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

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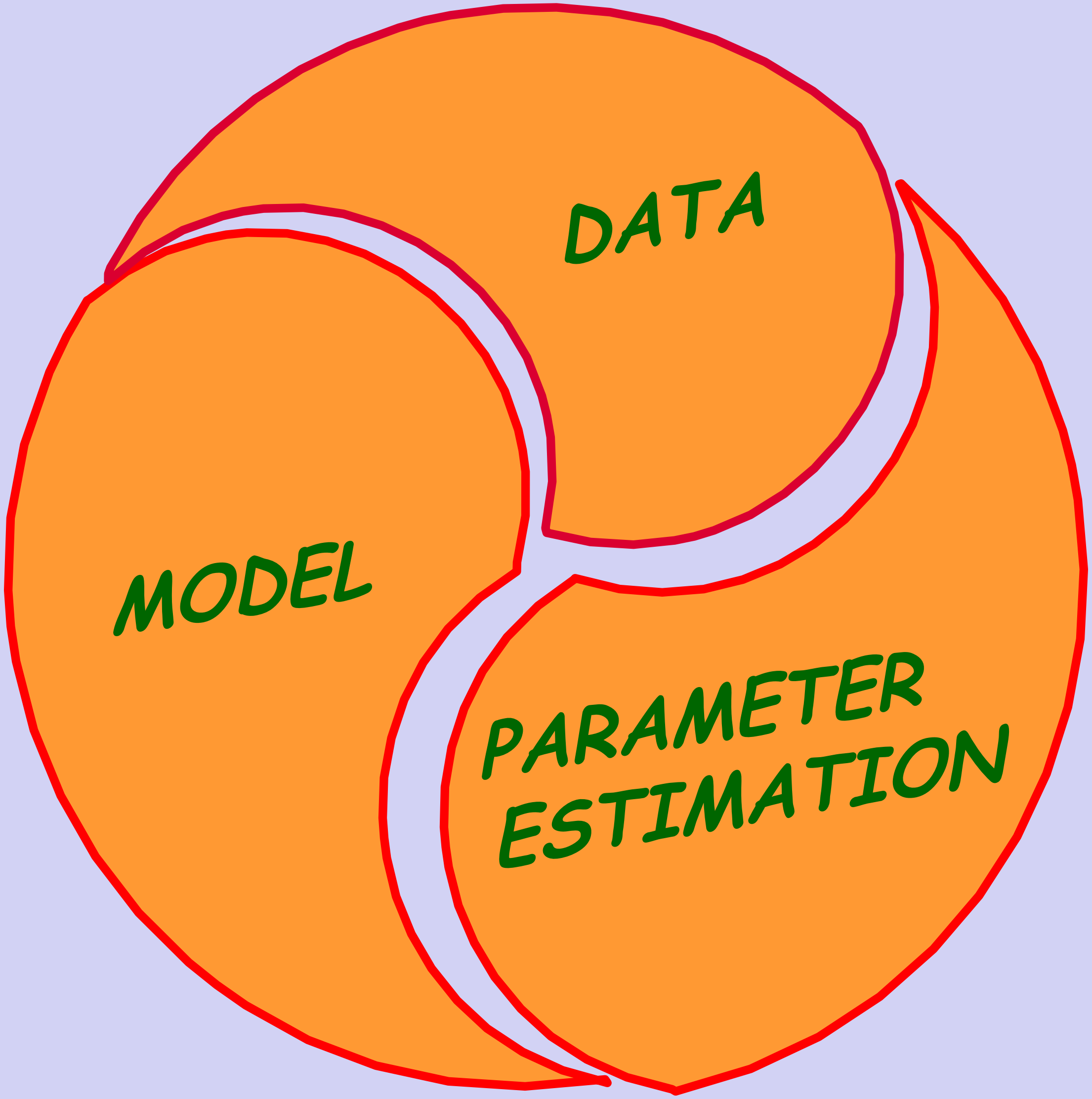
The Abdus Salam ICTP Workshop on:

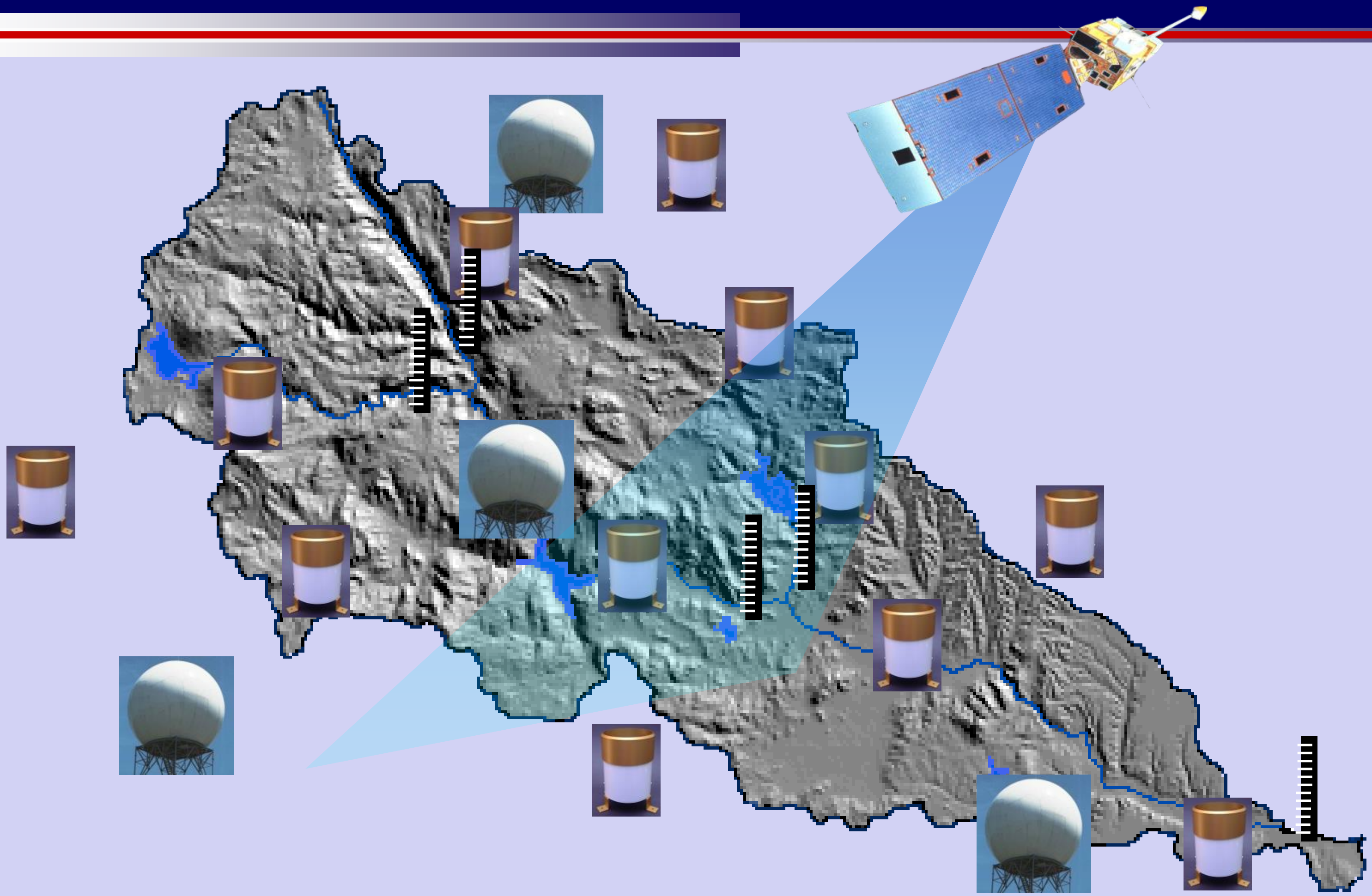
Water Resources in Developing Countries - Planning and Management in a Climate Change Scenario

Trieste, Italy: May 6th – 17th 2013

Data



Data Requirements for Hydrologic Modeling



Data Limitation is an Important Factor in Success of Hydrologic Modeling

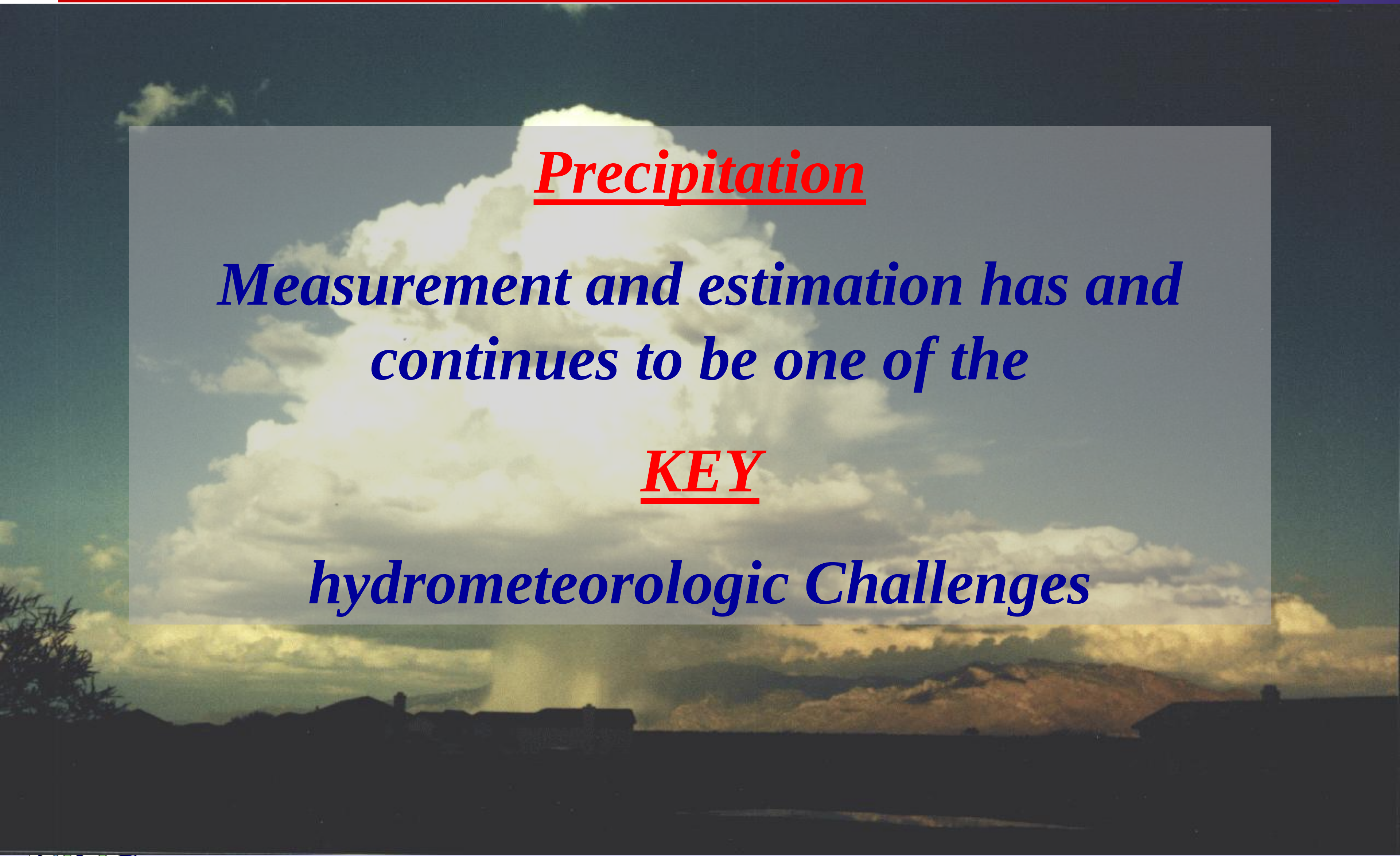
Big Challenge For "us":

Adequacy of Hydrologic Observations

Observation of Primary Hydrologic Variables

Precipitation

Stream flow



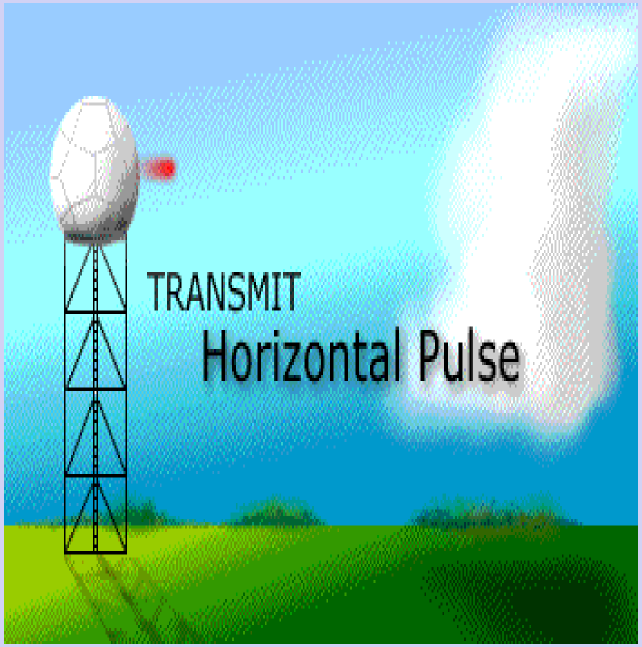
Precipitation

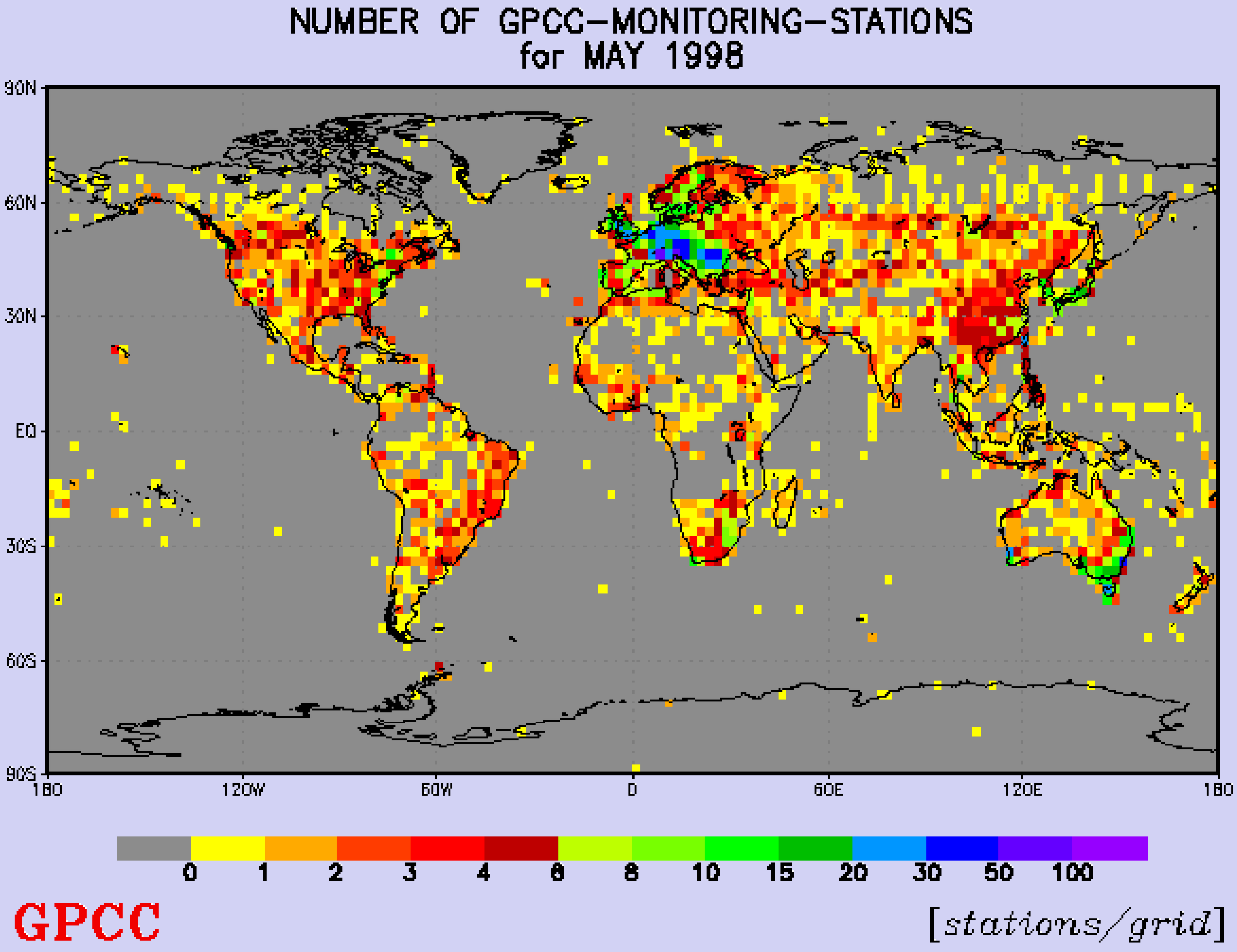
Measurement and estimation has and continues to be one of the

KEY

hydrometeorologic Challenges

Precipitation Observations: Which to trust??

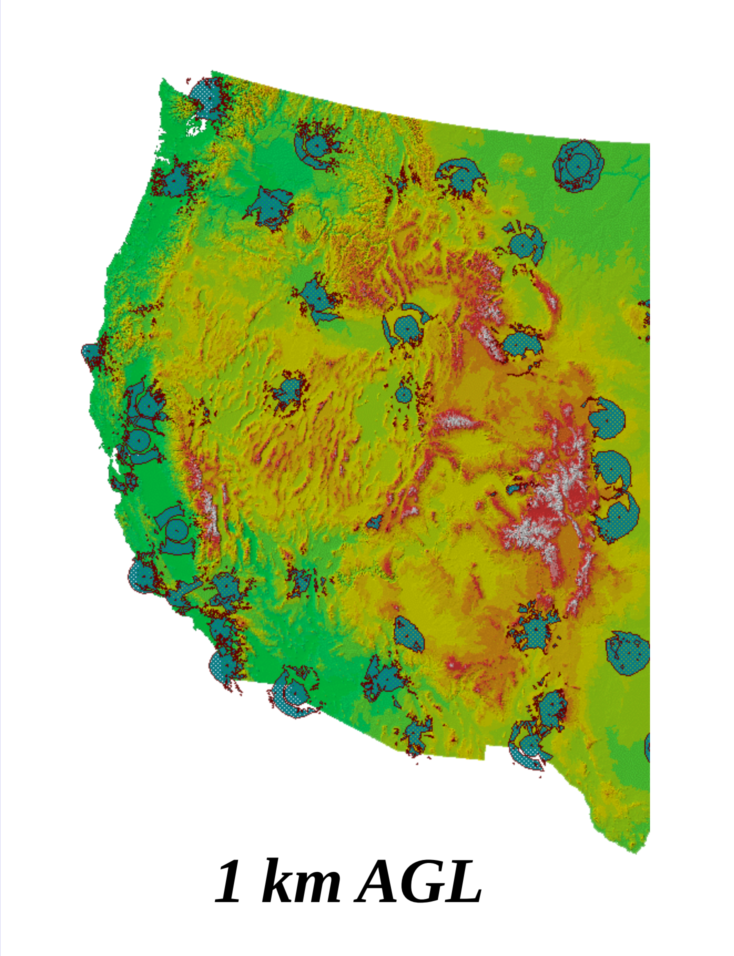




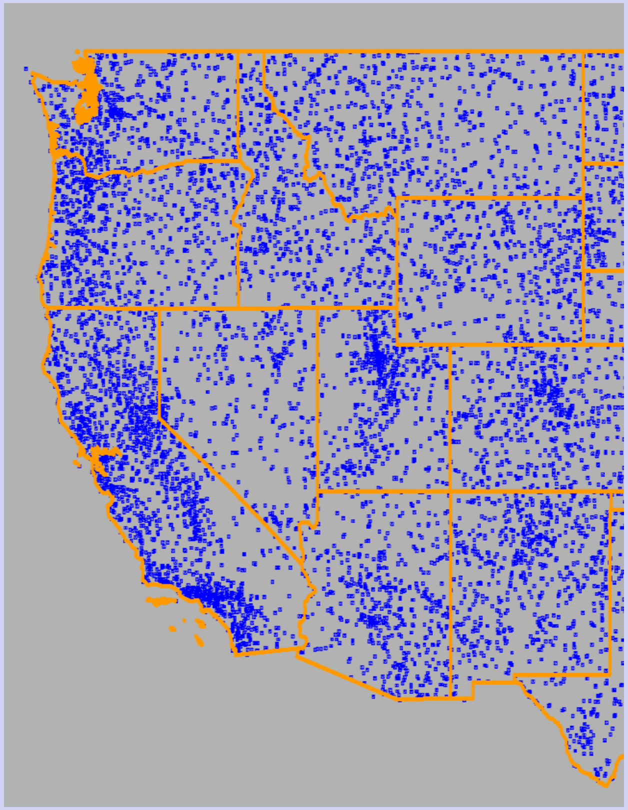
Number of range gauges per grid box*. These boxes are* ***2x2 degrees***

(Source: Global Precipitation Climatology Project)

Coverage of the WSR-88D and gauge networks



Maddox, et al., 2002

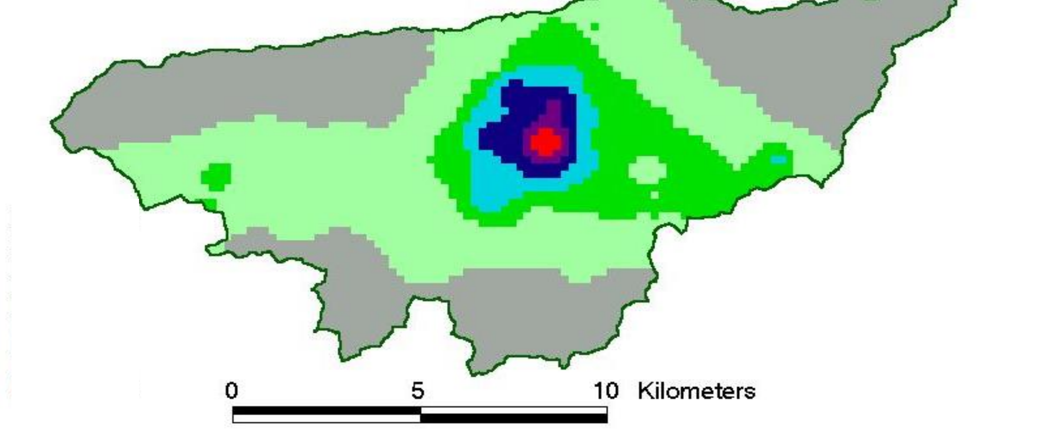


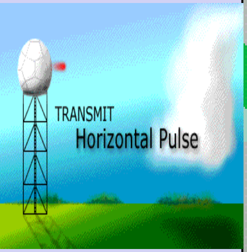
Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse

Radar-Gauge Comparison (Walnut Gulch, AZ)

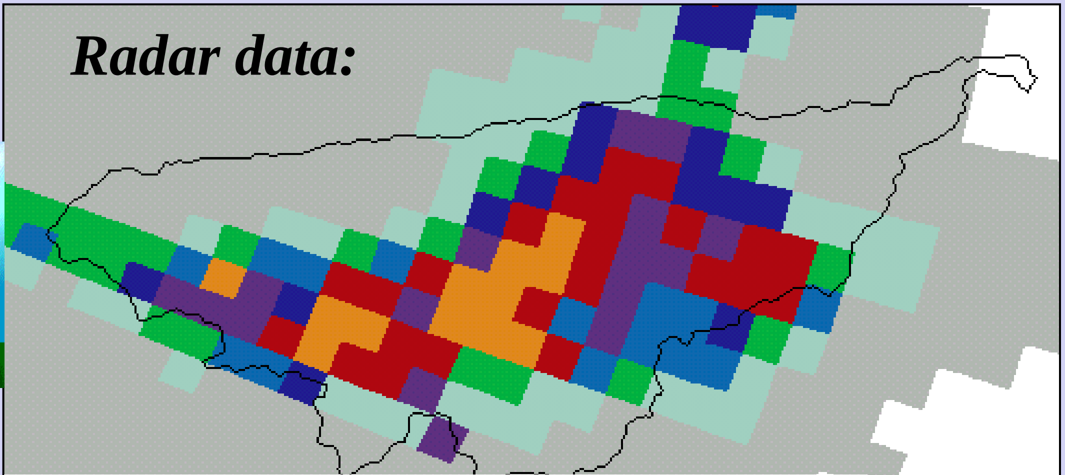
Precipitation event: Aug. 11, 2000

Rain gauge data:



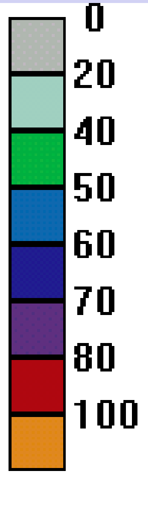


Radar data:



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

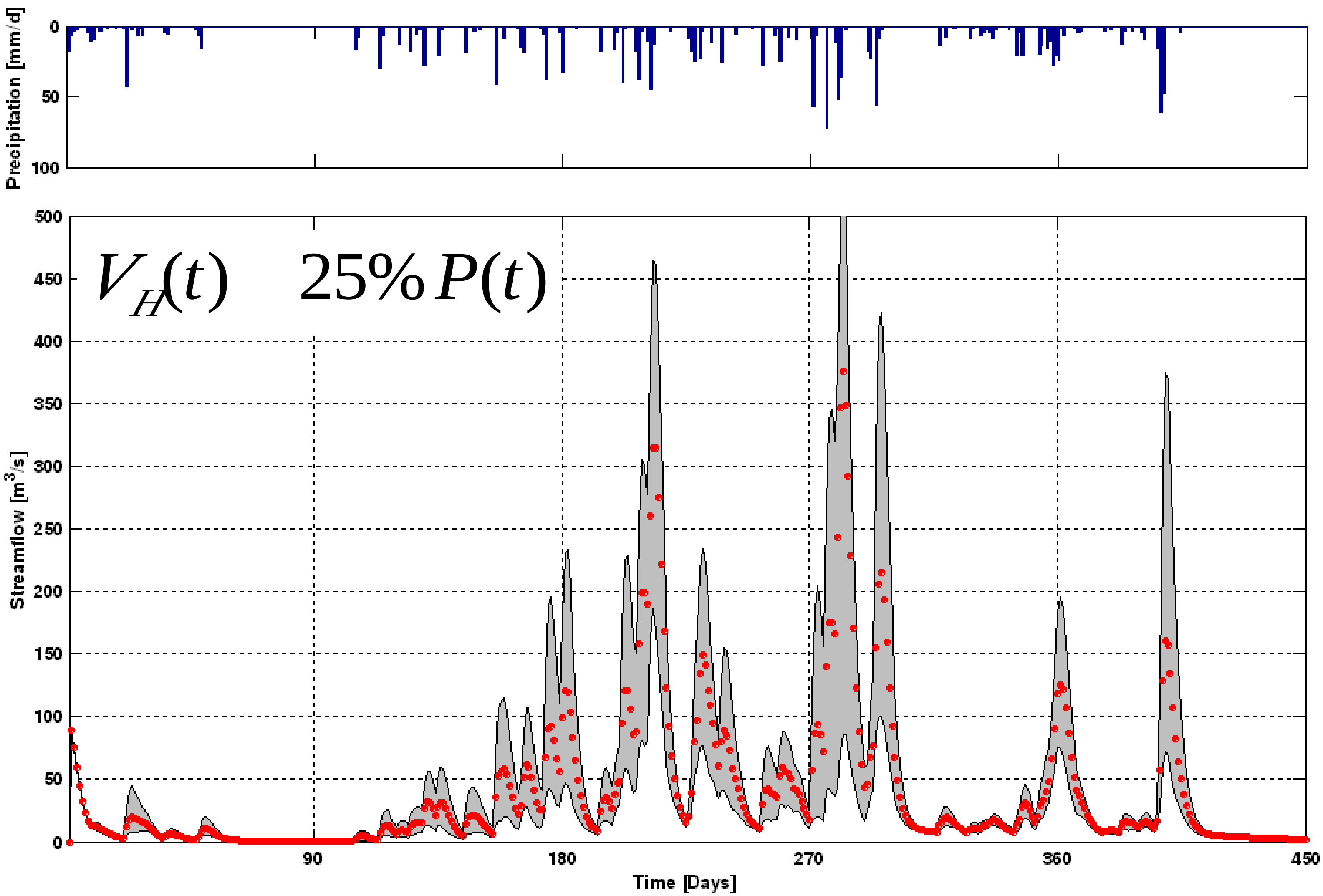
Storm depth (mm)



70% overestimation by the radar!

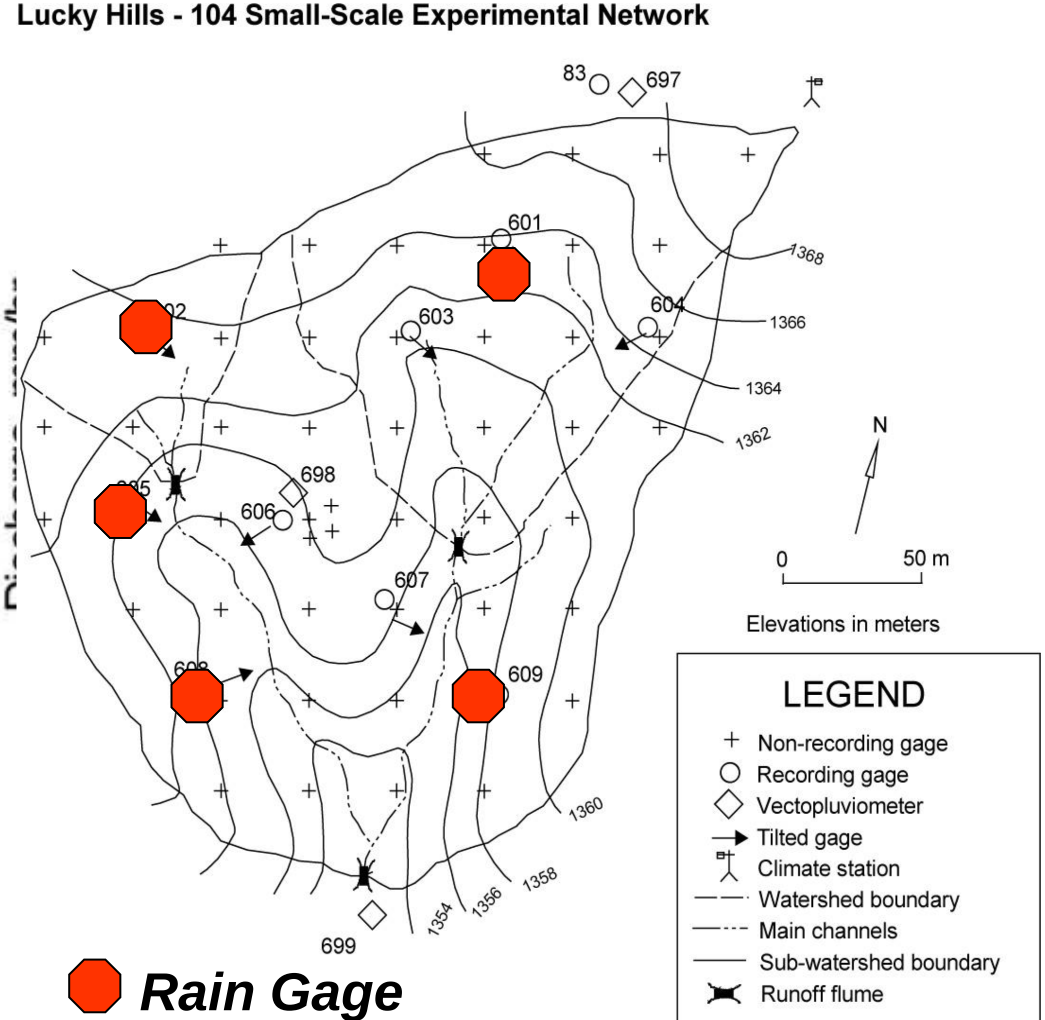
Morin et al ADWR 2005

Streamflow Simulation vs. Precipitation Uncertainty:

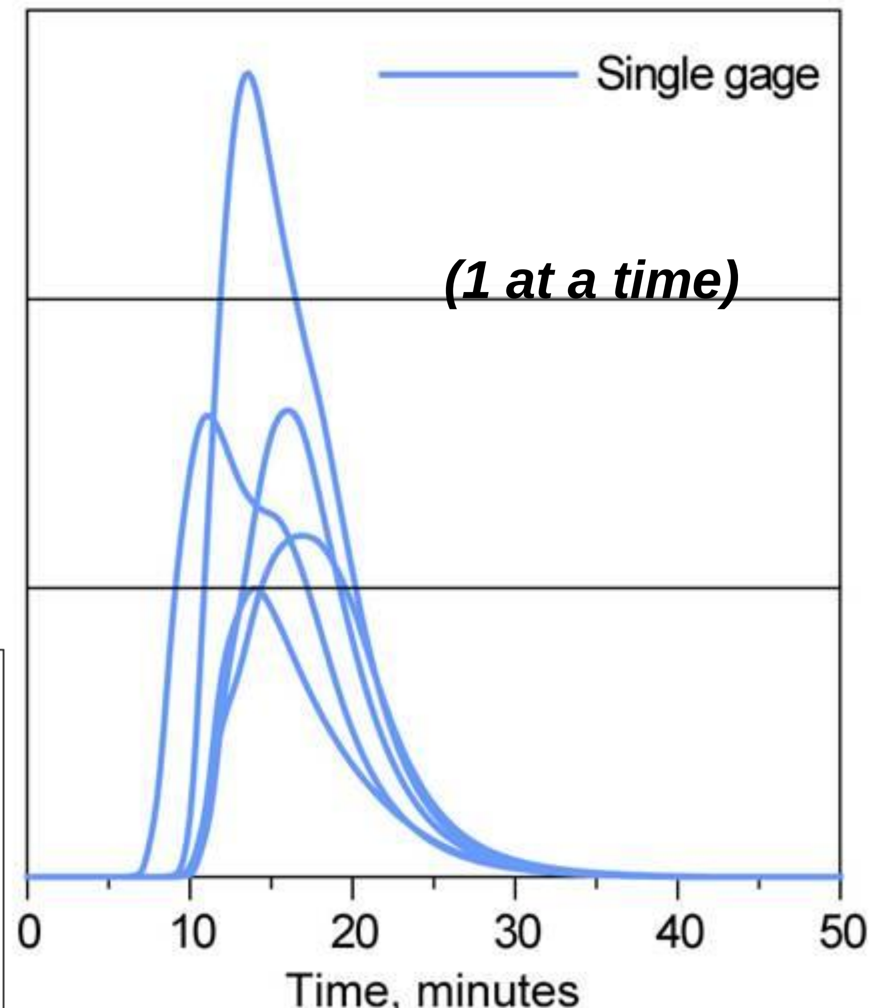


Uncertainty in Runoff Simulation due to Rainfall Variability

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



Modeled runoff (KINEROS)



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

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

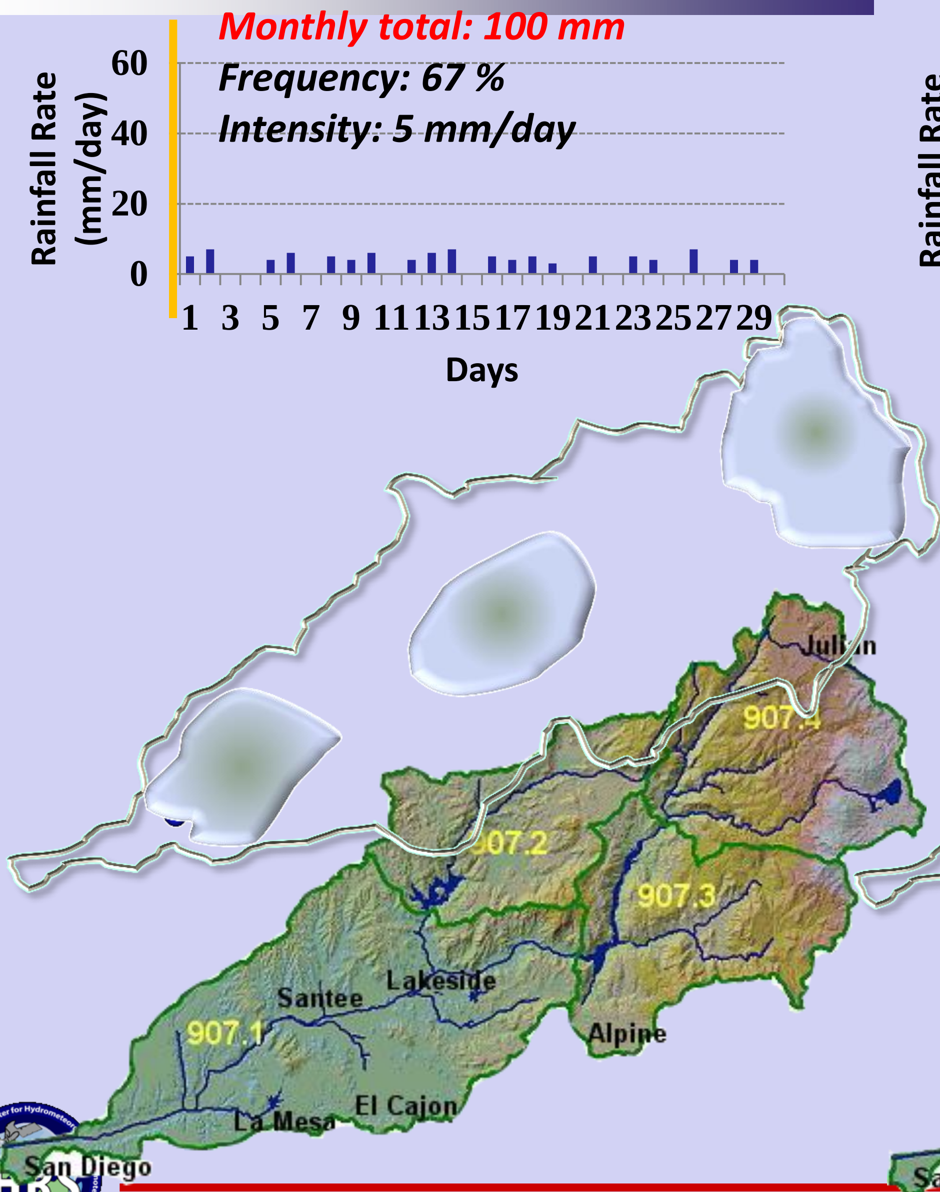
B

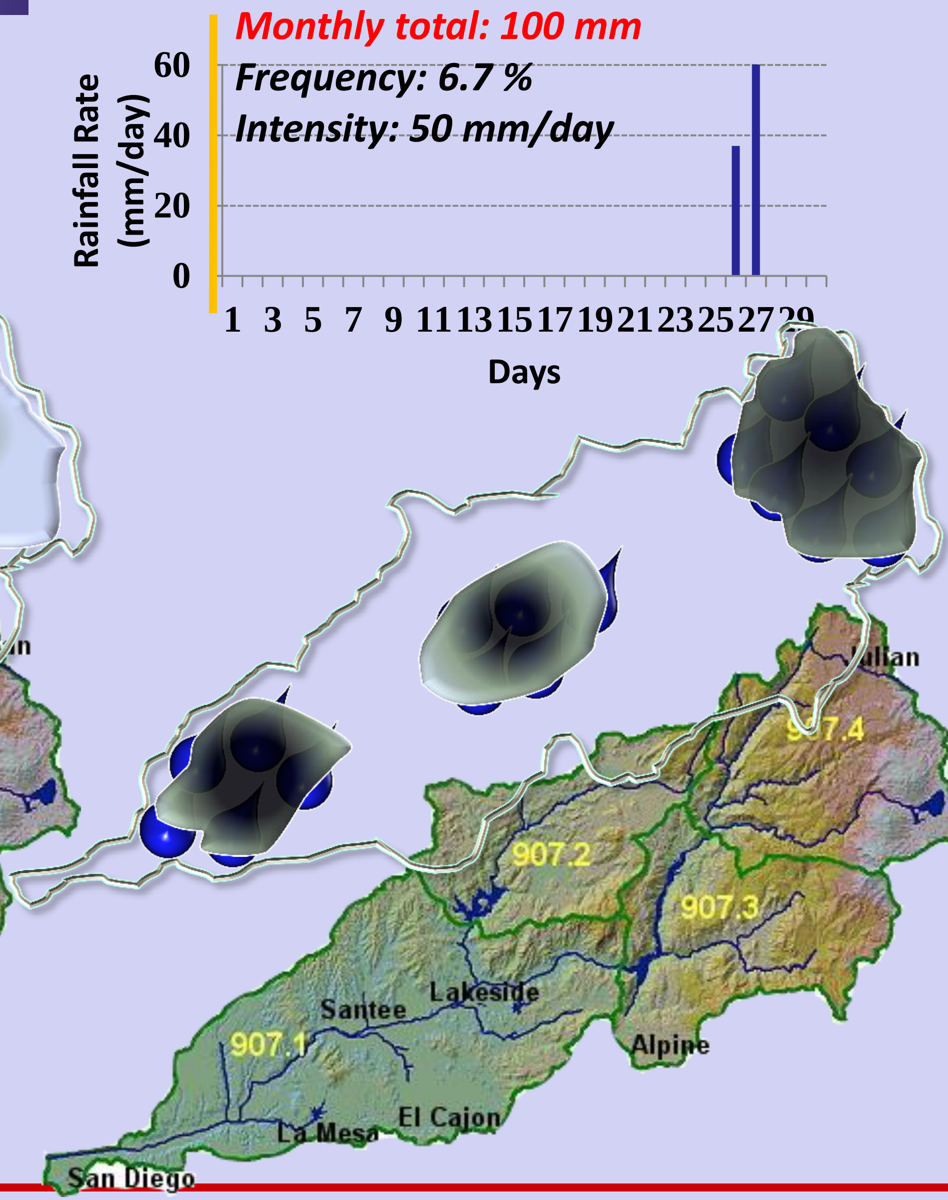
100 mm

Frequency 67%
Intensity 5.0 mm

Idea from: K. Trenberth, NCAR

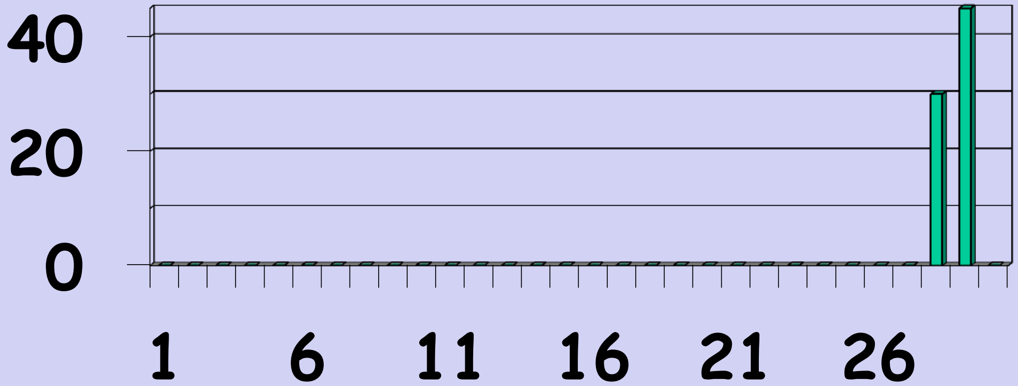
Temporal Scale Importance: *Daily Precip. at 2 stations*





2 Rain gages with different Temporal properties

A



Monthly

Amount 100 mm

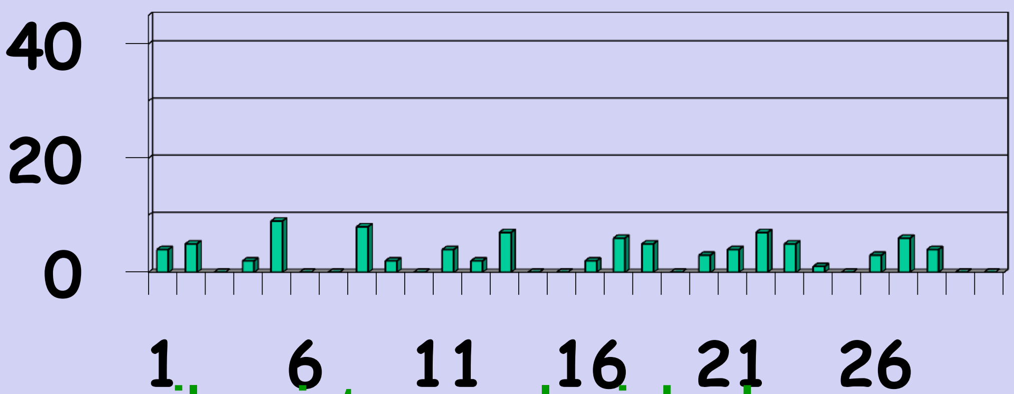
Frequency 6.7%

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

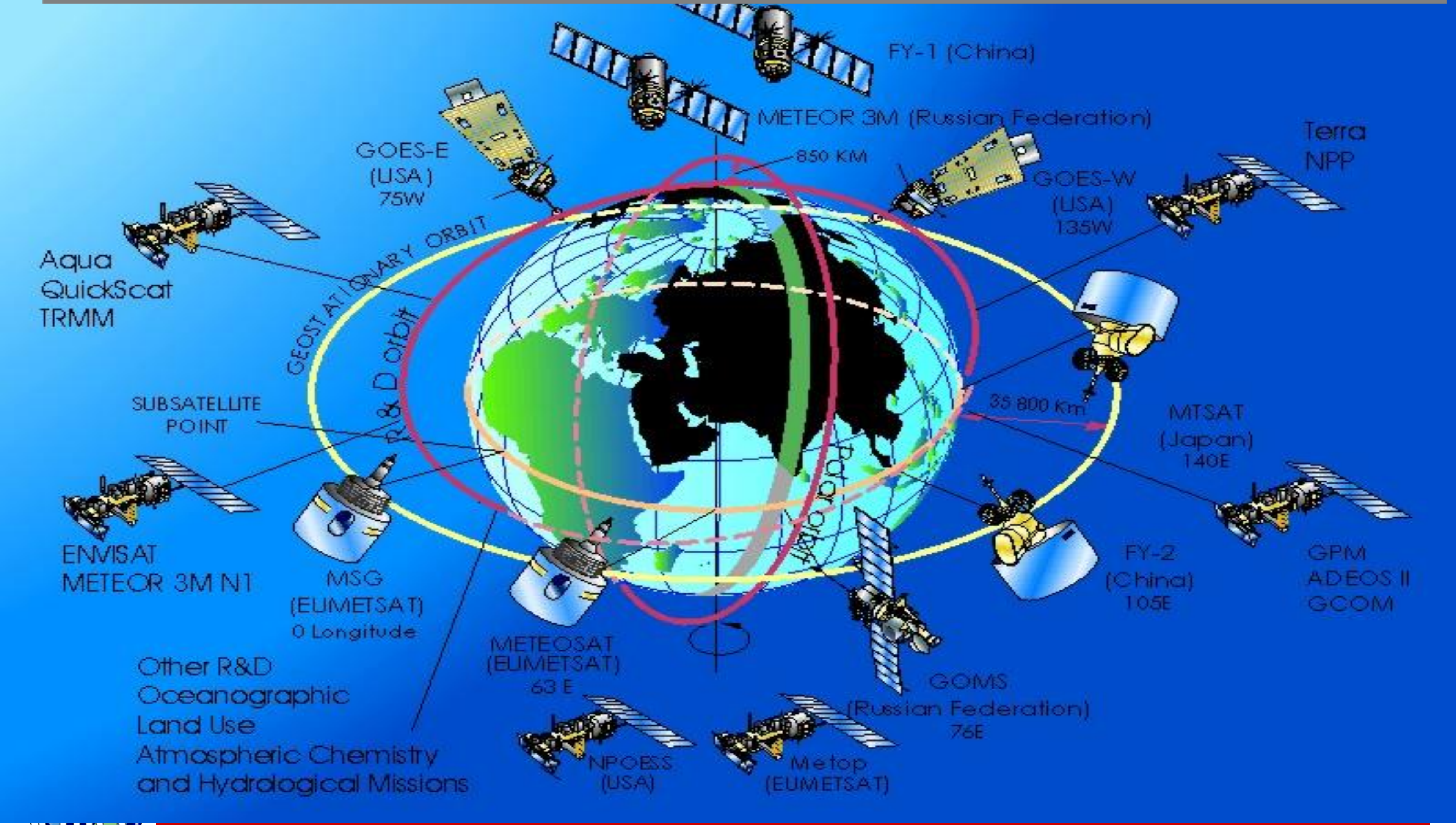
Idea from: K. Trenberth, NCAR

Space-Based Observations

Satellite Observations: Rainfall Estimation

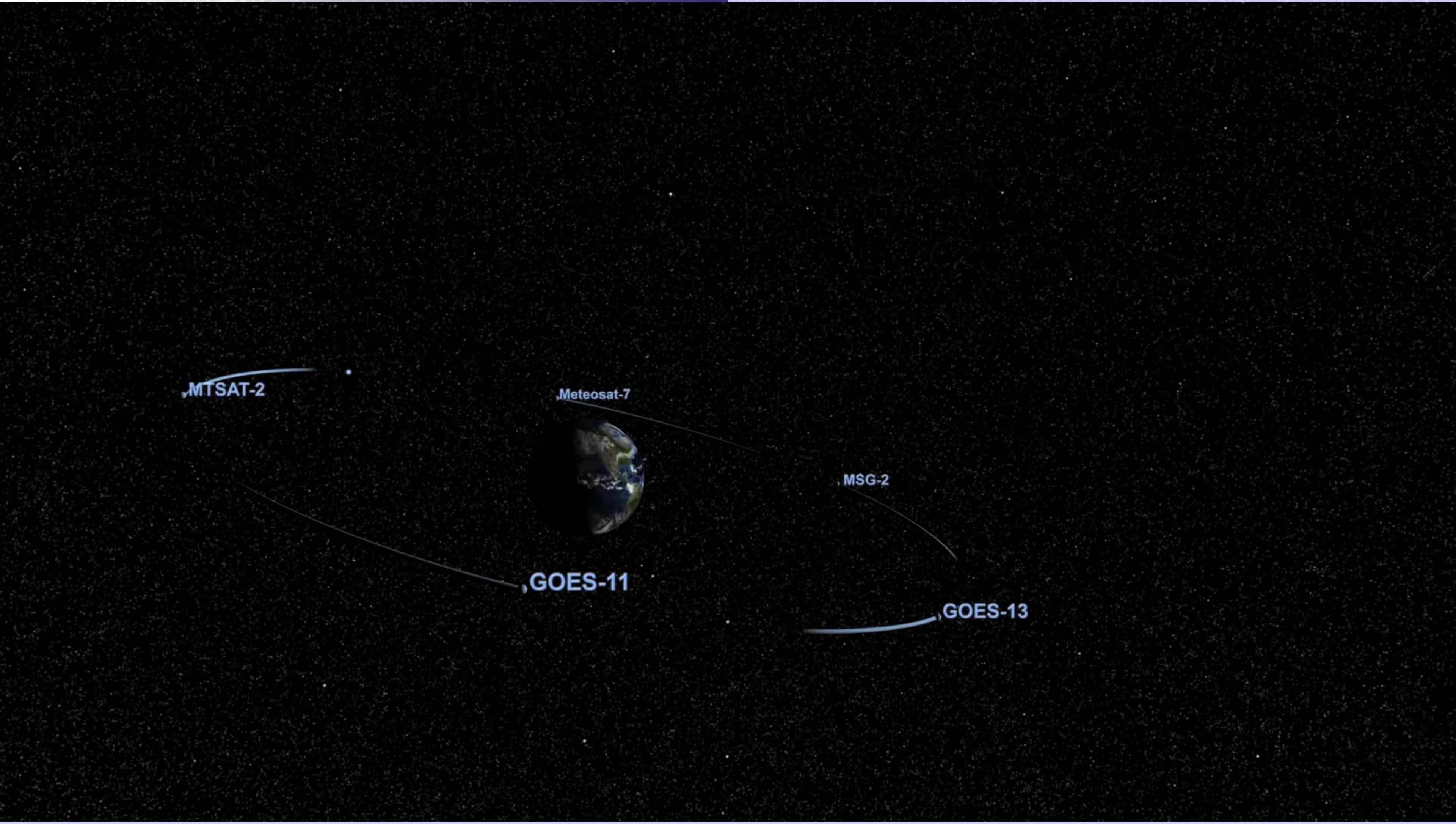
Satellite-Based Rainfall Estimation: Promising !

Observations from space: **Near-continuous, global coverage,**

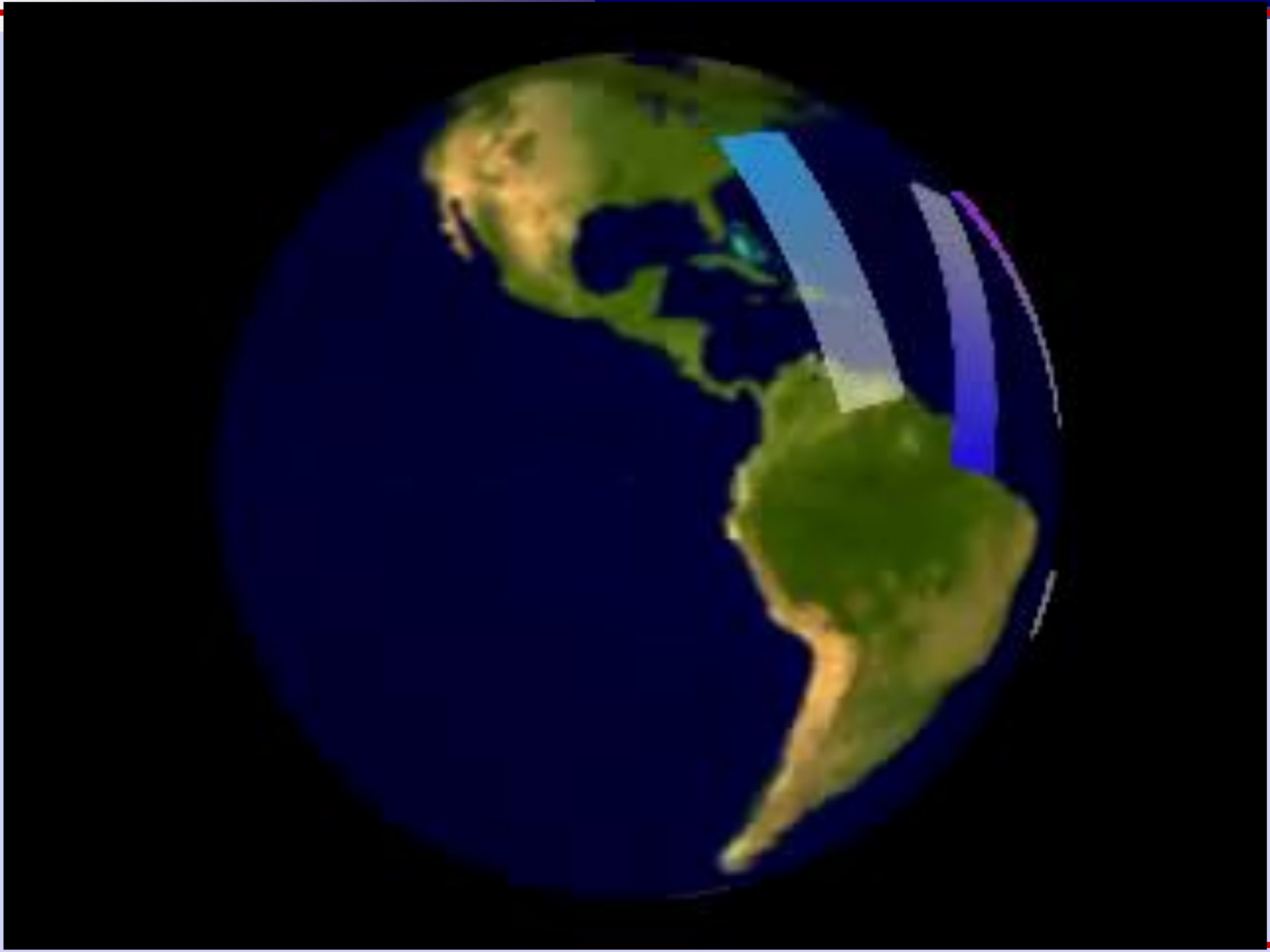


Geostationary Satellite Constellation

Courtesy: NASA's ESE

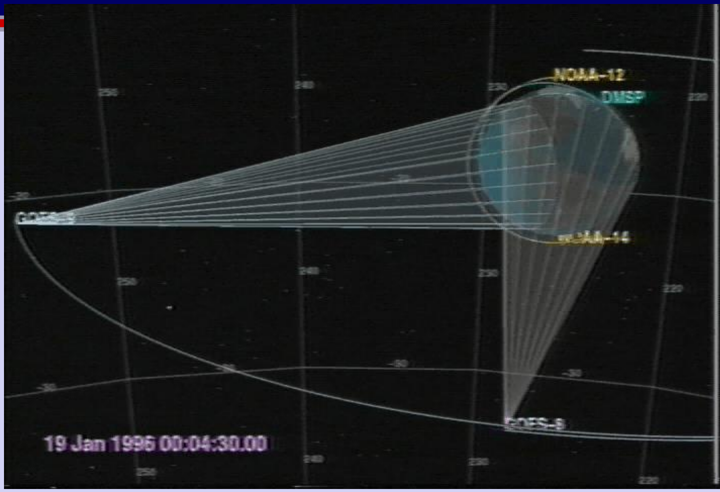


Polar Orbiting Satellites



Satellite precipitation retrieval instruments

1) Using GEO satellites (Infrared/Visible channels)



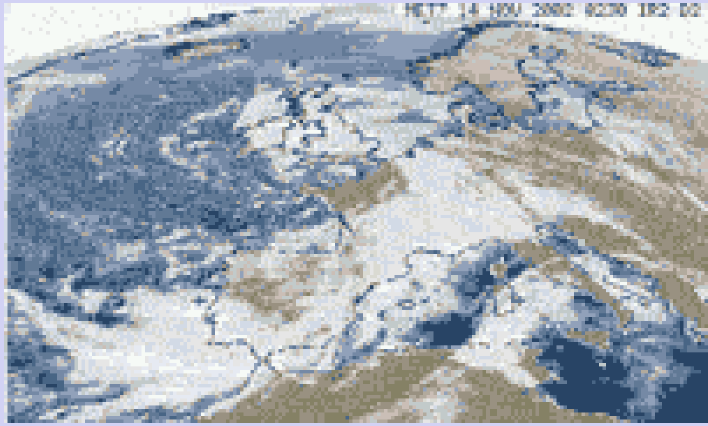
Advantage:

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

Disadvantage:

-Receives mostly cloud –top information

-Indirect estimation of precipitation.



Problems with IR only algorithm

Assumption: higher cloud → colder → more 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)

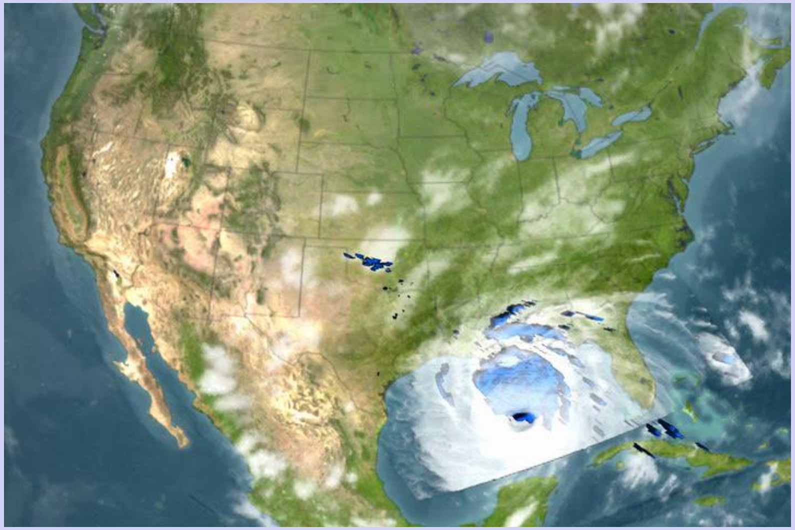
Satellite precipitation retrieval instruments

3) Active Radar

Advantage:

-More accurate

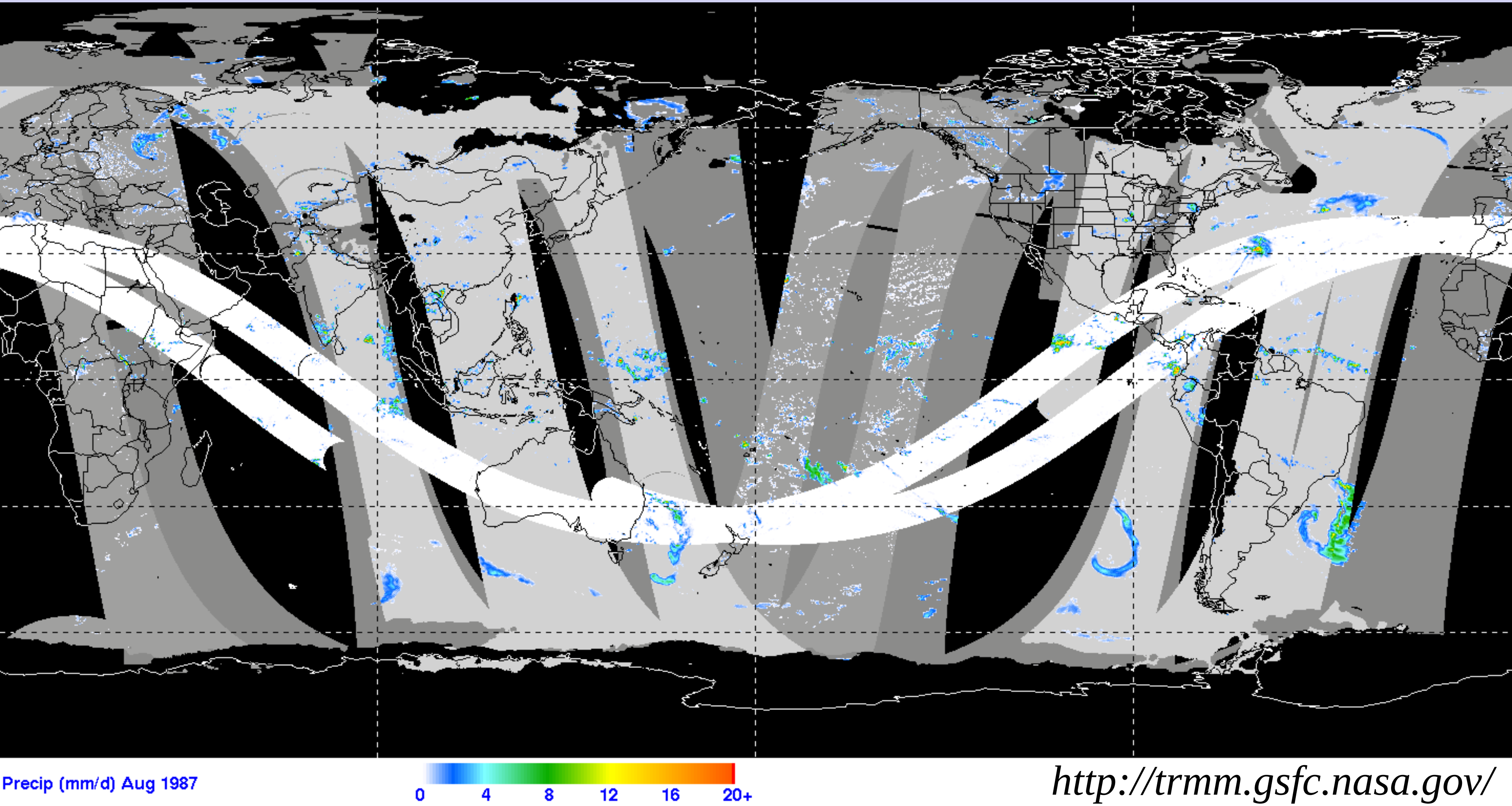
- good spatial resolution



Disadvantage:

- Poor temporal resolution

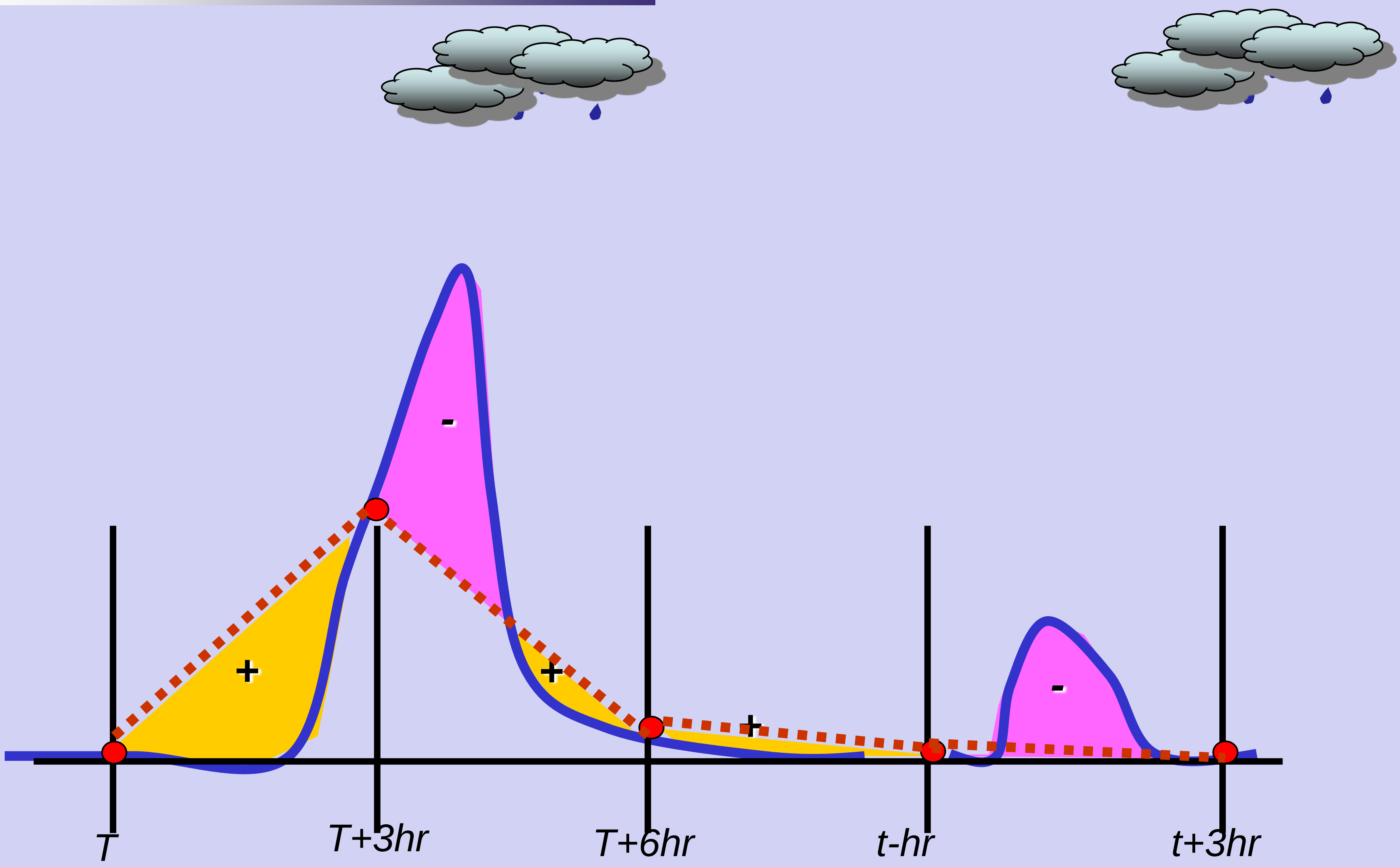
Typical Microwave Coverage in 3 Hr



http://trmm.gsfc.nasa.gov/

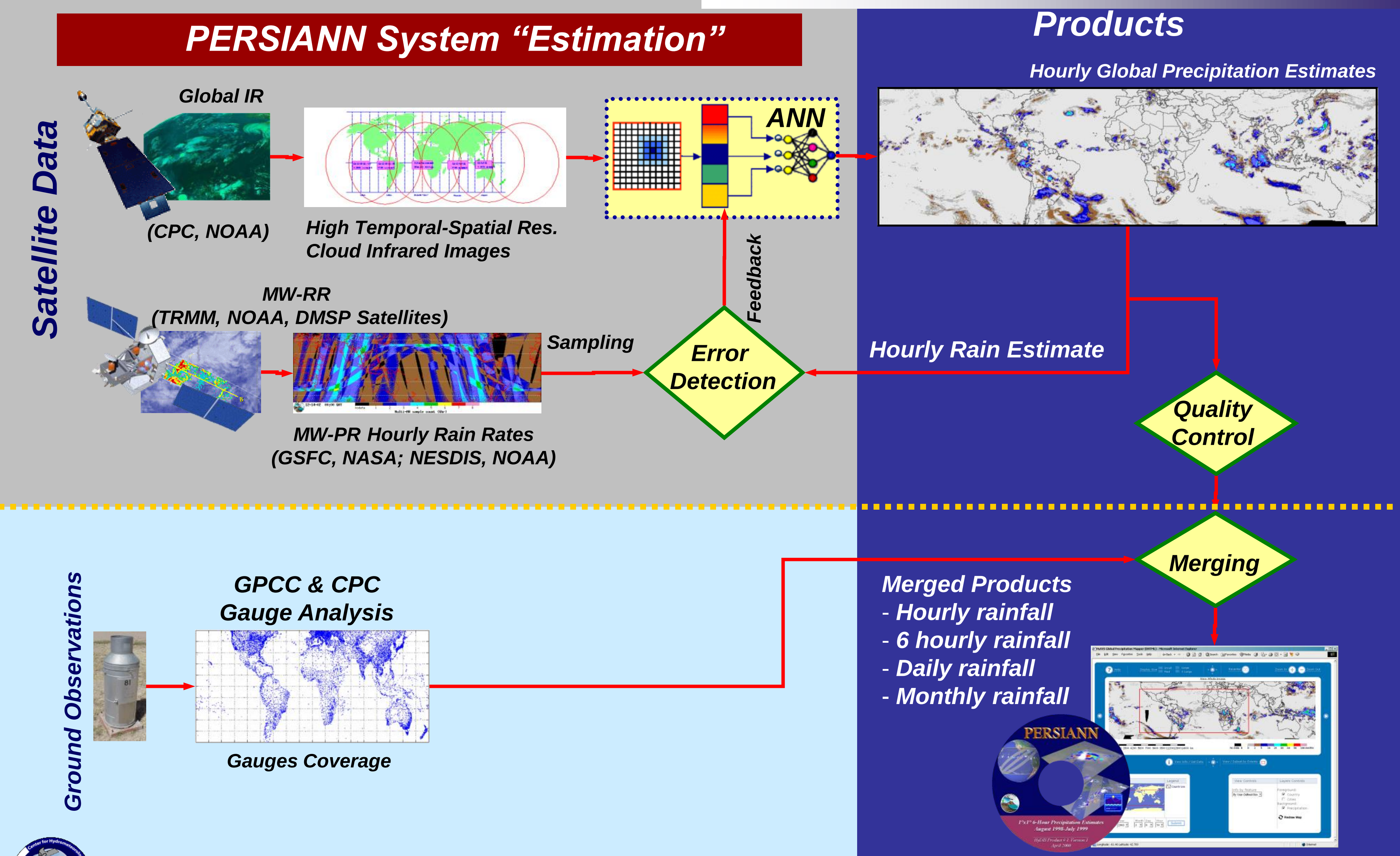
TMI – white
SSM/I – light grey
AMSR-E – medium grey
AMSU-B – dark grey

Interpolation of 3-hour Precipitation



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

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



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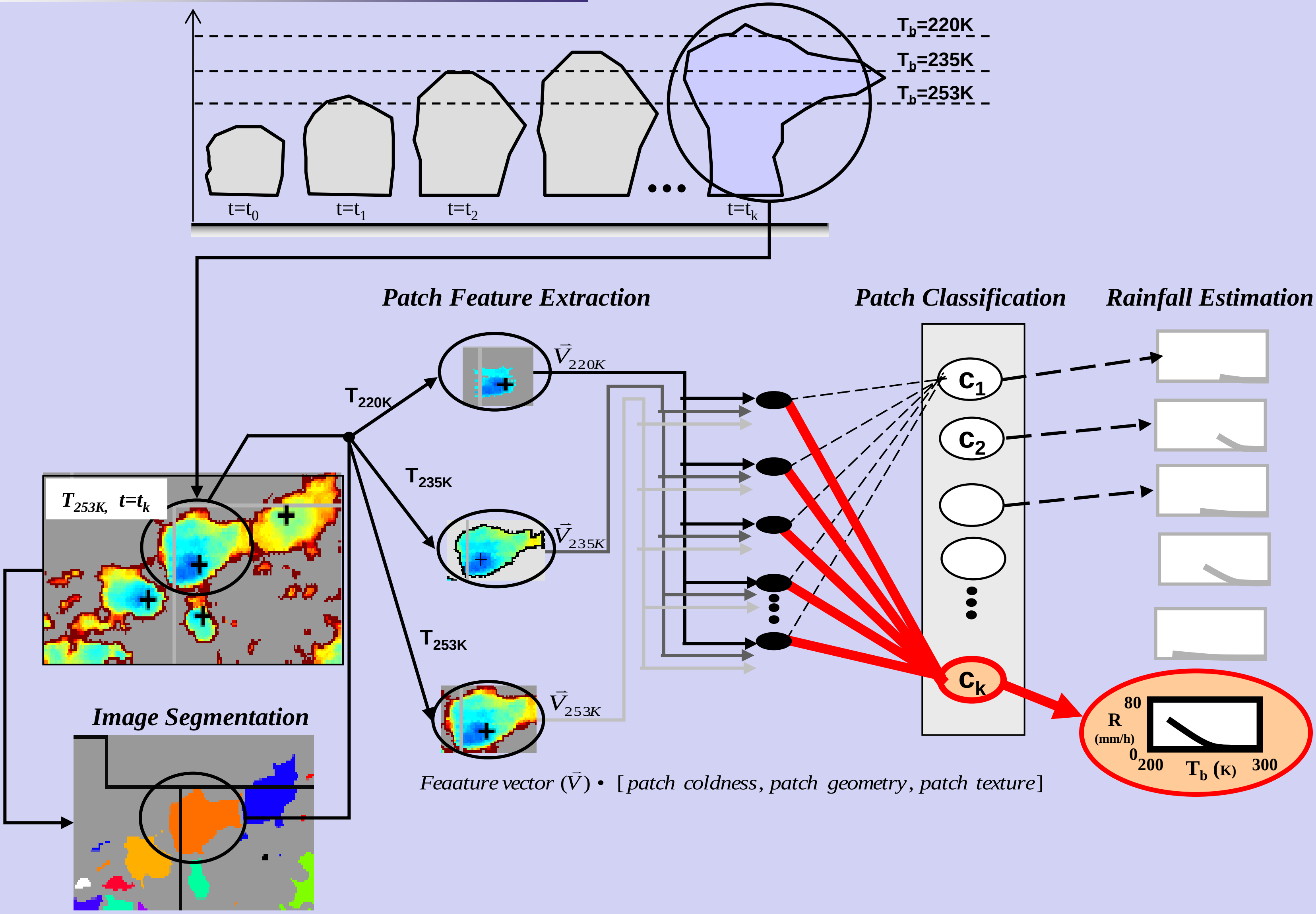
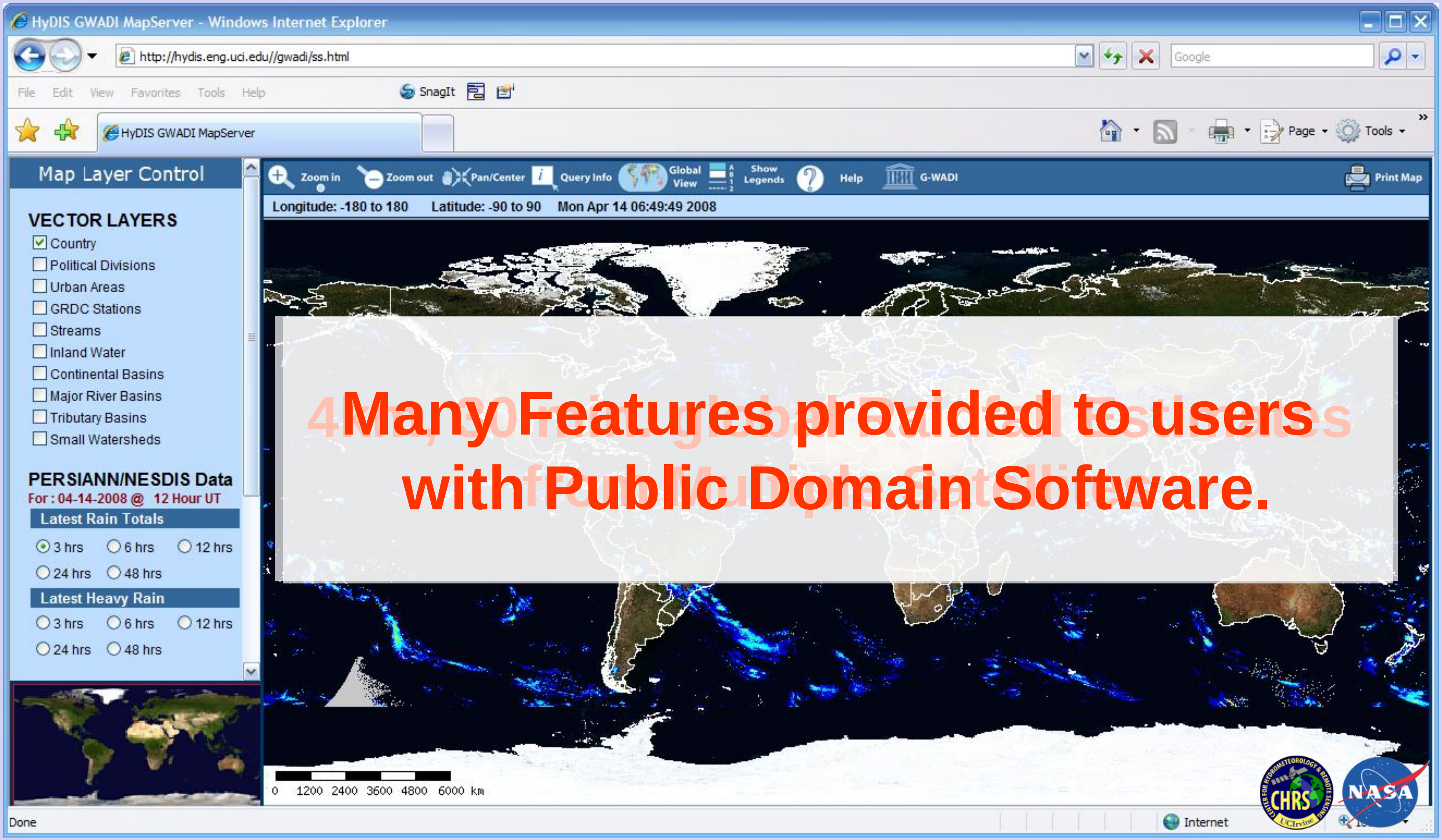
High Resolution Precipitation Estimates
PERSIANN-CCS

Cloud Segmentation Algorithm

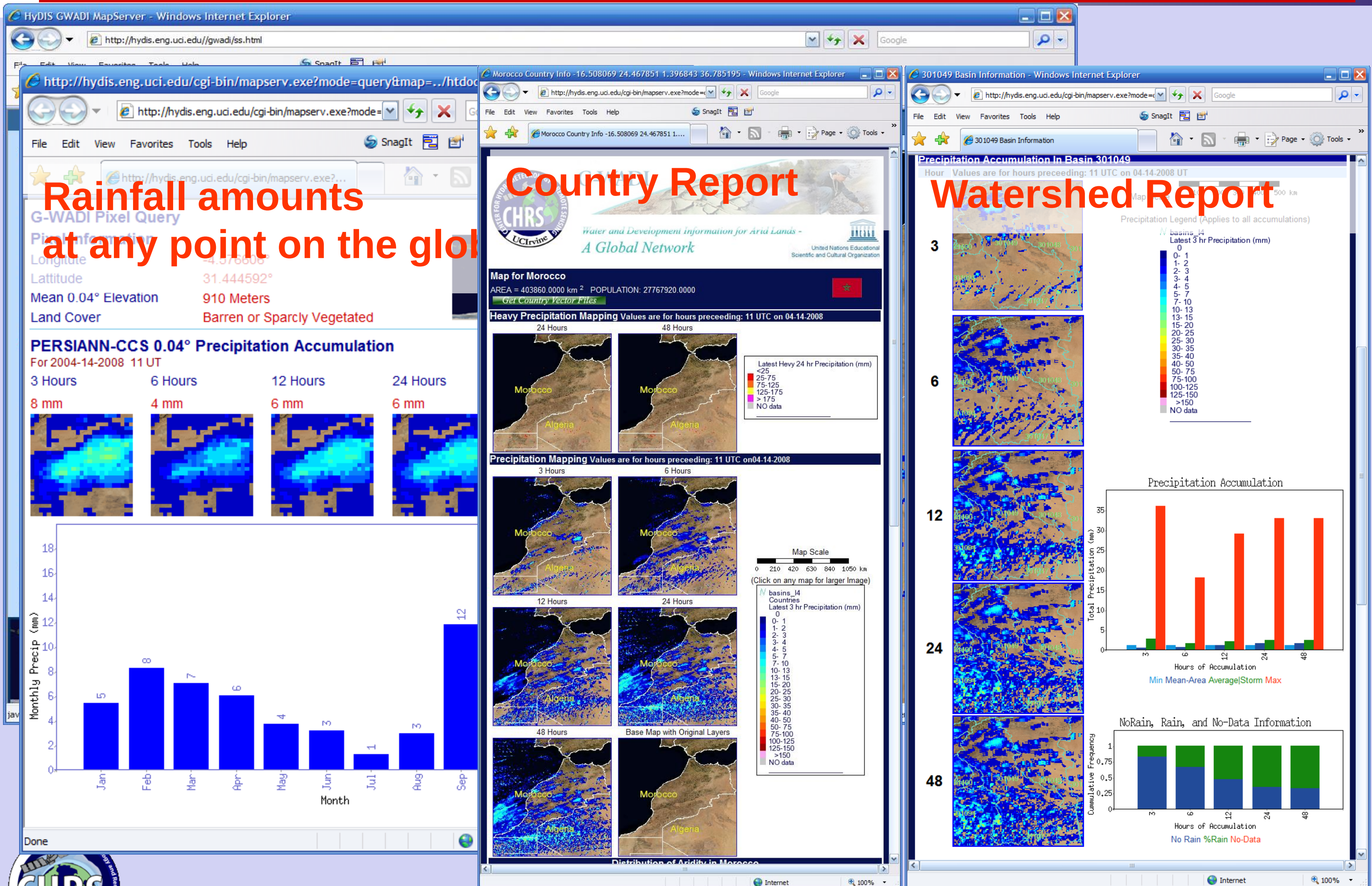


Real Time Global Data: Cooperation With UNESCO



Many Features provided to users with Public Domain Software.

Real Time Global Data: Cooperation With UNESCO



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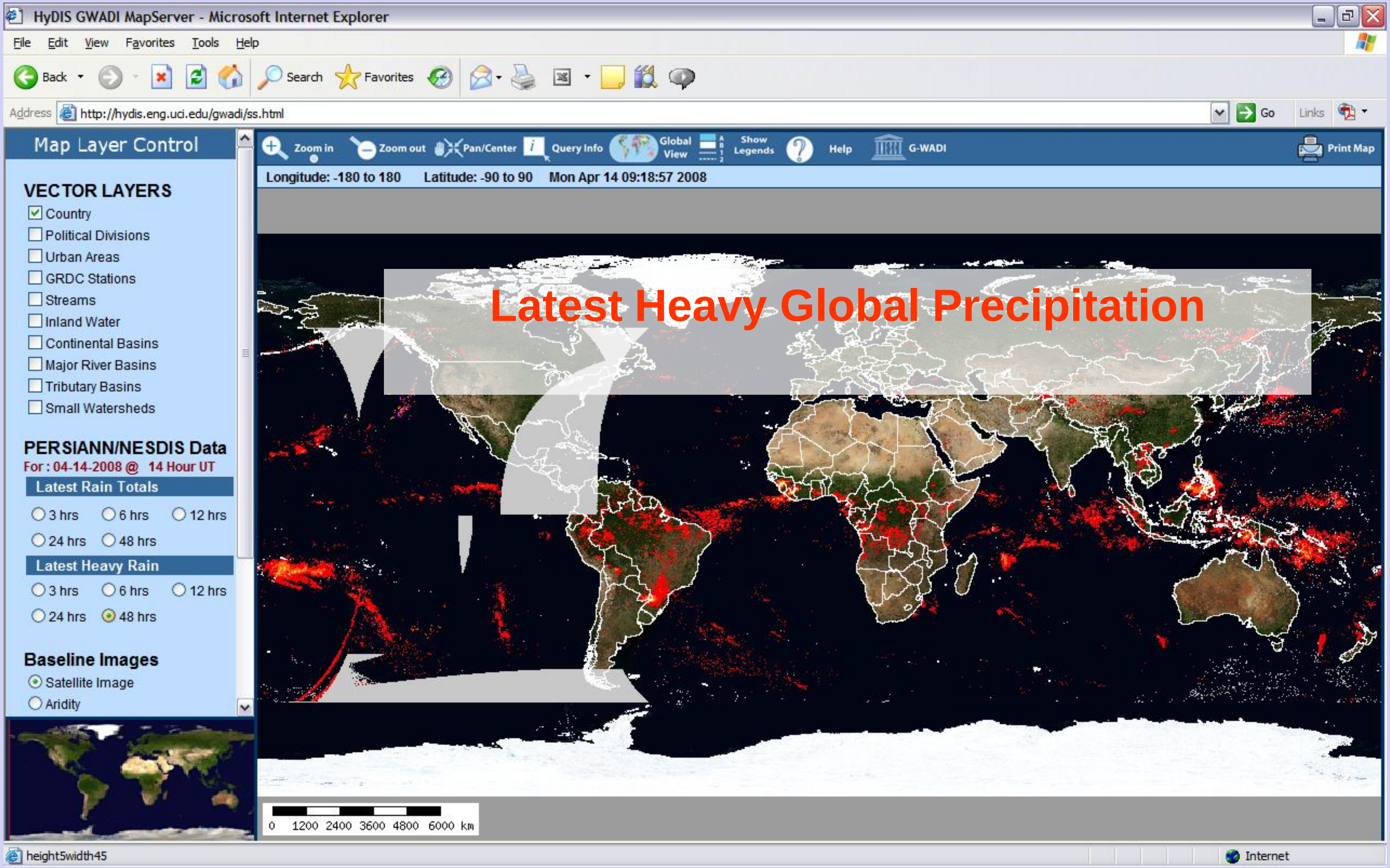

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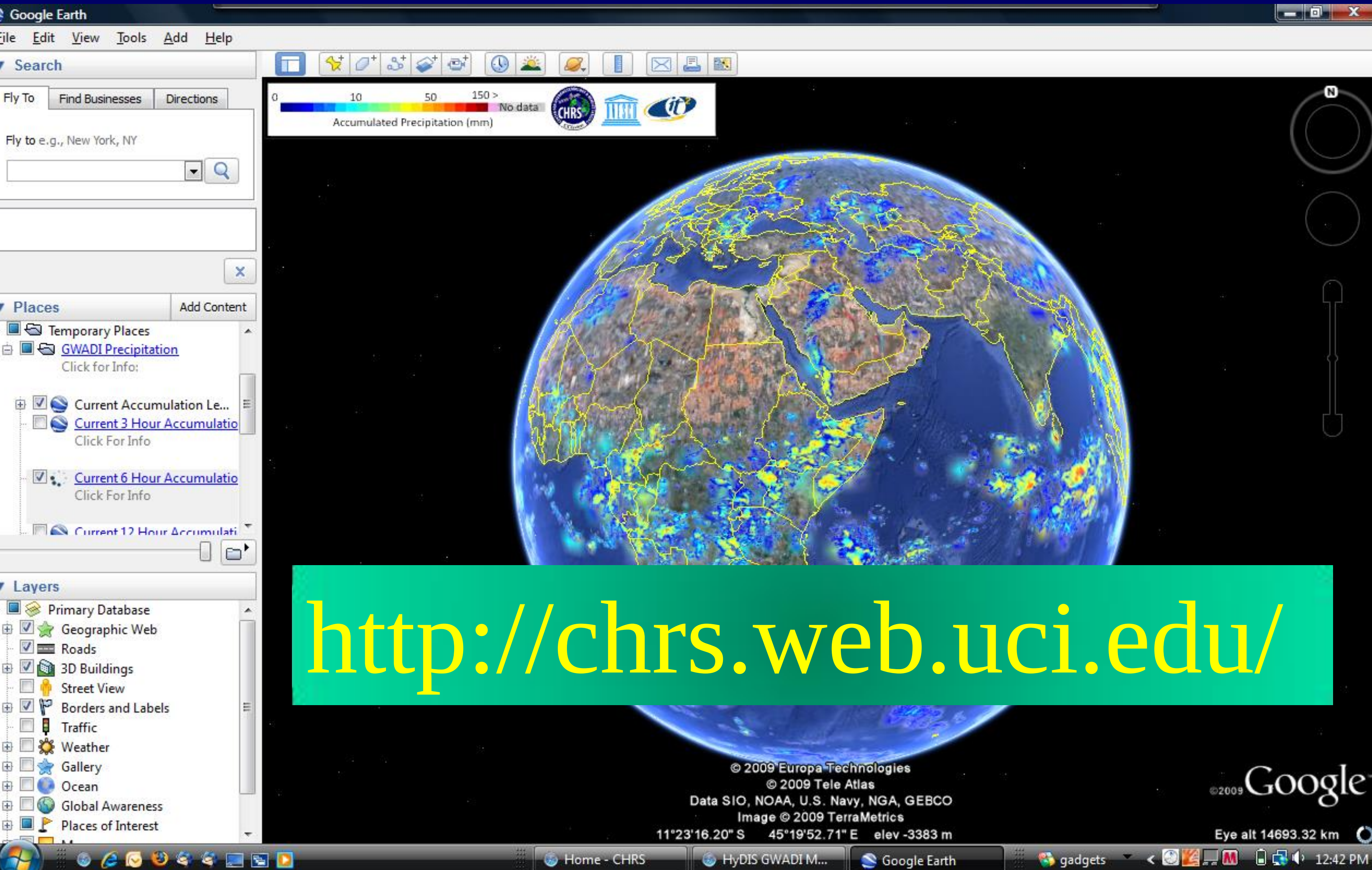
PERSIANN Satellite Product On Google Earth



http://chrs.web.uci.edu/

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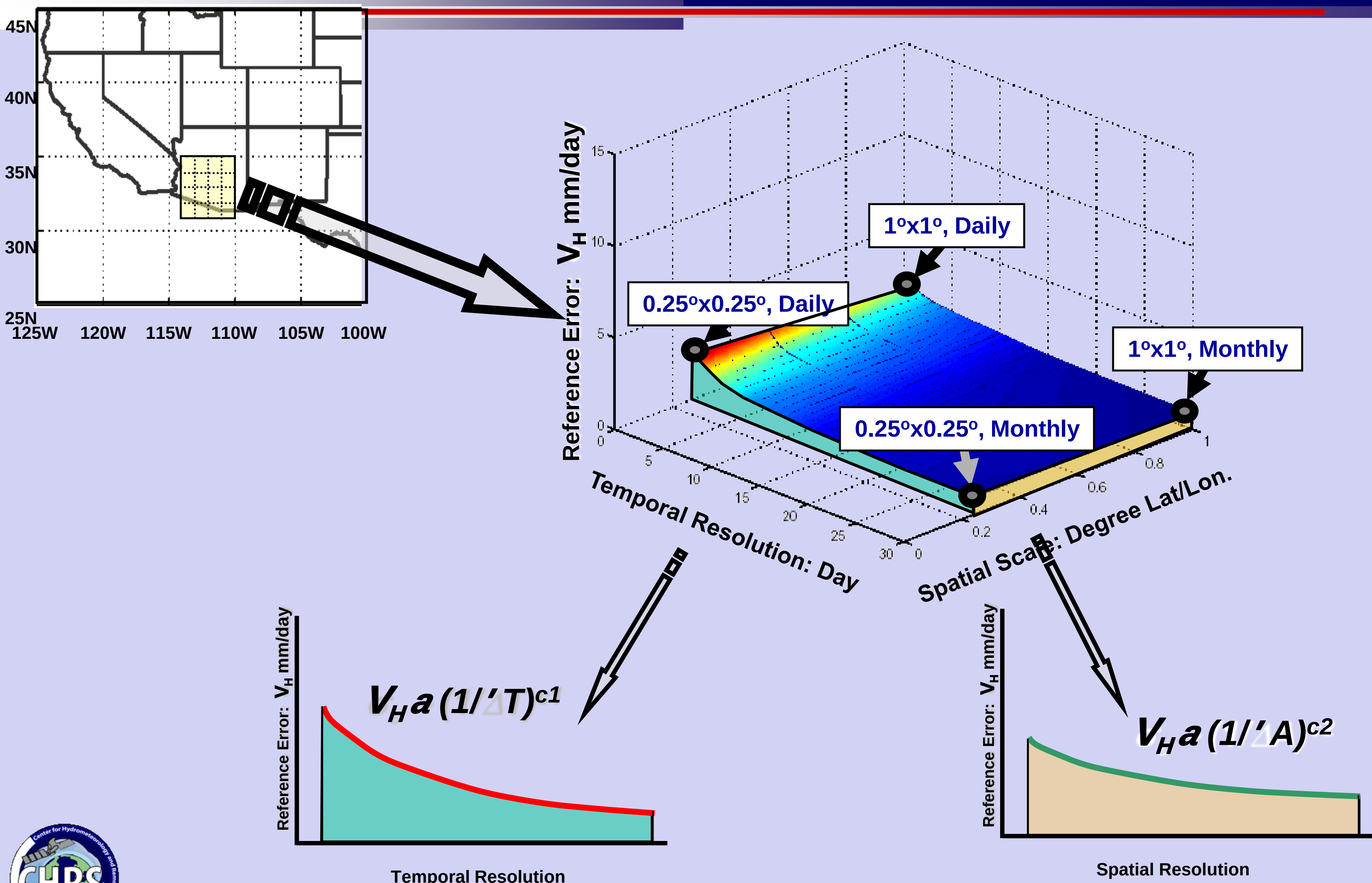
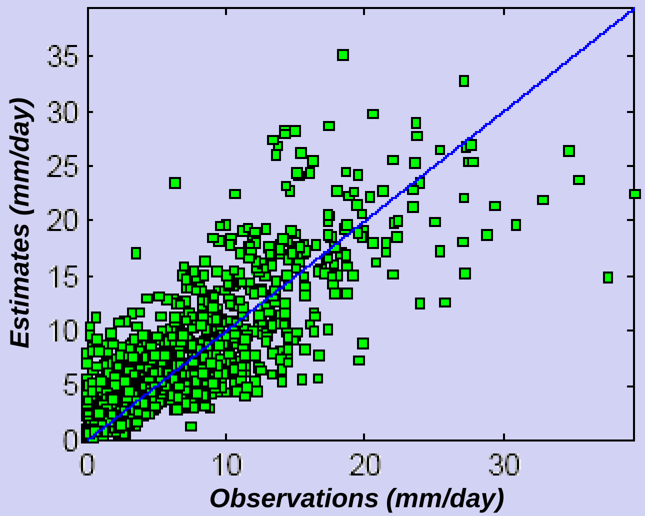
- Uncertainty of Estimates

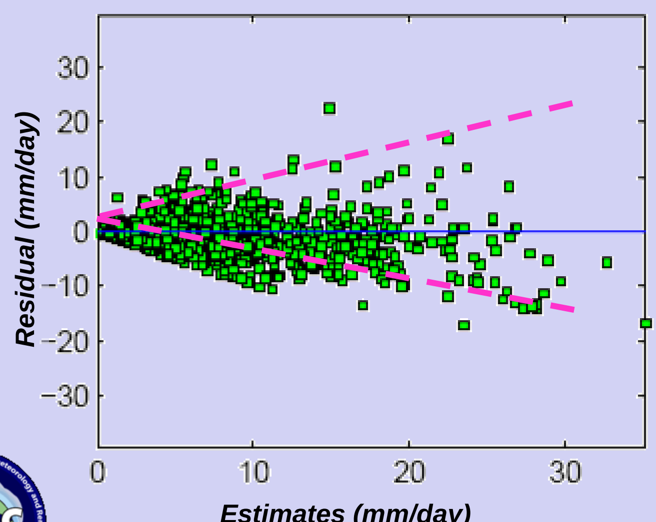
  Error Analysis

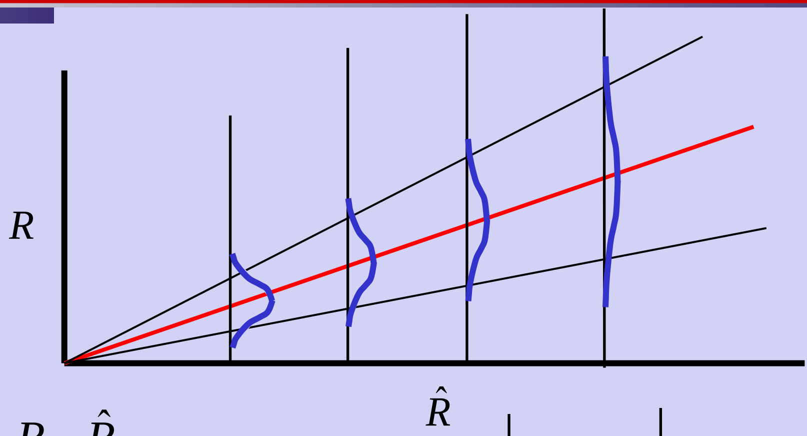
Spatial-Temporal Property of Reference Error

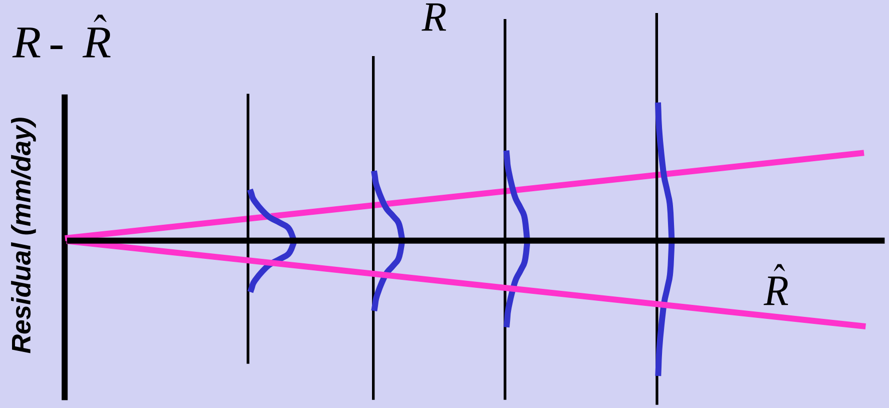


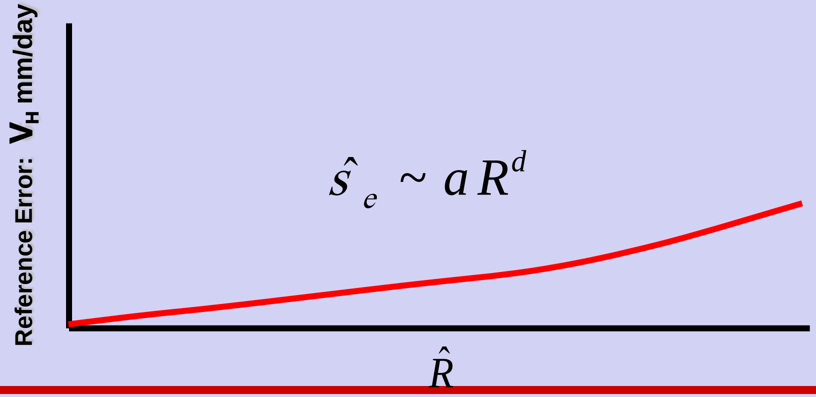
Reference Error: ’T = 24-hour, ’A = 0.25ºx0.25º





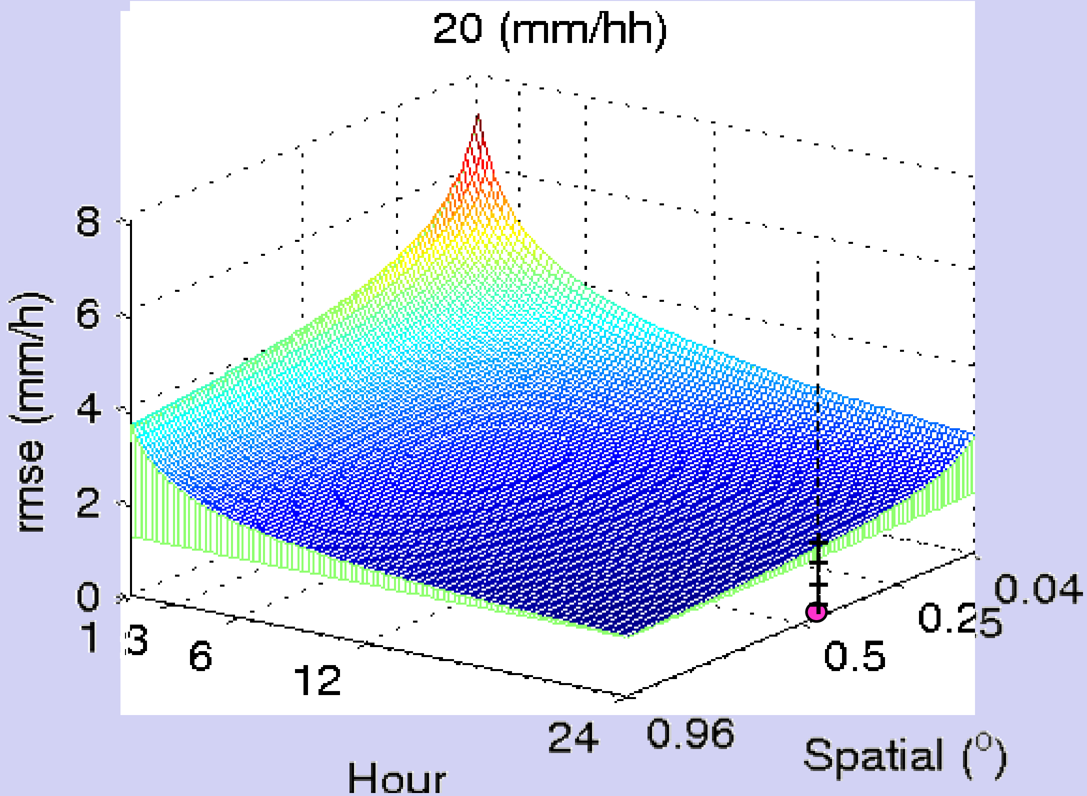






Scaling Property of PERSIANN-CCS Reference Error

$$\hat{V}_H = a_1 \cdot \left(\frac{1}{A}\right)^{b_1} \left(\frac{1}{T}\right)^{c_1} \hat{R}^{d_1}$$



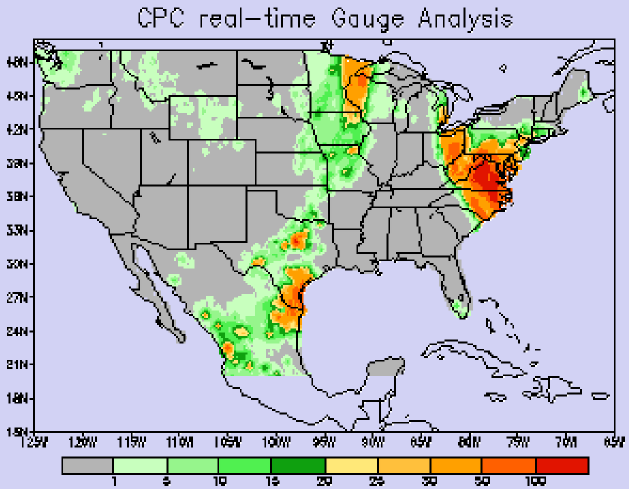
Validation and Application of Satellite Products

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



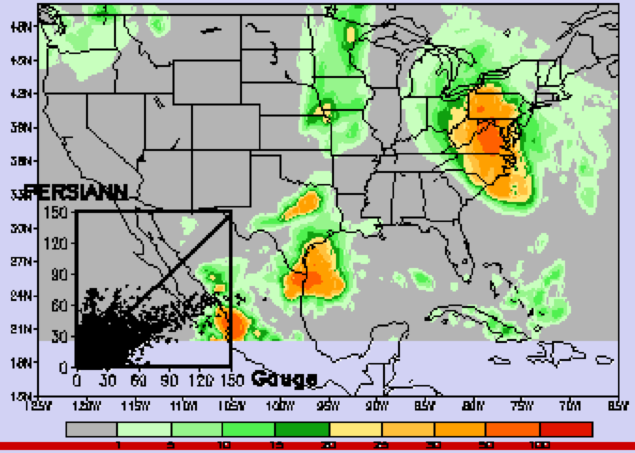
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.56	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45

	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

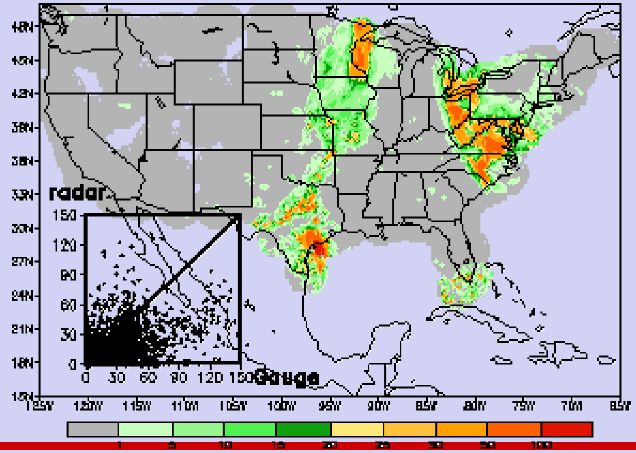
gauge	PERSIANN < 1	PERSIANN ≥ 1
< 1	8082.	1497.
≥ 1	1081.	3168.

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

PERSIANN

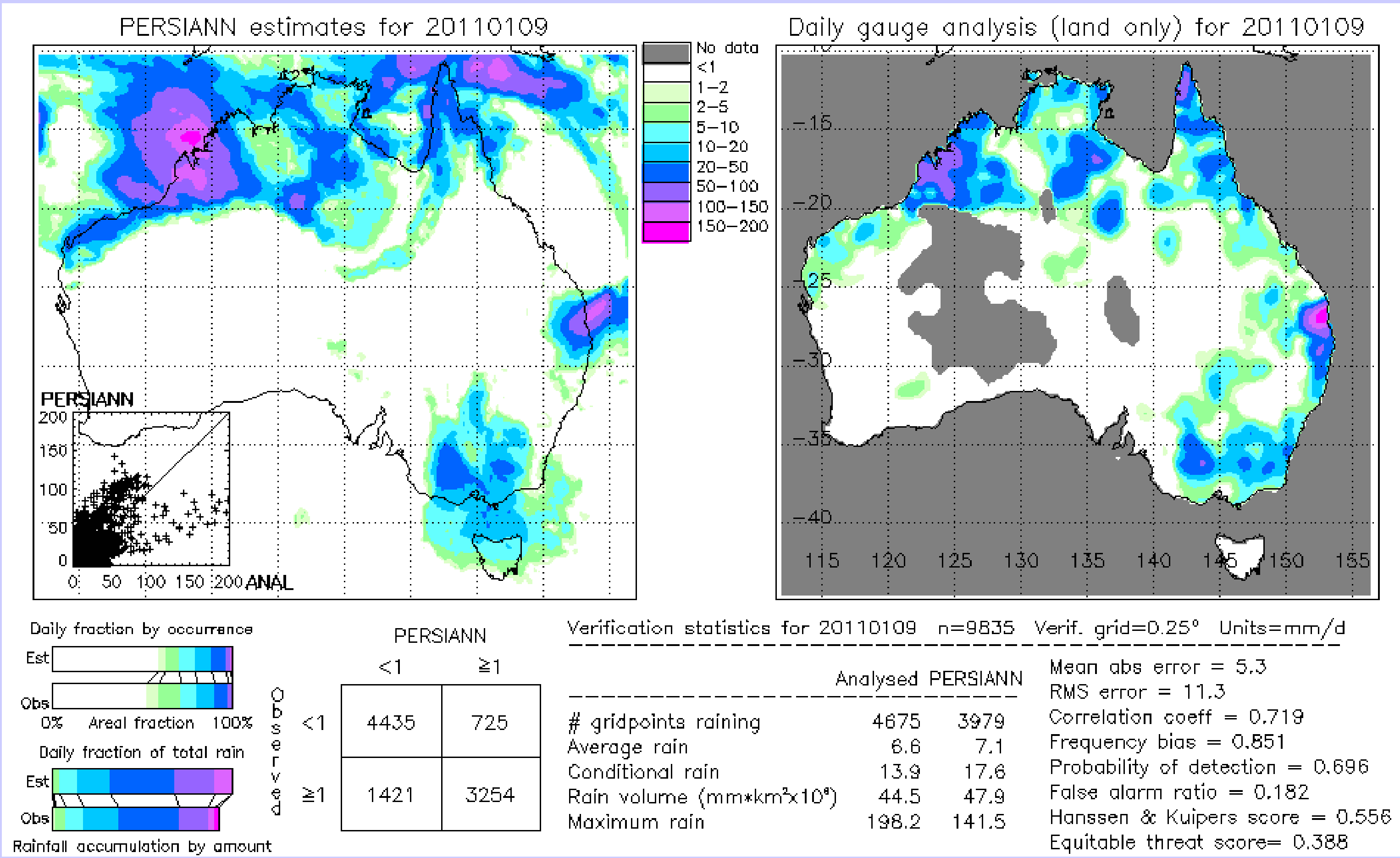


Radar



Evaluation of PERSIANN Daily Rainfall

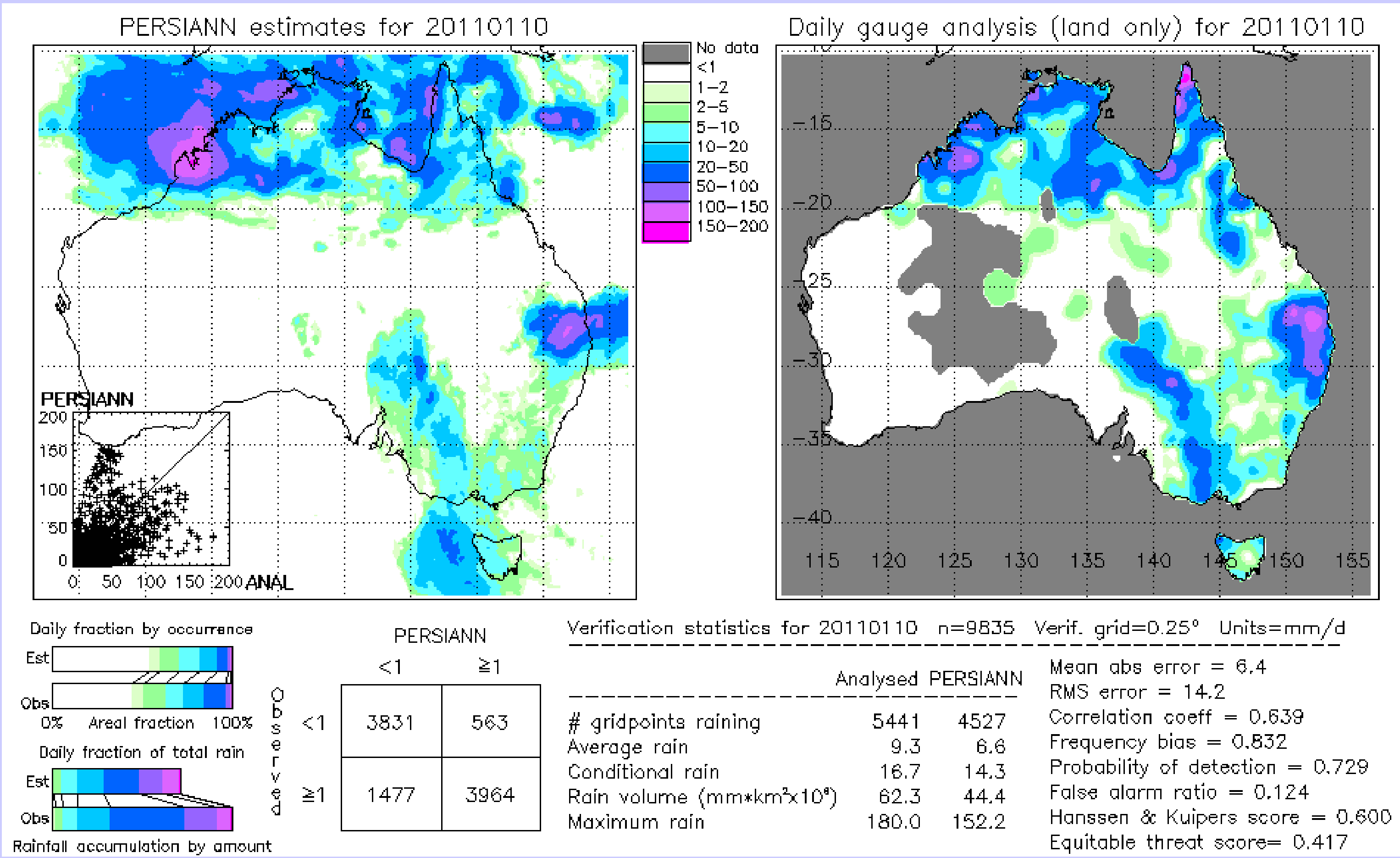
01-09-2011 (0.25-degree resolution)



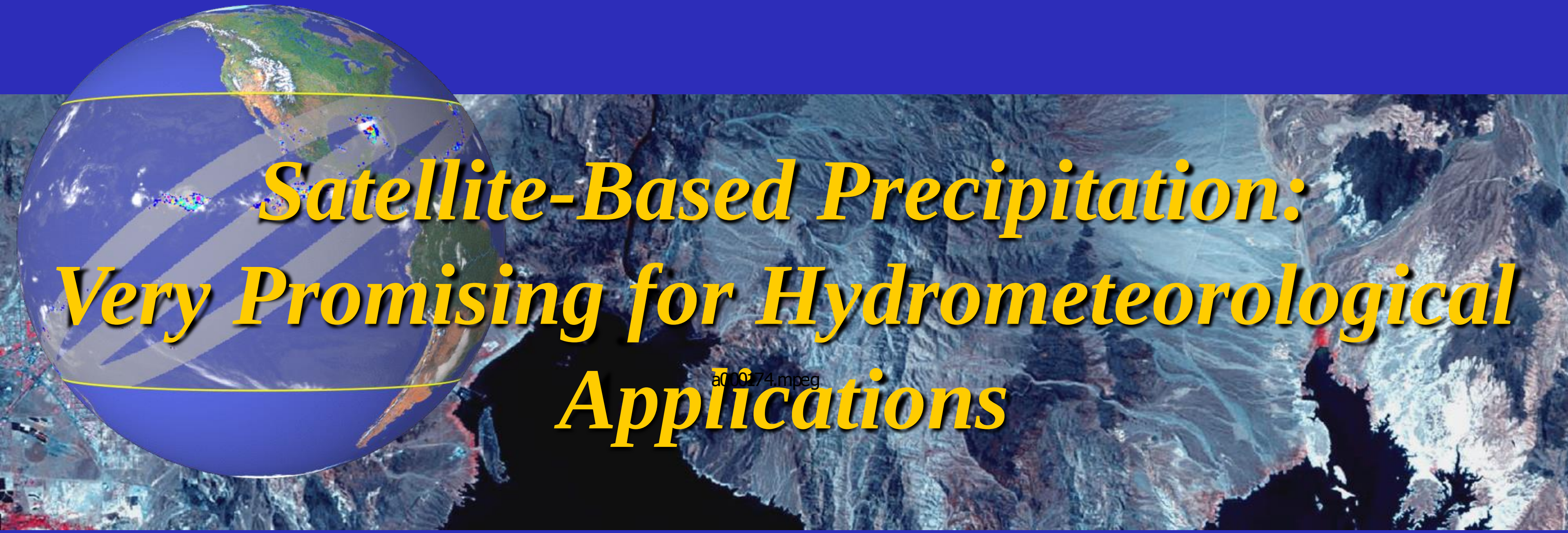
Source: IPWG Validation over Australia: http://cawcr.gov.au/projects/SatRainVal/sat_val_aus.html

Evaluation of PERSIANN Daily Rainfall

01-10-2011 (0.25-degree resolution)



Source: IPWG Validation over Australia: http://cawcr.gov.au/projects/SatRainVal/sat_val_aus.html

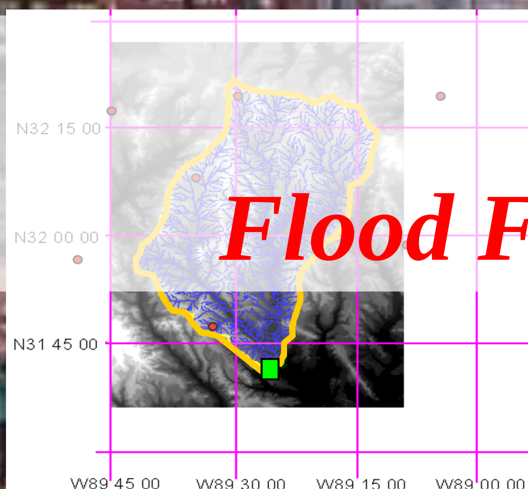


Satellite-Based Precipitation: Very Promising for Hydrometeorological Applications

Satellite Rainfall Estimation for Operational Use

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

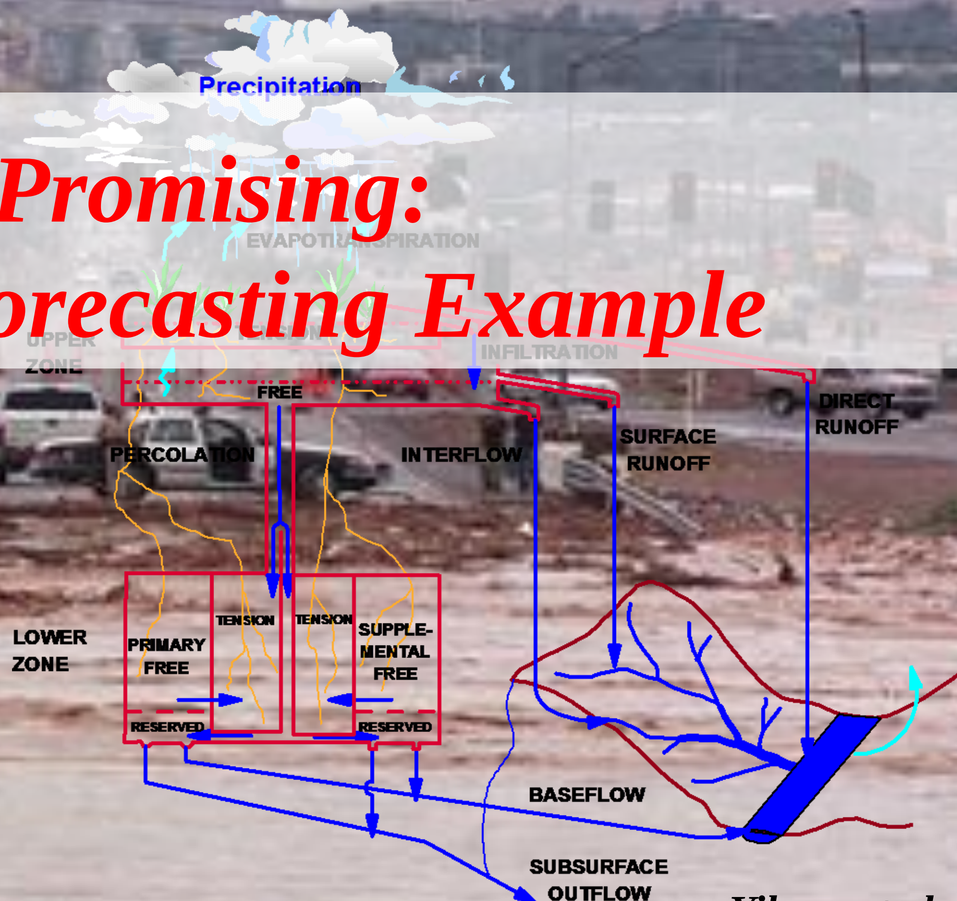
Promising: Flood Forecasting Example



● Gages used by NWS

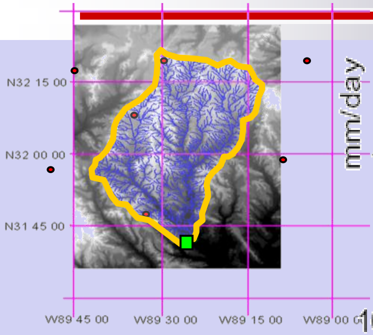
Leaf River Near Collins
Mississippi
USGS # 02472000

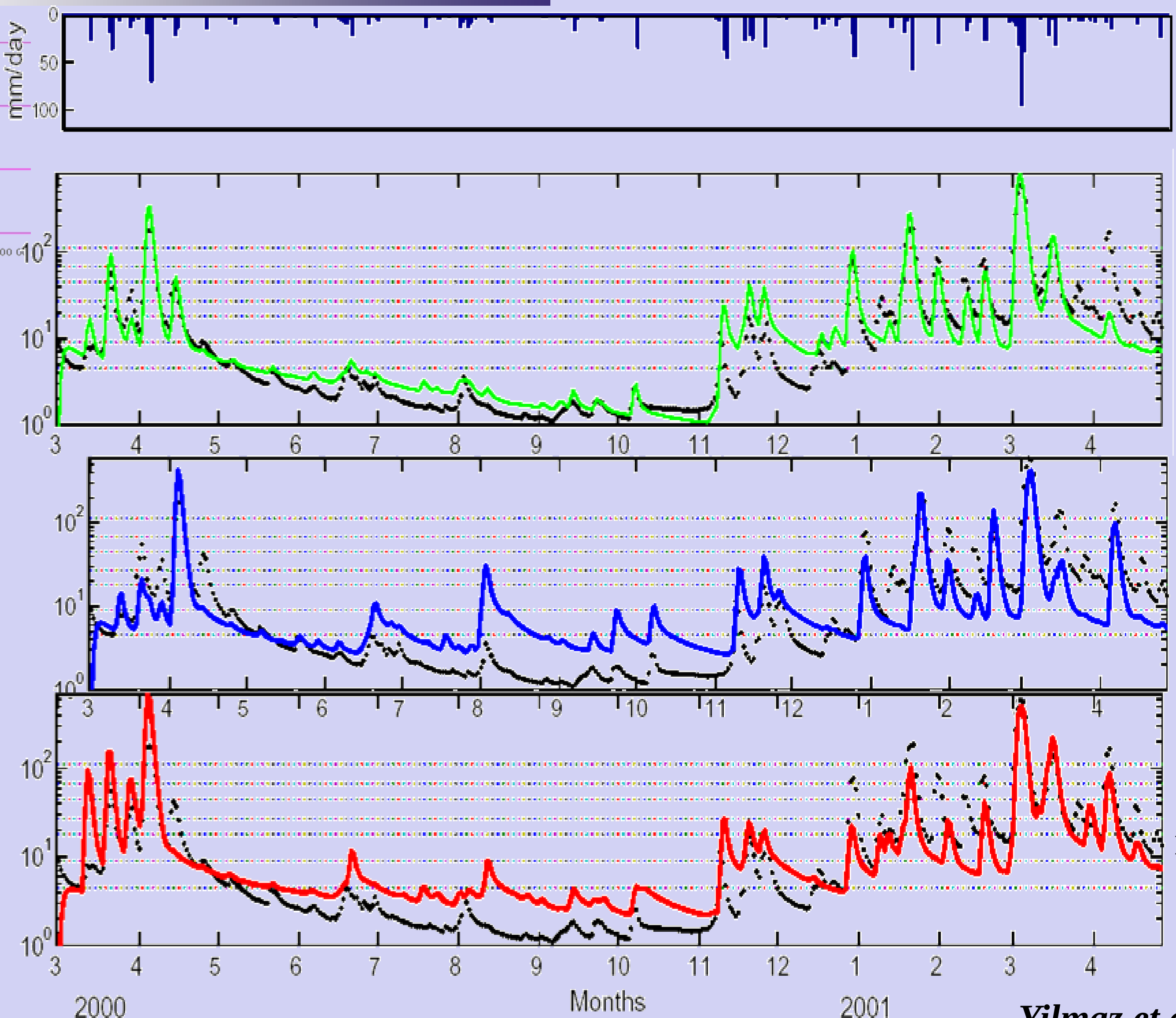
Basin Area : 753 mi^2



Yilmaz et al. JHM 2005

Satellite Rainfall Estimation: Research at UC Irvine

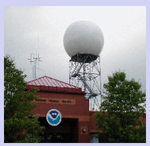




RAINGAGE

Corr =0.95
RMS =23.9
BIAS =-1.32

RADAR



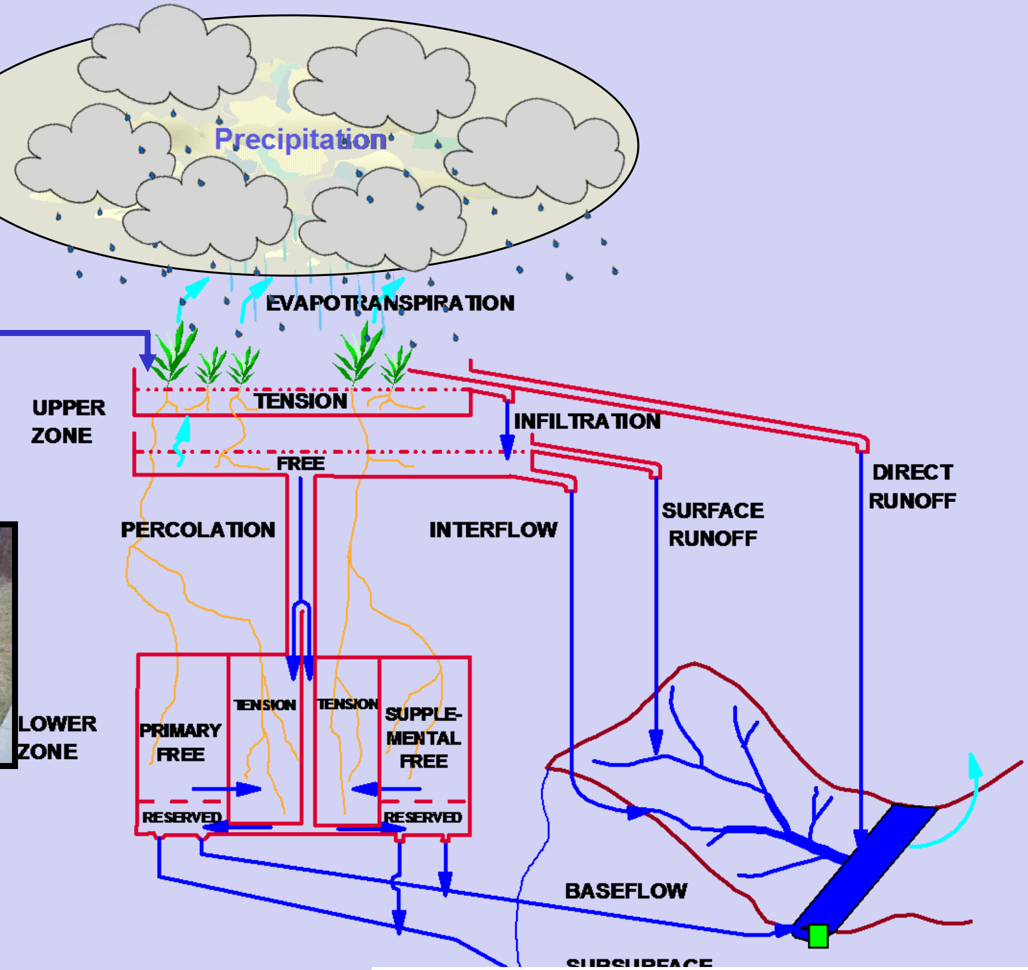
Corr =0.92
RMS =28.8
BIAS =-6.74

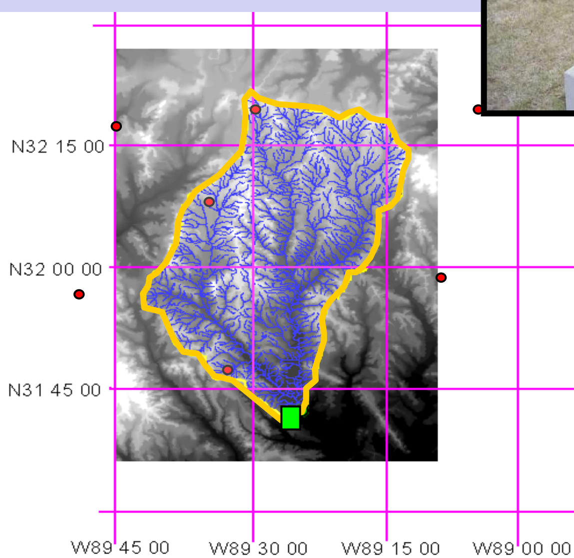
PERSIANN

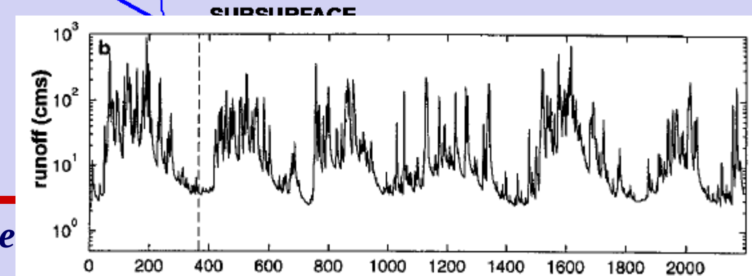
Corr =0.94
RMS =22.6
BIAS =-5.15

Yilmaz et al. JHM 2005

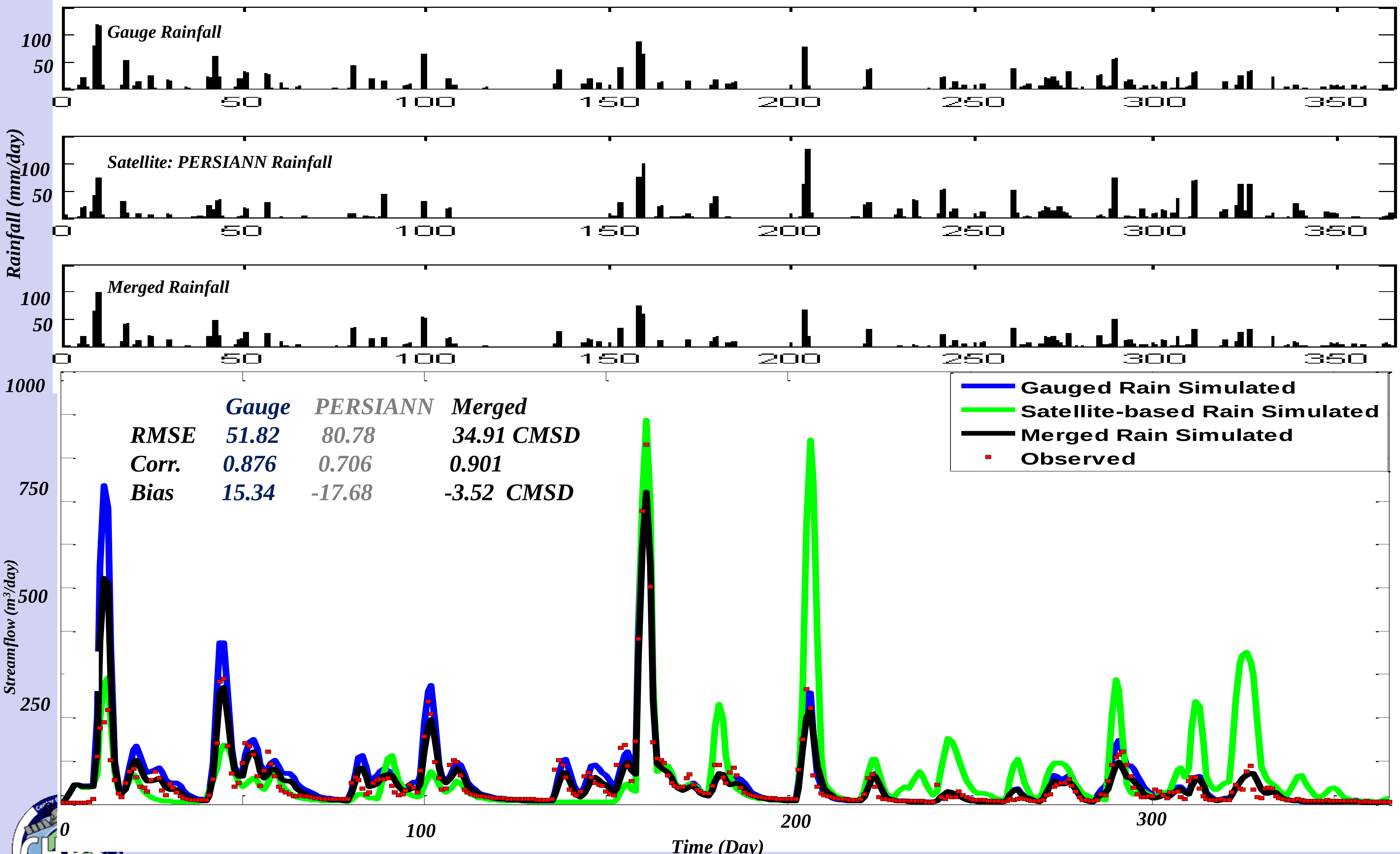
Basin Scale Precipitation Data Merging







Runoff Forecasting from Gauge, PERSIANN, and Merged Rainfall



Finally: Will to Doubt!

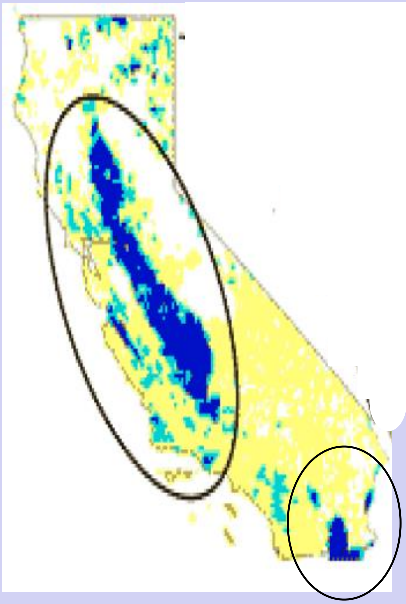
Accuracy of:

- ***Observations***
- ***Model simulations***

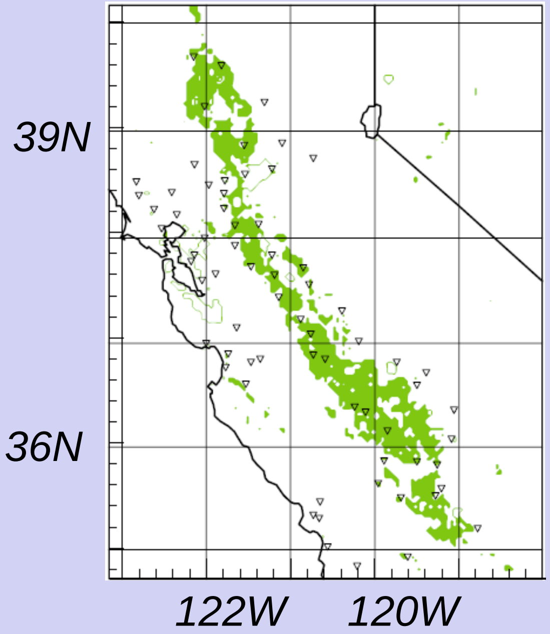
Impact of Irrigation

"Observed" vs "Model-Generated" Data

Irrigation areas



CIMIS stations

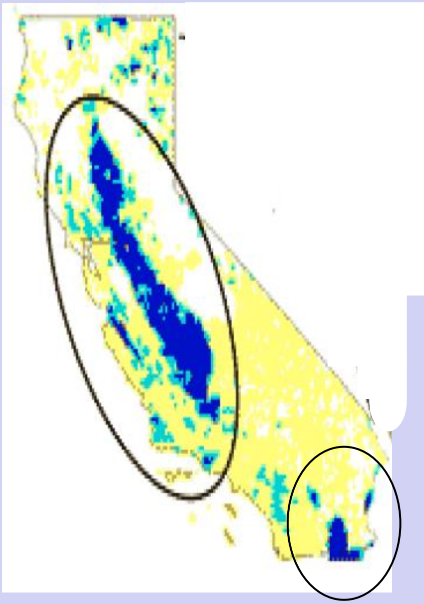


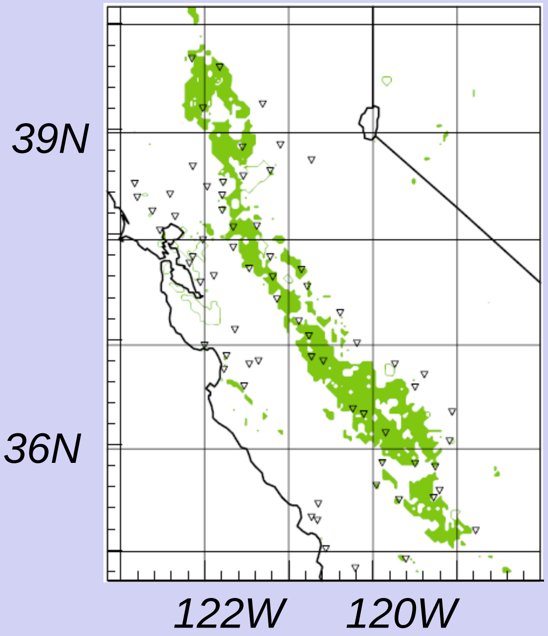
Studies over California's Central Valley Irrigation Region

Sorooshian et al. 2011 & 2012

Irrigation over central California

Irrigation areas





• ***Meteorological conditions are the key factors to decide when and how much water to apply,***

• ***Californian Irrigation Management Information System (CIMIS) with more than 200 stations (nearly 150 active) provides the information to farmers.***

Previous studies:

1) Based on temperature variation

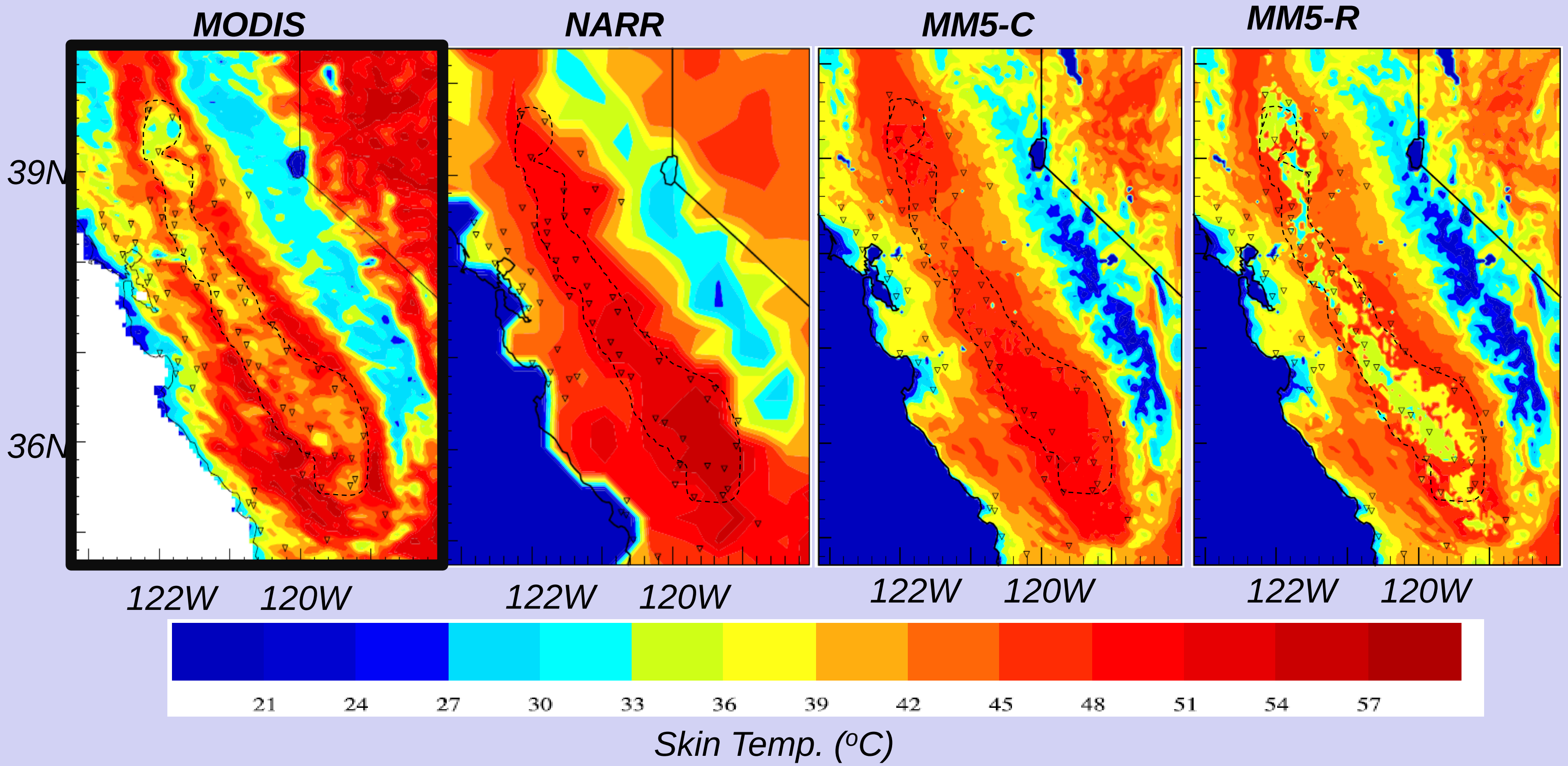
2) Assuming soil water at field capacity (saturation)

- *the modeled soil layers are kept at field capacity or at full saturation during the simulation runs (e.g.Adegoke, et al. 2003; Haddand et al. 2006; Kueppers at al. 2007)*

Our study

Implementing a more realistic irrigation method recommended by Hanson et al. (2004)

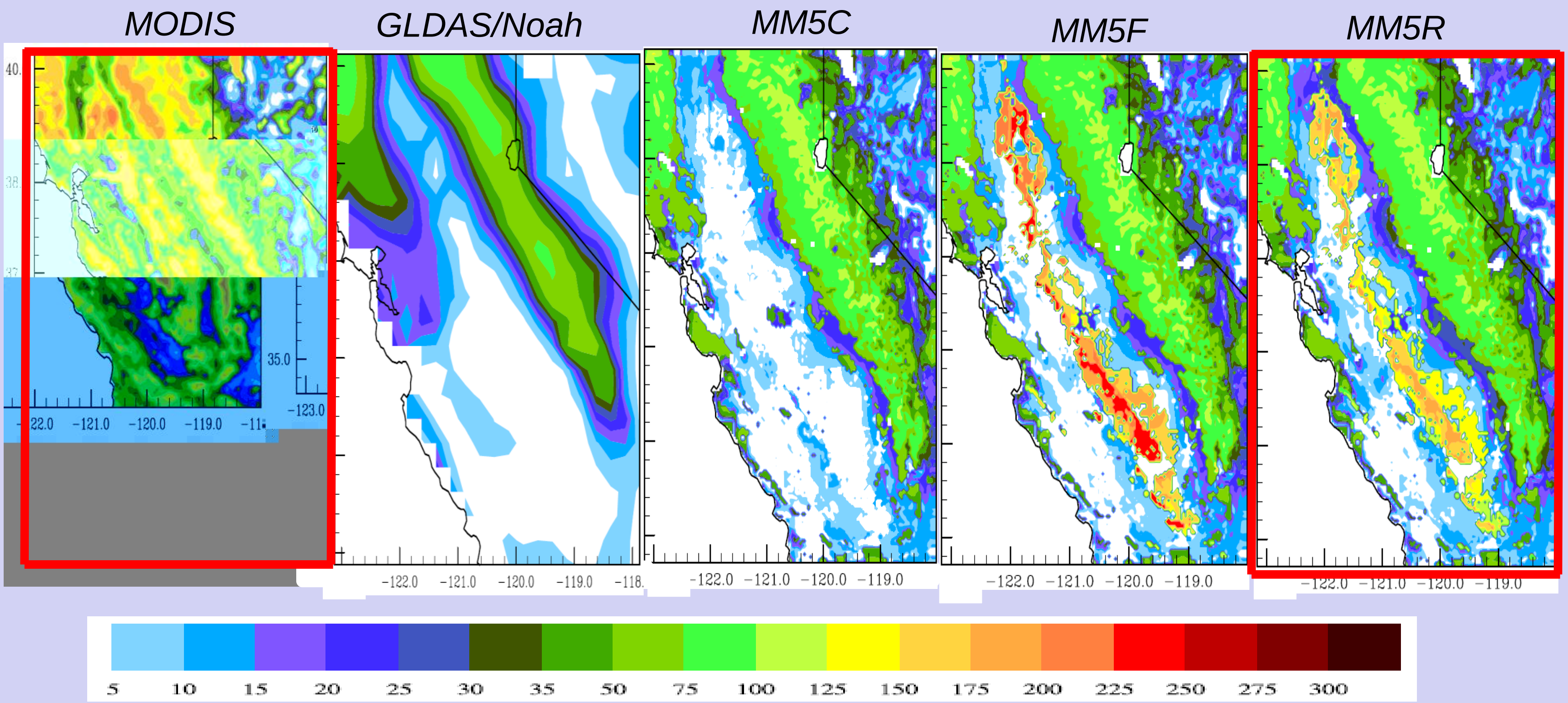
Mean skin surface temp. at daytime in June, July and August, 2007.



Adding irrigation into RCM (MM5), Improves the model's ability to simulate, more closely, the temperature patterns observed by MODIS

Sorooshian et al, (JGR 2011)

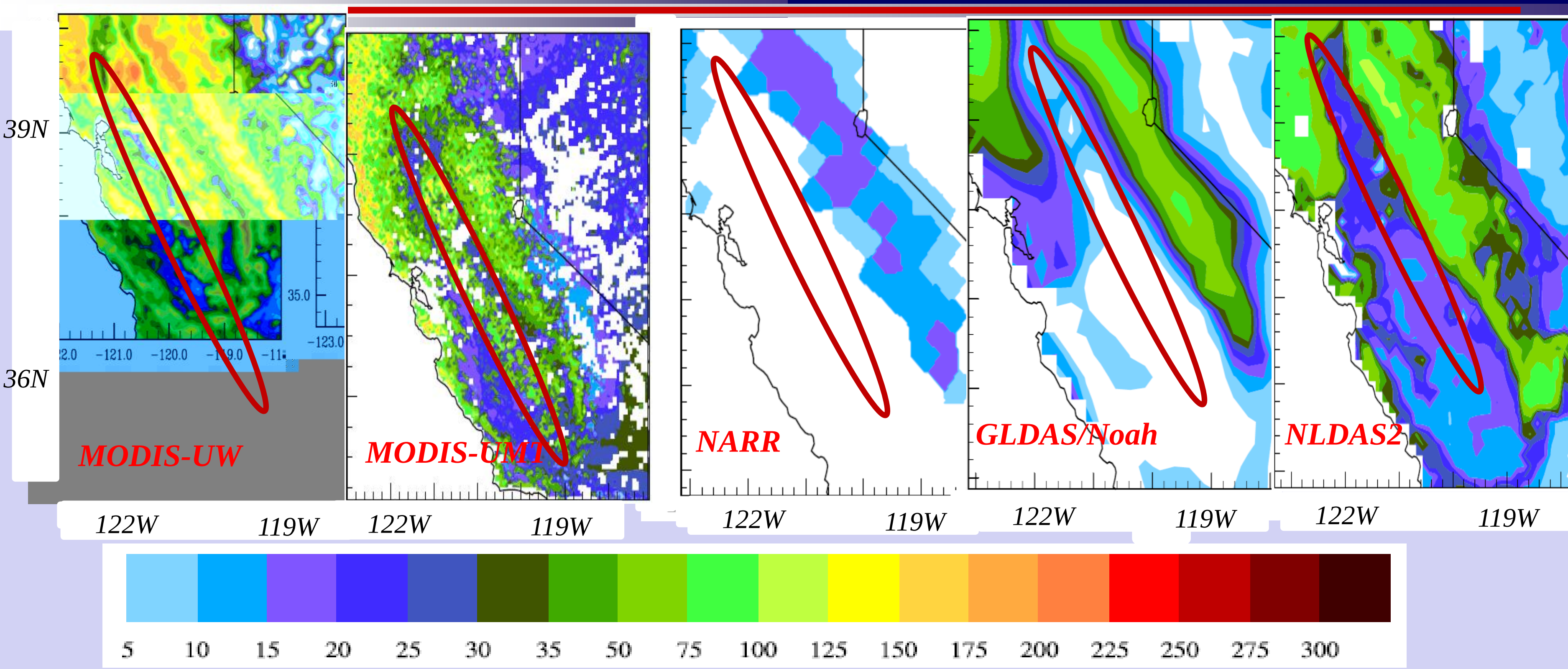
Actual ET comparison-spatial distribution – JJA 2007



Monthly ET (mm/month)

Results from MM5, with more realistic irrigation scheme, show significant improvement in capturing ET over irrigated Central Valley in California (compared to MODIS - ET estimates). MM5F overestimated.

Actual ET Estimates From Different Data sets– JJA 2007



2007 JJA Monthly ET (mm)

Li et al, 2011

In a nutshell!

- ***ET Underestimation by MM5 control run is roughly about 10 million Ac-Ft of water/yr***
- ***ET Overestimation by MM5 with "full-saturation" irrigation is about 6.5 Million Ac-Ft/yr***
- ***Use of the realistic irrigation scheme results in only 1.5 Million Ac-Ft/yr of overestimation.***

placed in Societal context :

Roughly speaking, the amount of ET underestimation equals supply requirement of 13 million households and the overestimation covers the needs of 9 million households per year.

In Brief:

While some of the results shown are based on very short life span of Satellite-Based Information

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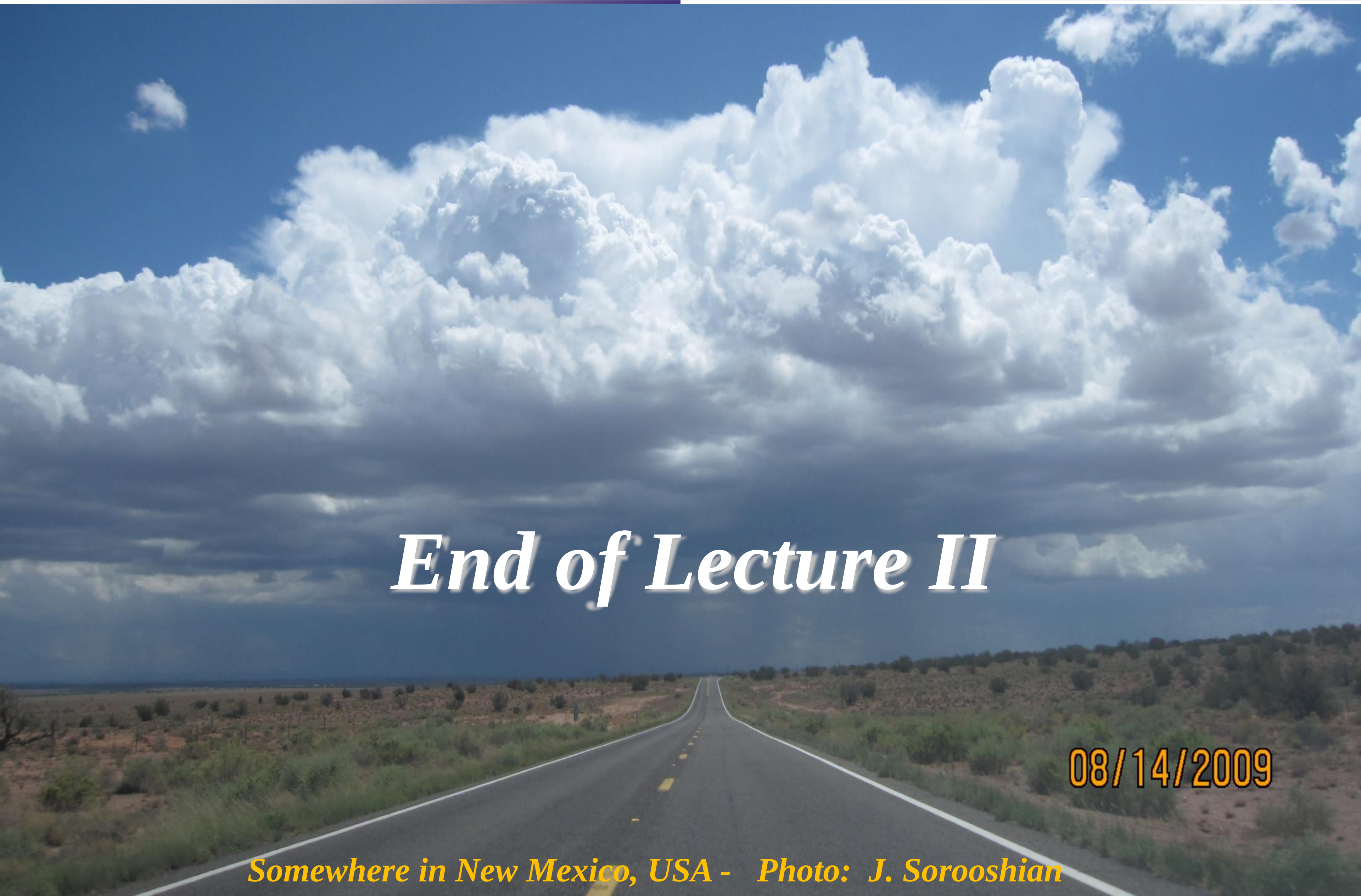
End of Lecture II



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