Lecture II
Hydrological modeling requirements for Water Resources Applications - Data Issues

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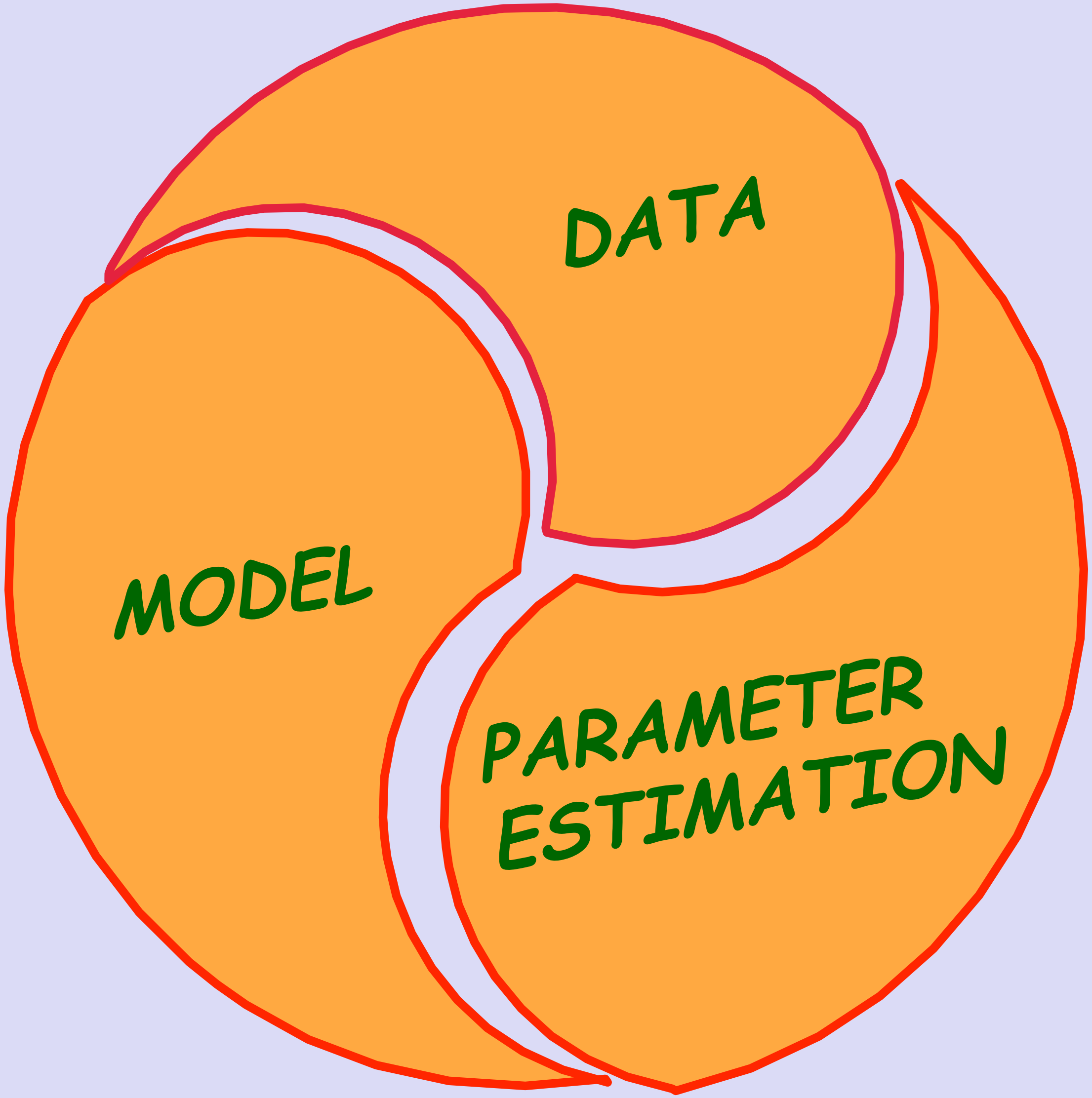
Center for Hydrometeorology and Remote Sensing

University of California Irvine

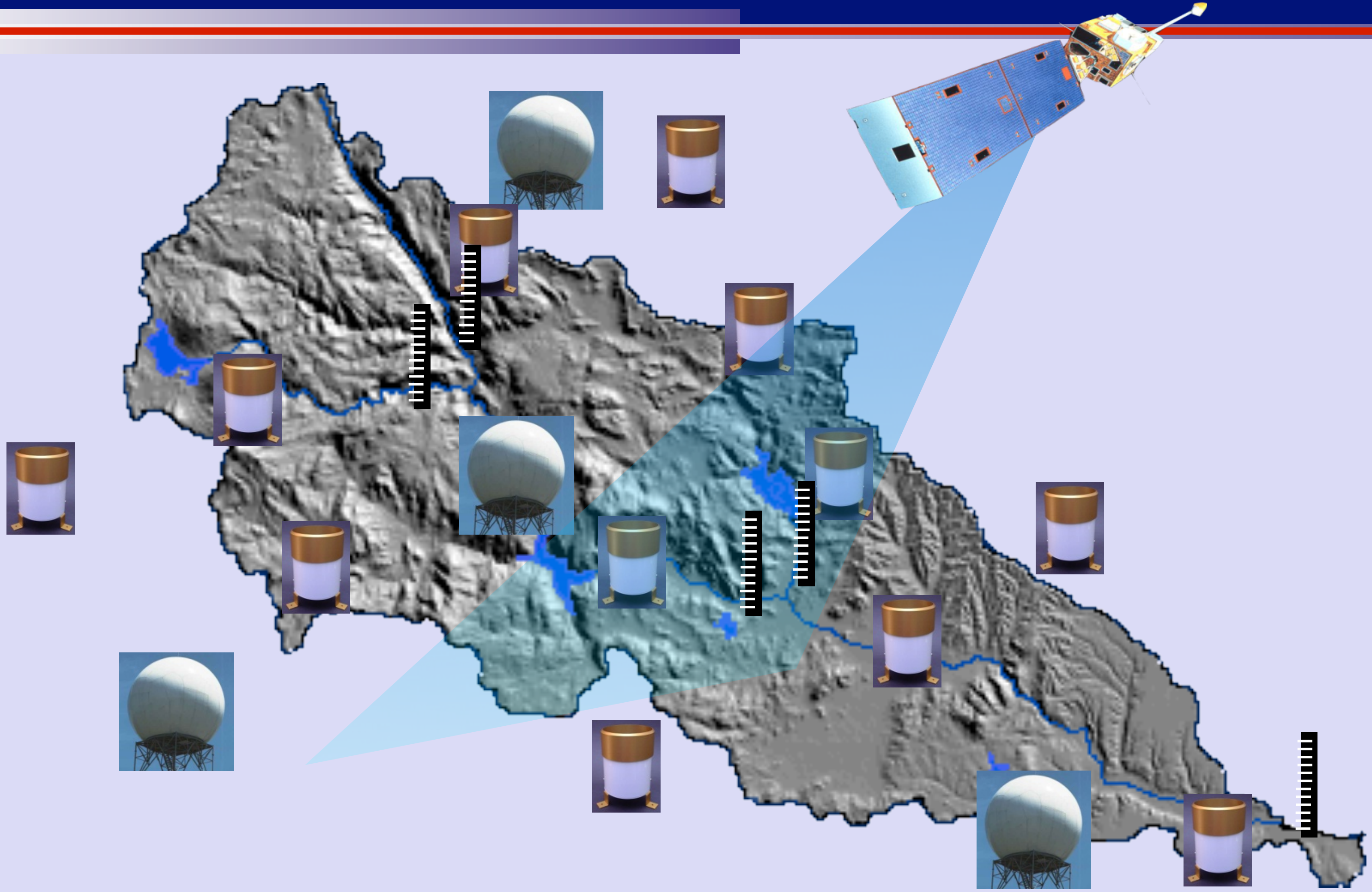
ICTP 4th Workshop on: Water Resources in Developing Countries: Hydroclimate Modeling and Analysis Tools

Trieste, Italy: June 12th – June 23rd 2017

Data



Data Requirements for Hydrologic Modeling



Data Limitation is an Important Factor in Success of Hydrologic Modeling

Big Challenge For "us":

Adequacy of Hydrologic Observations

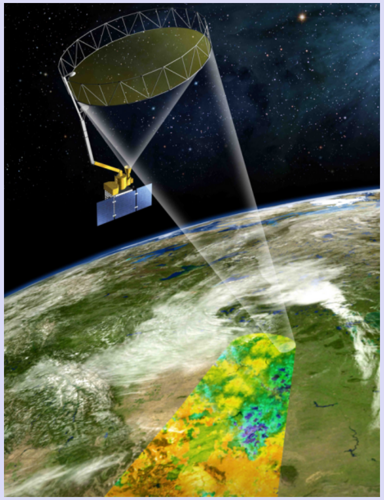
Observation of Primary Hydrologic Variables

Stream flow

Precipitation

Hydrologically - Relevant Remote Sensing Missions

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



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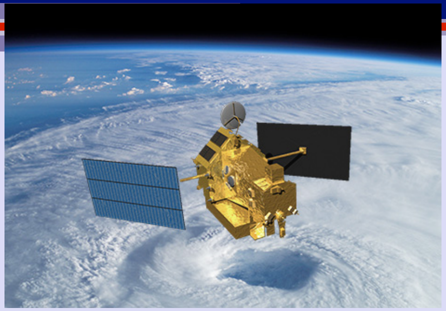
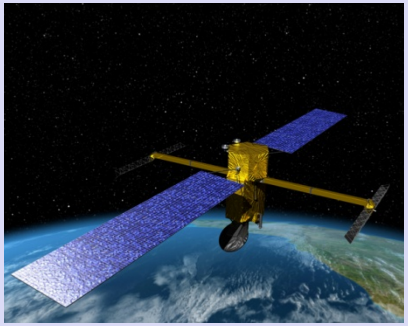
Soil Moisture Active Passive Satellite(2014)



TRMM
The Tropical Rainfall Measuring Mission

GPM
Global Precipitation Measurements (2014)



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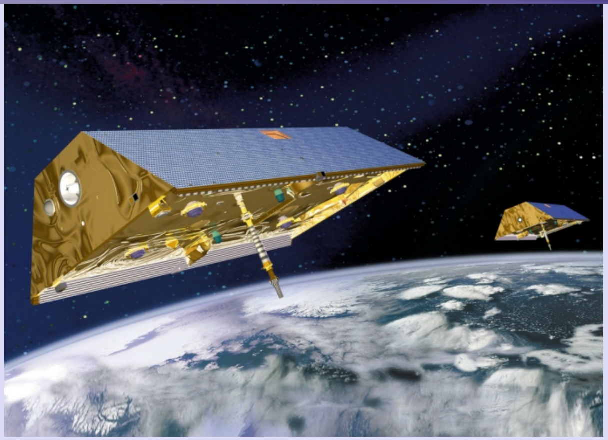
Surface Water and Ocean Topography (2020)



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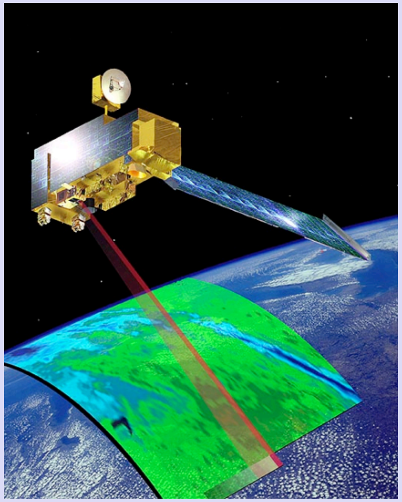
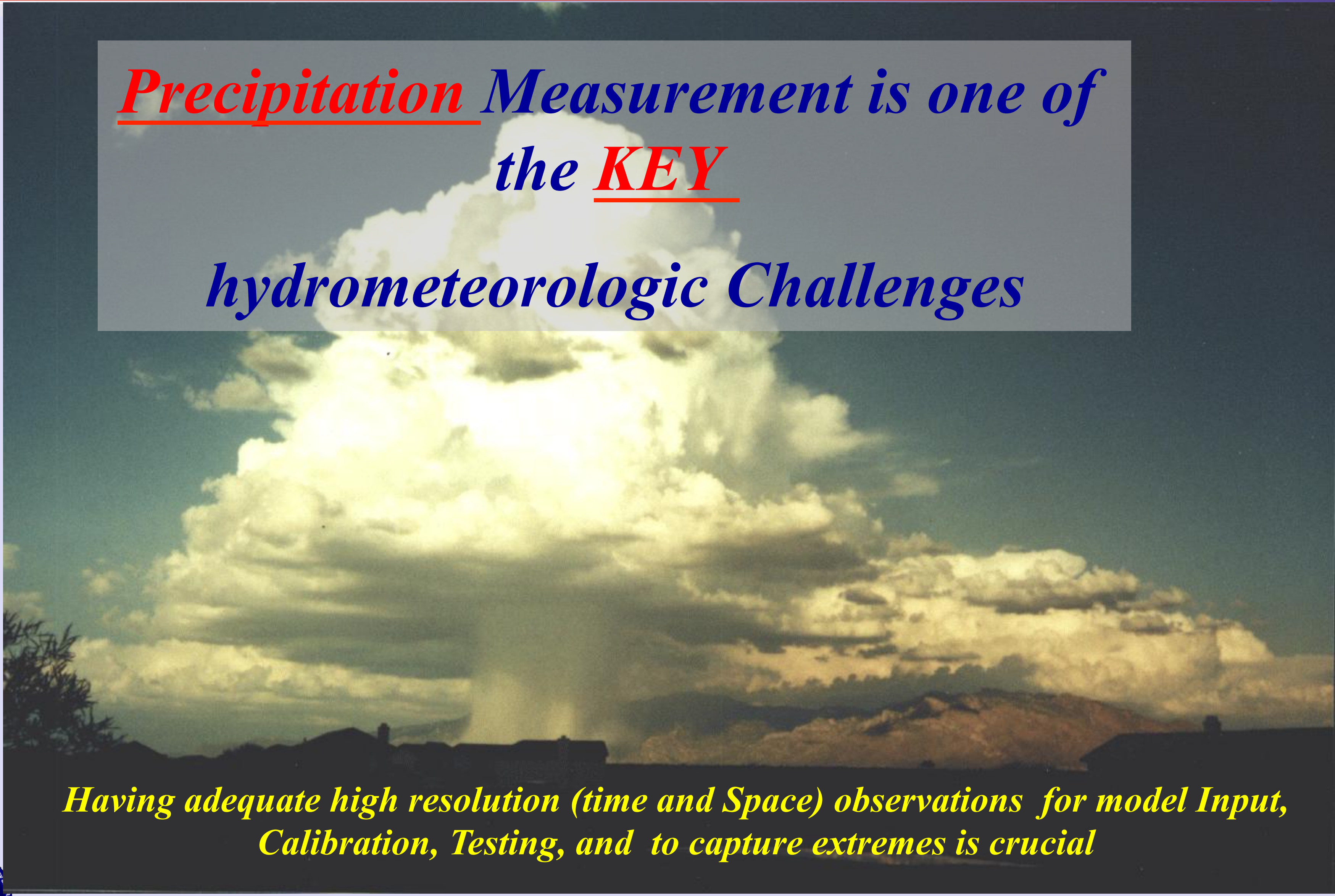


MODIS
Moderate Resolution Imaging Spectroradiometer
(1999) , (2002)

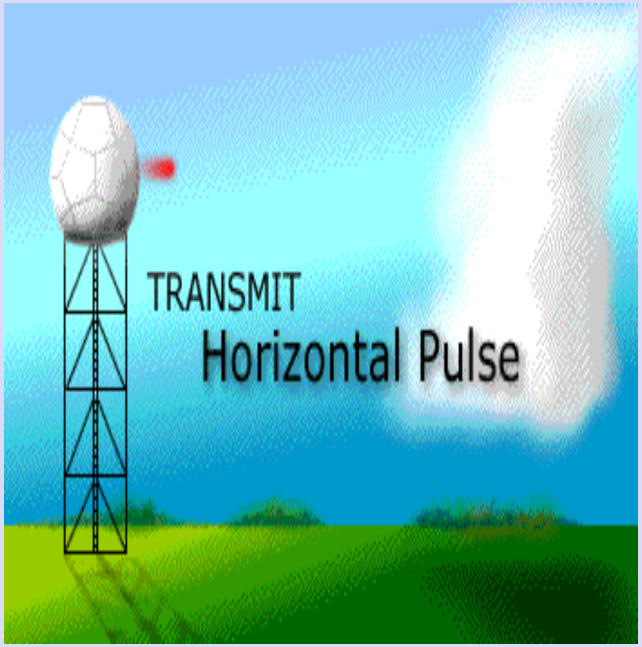
A Key Requirement!

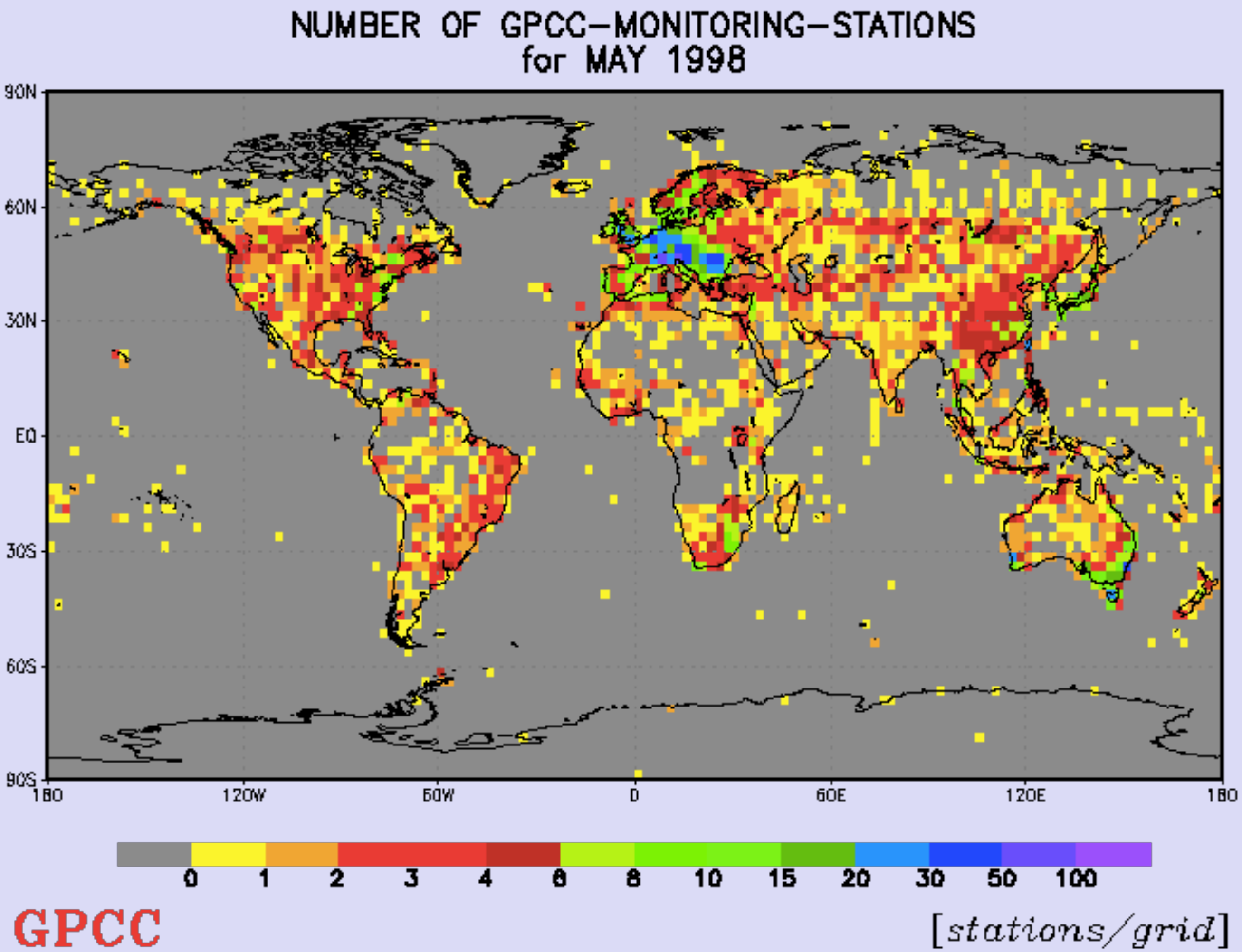


Precipitation Measurement is one of the KEY hydrometeorologic Challenges

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

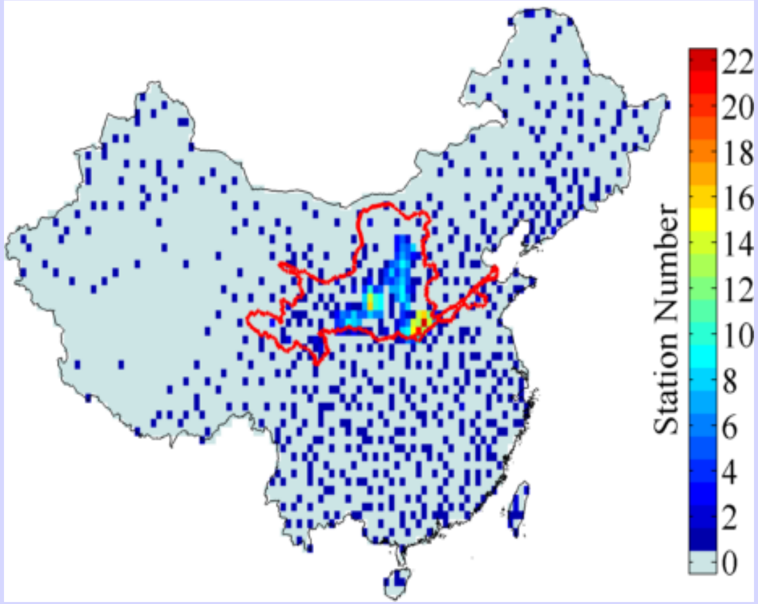
Precipitation Observations: Which to trust??



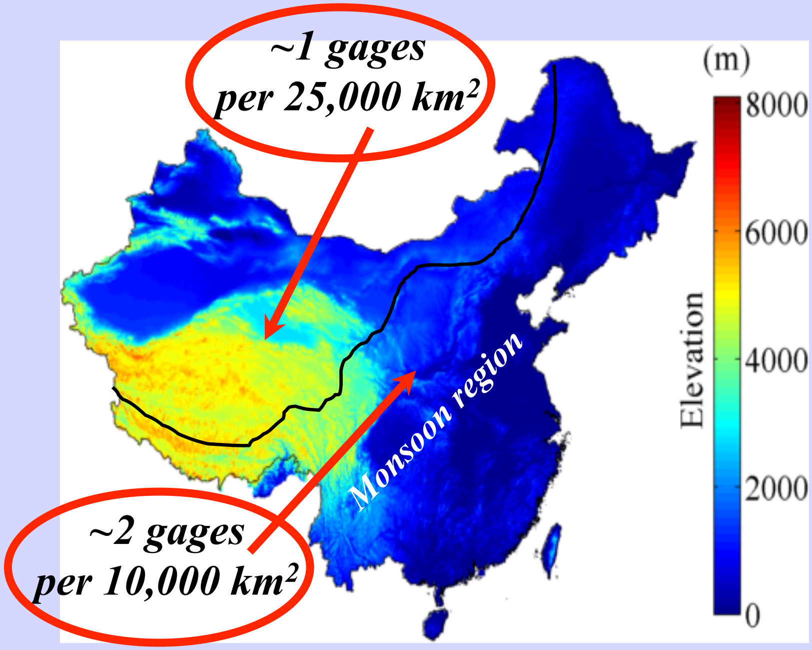


Number of range gauges per grid box**. These boxes are **2x2 degrees
(Source: Global Precipitation Climatology Project)

Rain Gauge Coverage over China

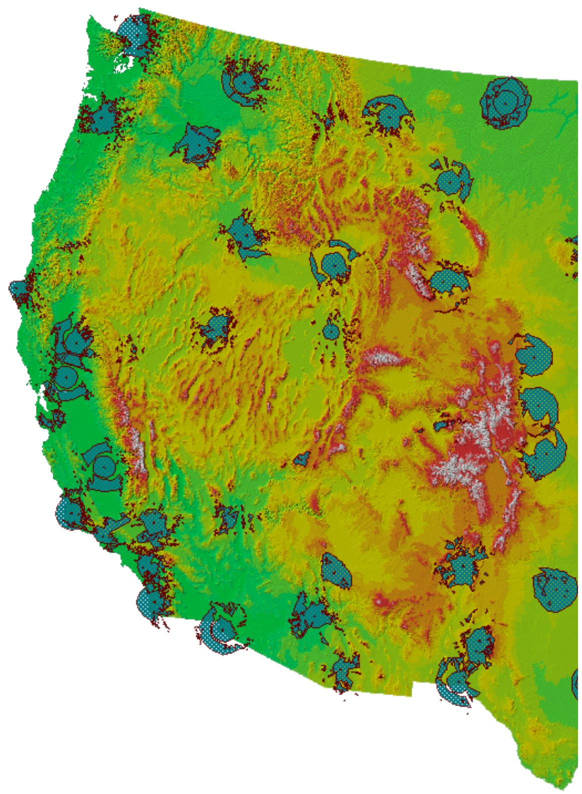


EA Rain Gauge Distribution



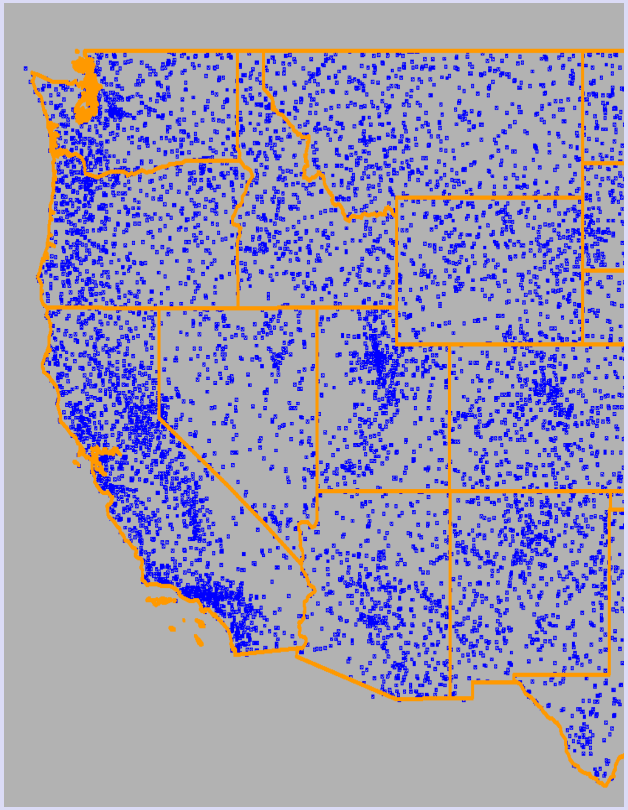
Elevation Map

Coverage of the WSR-88D and gauge networks



1 km AGL

Maddox, et al., 2002

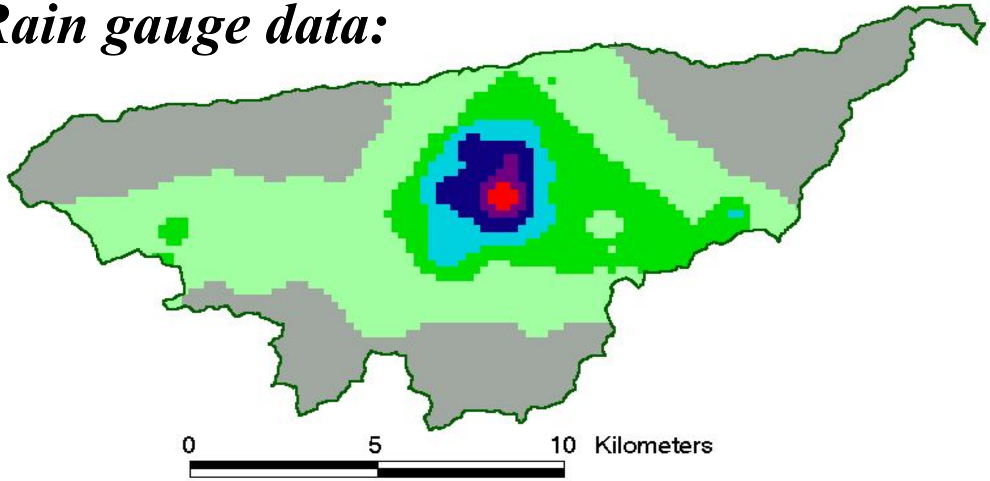


Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse

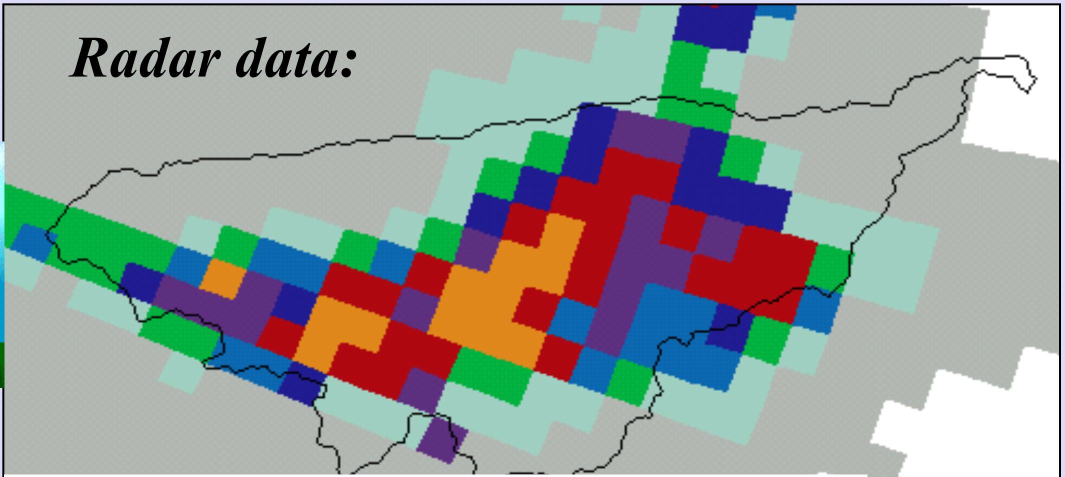
Radar-Gauge Comparison (Walnut Gulch, AZ)

Precipitation event: Aug. 11, 2000

Rain gauge data:

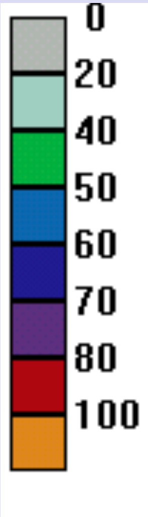


Radar data:



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

Storm depth (mm)

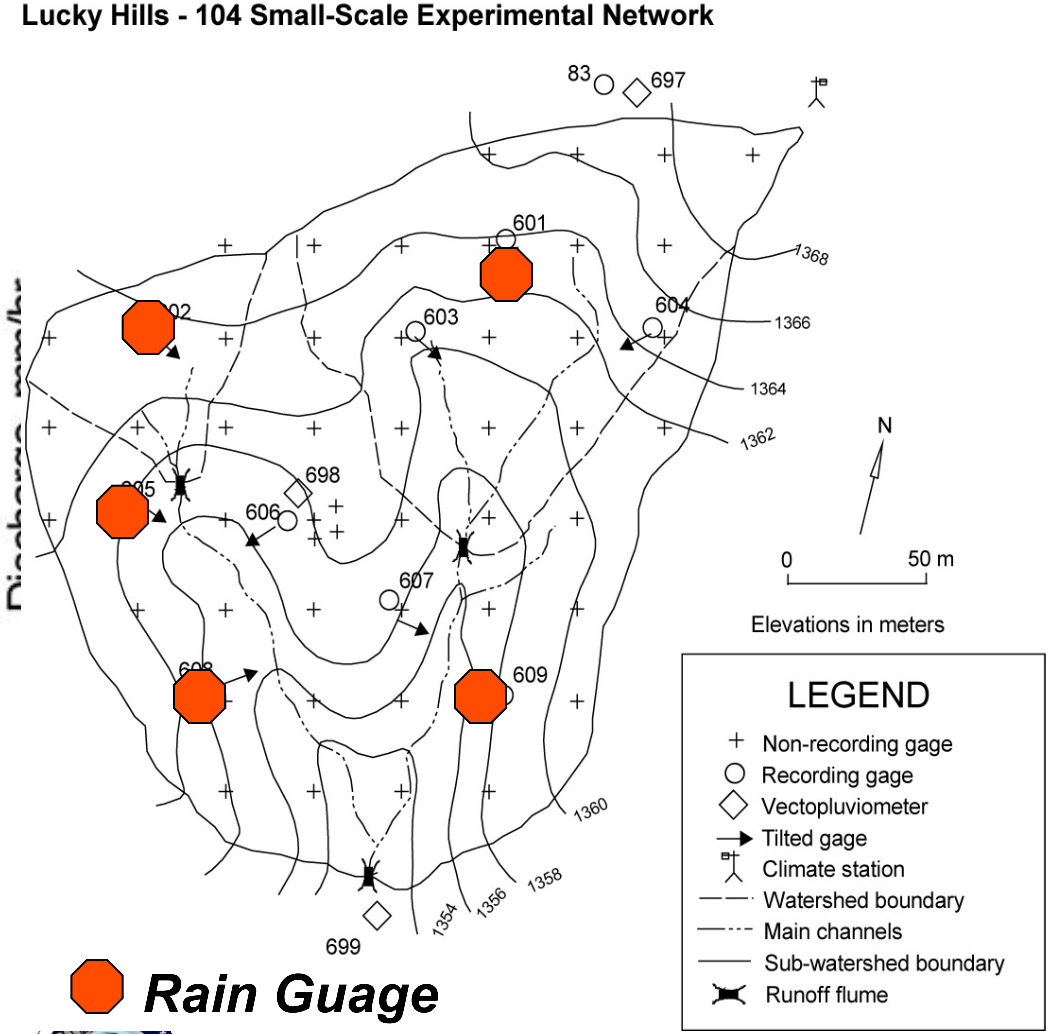


70% overestimation by the radar!

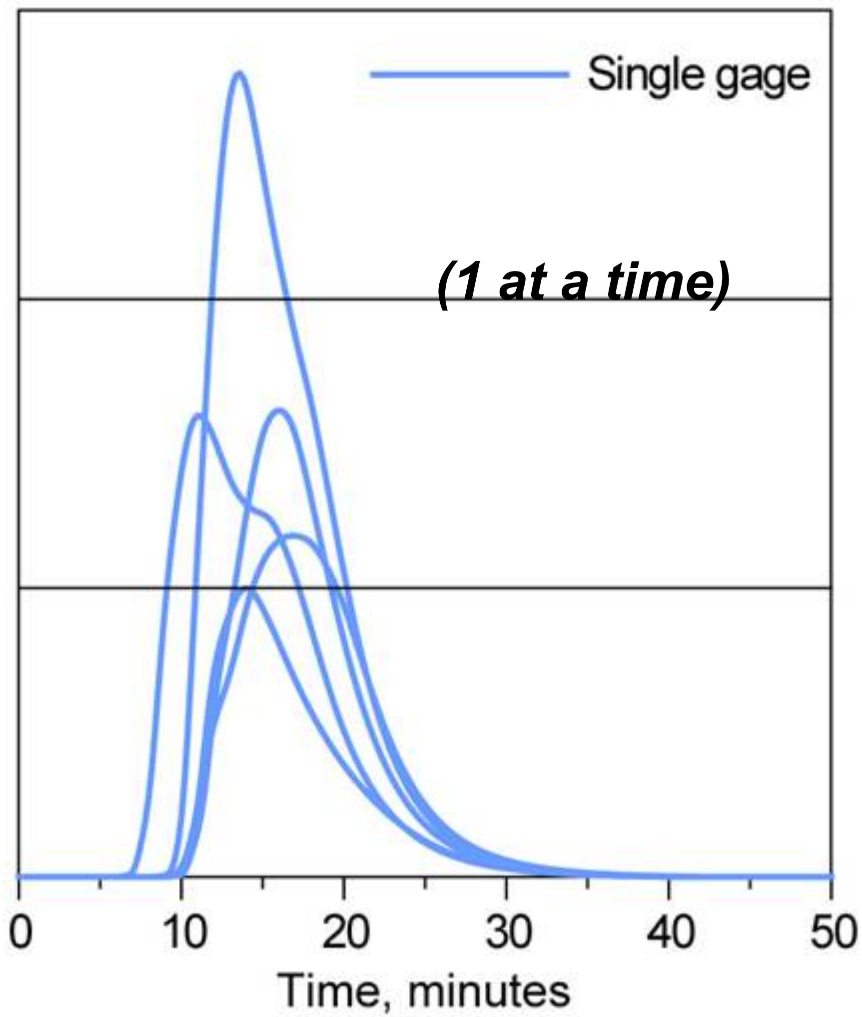
Morin et al ADWR 2005

Uncertainty in Runoff Simulation due to Rainfall Variability

Small scale spatial variability of rainfall (on the order of ~150 m)

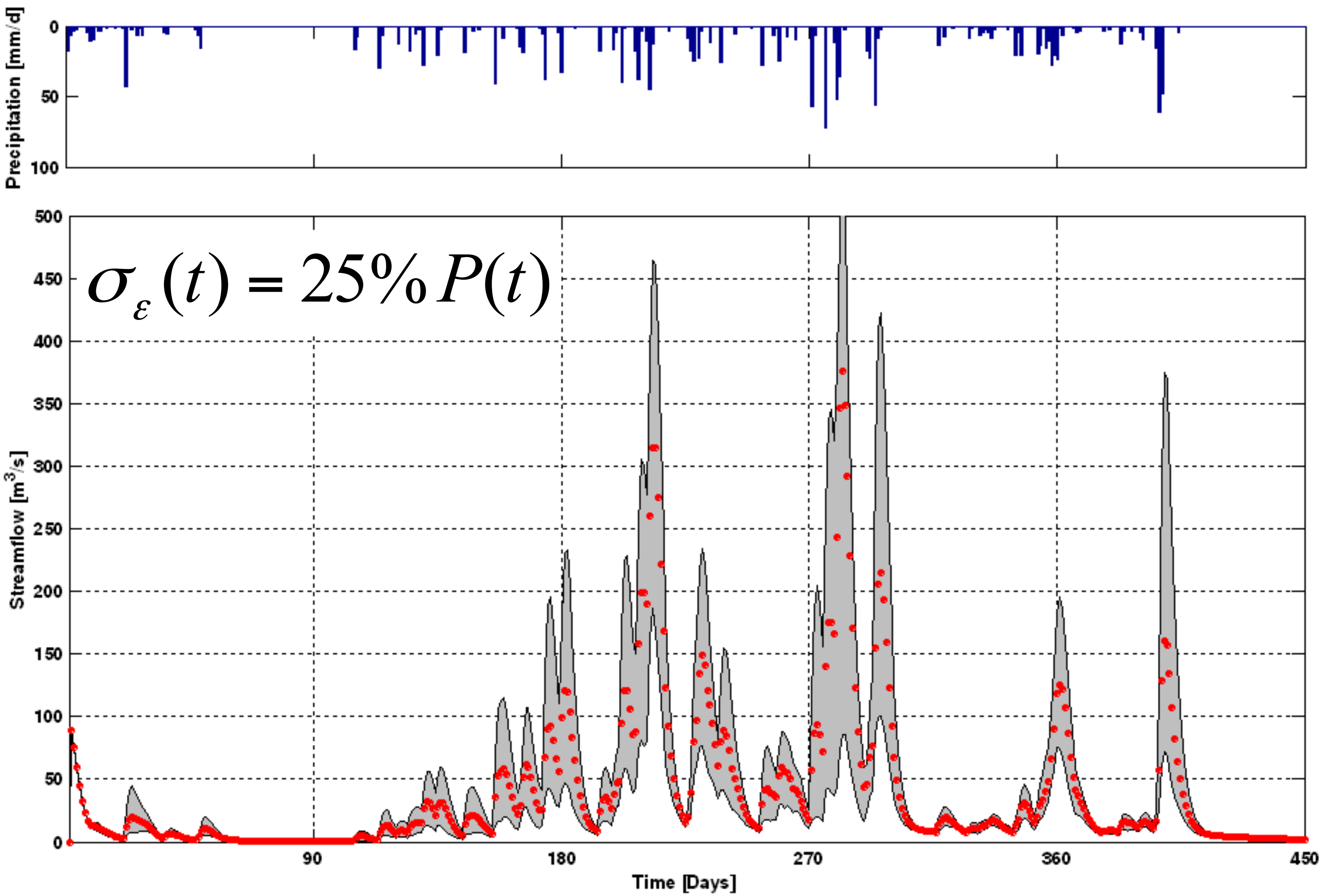


Modeled runoff (KINEROS)



Faures, JM et.al. J.of Hydrology 1995

Streamflow Simulation vs. Precipitation Uncertainty:



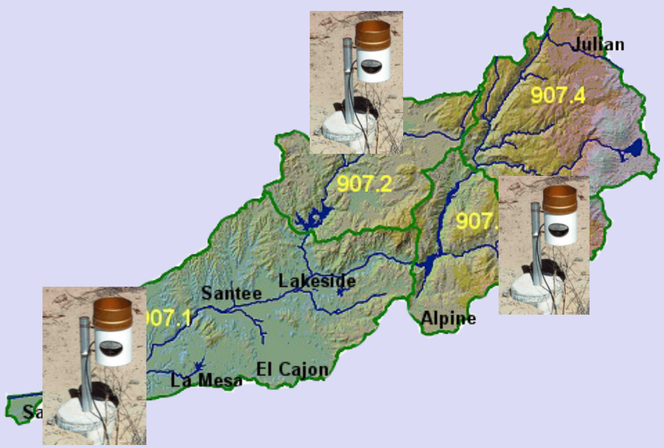
Even A Bigger Challenge!

Having adequate high resolution (time and Space) observations of precipitation to capture extremes?

2 Precipitation Scenarios with different Temporal properties

Monthly Total

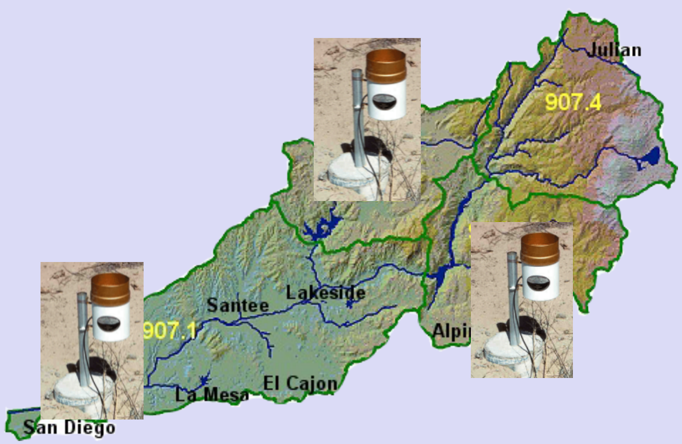
A



100 mm

Frequency 6.7%
Intensity 50.0 mm

B

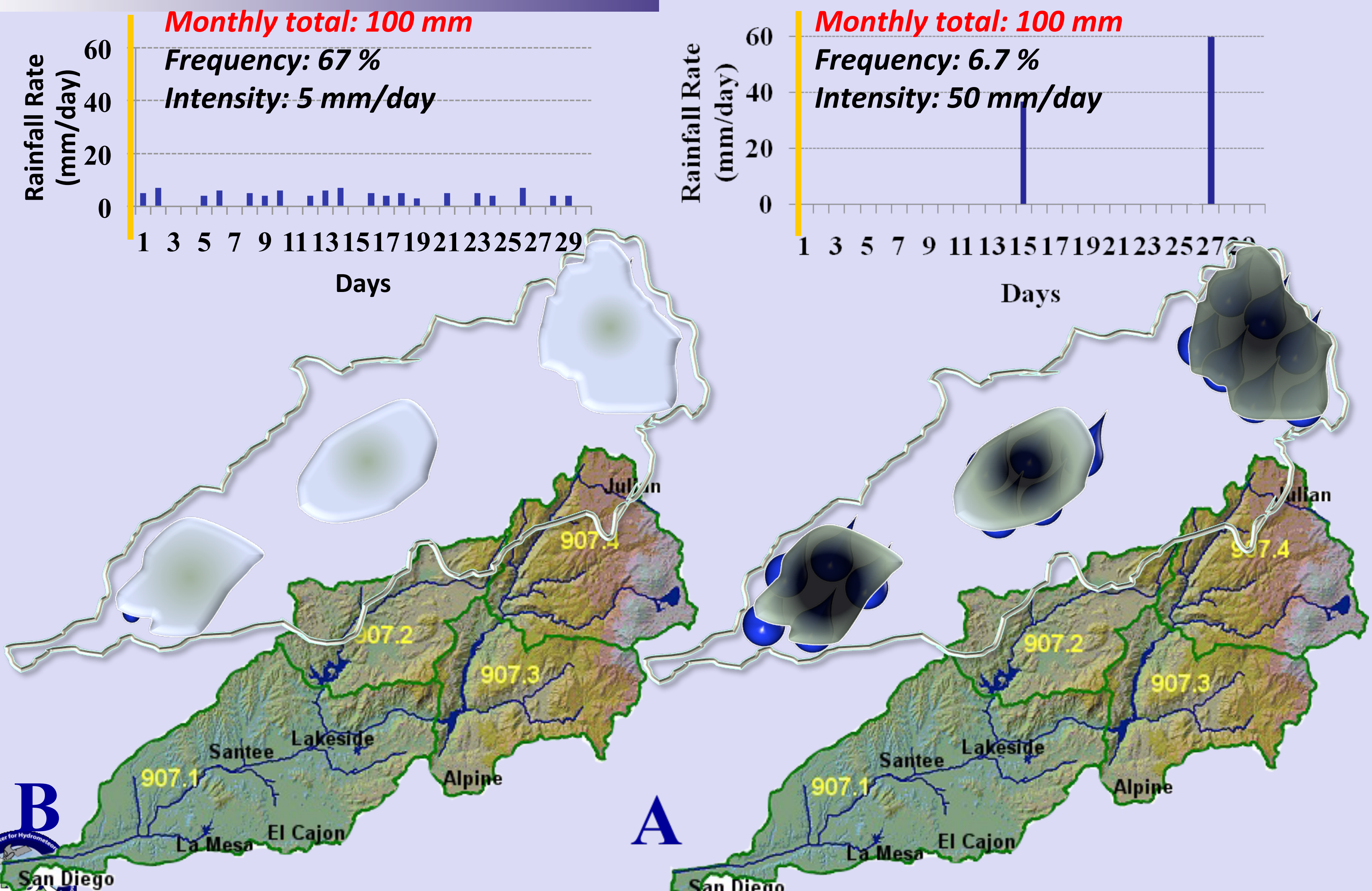


100 mm

Frequency 67%
Intensity 5.0 mm

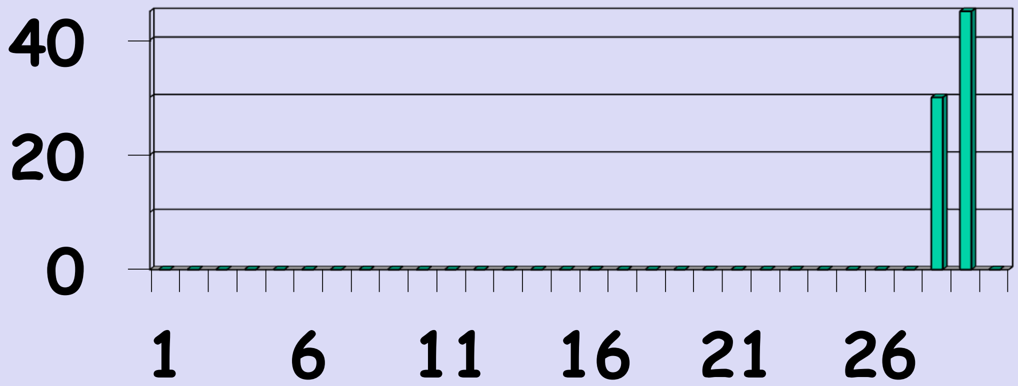
Idea from: K. Trenberth, NCAR

Temporal Scale Importance: Daily Precip. at 2 stations



2 Rain gages with different Temporal properties

A

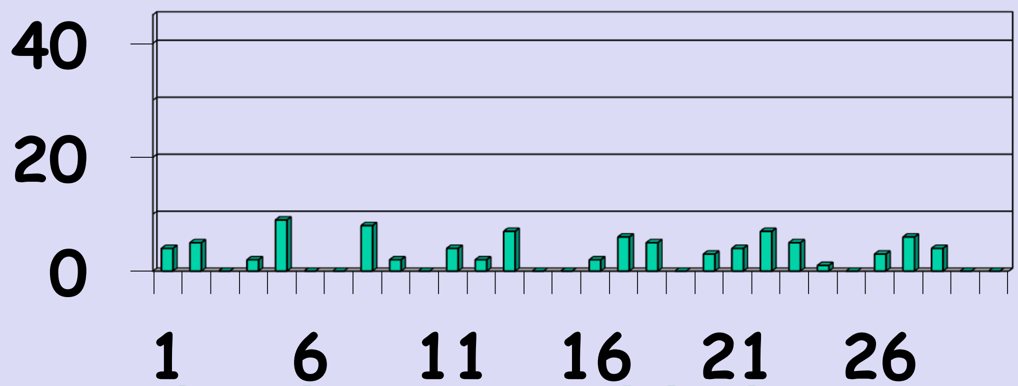


Monthly
Amount 100 mm

Frequency 6.7%
Intensity 50.0 mm

local Floods
Stream bed Recharge

B



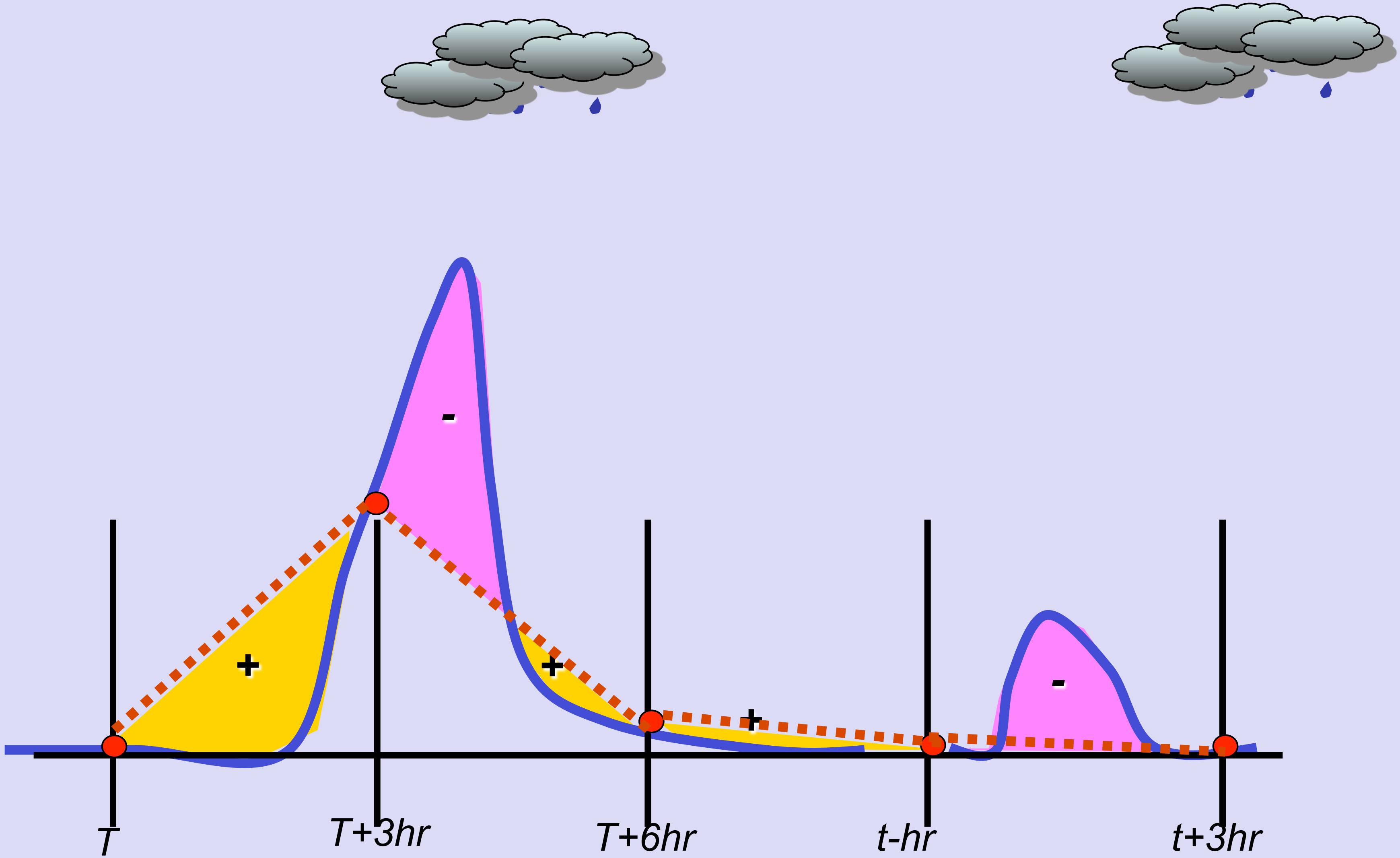
Amount 100 mm

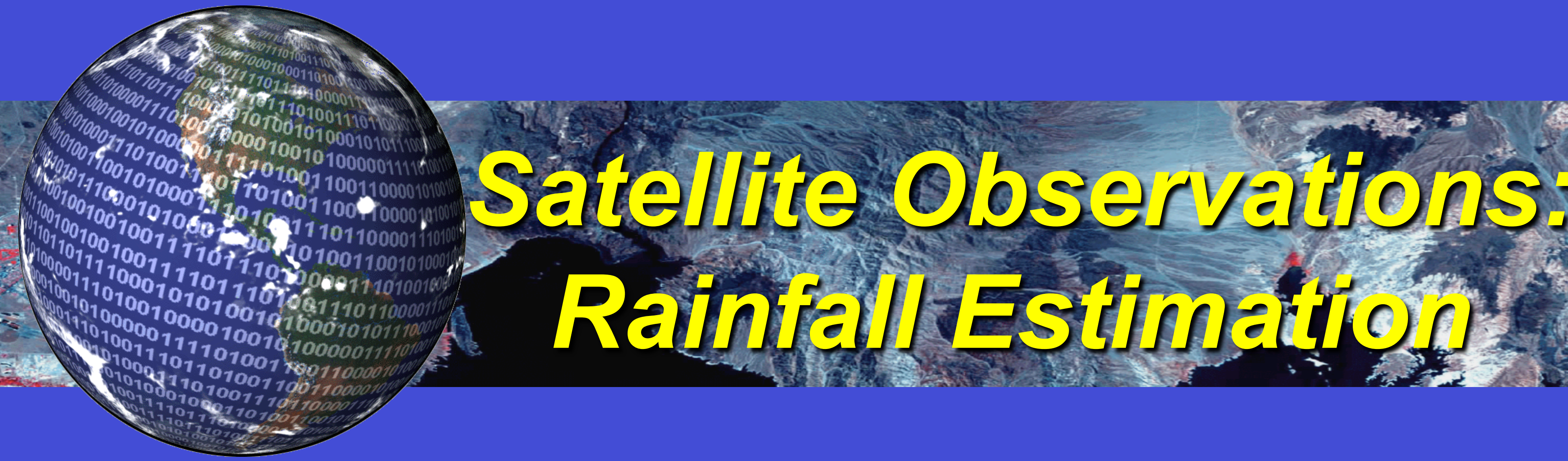
Frequency 67%
Intensity 5.0 mm

soil moisture replenished
virtually no runoff

Idea from: K. Trenberth, NCAR

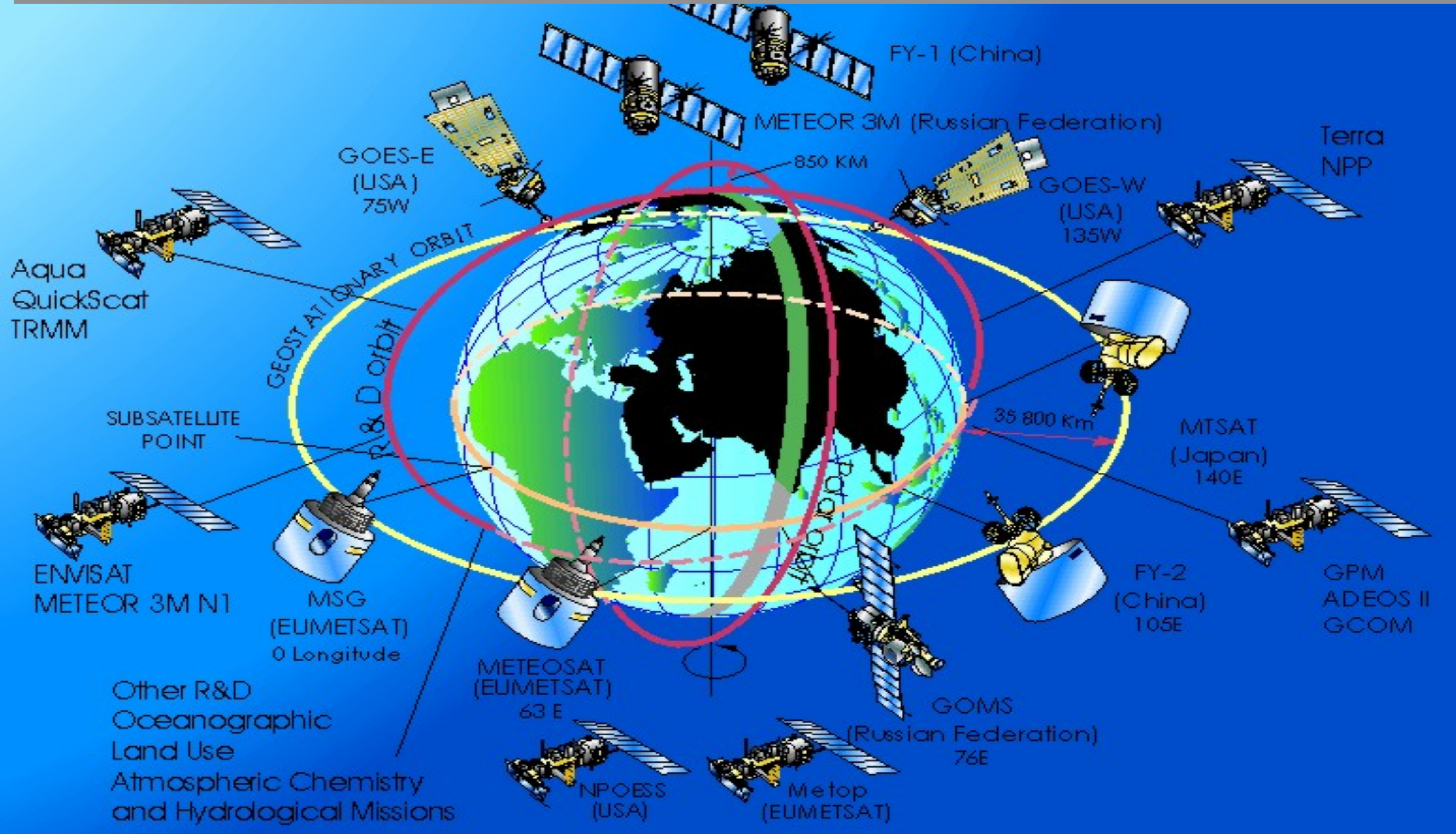
Interpolation of 3-hour Precipitation



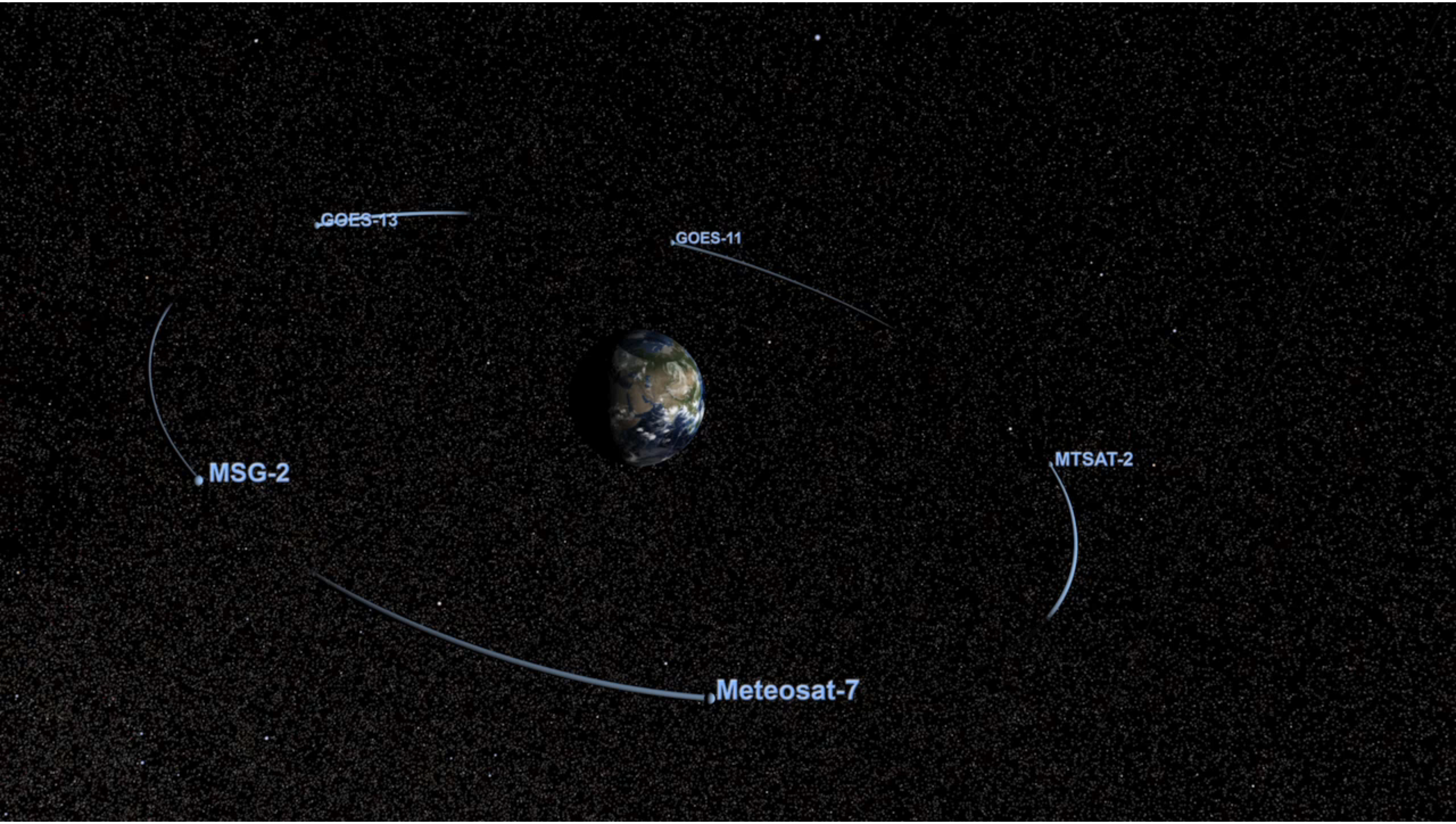

Satellite Observations:
Rainfall Estimation

Satellite-Based Rainfall Estimation: Promising !

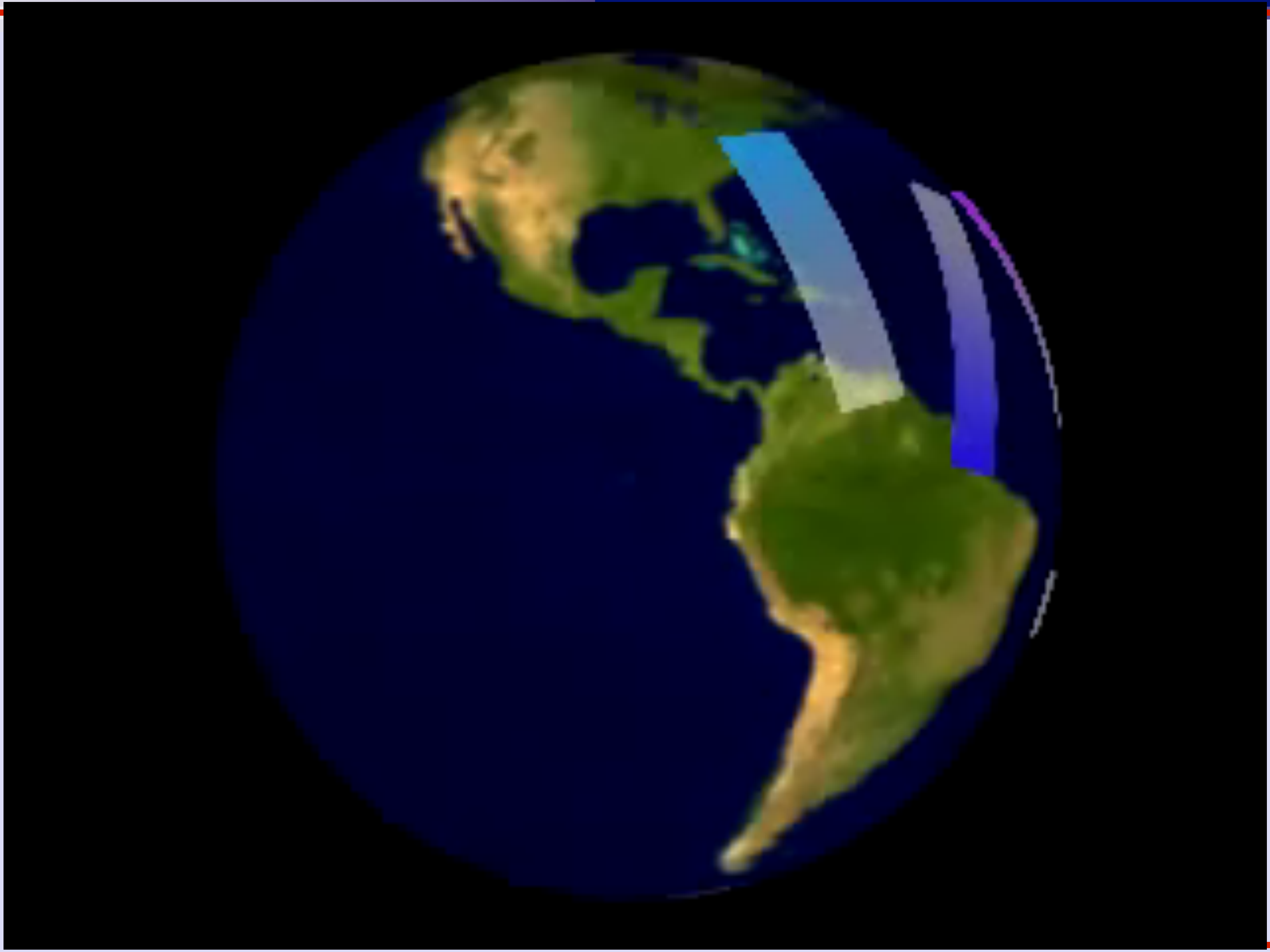
Observations from space: Near-continuous, global coverage,



Geostationary Satellites Infrared (IR) Channel Tb

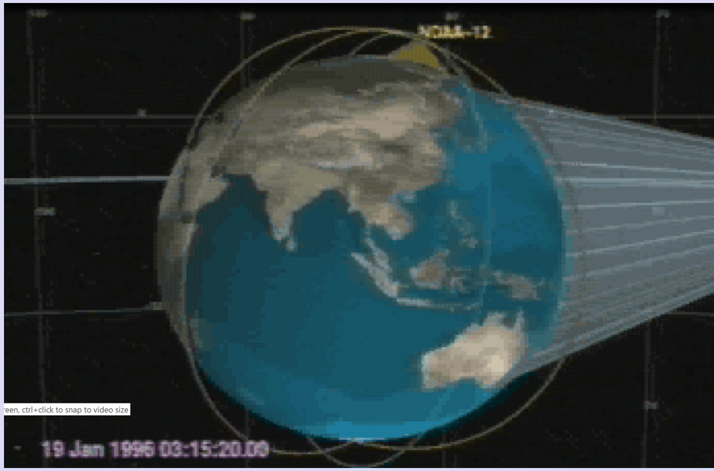


Polar Orbiting Satellites



Satellite precipitation retrieval instruments

1)Using GEO satellites
(Infrared/Visible channels)



***Advantage*:**

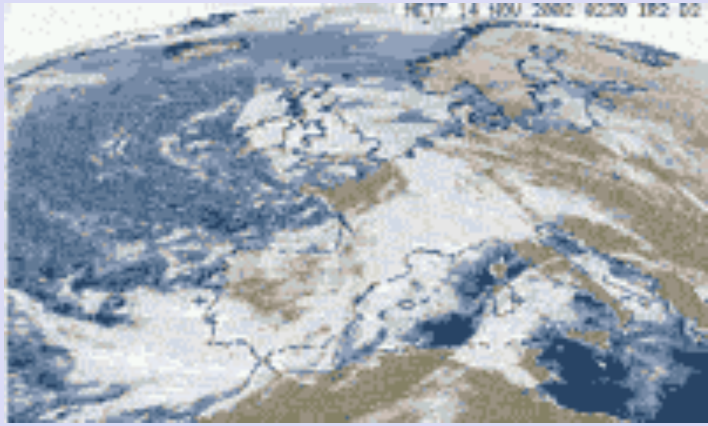
- ***Good temporal and spatial resolution (30 min or less, 4 km)***

- ***very good coverage***

***Disadvantage*:**

-Receives mostly cloud –top information

-Indirect estimation of precipitation.



Satellite precipitation retrieval instruments

2) Microwave

***Advantage*:**

- Responds directly to hydrometeors and penetrates into clouds

- More accurate estimates

***Disadvantage*:**

-low temporal and spatial resolution (~5-50km)

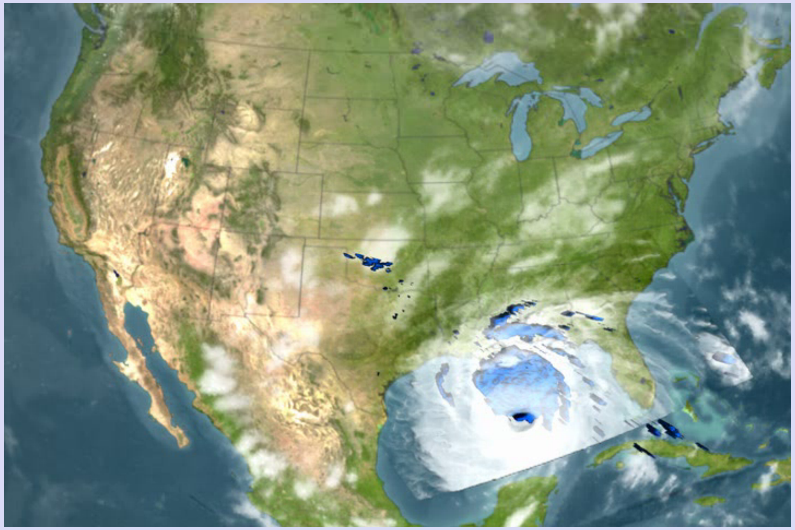
-Heterogeneous emissivity over land: (e.g., problem with warm rainfall over land)

Satellite precipitation retrieval instruments

3) Active Radar

Advantage:

- More accurate
- good spatial resolution

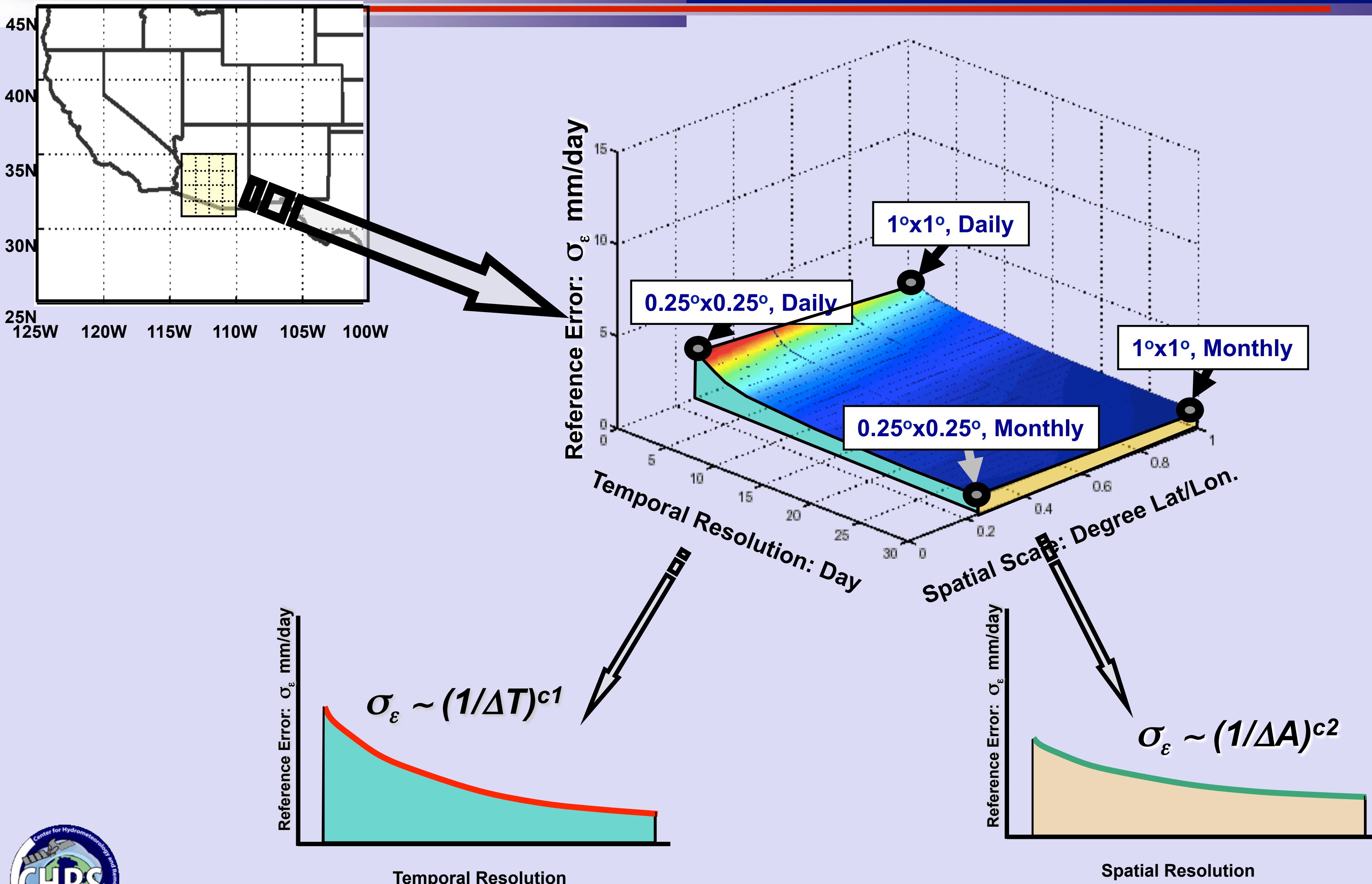


Disadvantage:

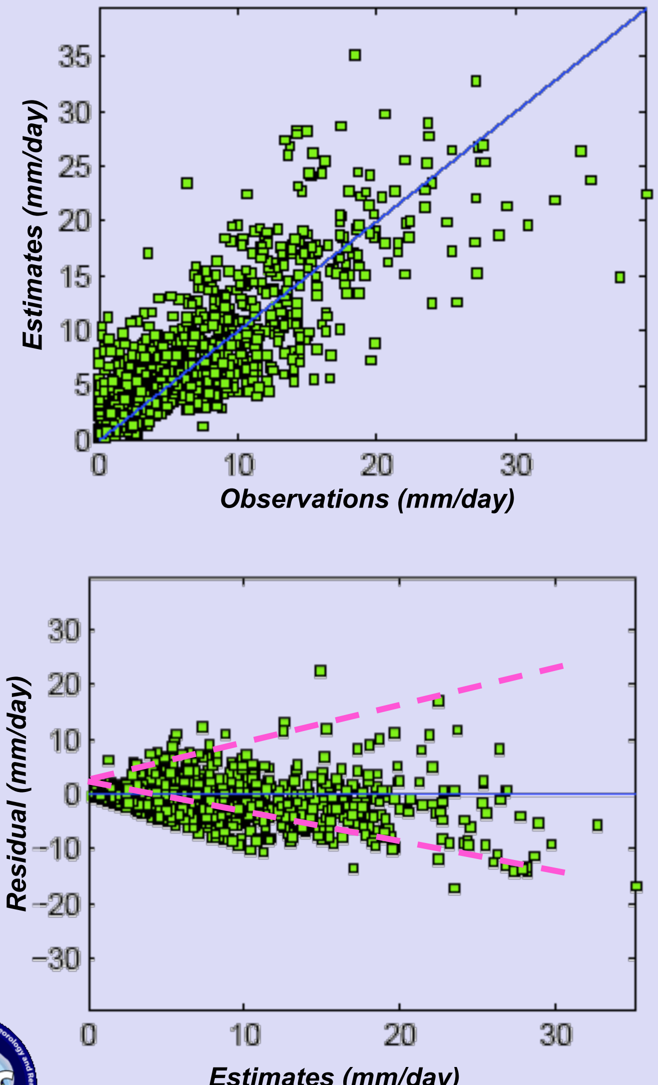
- Poor temporal resolution

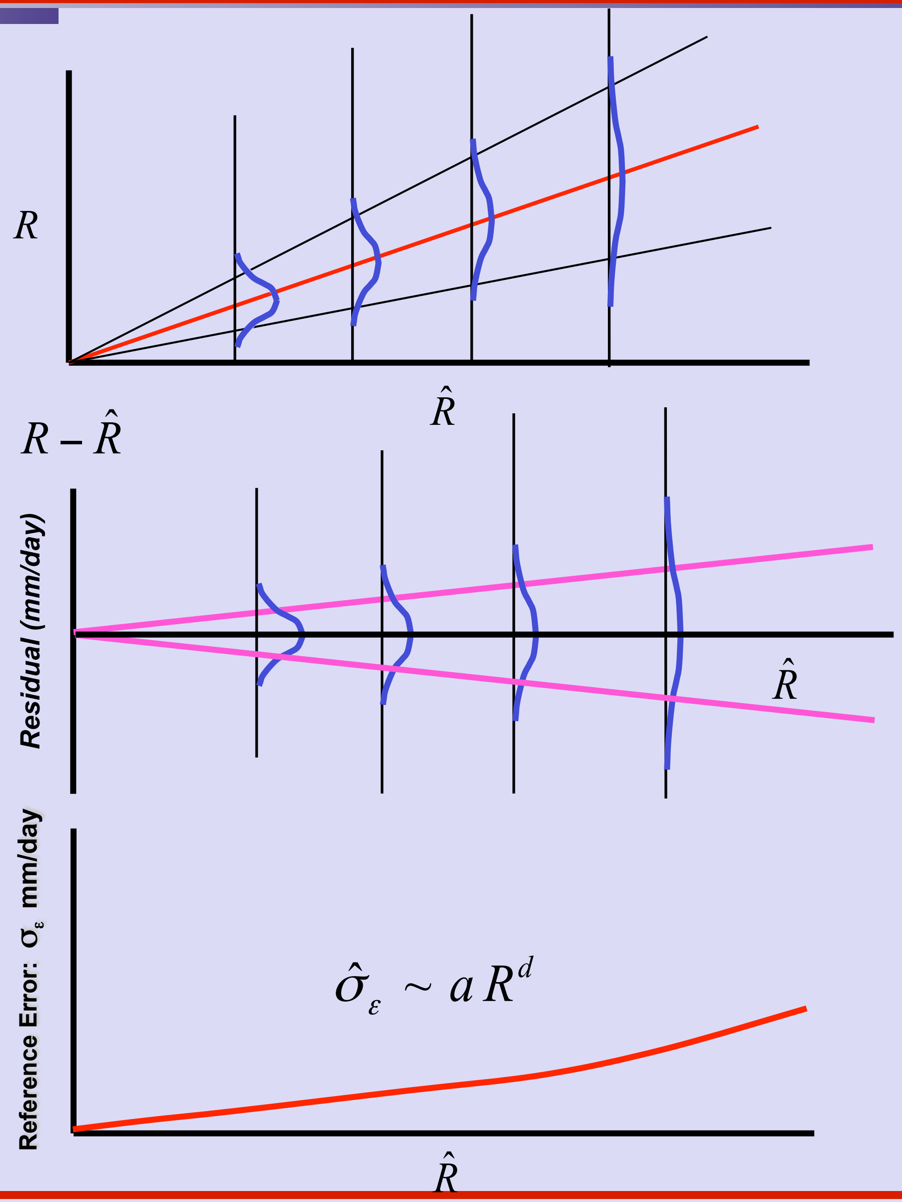
➢ Uncertainty of Estimates
Error Analysis

Spatial-Temporal Property of Reference Error



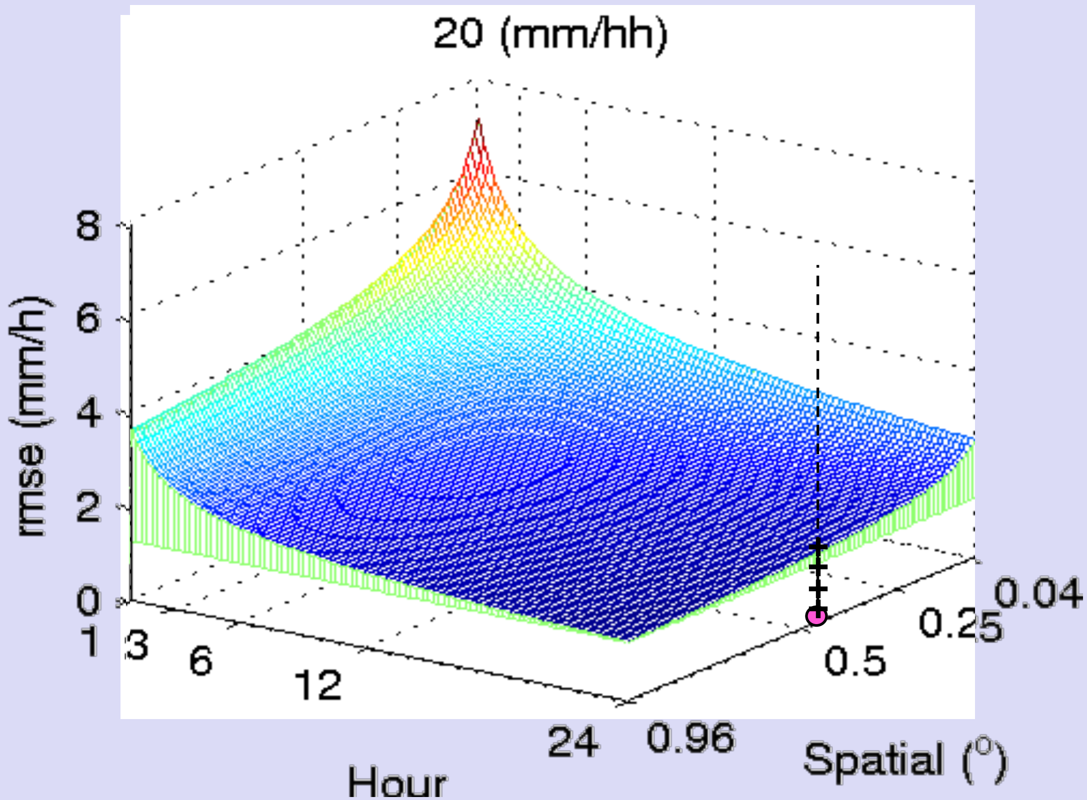
Reference Error: ΔT = 24-hour, $\Delta A = 0.25^o x 0.25^o$



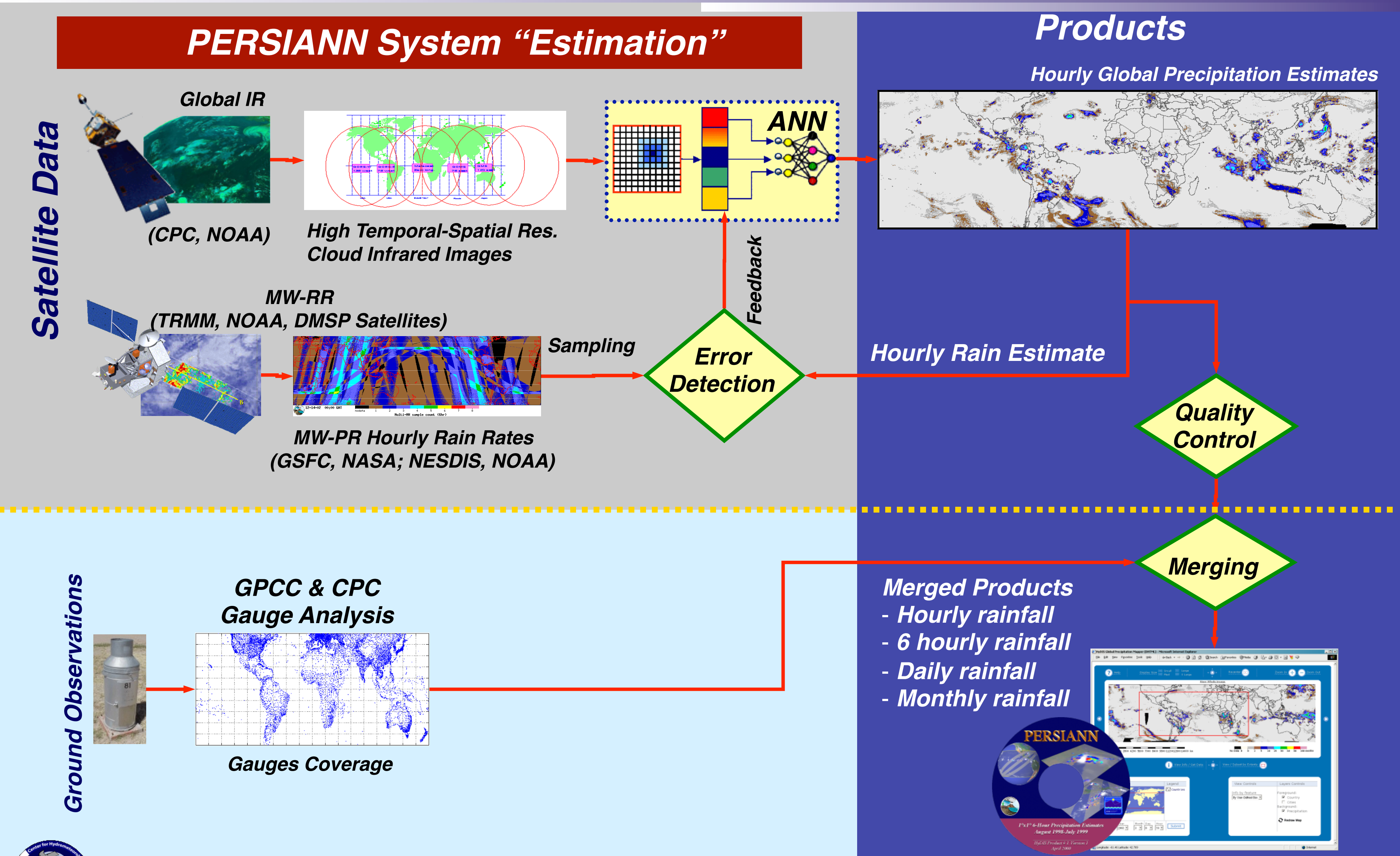


Scaling Property of PERSIANN-CCS Reference Error

$$\hat{\sigma}_{\varepsilon} = a_1 . \left(\frac{1}{\Delta A}\right)^{b_1} \left(\frac{1}{\Delta T}\right)^{c_1} \left(\hat{R}\right)^{d_1}$$



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



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

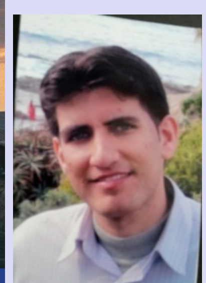
PERSIANN Extensions: Climate-Related

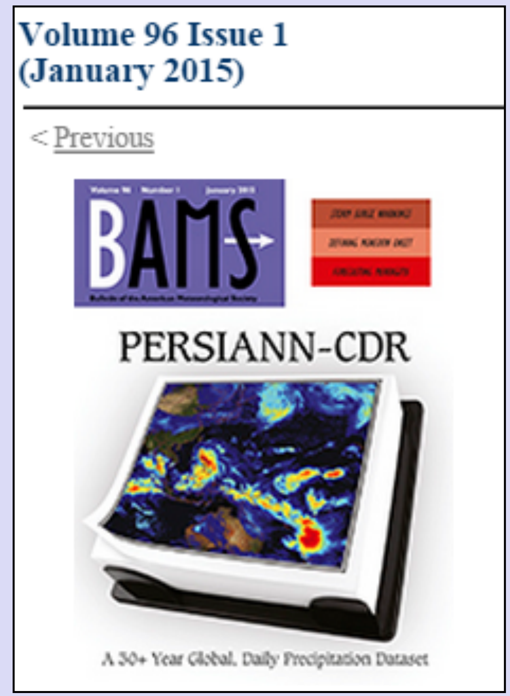
- PERSIANN- CDR (Climate Data Record)

PERSIANN -CDR

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

- *Daily Precipitation Data*
- *Data Period: 1983~2016*
- *Coverage: 60ºS ~ 60ºN*
- *Spatial Resolution: 0.25ºx0.25º*





Ashouri, Hsu et al., BAMS, 2015.

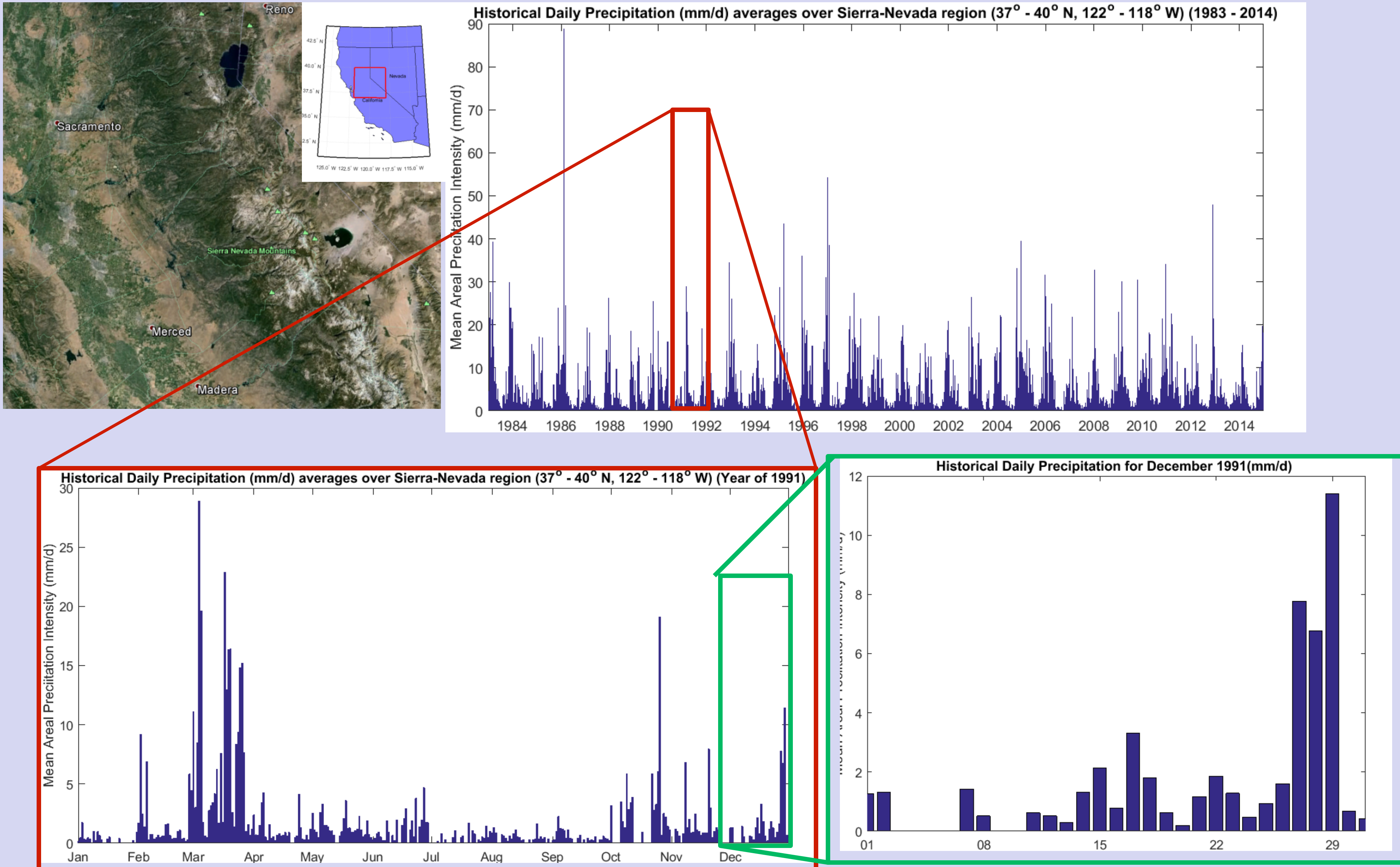
Sierra-Nevada Mountain Region

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

Length: 400 mile, Width: 64 mile.

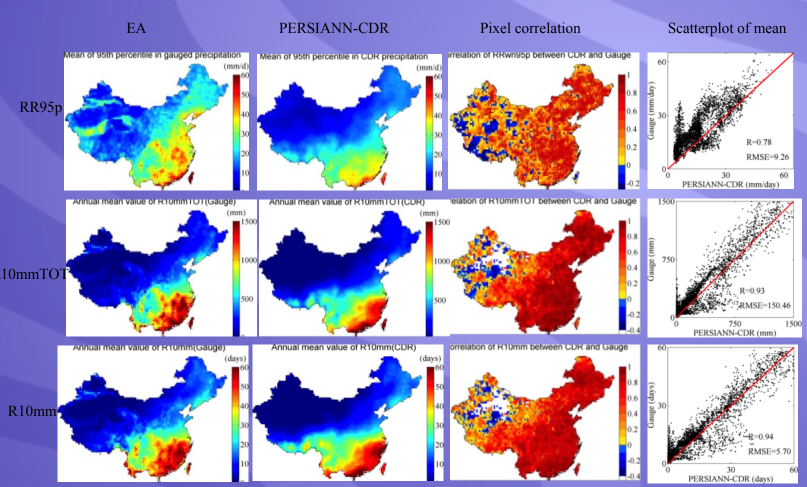
Map Source: Google Earth

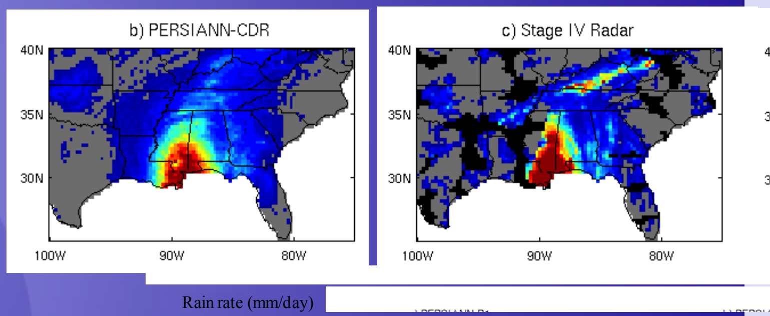
Sierra-Nevada Mountain (California and Nevada)

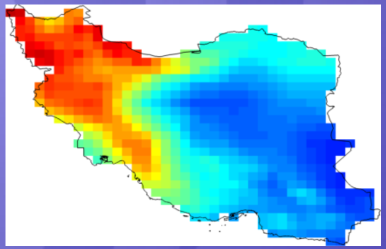


Regional Evaluations of PERSIANN CDR

Many Regional Evaluation of PERSIANN CDR Have Already Been Reported:



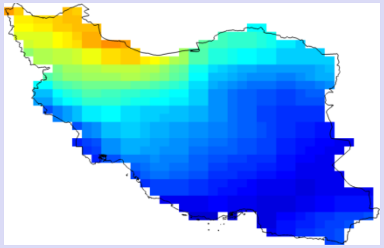




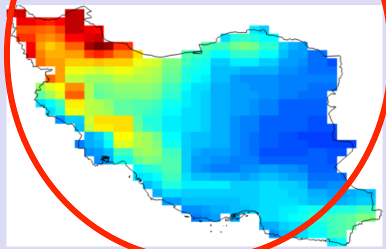
What is the value of this data set to application and Modeling communities?

Model historical simulation (1983-2005)

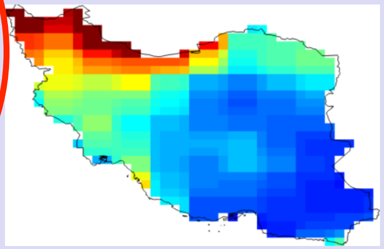
bcc_csm1_1_m
(Chinese GCM)



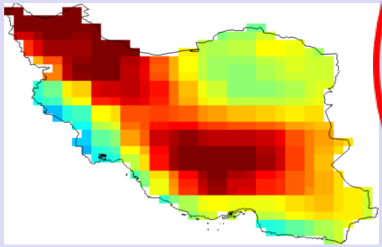
CCSM4
(NCAR, USA GCM)



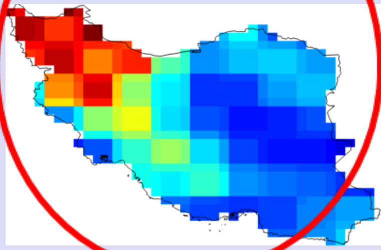
HadGEM2-ES
(U.K GCM)



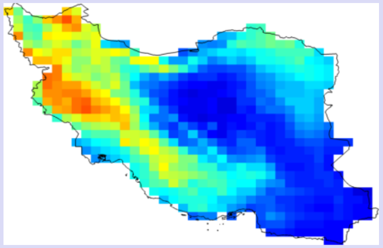
MIROC5
(Japan GCM)



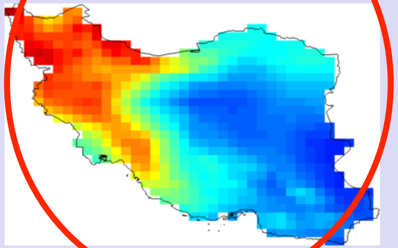
MPI-ESM-MR
(Germany GCM)

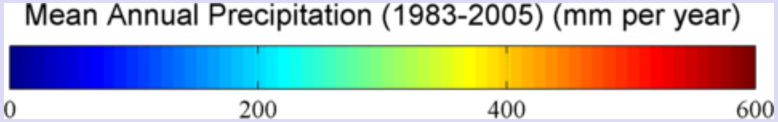


Observation
(CRU Dataset)



Remotely Sensed Estimates
(PERSIANN-CDR)





Satellite-Based Precipitation: Very Promising for Hydrometeorological Applications

PERSIANN Websites and Apps

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

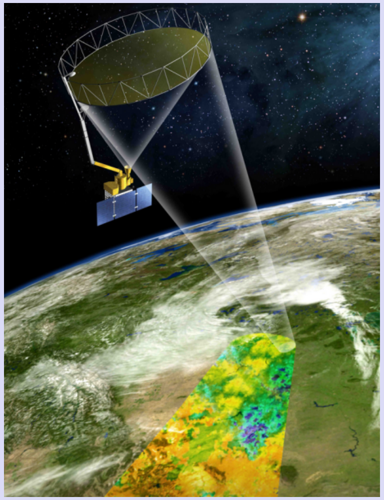
CHRS iRain and Rainsphere Development Team

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

How Much Trust in Remote Sensing Observations??

Hydrologically - Relevant Remote Sensing Missions

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



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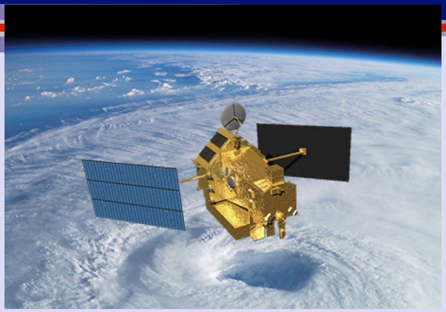
Soil Moisture Active Passive Satellite(2014)



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The Tropical Rainfall Measuring Mission

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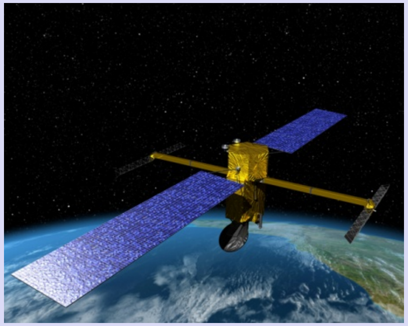
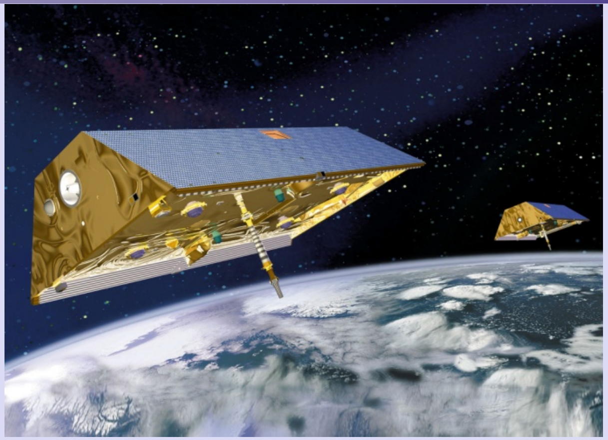
Global Precipitation Measurements (2014)



SWOT
Surface Water and Ocean Topography (2020)



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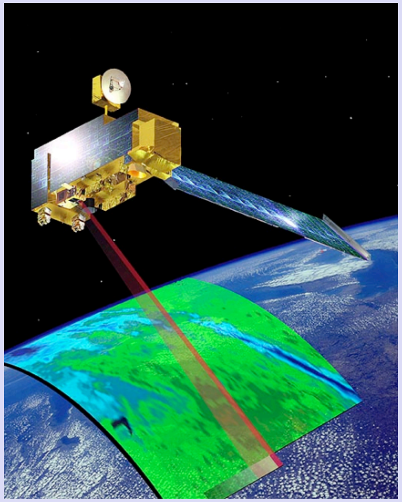
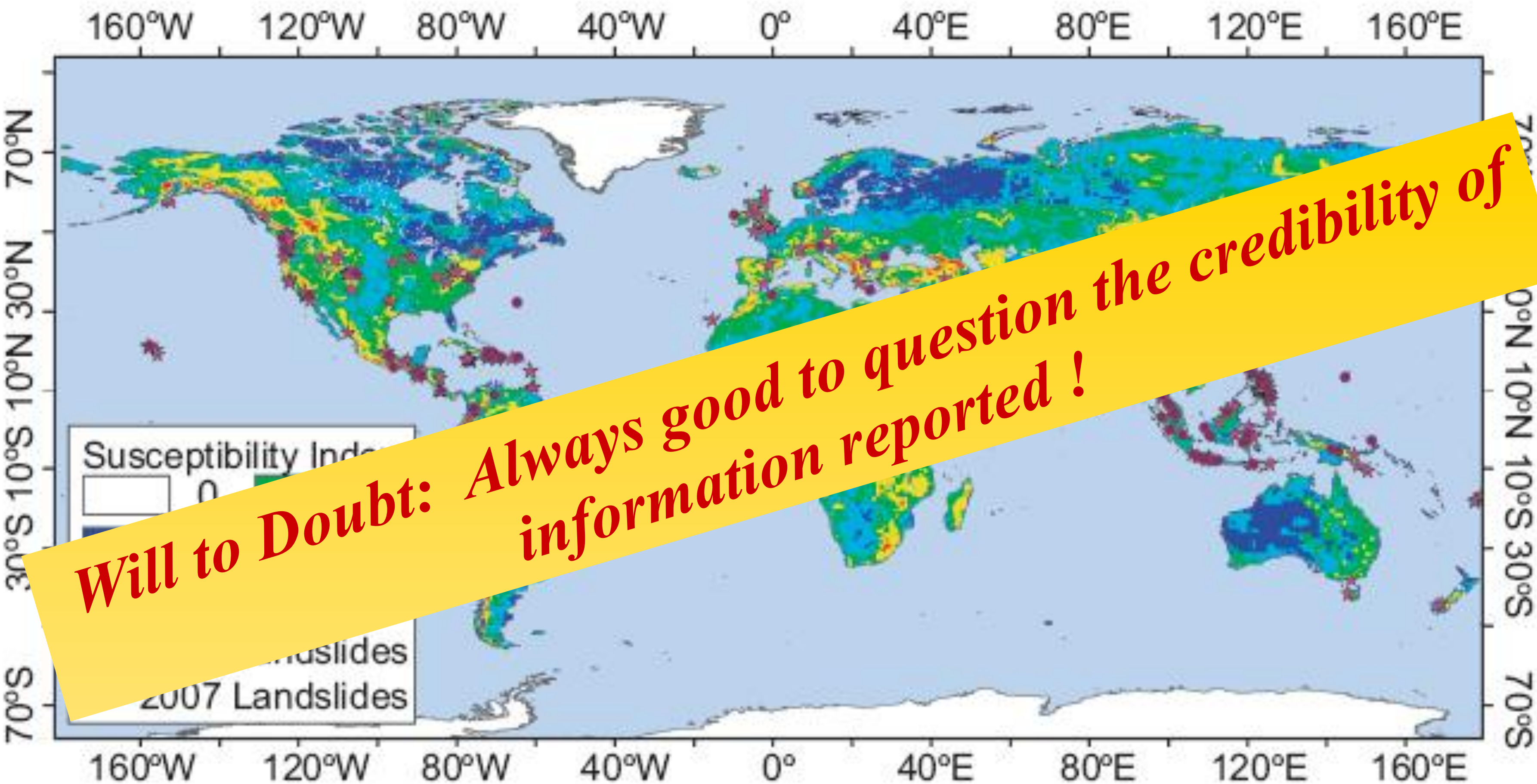


MODIS
Moderate Resolution Imaging Spectroradiometer
(1999) , (2002)

Landslide Risk map:



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

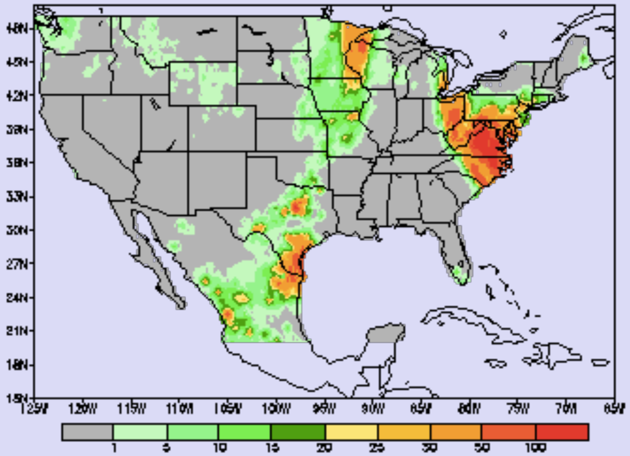
Validation and Application of Satellite Products

US Daily Precipitation Validation Page

http://www.cpc.ncep.noaa.gov/products/janowiak/us_web.html

13Z 19Sep2003 thru 12Z 19Sep2003
Data on 0.25 deg grid (UNITS are mm/day)

CPC real-time Gauge Analysis



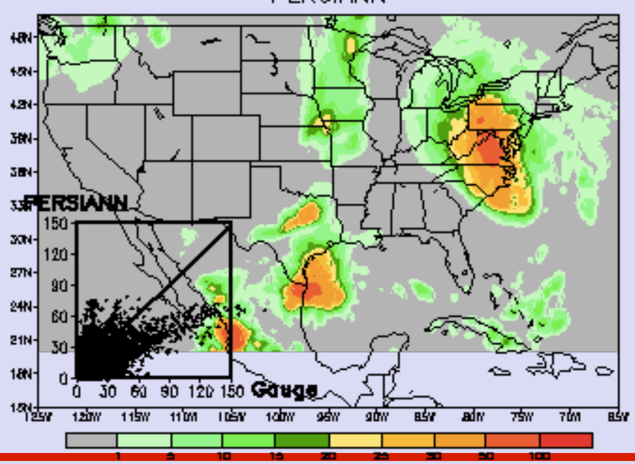
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.55	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45

	G−S	G−R	R−S
Correlation:	0.827	0.726	0.606
Mean Absolute Error:	3.63	3.42	3.35
RMSE (mm/day):	9.44	11.23	8.66
RMSE (normalized):	1.70	2.02	2.77
Probability of Detection:	0.746	0.654	0.855
False Alarm Ratio:	0.321	0.065	0.455
Bias Ratio (rain:no rain):	1.098	0.699	1.570
Heidke Skill Score:	0.574	0.692	0.546
Hanssen−Kuipers Score:	0.589	0.634	0.660
Equitable Threat Score:	0.402	0.528	0.376

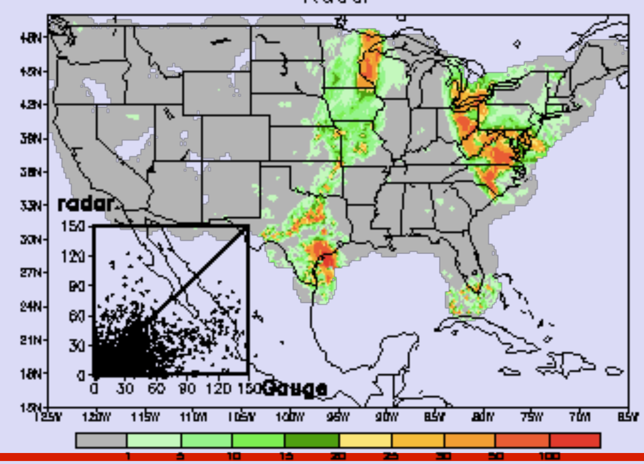
	PERSIANN < 1	PERSIANN ≥ 1
gauge < 1	8082.	1497.
gauge ≥ 1	1081.	3168.

	radar < 1	radar ≥ 1
gauge < 1	9386.	193.
gauge ≥ 1	1471.	2778.

PERSIANN

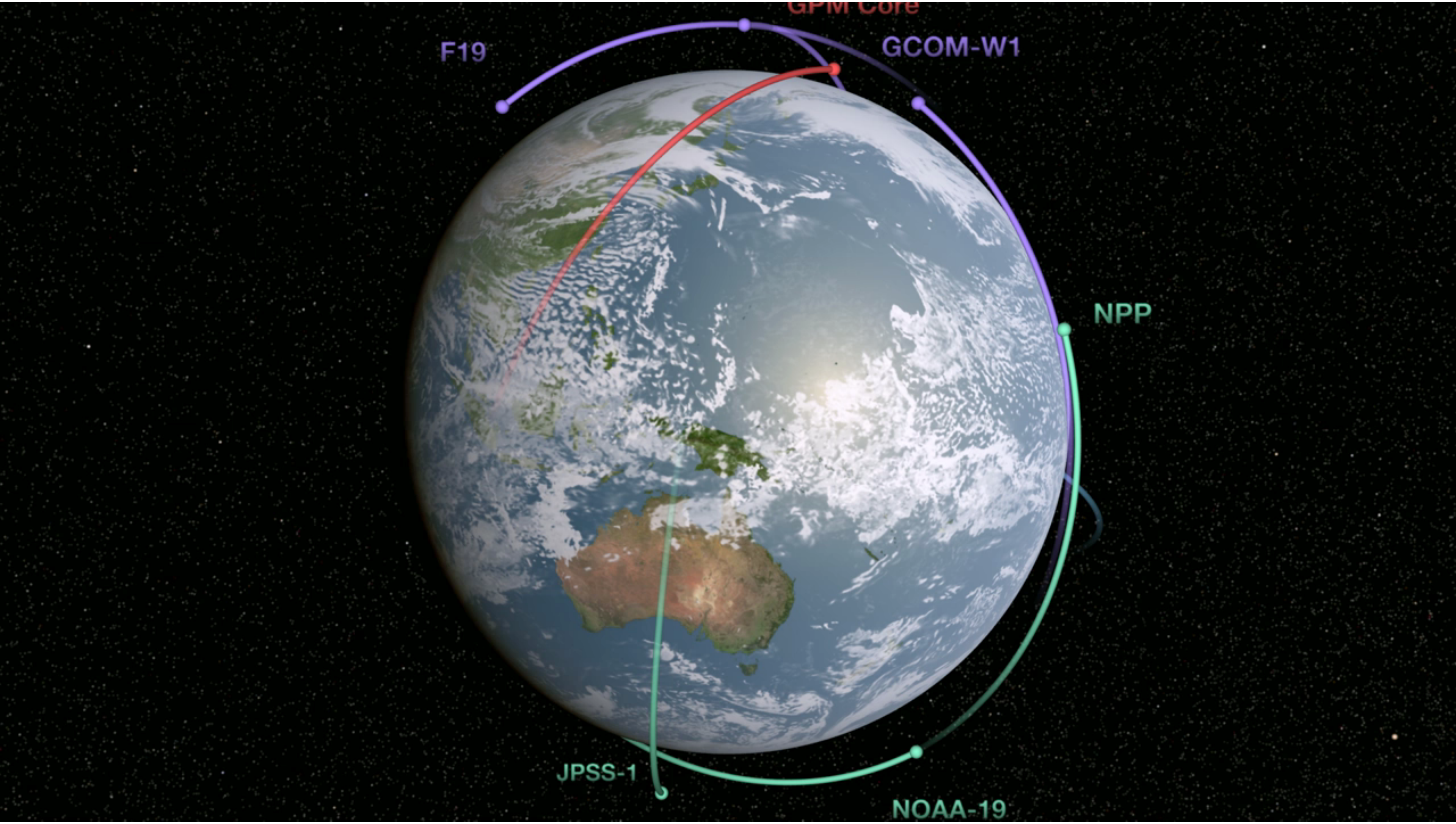


Radar

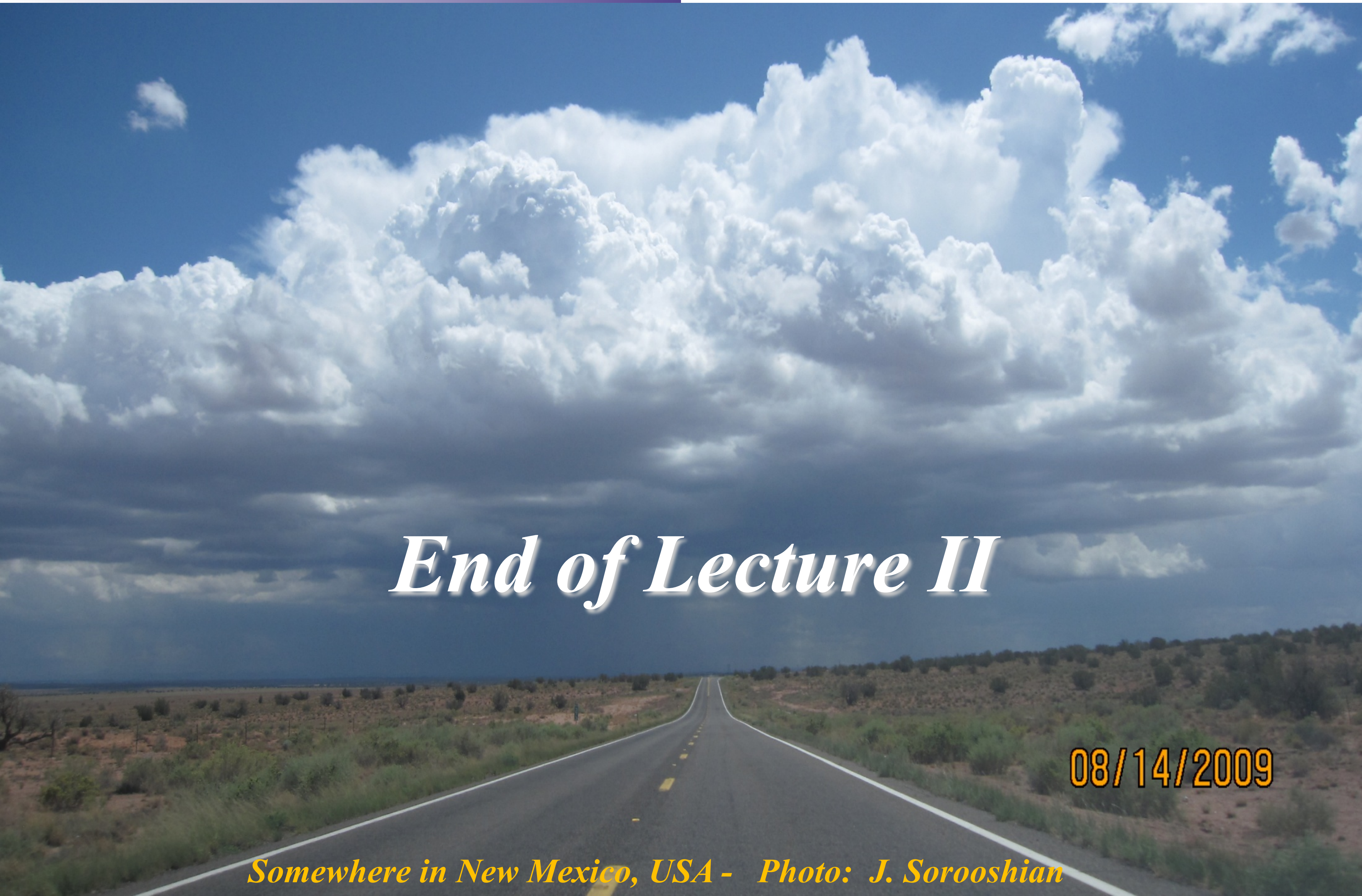


GPM Animation

Courtesy: NASA's ESE

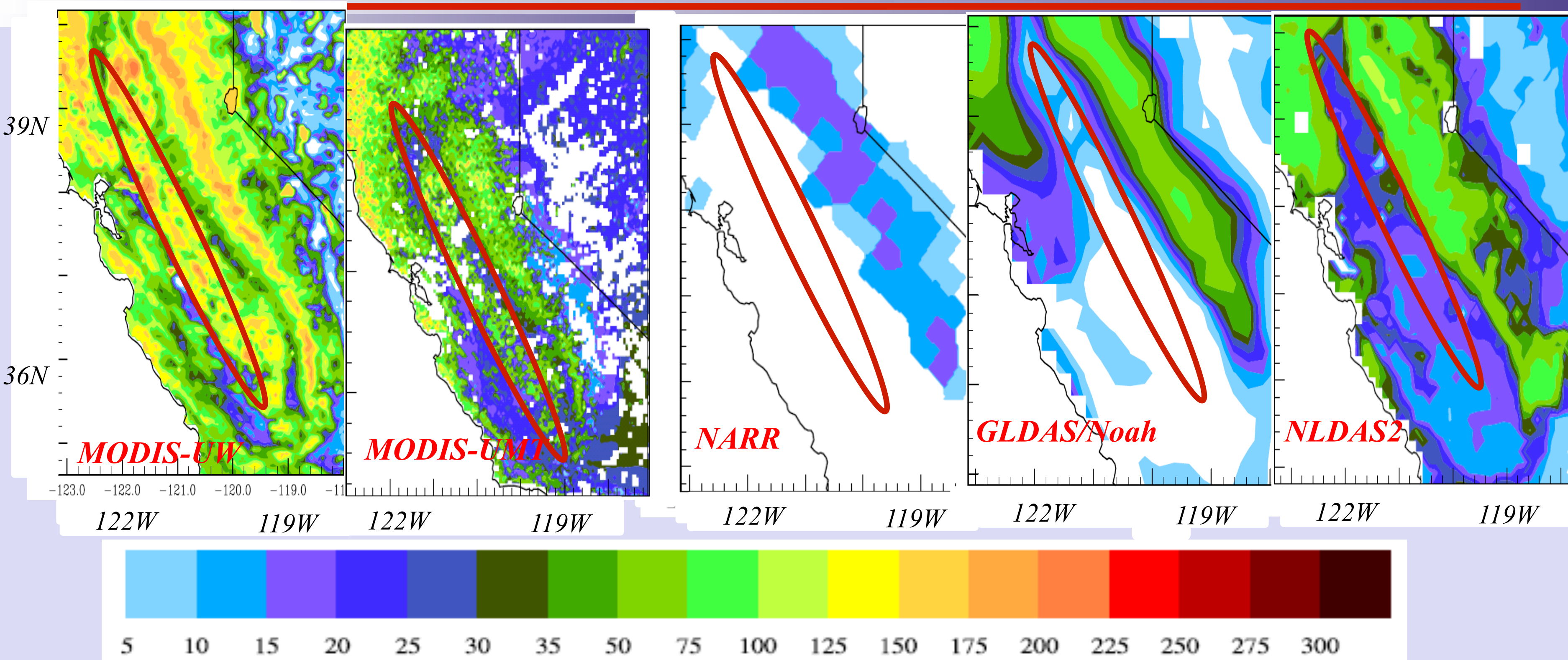


End of Lecture II



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

Actual ET Estimates From Different Data sets– JJA 2007



2007 JJA Monthly ET (mm)

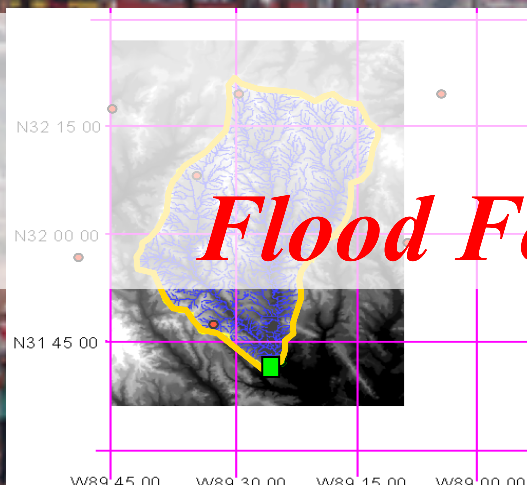
An Important Dilemma for the modeling application community will be:

Which Remotely Sensed ET Product should be used for model testing and validation??

Sorooshian et al. 2011, 2012 & 2014

Streamflow forecasting of a catchment in US using UCI-PERSIANN rainfall Estimates for use in the US National Weather Service Runoff Forecasting System (NWSRFS).

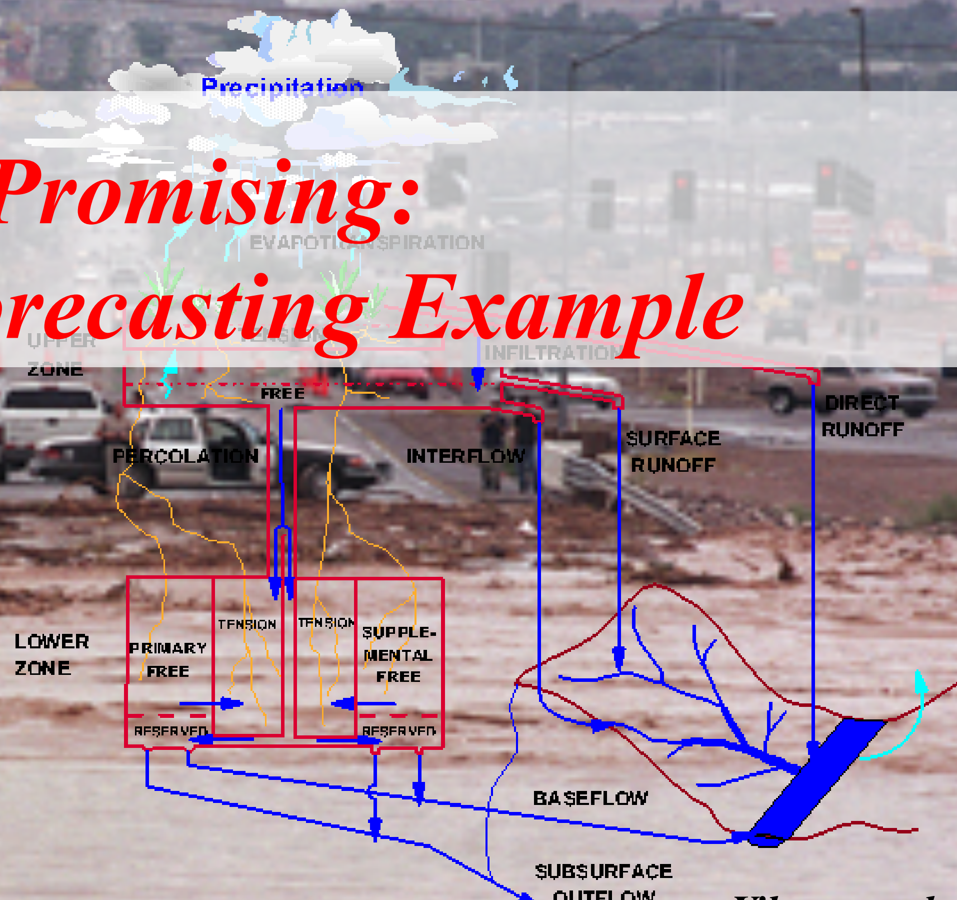
Promising:
Flood Forecasting Example



Gages used by NWS

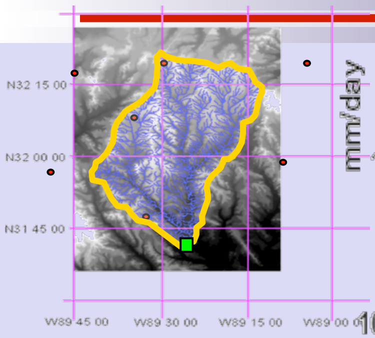
Leaf River Near Collins
Mississippi
USGS # 02472000

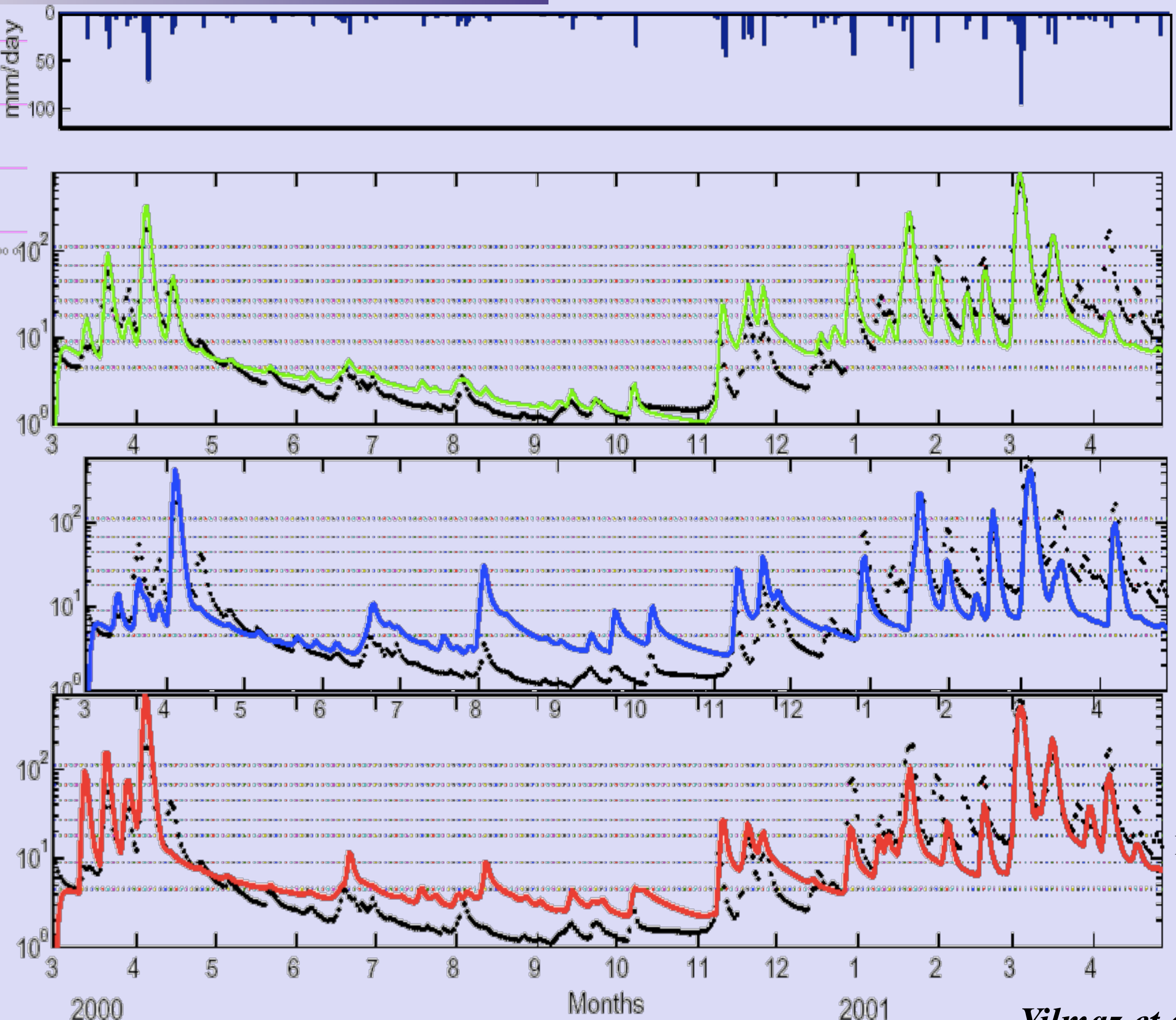
Basin Area : 753 mi^2



Yilmaz et al. JHM 2005

Satellite Rainfall Estimation: Research at UC Irvine

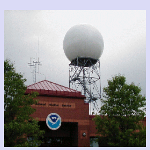




RAINGAGE

Corr =0.95
RMS =23.9
BIAS =-1.32

RADAR



Corr =0.92
RMS =28.8
BIAS =-6.74

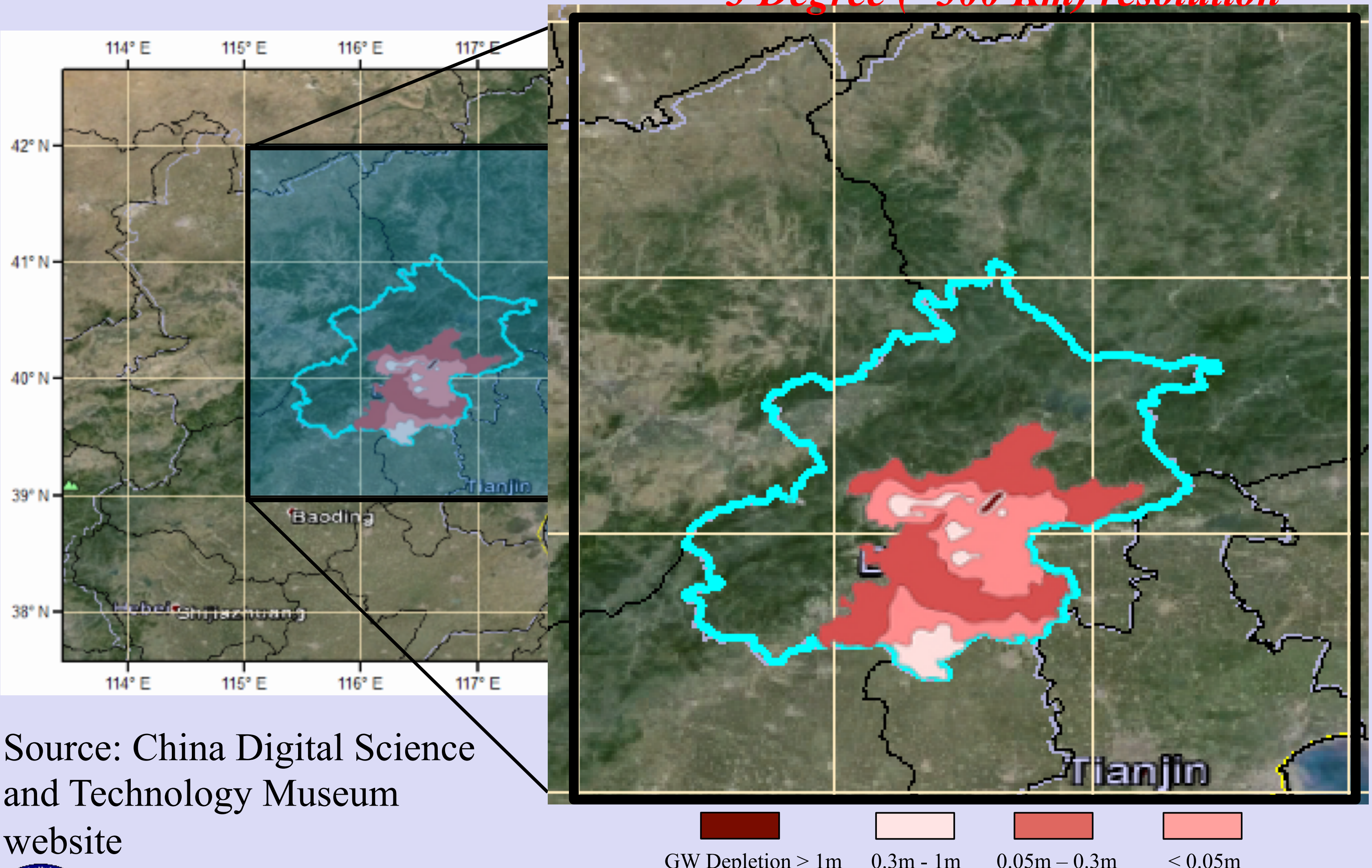
PERSIANN

Corr =0.94
RMS =22.6
BIAS =-5.15

Yilmaz et al. JHM 2005

GRACE Satellite Footprint

3 Degree (~300 Km) resolution



Source: China Digital Science and Technology Museum website

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

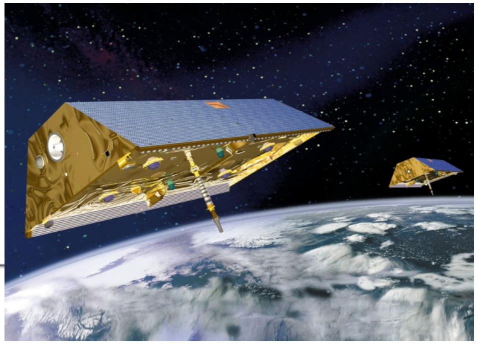
Finally: Recent Reaction to Overblown Stories About Ground Water Detection by Remote Sensing

Groundwater

Technical Commentary/

Bringing GRACE Down to Earth

by William M. Alley[1] and Leonard F. Konikow[2]



GRACE
Gravity Recovery and Climate Experiment (2002)

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^2 (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^2, much smaller than the GRACE footprint.