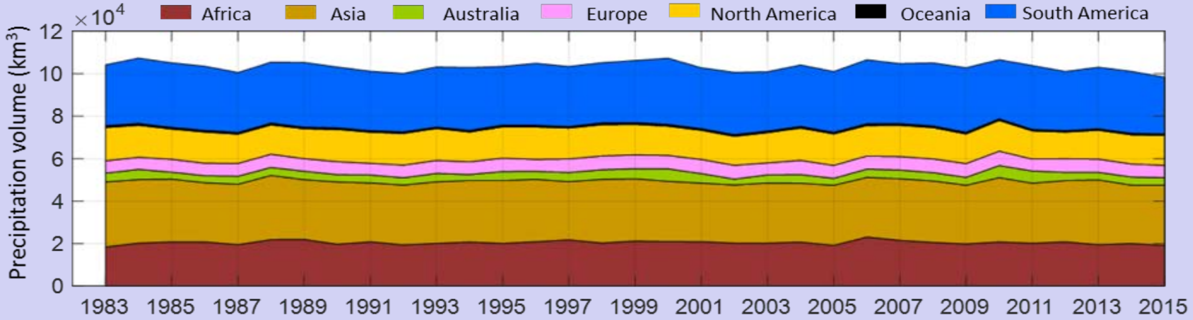
Rainfall Trend Analysis: Continents and Oceans

Nguyen et al.
BAMS (2018)

Precipitation trends over oceans and land



Precipitation changes over oceans
(No detectable trend)

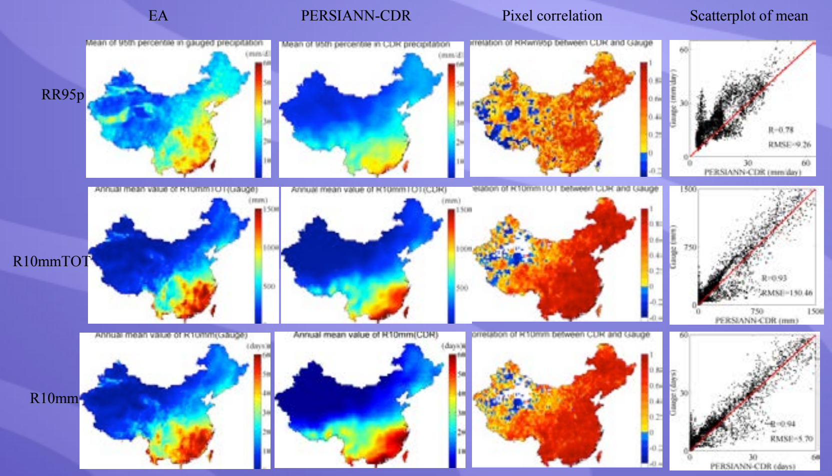


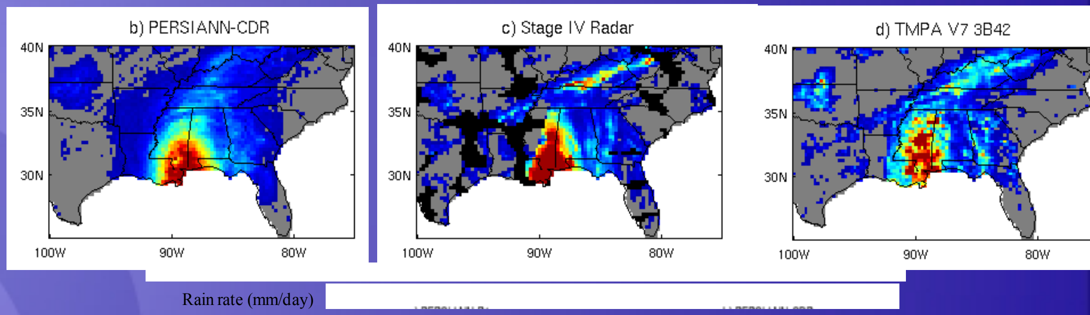
Precipitation changes over continents
(No detectable trend)

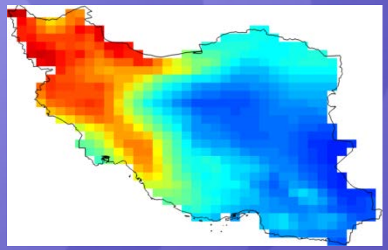
Changes in precipitation over oceans and land (60^{o}S-60^{o}N): PERSIANN-CDR dataset 1983 to 2015.

Regional Evaluations of PERSIANN-CDR

Many Regional Evaluation of PERSIANN-CDR Have Already Been Reported:



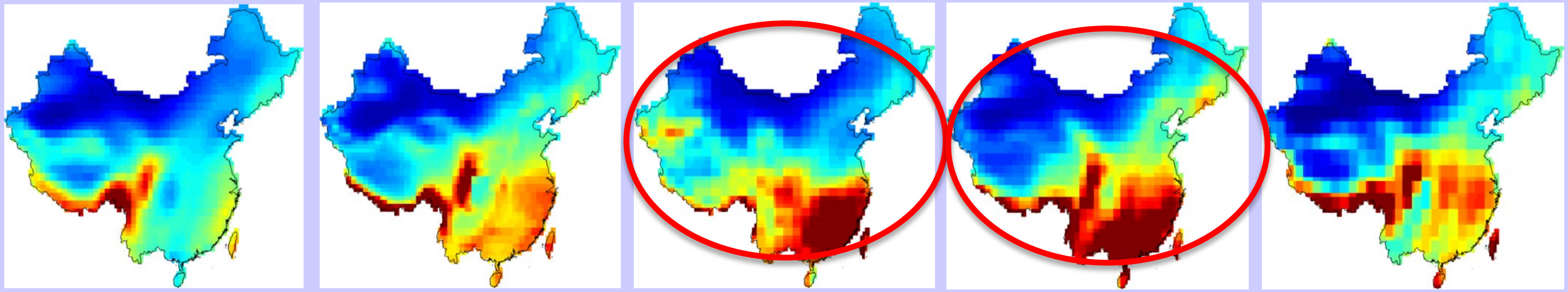




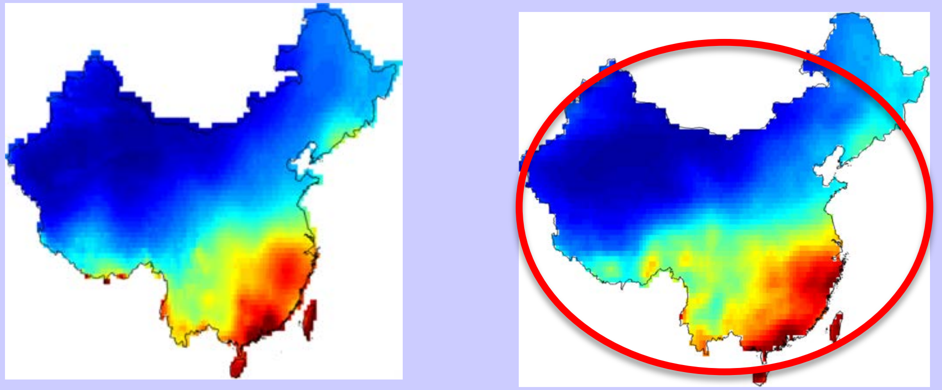
What is the value of this data set to application and Modeling communities?

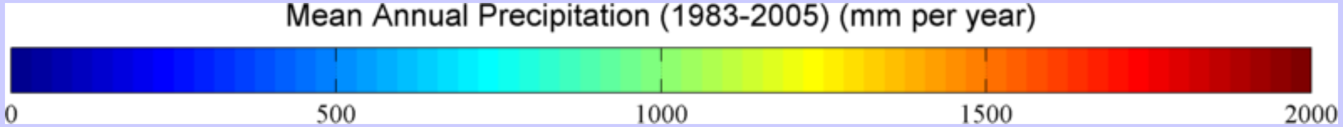
Model historical simulation- China (1983-2005)

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) | *Observation (PERSIANN-CDR)*





Model historical simulation (1983-2005)

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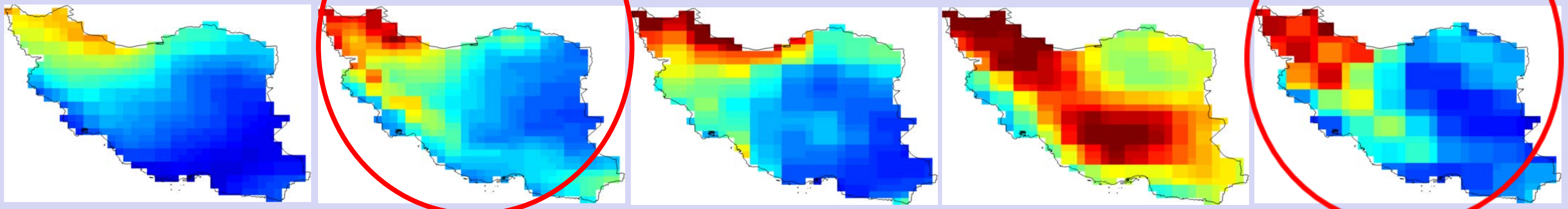
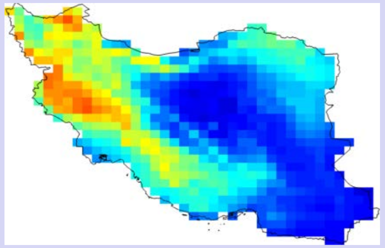
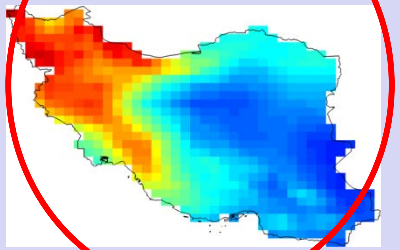
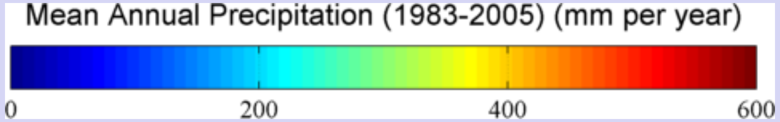


Observation (CRU Dataset)



Remotely Sensed Estimates (PERSIANN-CDR)





CHRS Data Portal

http://chrsdata.eng.uci.edu

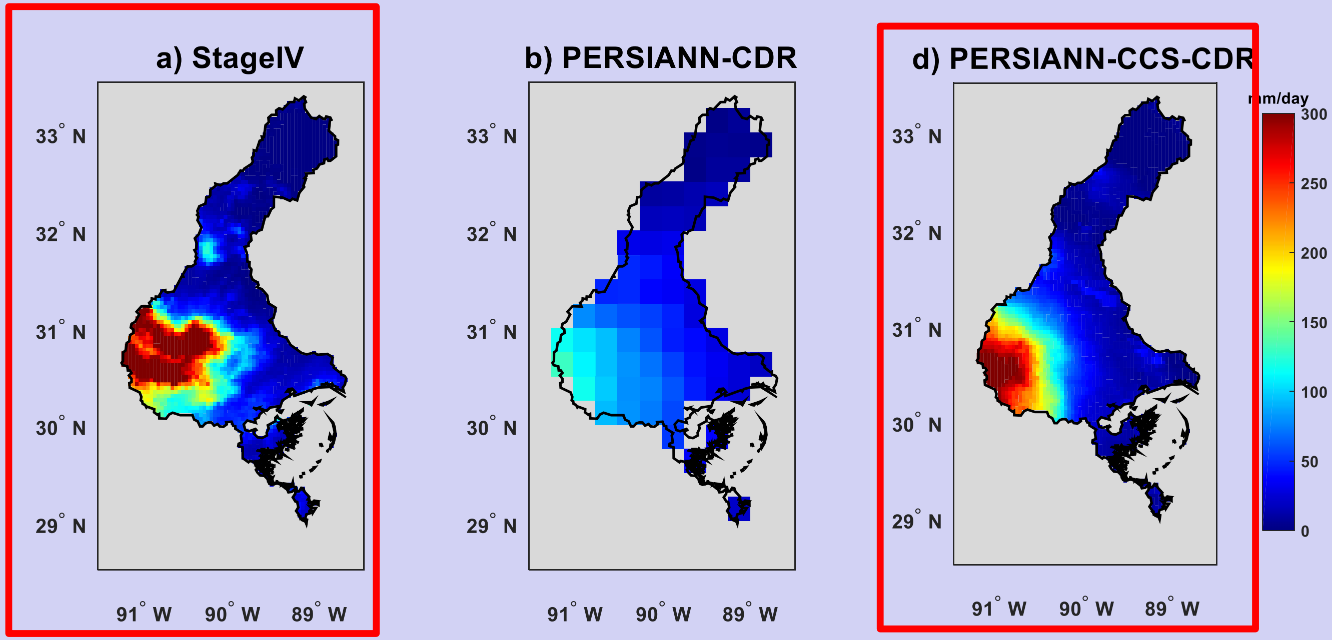
What is Next?

- *High-Resolution PERSIANN-CDR*
- *Next Version of PERSIANN-CCS*

High Resolution Precipitation Climate Data Record (PERSIANN CCS-CDR)

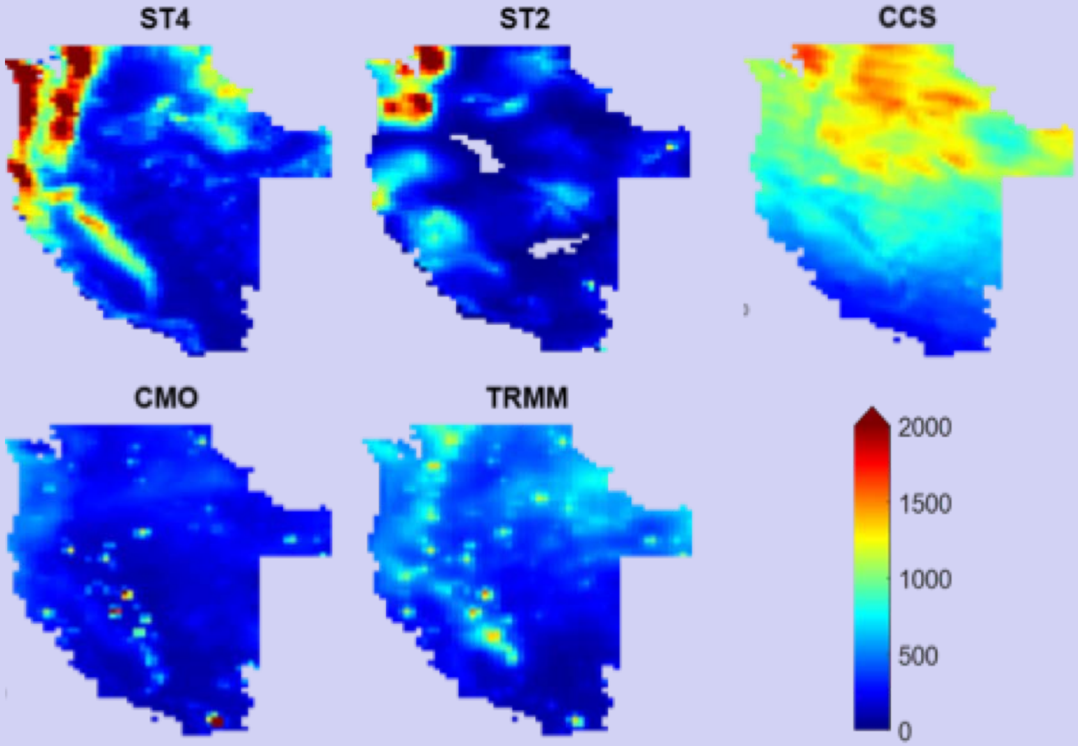
- *PERSIANN-CCS estimation at 0.04° x 0.04° lat-lon scale*
- *Bias adjustment of PERSIANN-CCS estimation using passive microwave rainfall estimation*
- *Bias adjustment using GPCP estimation at 2.5 degree monthly*

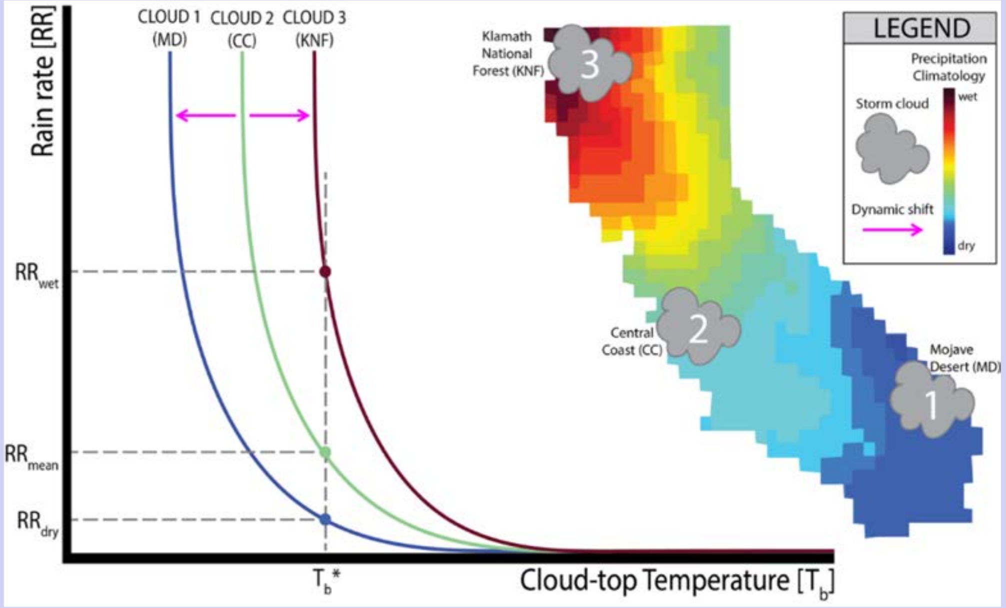
Louisiana flood, August 12, 2016



PERSIANN Dynamic Infrared - Rain rate model (PDIR)

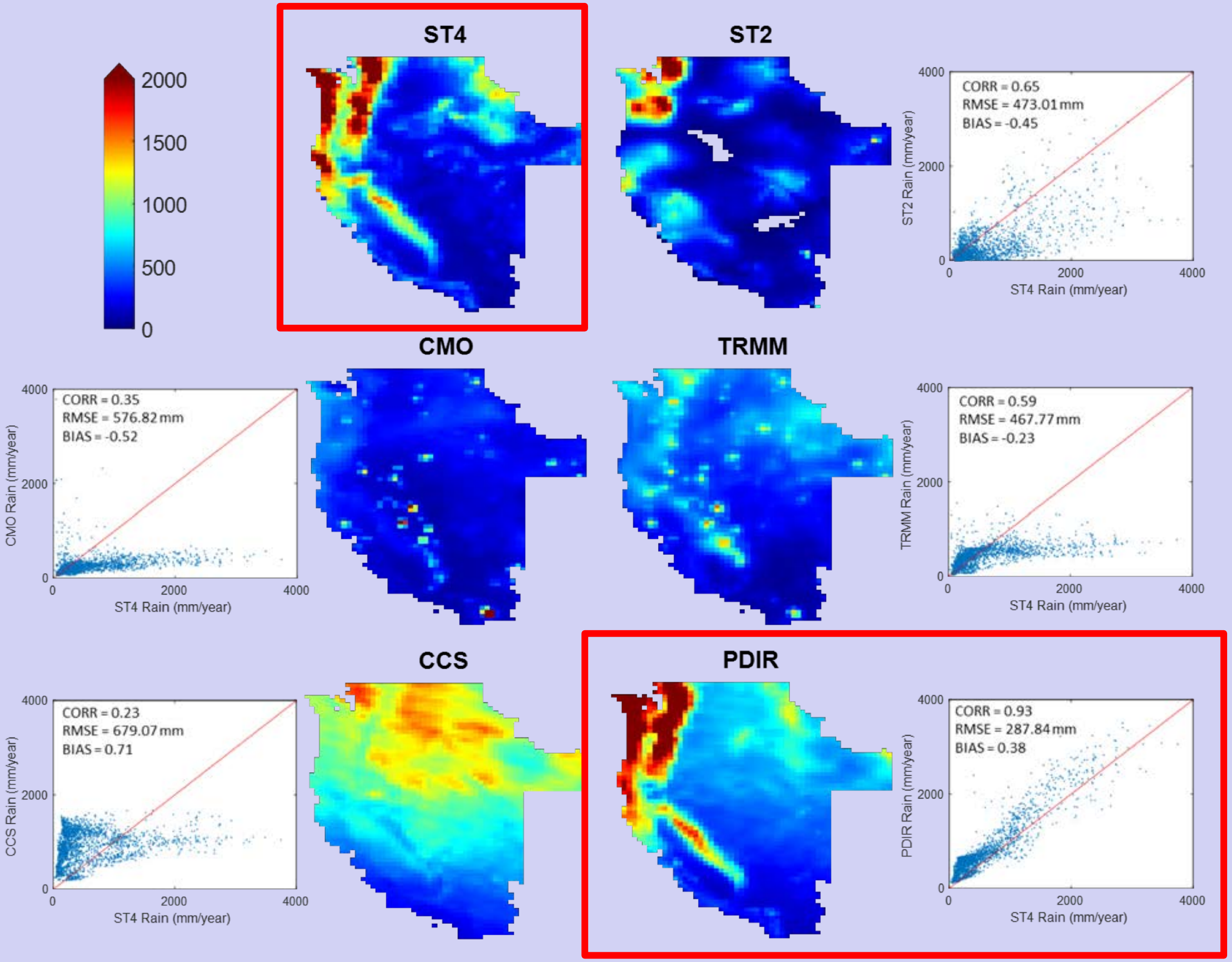
Average annual rainfall in mm/year (2008-2013)





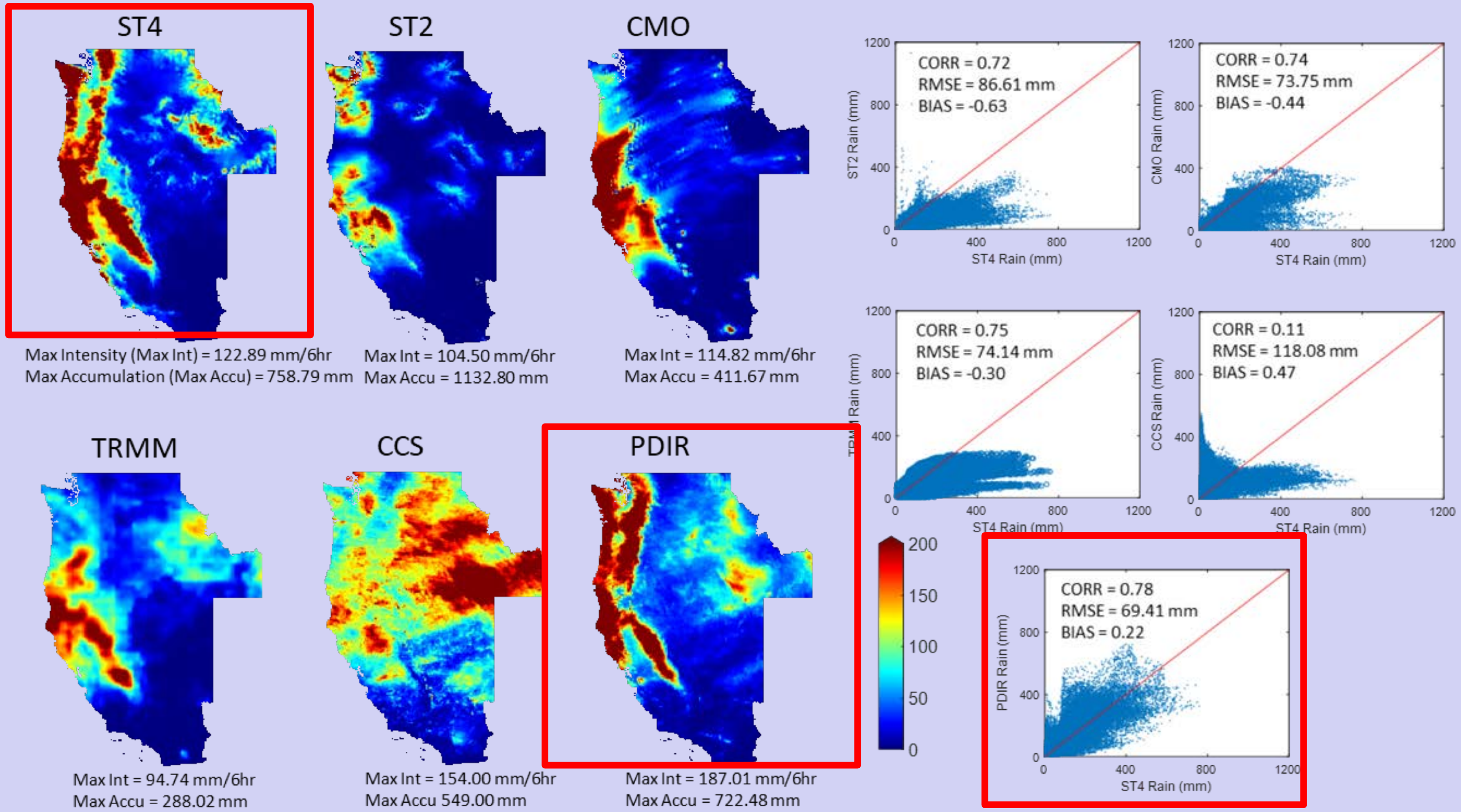
The Dynamic Infrared – Rain rate model

PERSIANN Dynamic Infrared - Rain rate model (PDIR)



Average annual rainfall in mm/year for the validation period (2008-2013) for the baseline product Stage IV (ST4), the near real-time Stage II (ST2), the three satellite-based precipitation products (CMORPH (CMO), TRMM, and PERSIANN-CCS (CCS)) and the new product, PDIR.

PERSIANN Dynamic Infrared - Rain rate model (PDIR)



Rainfall during the period November 28th, 2012 to December 7th, 2012 associated with an extreme AR event over California

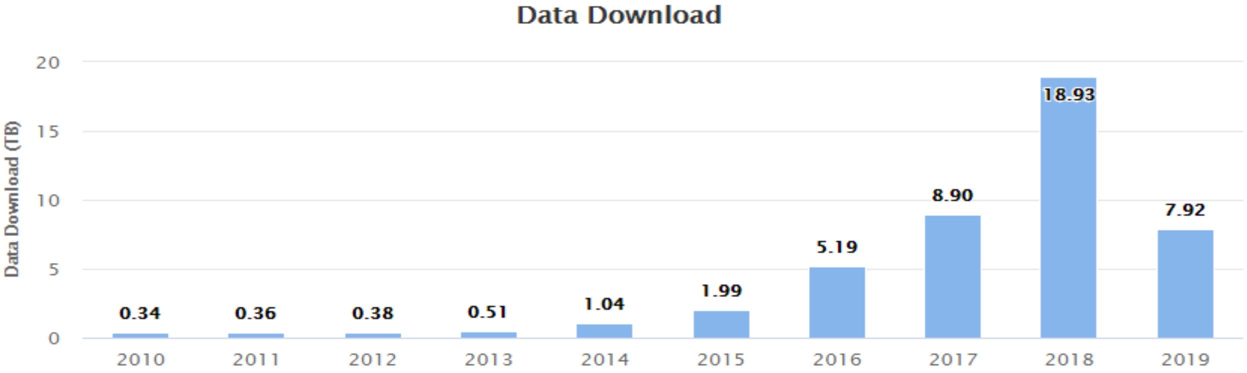
Usage of CHRS's products

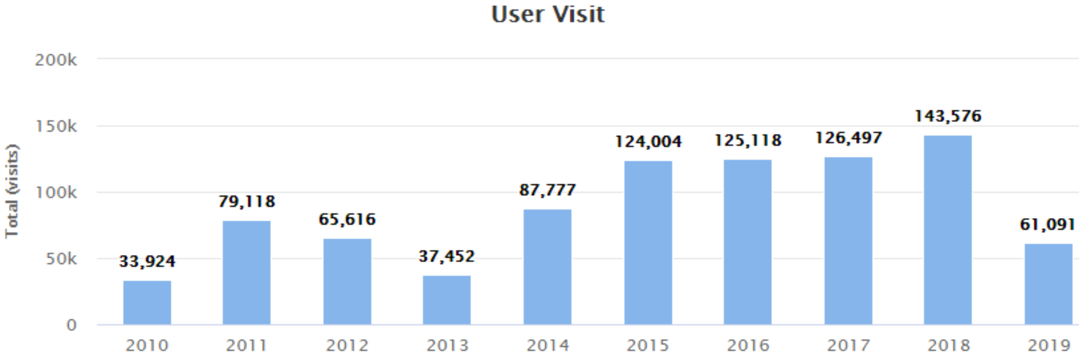
CHRS User Statistics

Overall | CHRS Homepage | iRain | RainSphere | Data Portal | CONNECT

Total Visits: 885,619 since 01-Jan-2010
Countries: 205 countries registered

#	Country	Total Visits
1	United States	492,012
2	China	45,838
3	Israel	37,999
4	Private IP	32,589
5	Thailand	32,336
6	France	22,660
7	Iran, Islamic Republic Of	19,736
8	Japan	17,001
9	Germany	14,817





Take Home Message

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

- ***Natu re is complex and observing and modeling its nonlinear behav llenging. So, "have a will to doubt" the credib models.***

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

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

Thank You for the Invitation and Listening

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