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

Soroosh Sorooshian

Center for Hydrometeorology and Remote Sensing

University of California Irvine

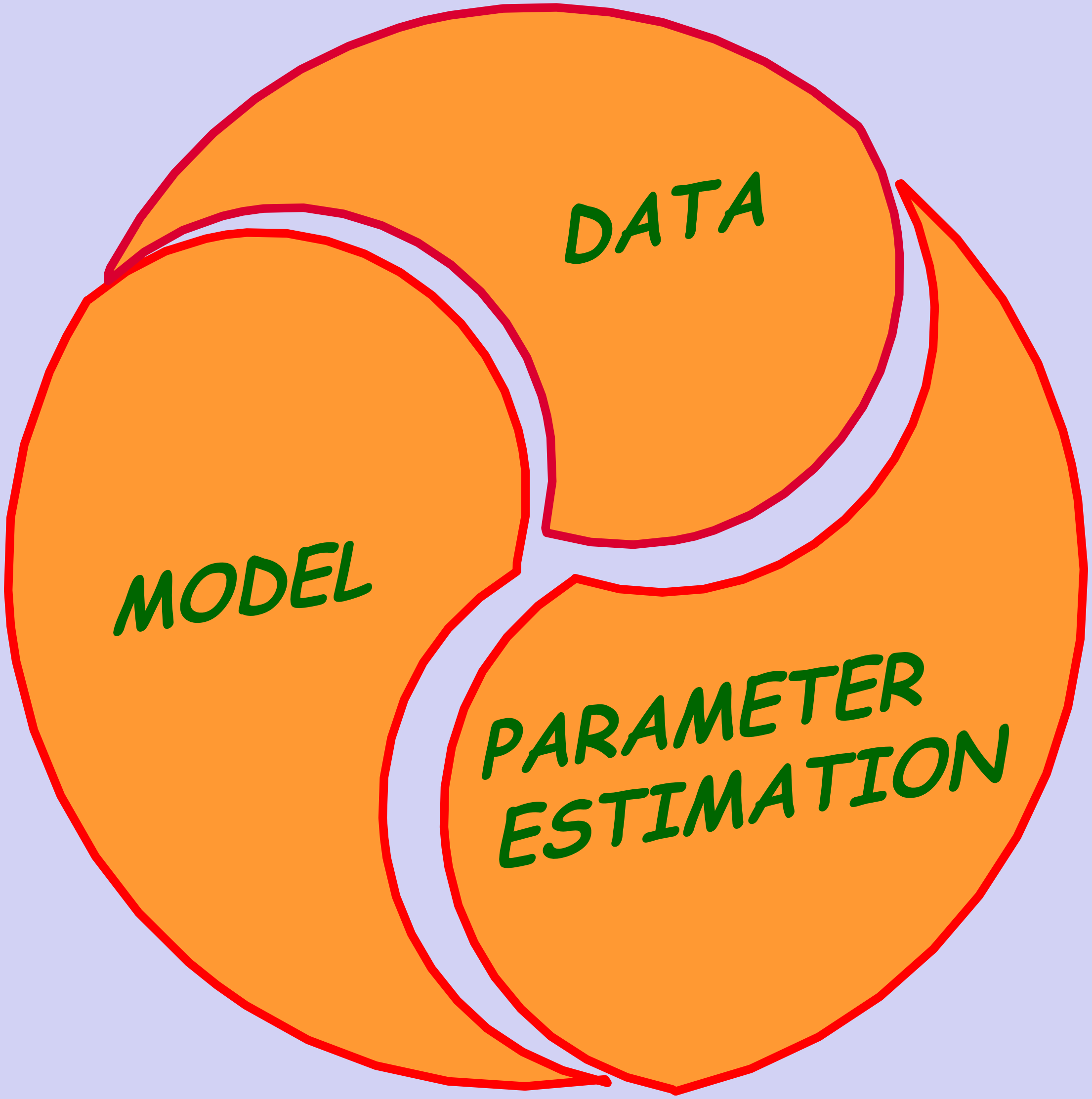
The Abdus Salam ICTP Summer School on:

Climate Impact Modeling for Developing Countries:

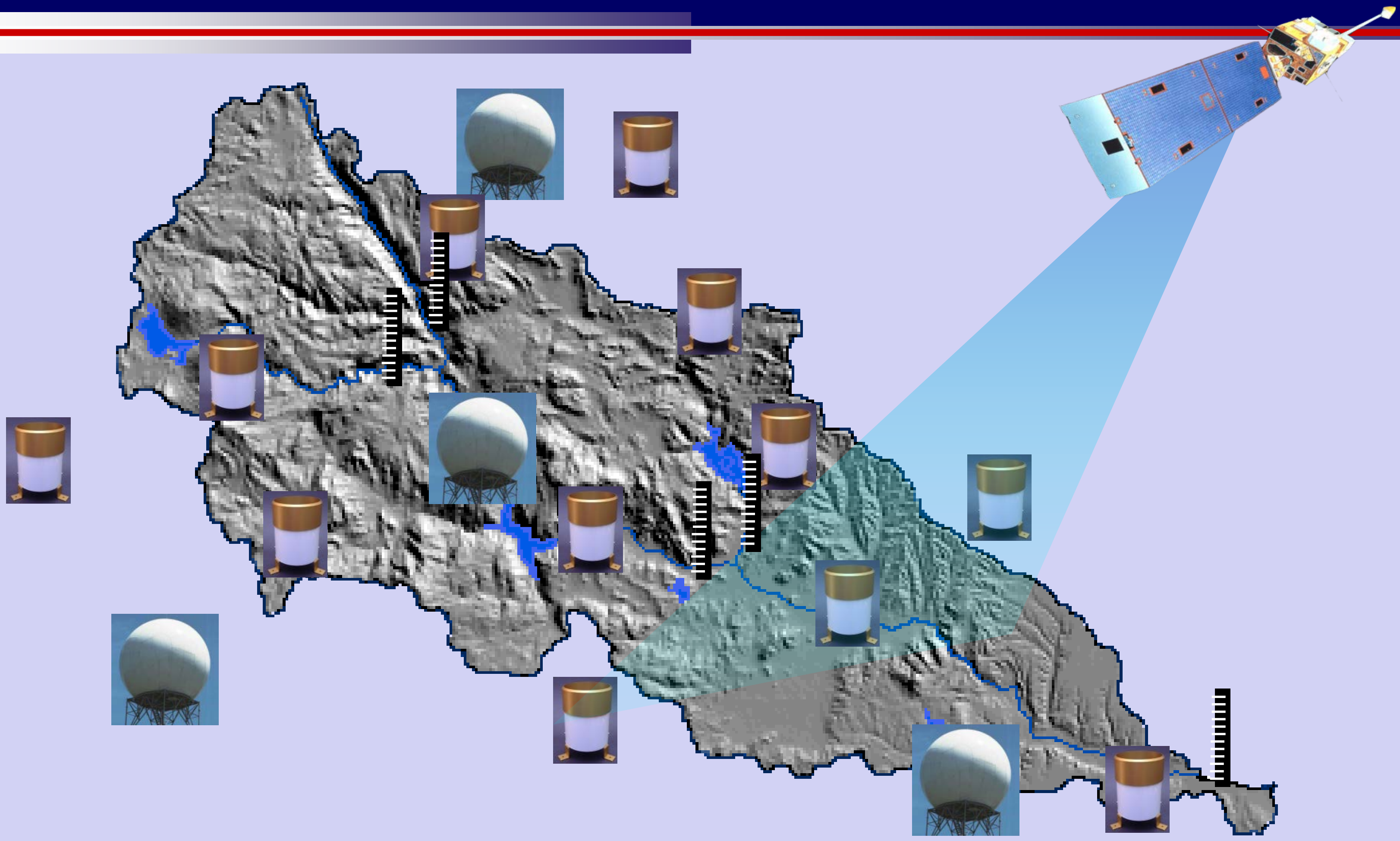
Water, Agriculture & Health

Trieste, Italy: Sept. 5th – 16th 2011

Data



Data Requirements for Hydrologic Modeling



Data Limitation is an Important Factor in Success of Hydrologic Modeling

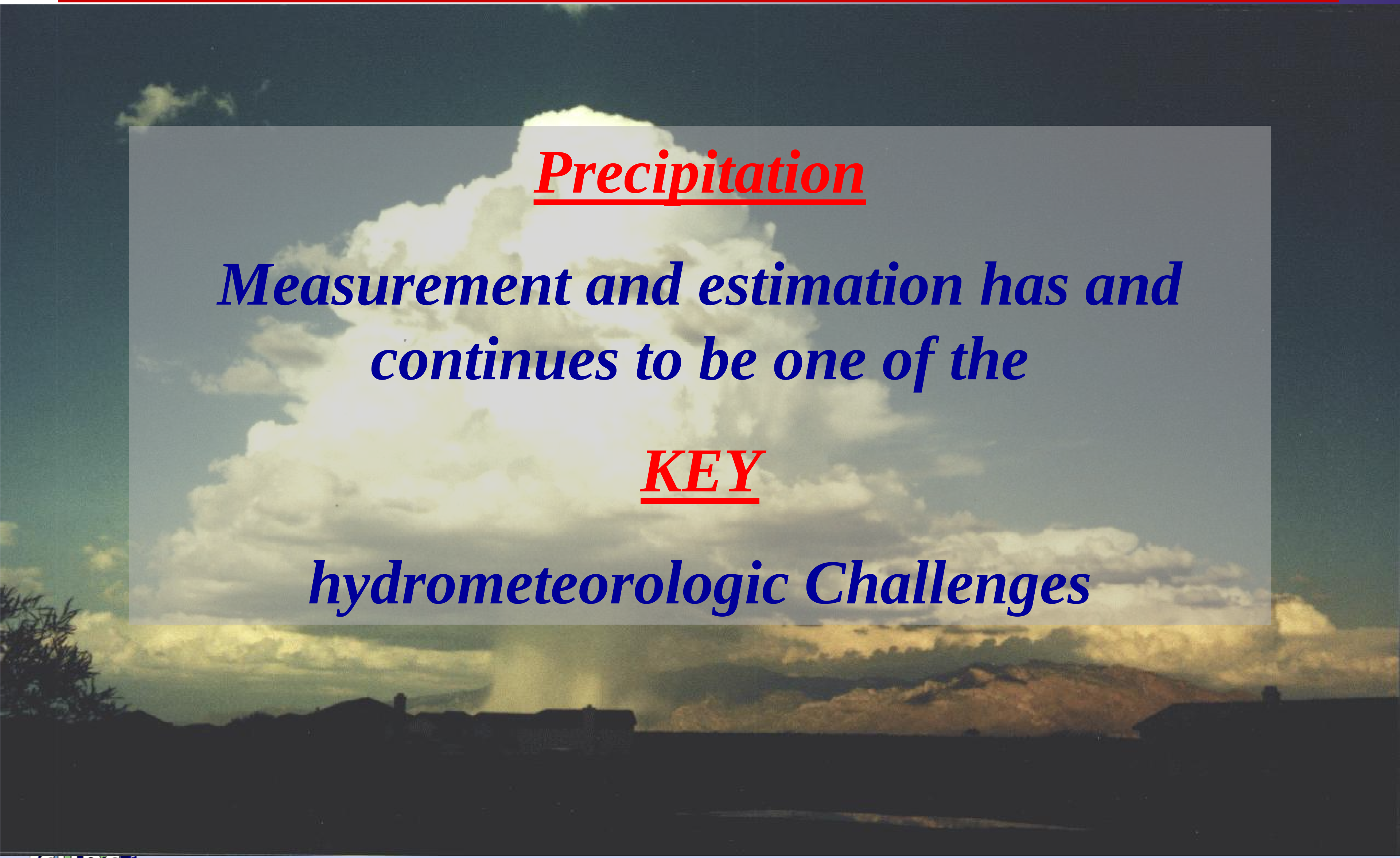
Big Challenge For "us":

Adequacy of Hydrologic Observations

Observation of Primary Hydrologic Variables

Precipitation

Stream flow



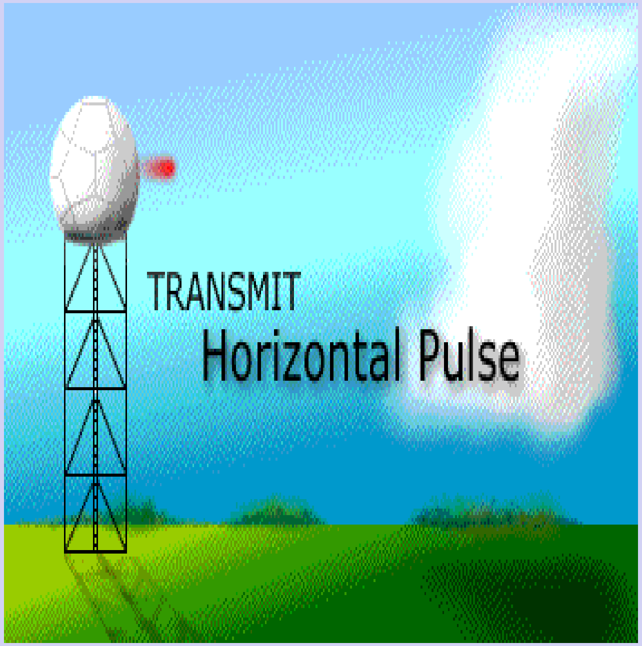
Precipitation

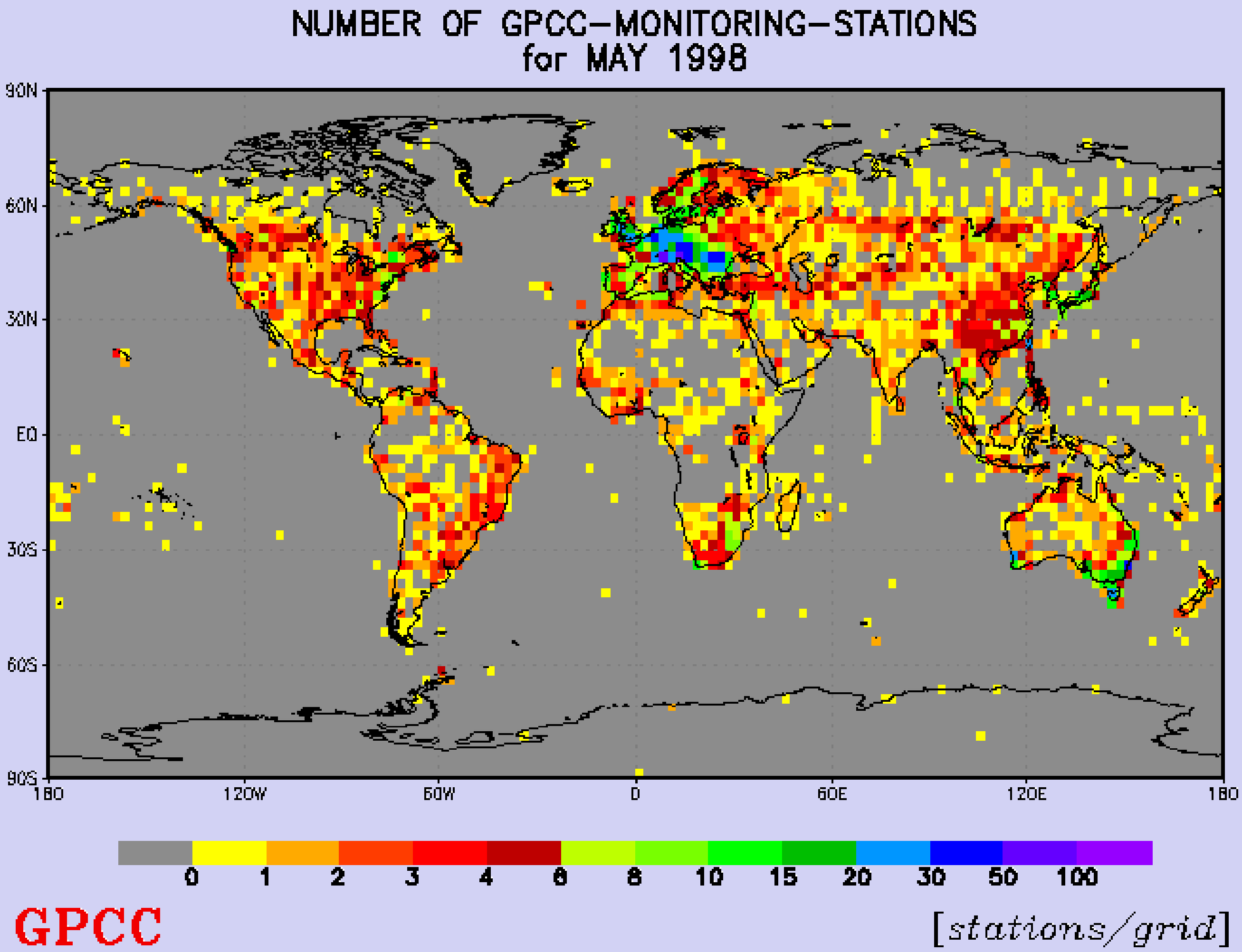
Measurement and estimation has and continues to be one of the

KEY

hydrometeorologic Challenges

Precipitation Observations: Which to trust??

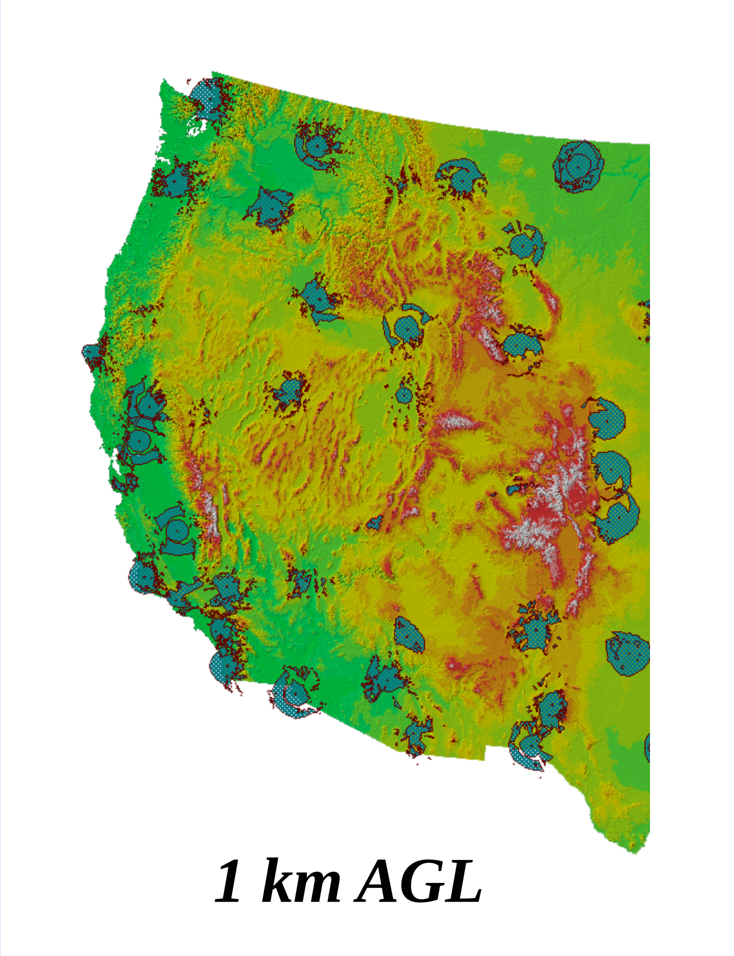




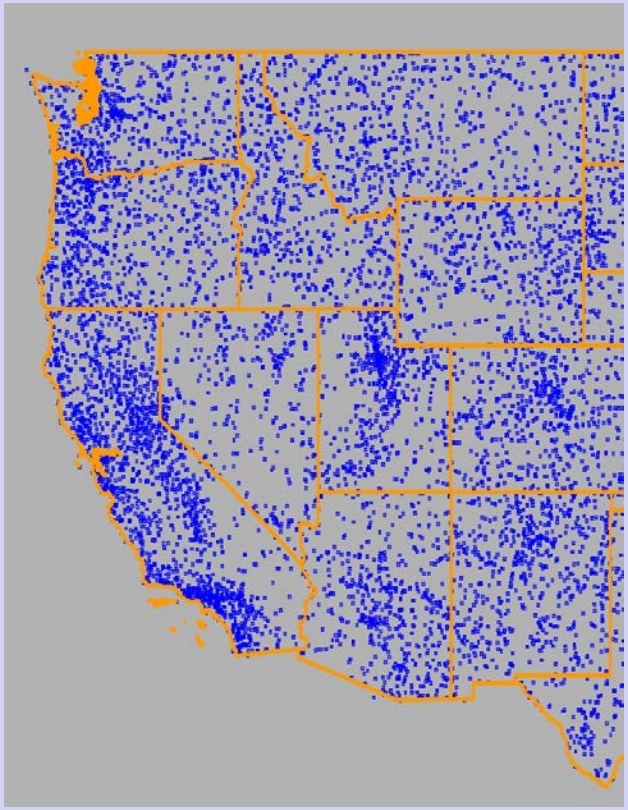
Number of range gauges per grid box**. These boxes are **2x2 degrees

(Source: Global Precipitation Climatology Project)

Coverage of the WSR-88D and gauge networks



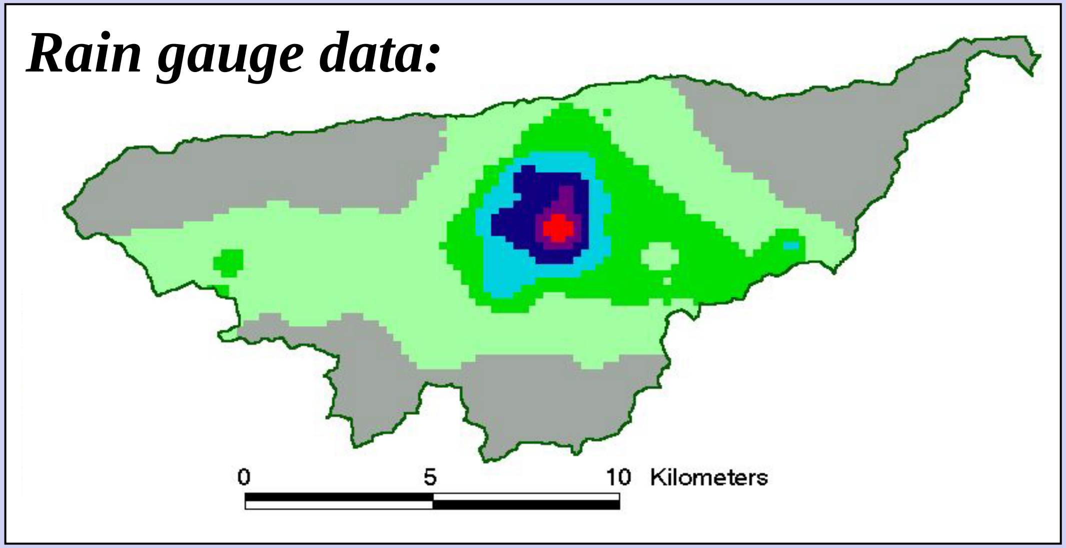
Maddox, et al., 2002

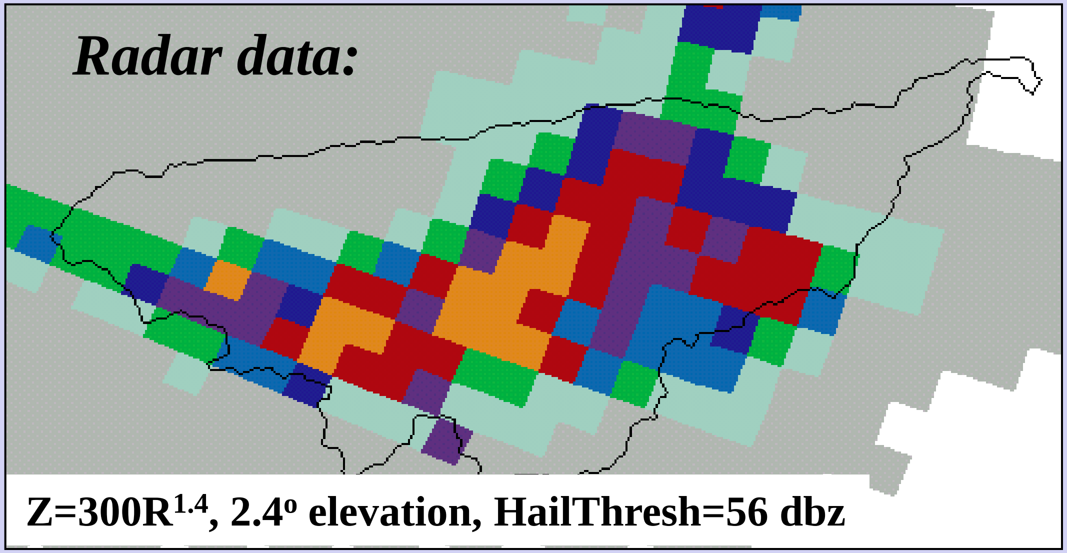


Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse

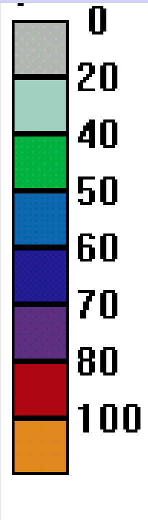
Radar-Gauge Comparison (Walnut Gulch, AZ)

Precipitation event: Aug. 11, 2000





Storm depth (mm)



70% overestimation by the radar!

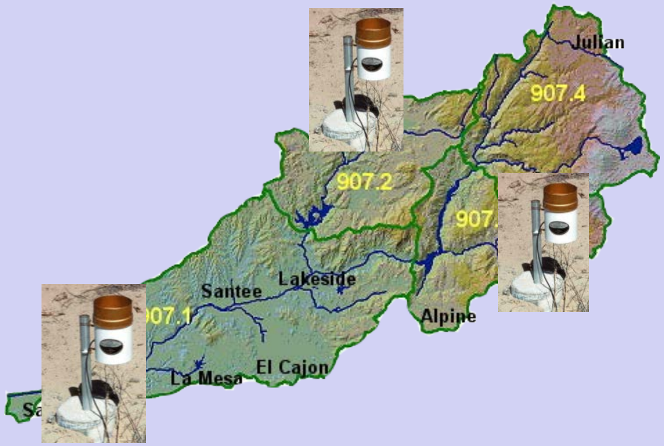
Even A Bigger Challenge!

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

2 Precipitation Scenarios with different Temporal properties

Monthly Total

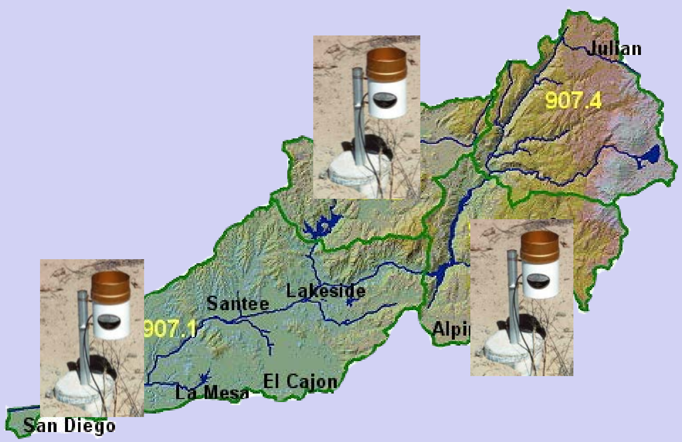
A



100 mm

Frequency 6.7%
Intensity 50.0 mm

B

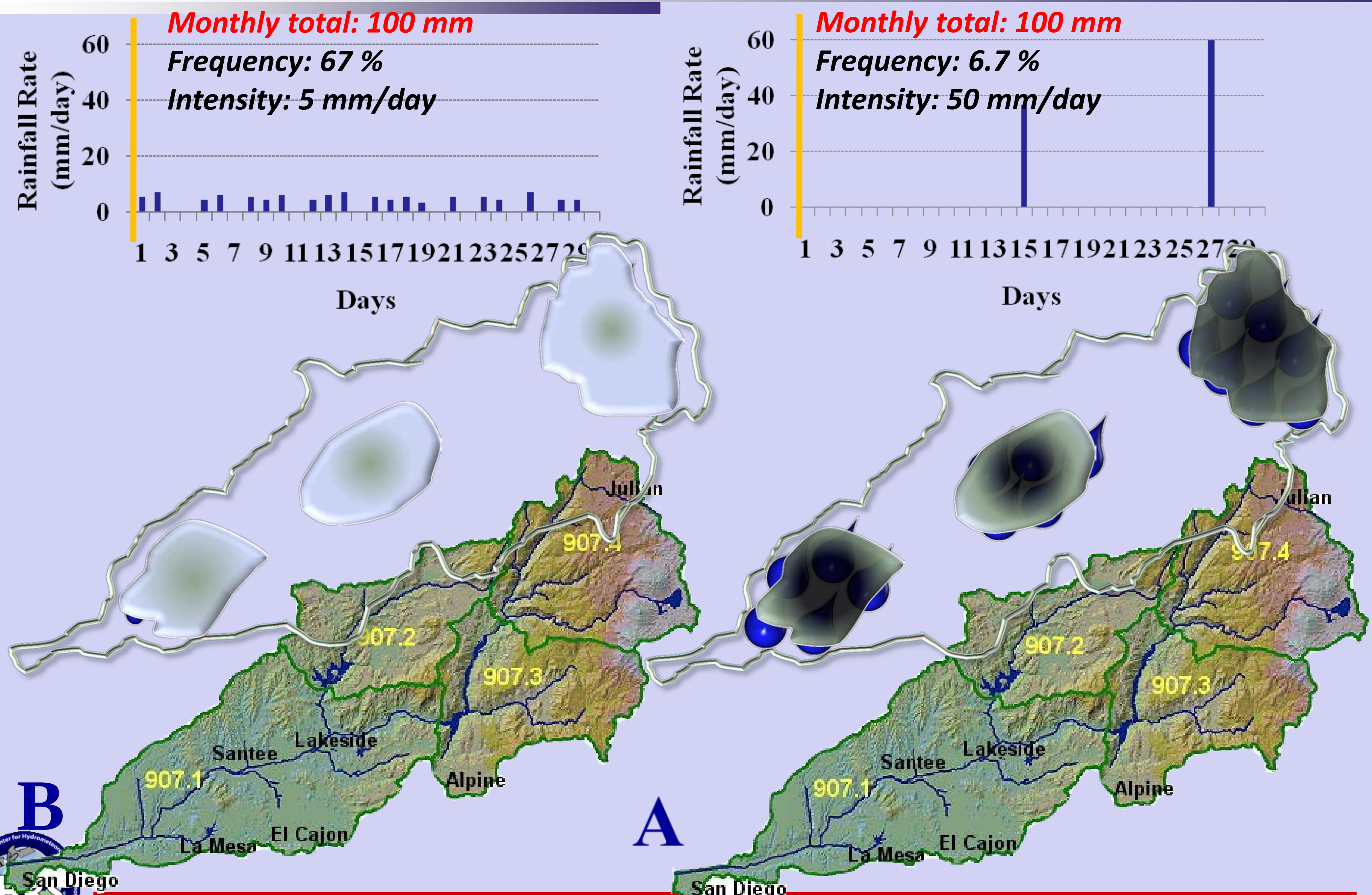


100 mm

Frequency 67%
Intensity 5.0 mm

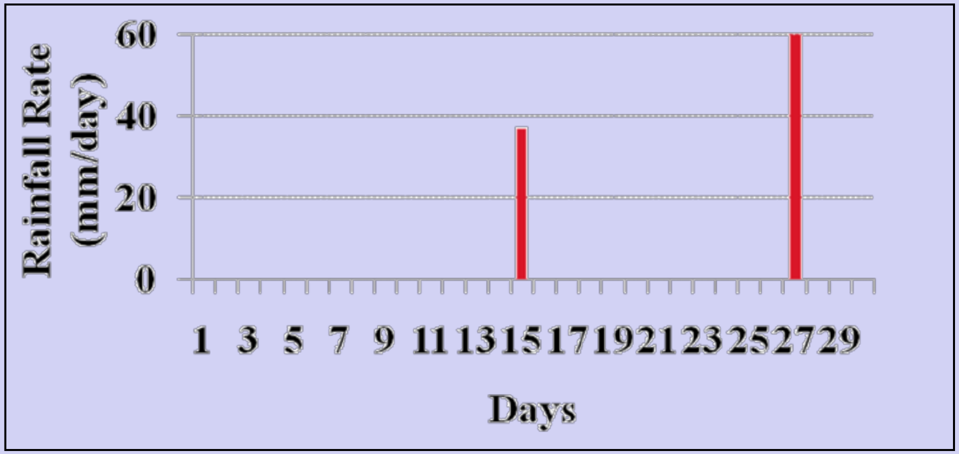
Idea from: K. Trenberth, NCAR

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



Importance of Temporal Scale : Daily Precip. at 2 stations

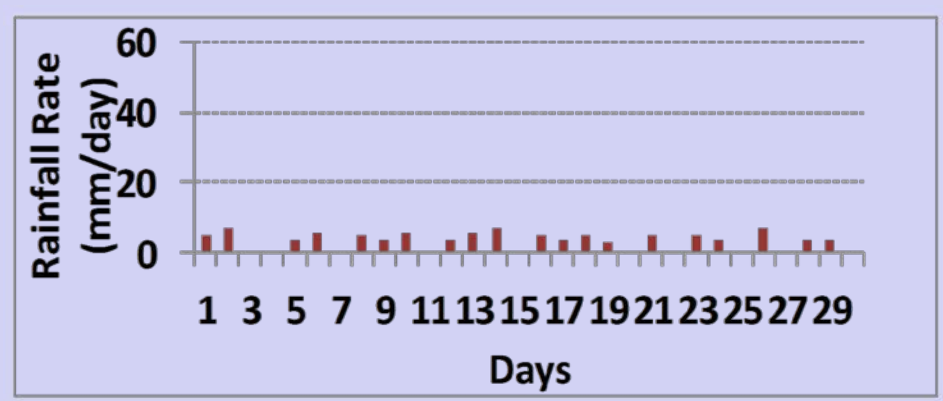
A



Frequency 6.7%
Intensity 50.0 mm

- *Localized Flooding*
- *Stream bed Recharge*

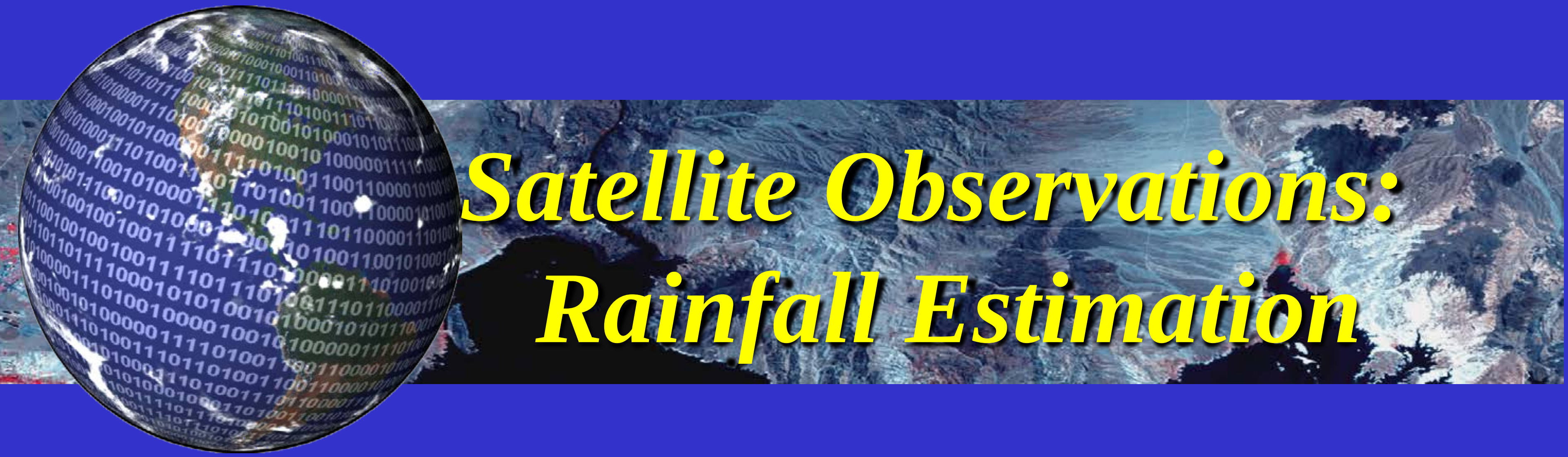
B



Frequency 67%
Intensity 5.0 mm

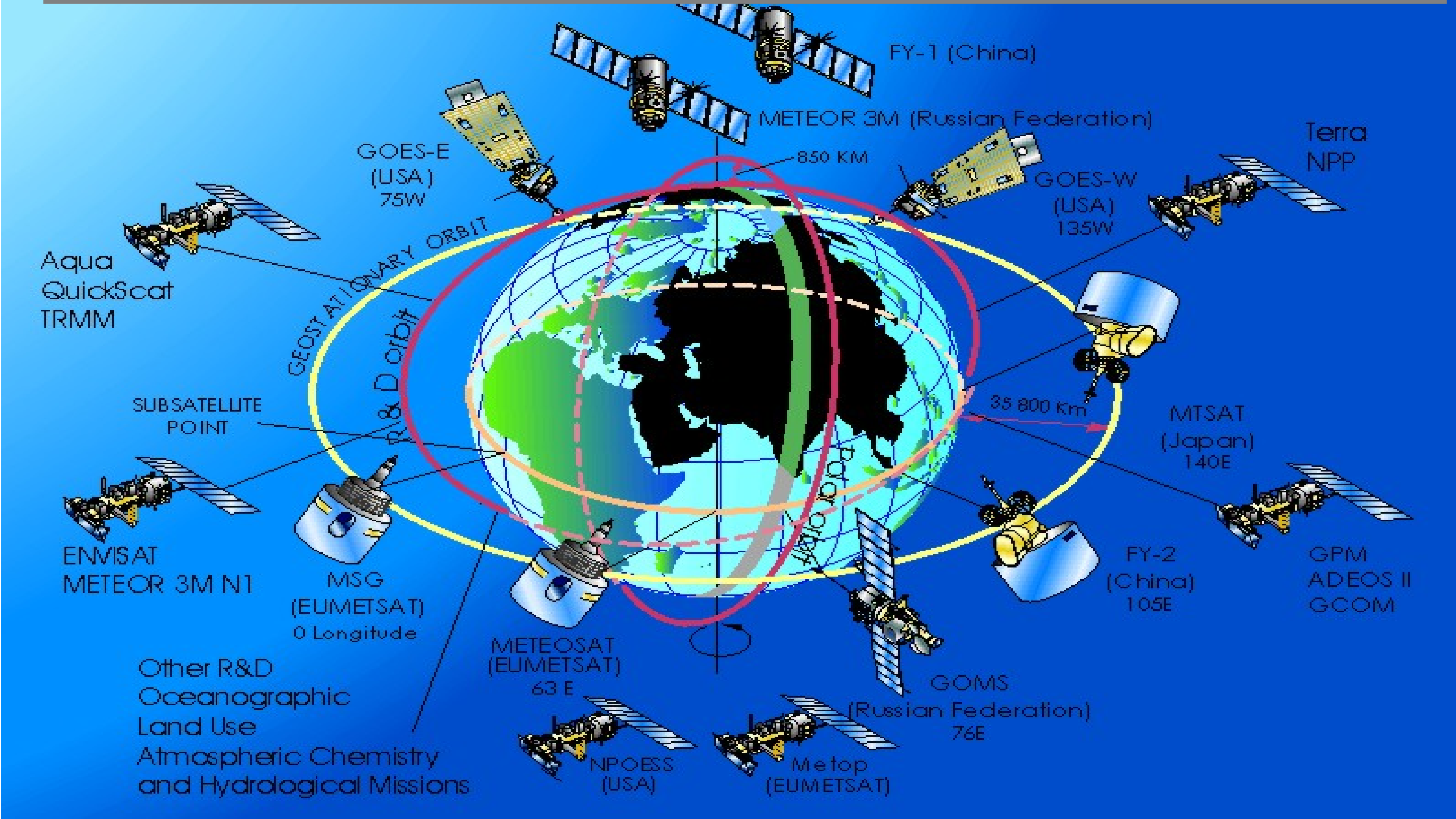
- ***soil moisture replenished***
- ***Little (if any) runoff***

Idea from: K. Trenberth, NCAR


Satellite Observations:
Rainfall Estimation

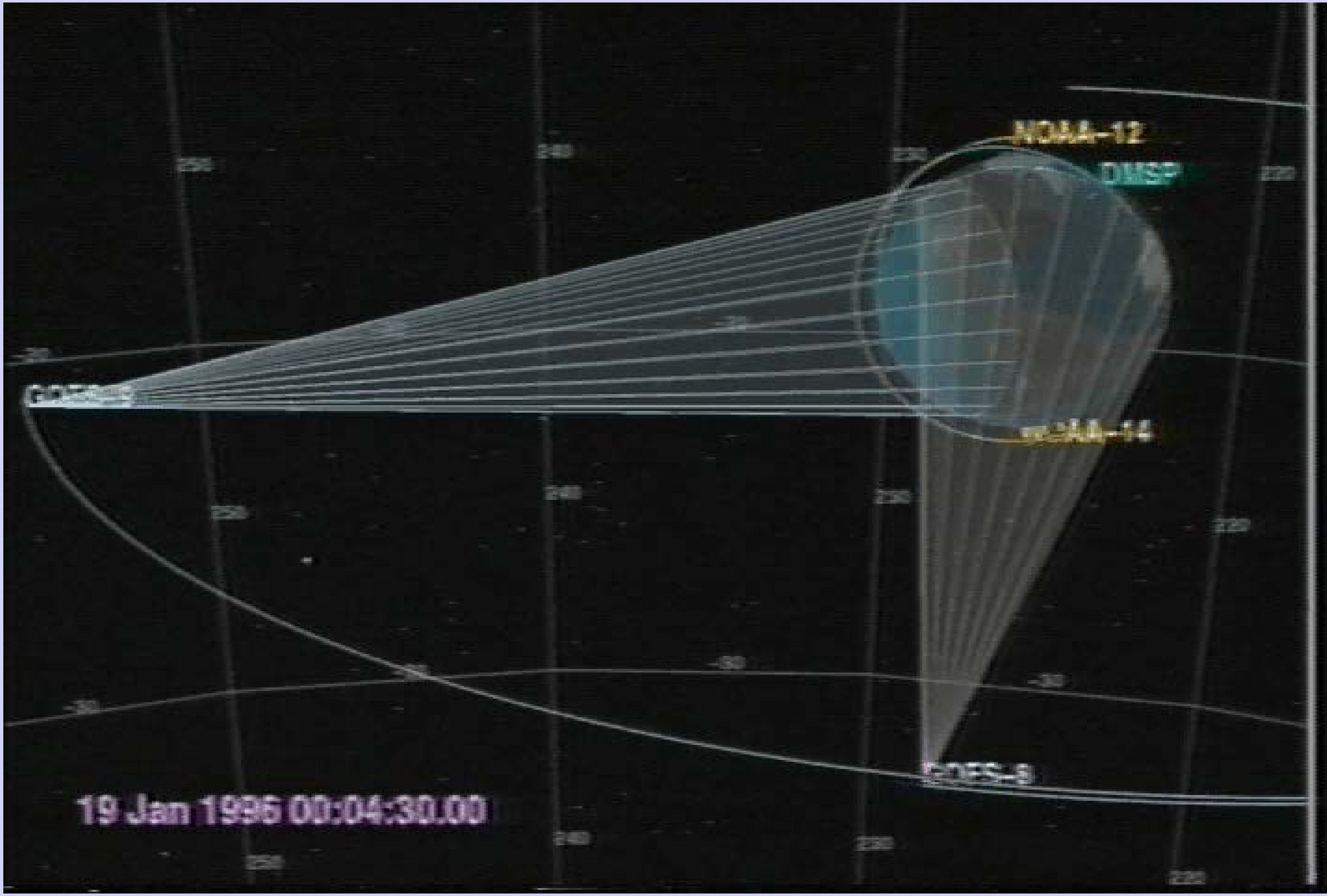
Satellite-Based Rainfall Estimation: Promising !

Observations from space: Near-continuous, global coverage,



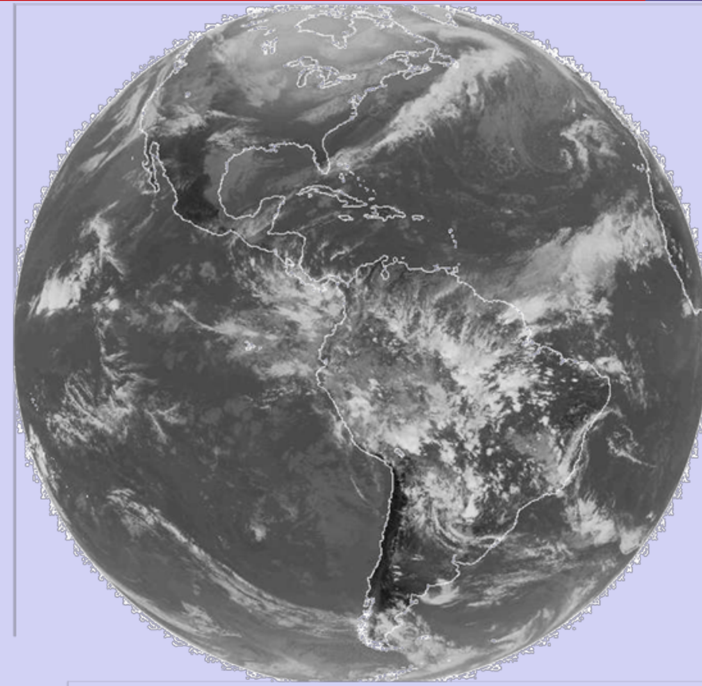
Geostationary and Polar Satellites

Courtesy: NASA's ESE



Satellite precipitation retrieval instruments

1) Using GEO satellites (Infrared/Visible channels)



Advantage:

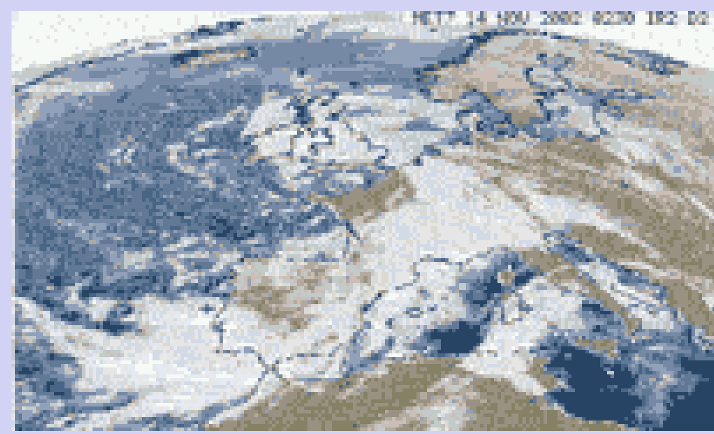
- ***Good temporal and spatial resolution (30 min or less, 4 km)***

- ***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

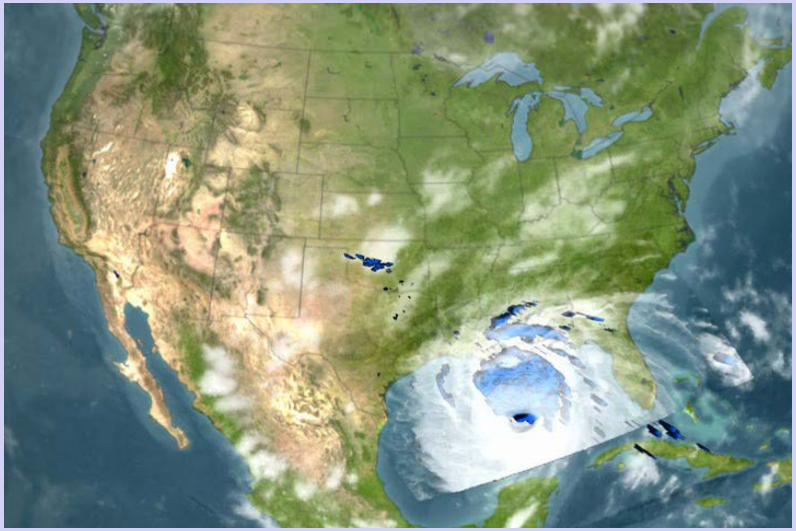
***Disadvantage*:**

-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



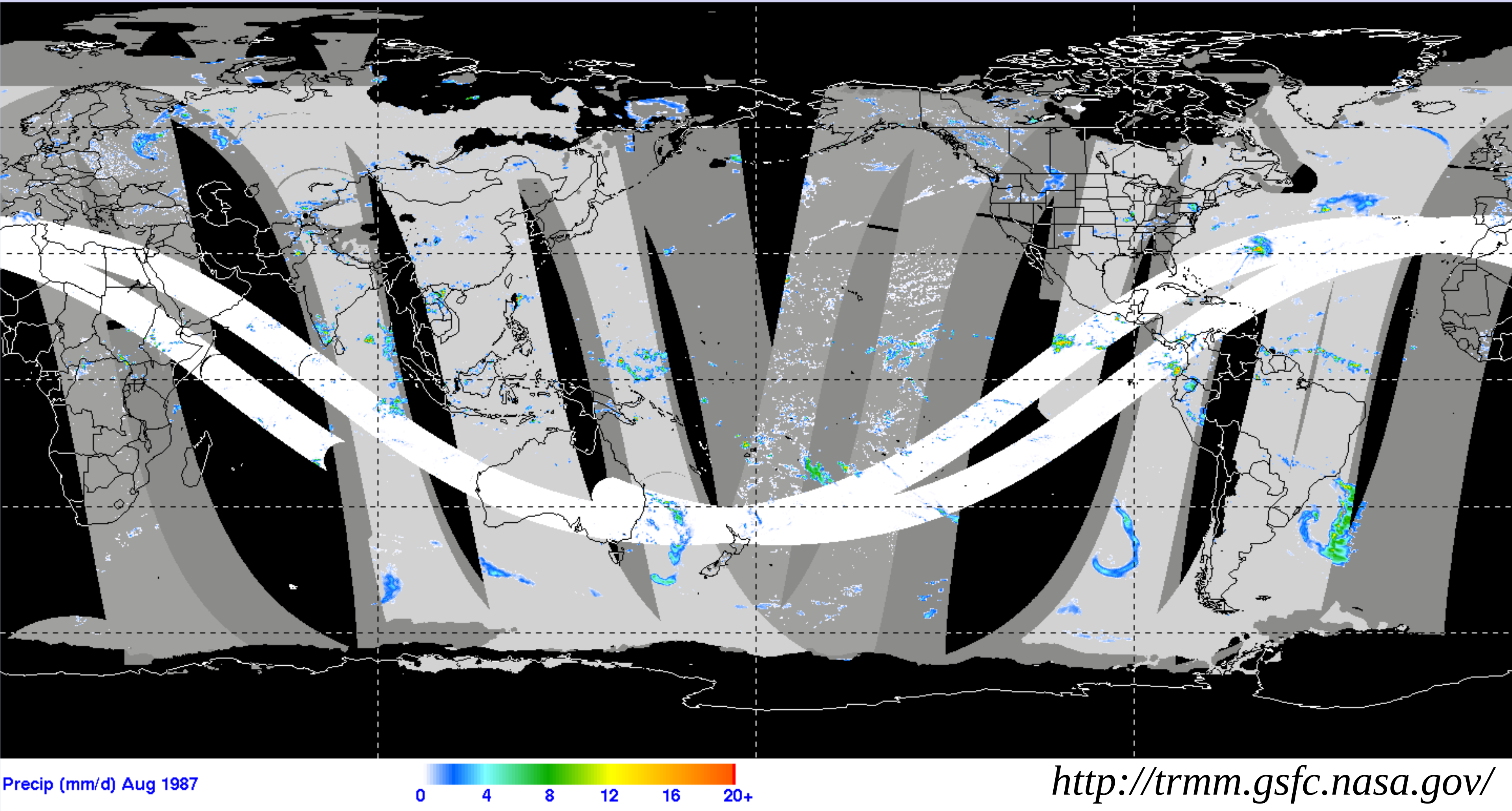
Advantage:

- More accurate
- good spatial resolution

Disadvantage:

- Poor temporal resolution

Typical Microwave Coverage in 3 Hr



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

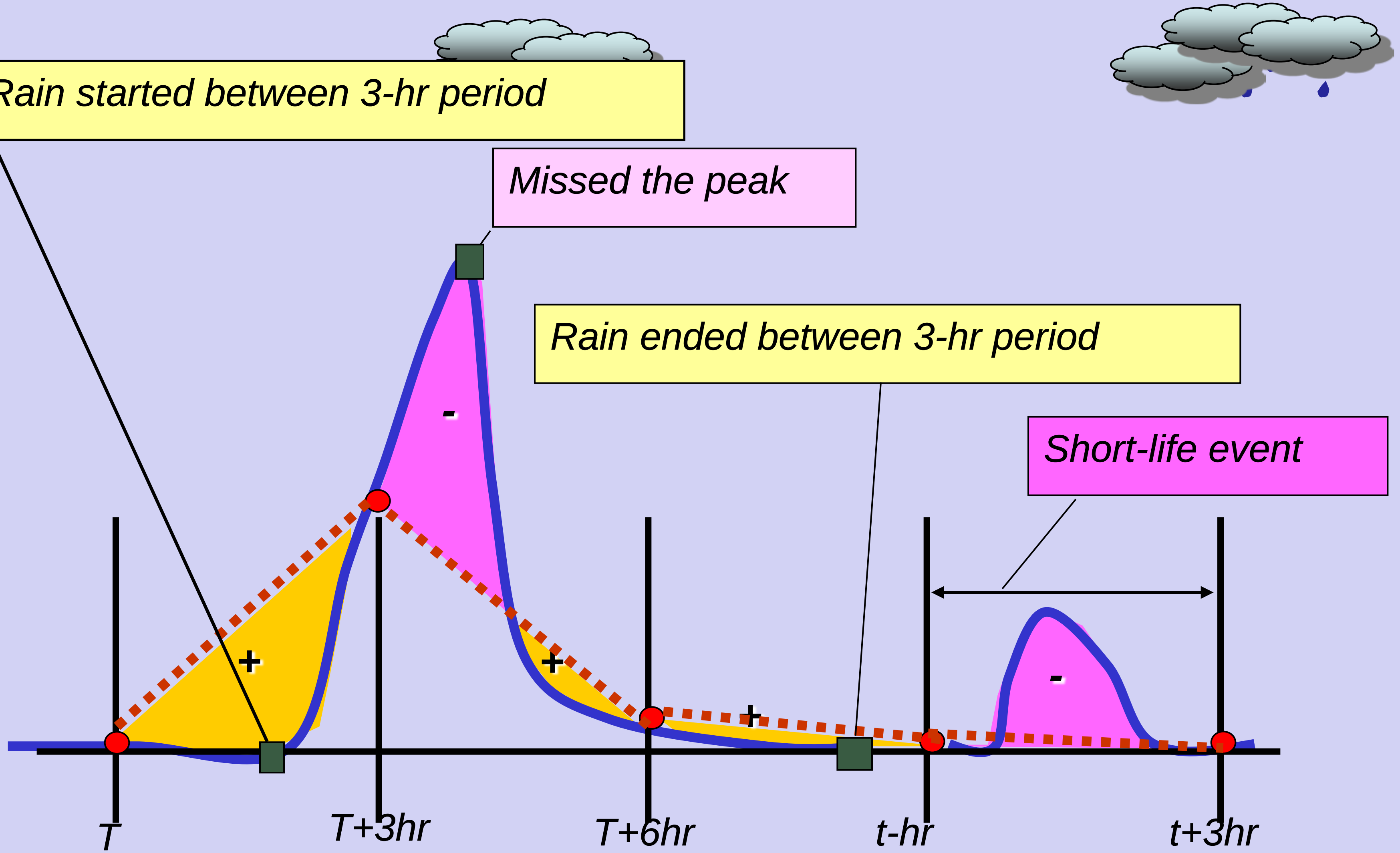
TMI – white

SSM/I – light grey

AMSR-E – medium grey

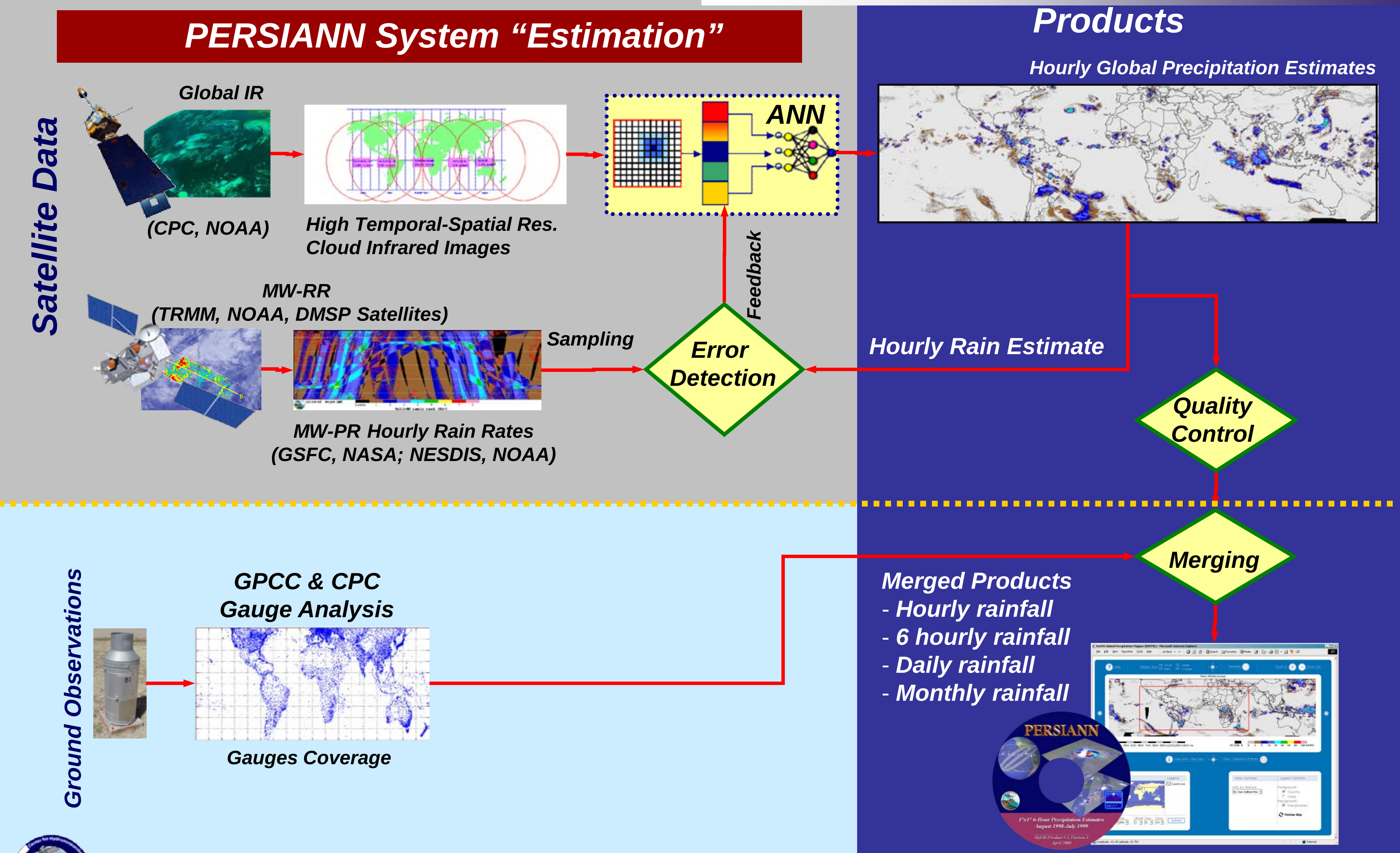
AMSU-B – dark grey

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)

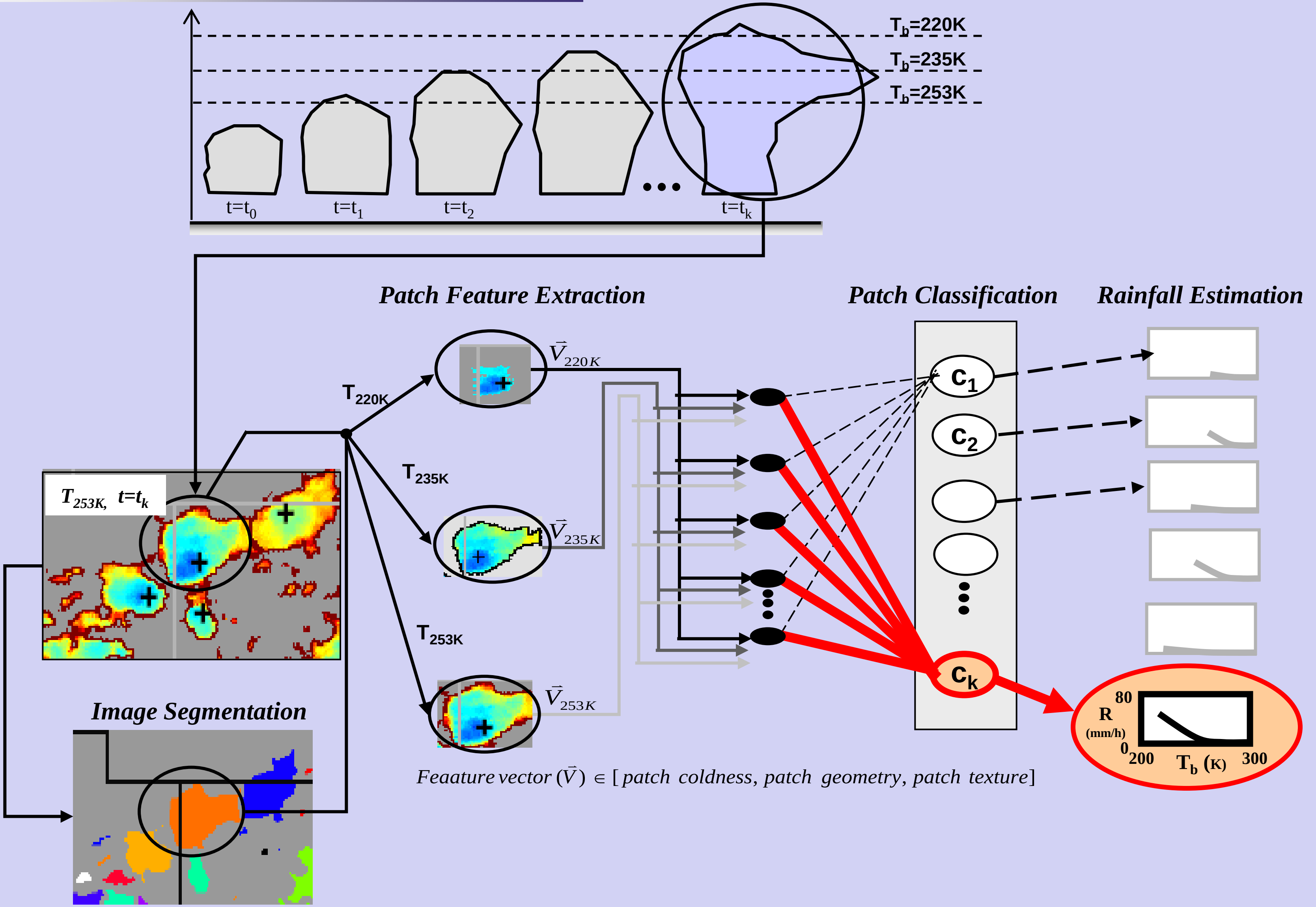


Center for Hydrometeorology and Remote Sensing, University of California, Irvine

High Resolution Precipitation Estimates

PERSIANN-CCS

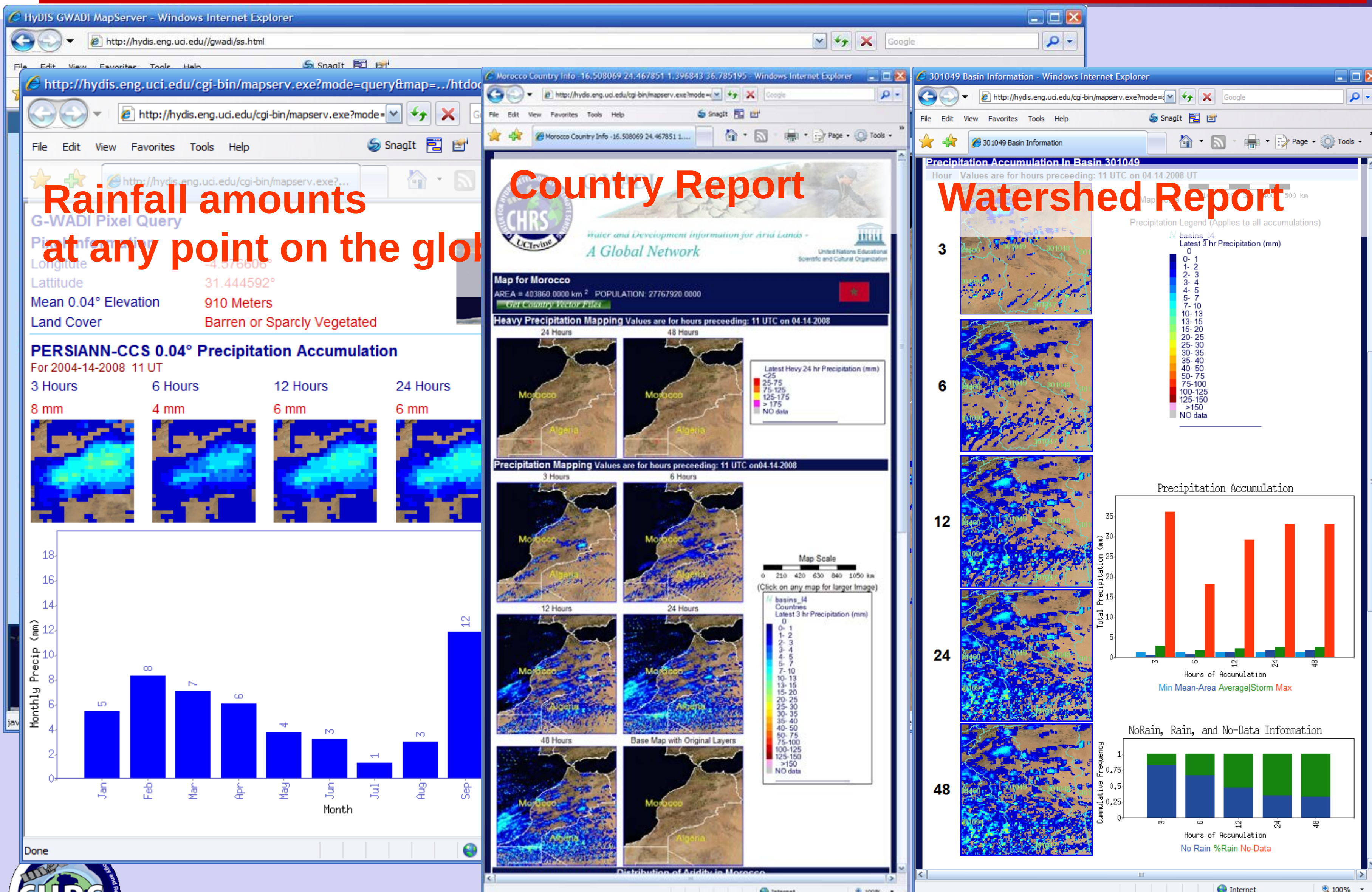
Cloud Segmentation Algorithm



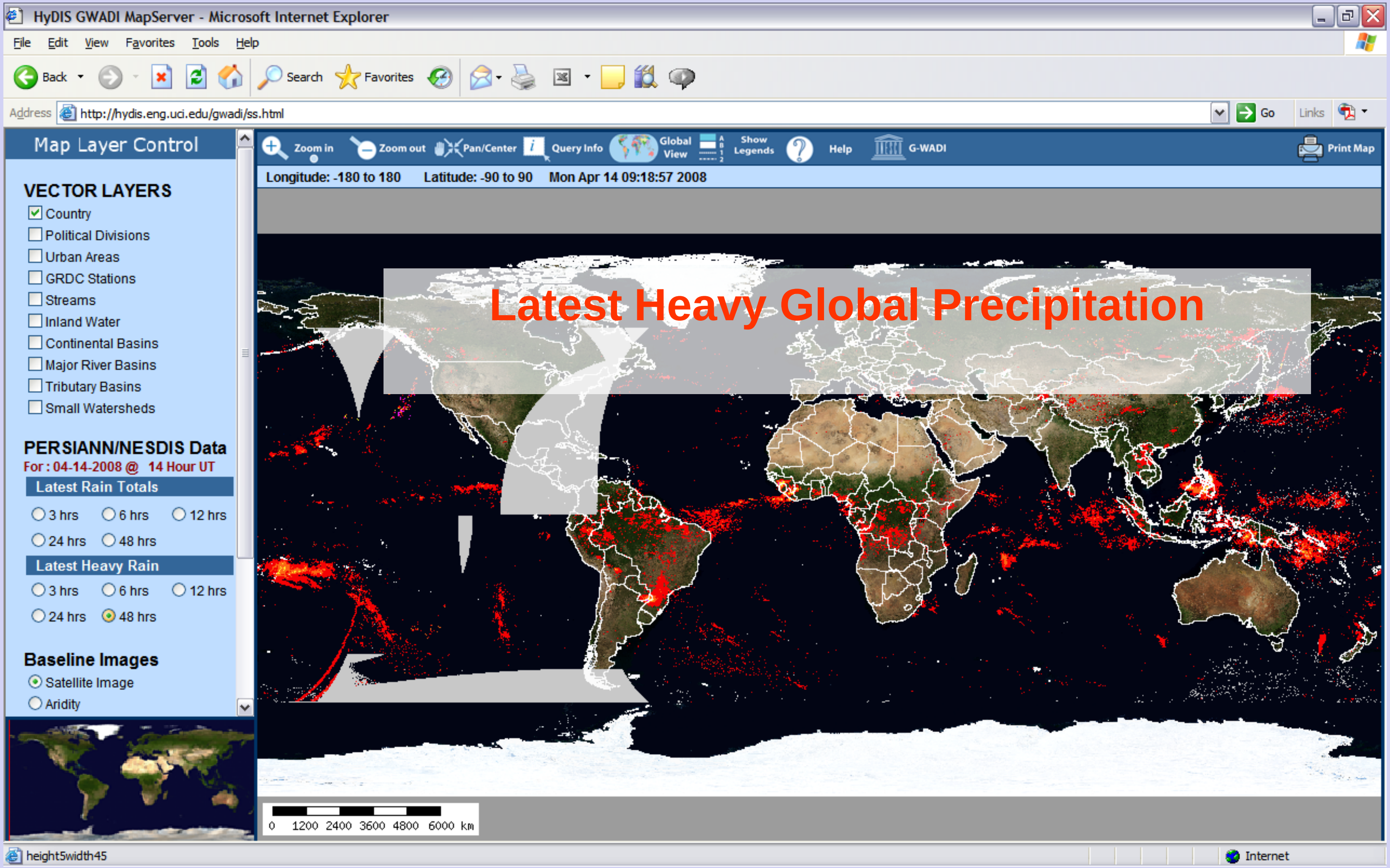
Real Time Global Data: Cooperation With UNESCO

Many Features provided to users with Public Domain Software.

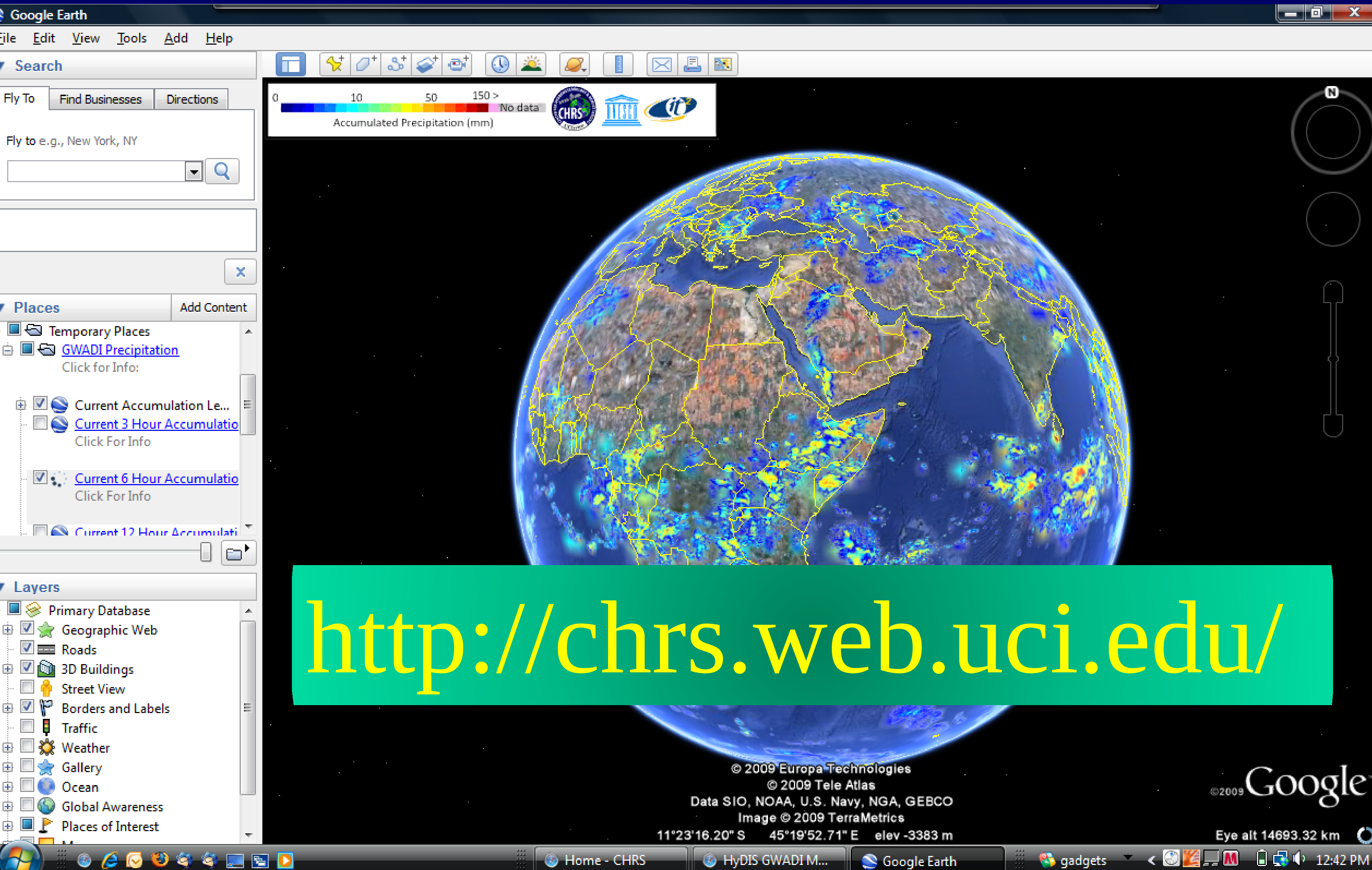
Real Time Global Data: Cooperation With UNESCO



Real Time Global Data: Cooperation With UNESCO

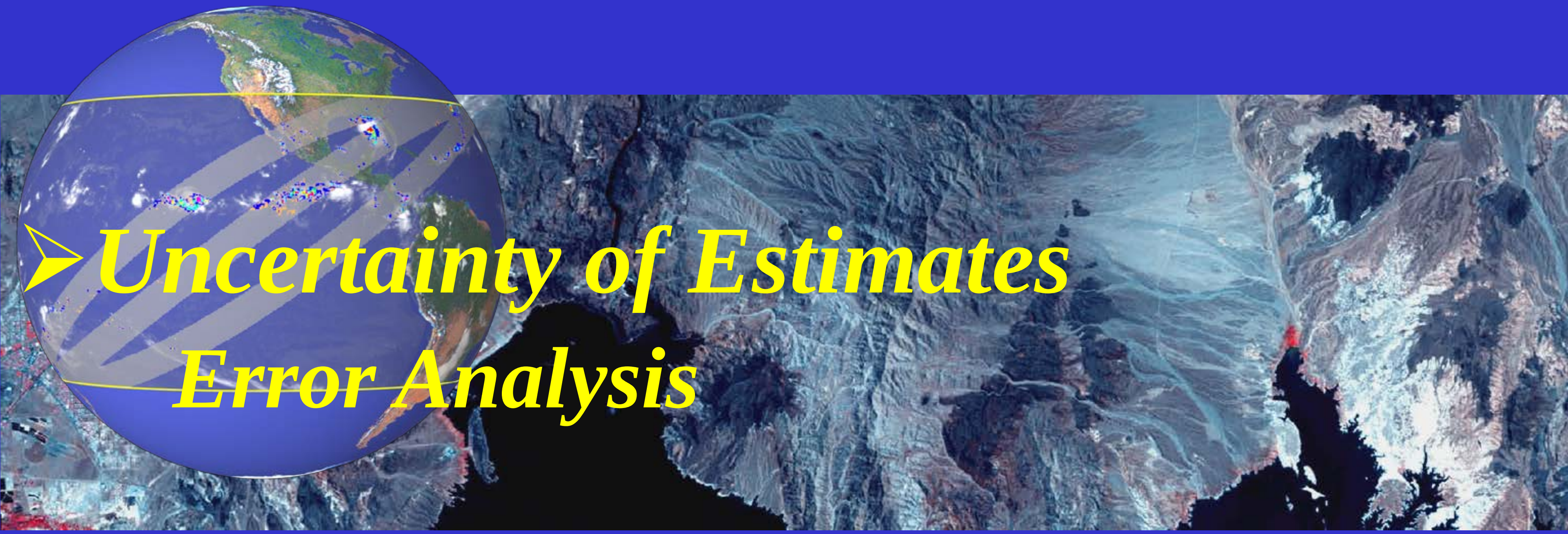


PERSIANN Satellite Product On Google Earth



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

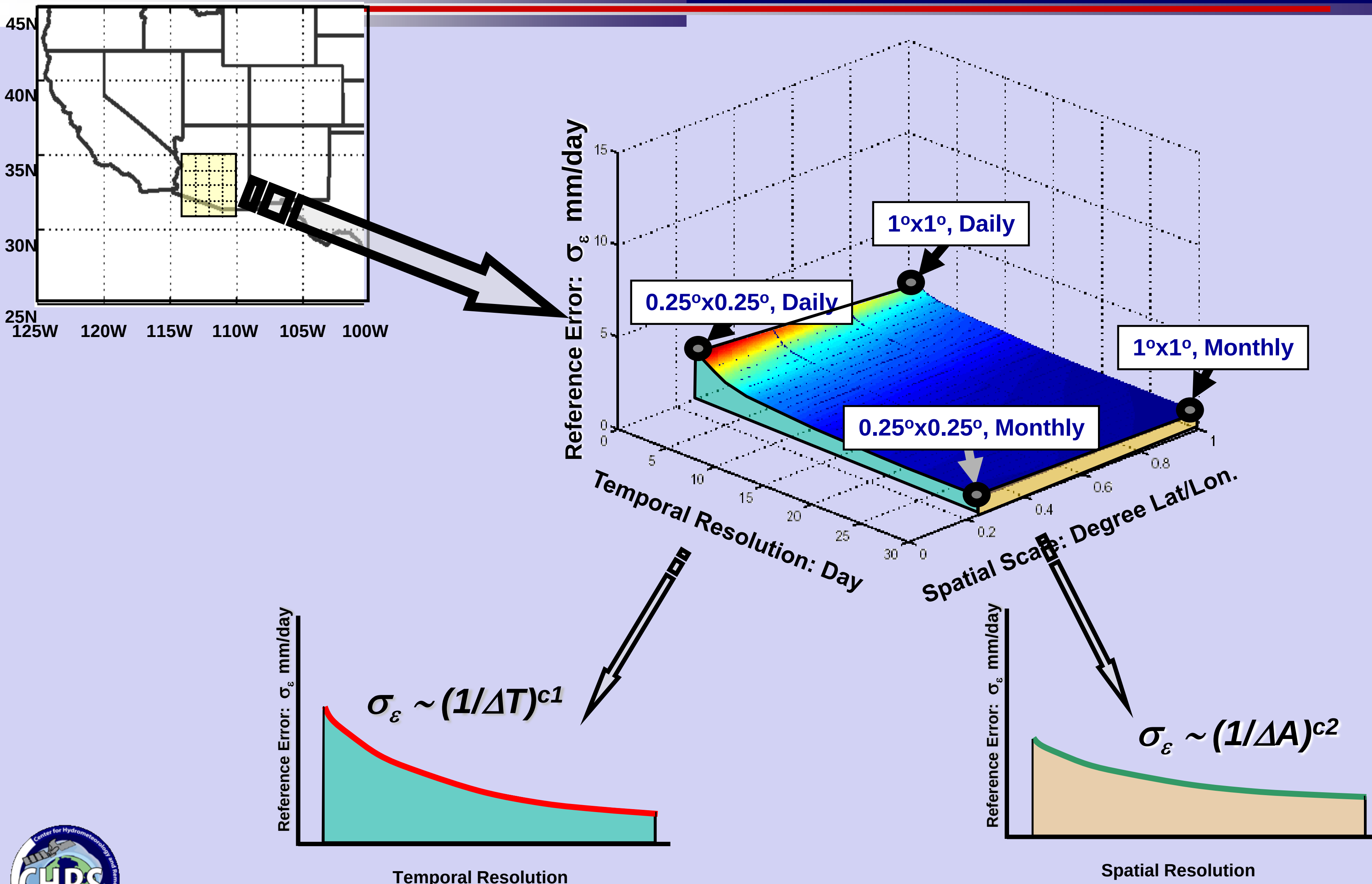
Center for Hydrometeorology and Remote Sensing, University of California, Irvine



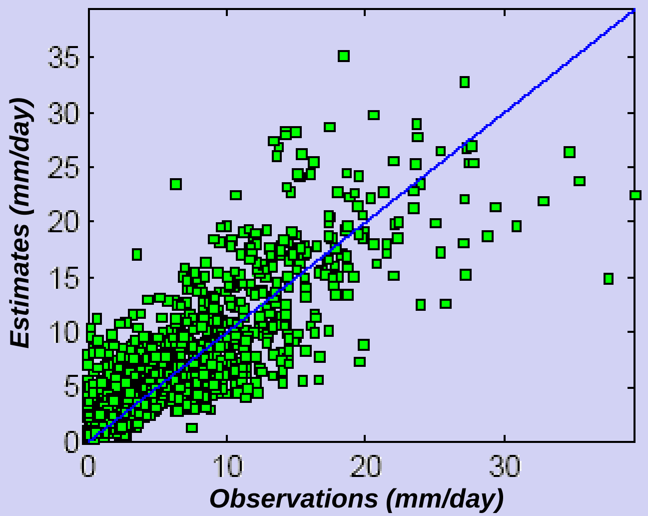
➢Uncertainty of Estimates

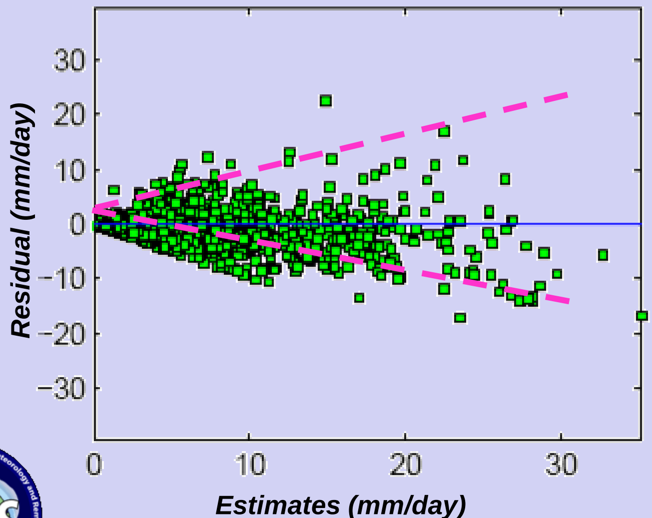
Error Analysis

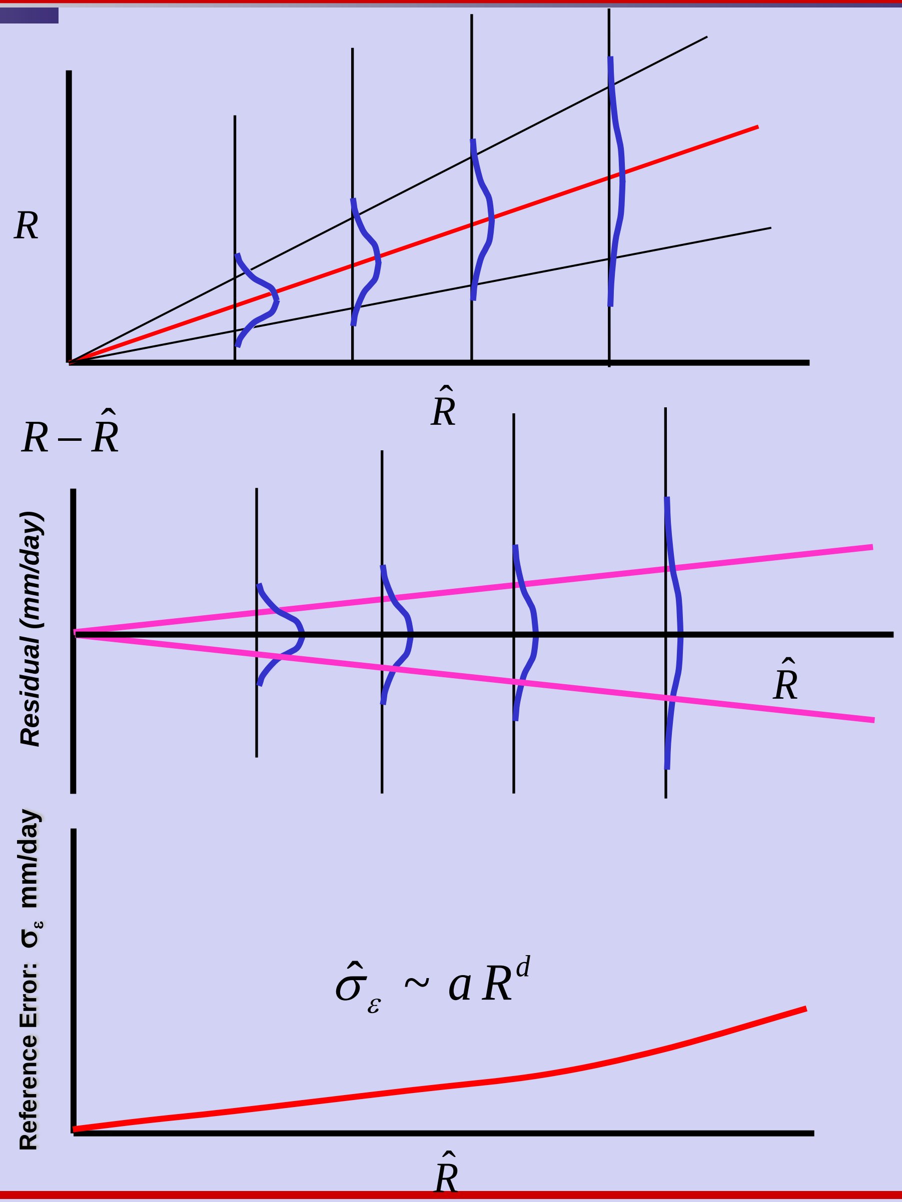
Spatial-Temporal Property of Reference Error



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

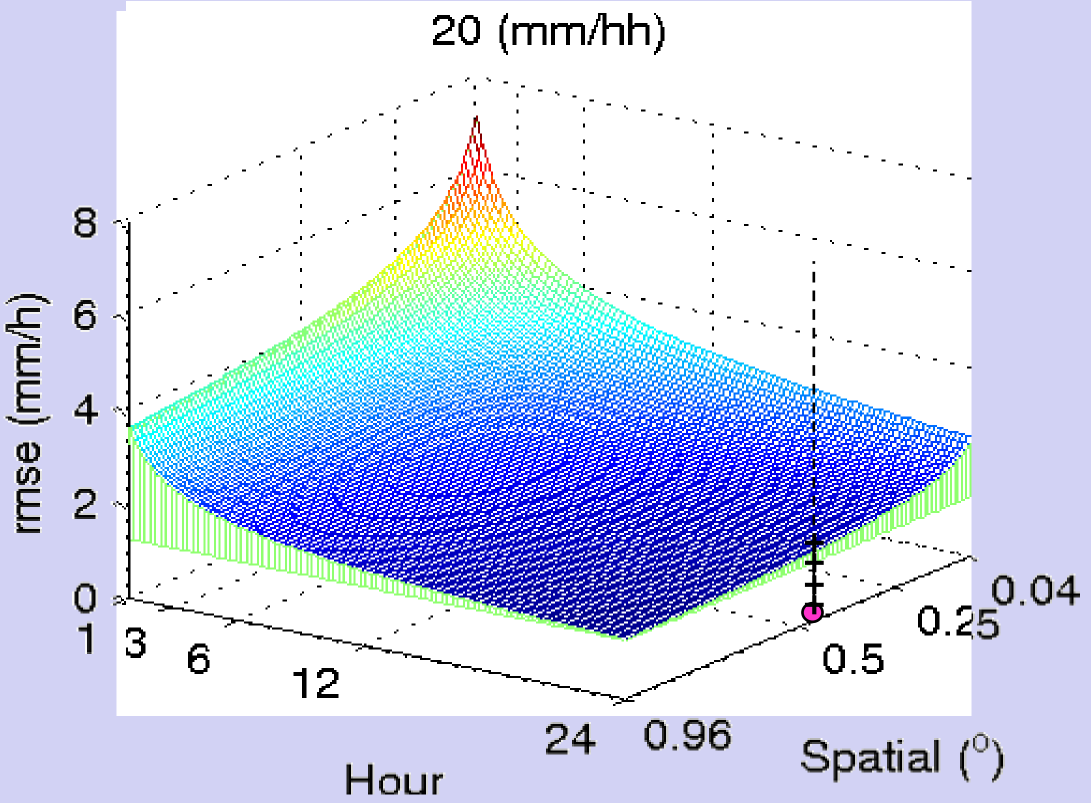






Scaling Property of PERSIANN-CCS Reference Error

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



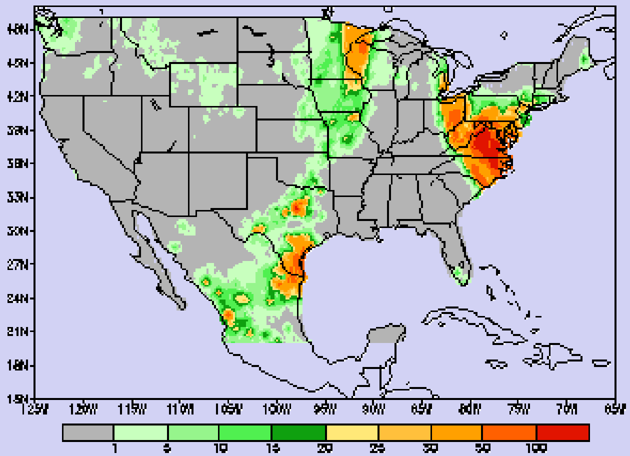
Validation and Application of Satellite Products

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



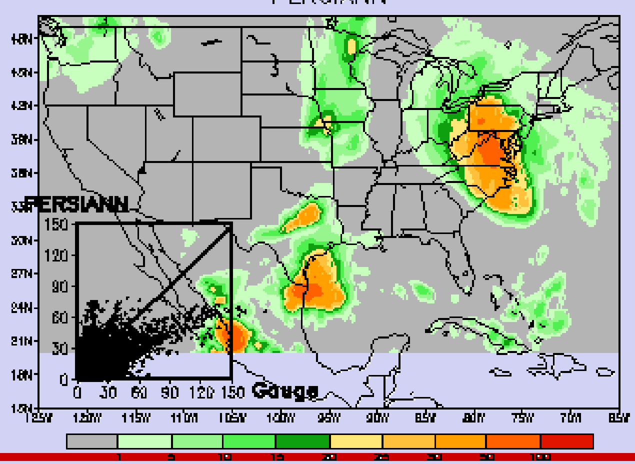
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.55	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45

	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

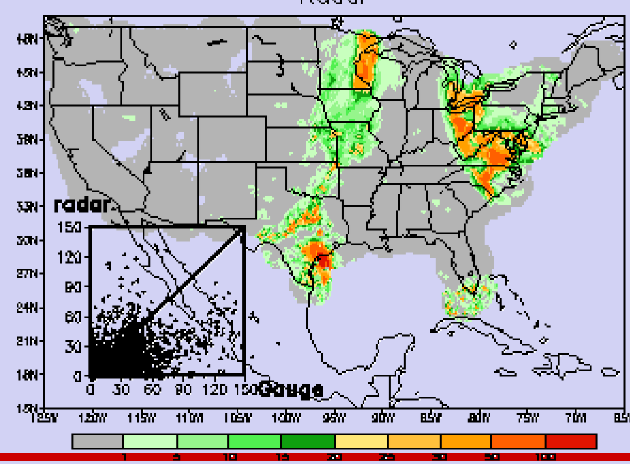
gauge	PERSIANN < 1	PERSIANN ≥ 1
< 1	8082.	1497.
≥ 1	1081.	3168.

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

PERSIANN



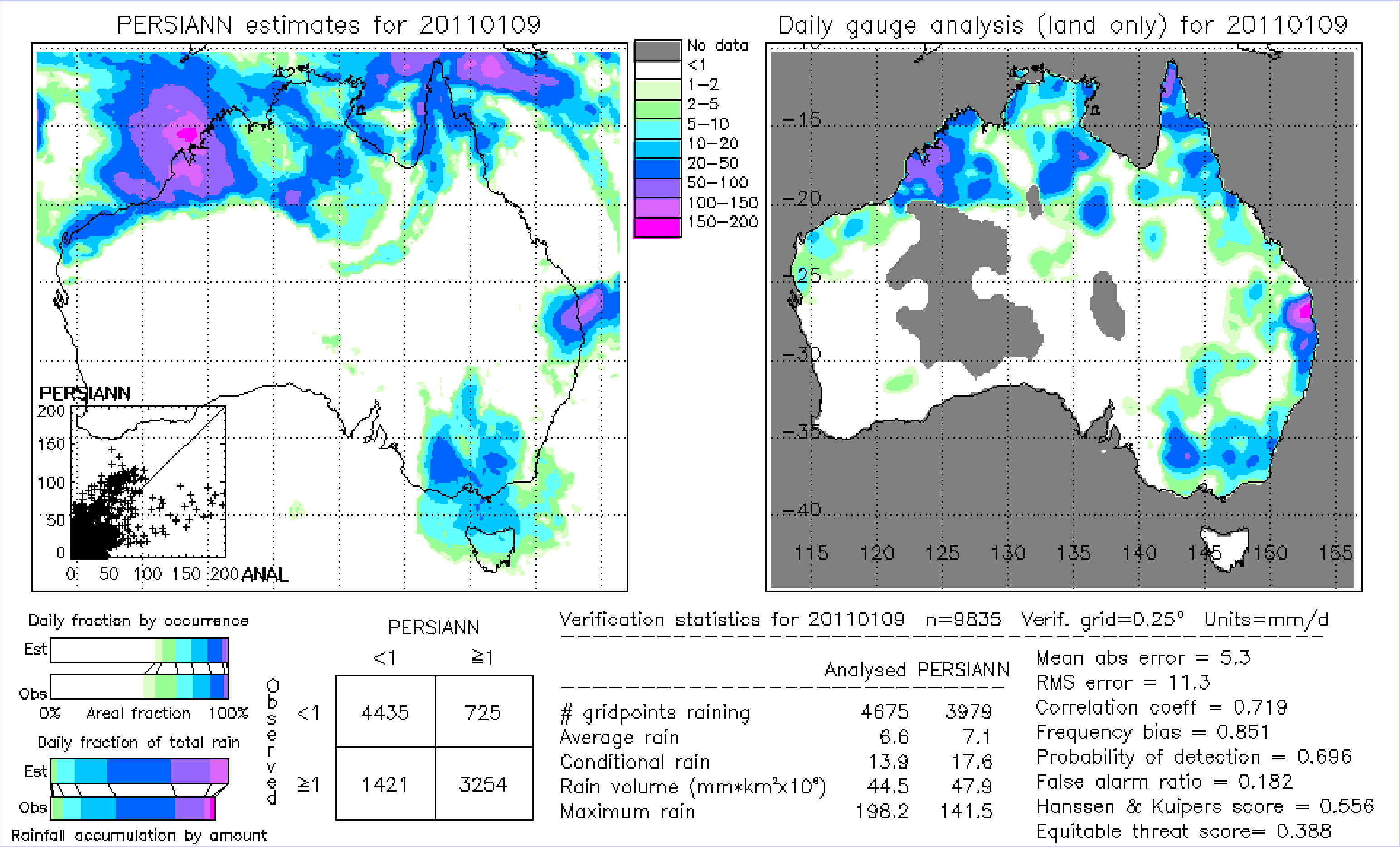
Radar



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

Evaluation of PERSIANN Daily Rainfall

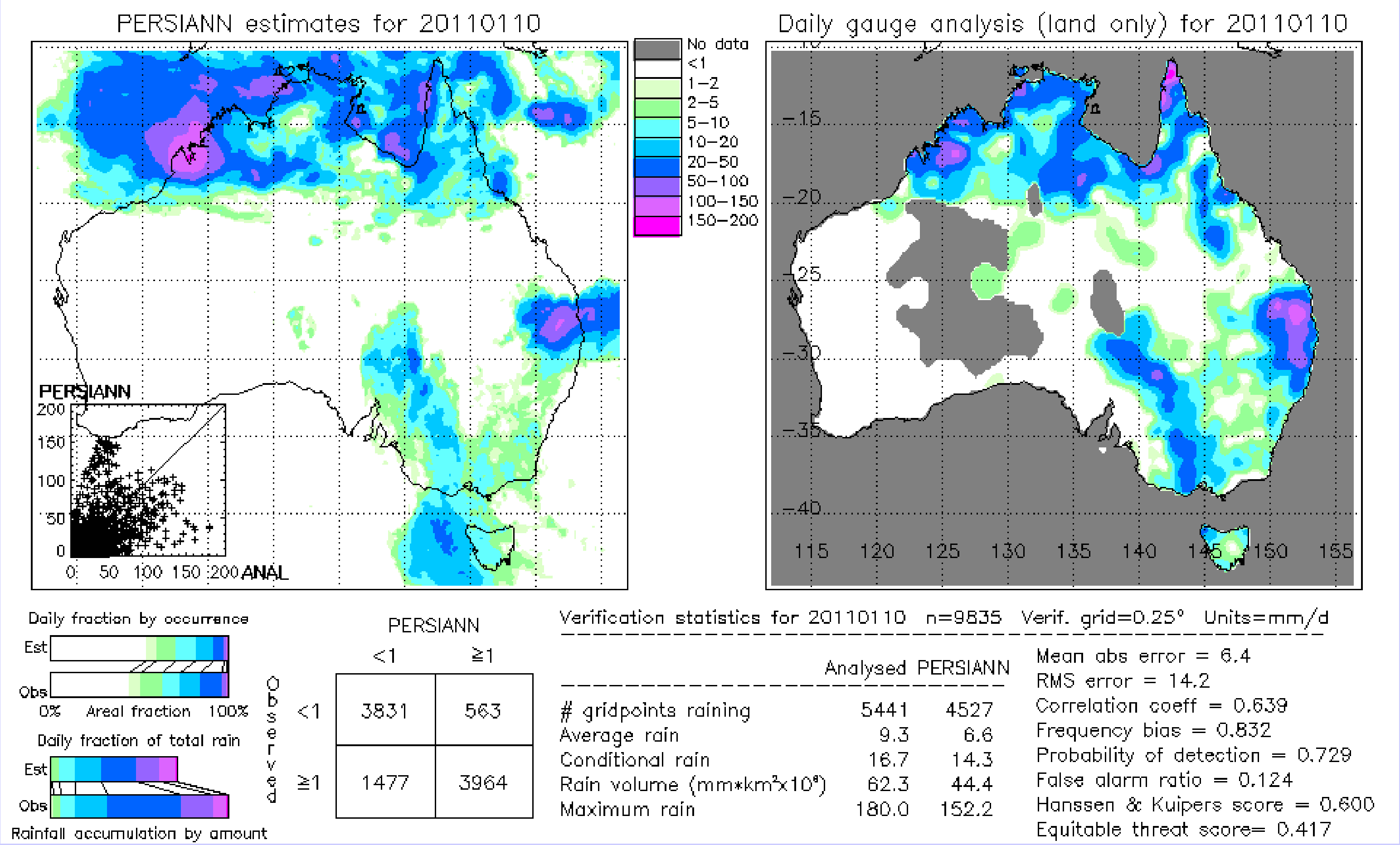
01-09-2011 (0.25-degree resolution)



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

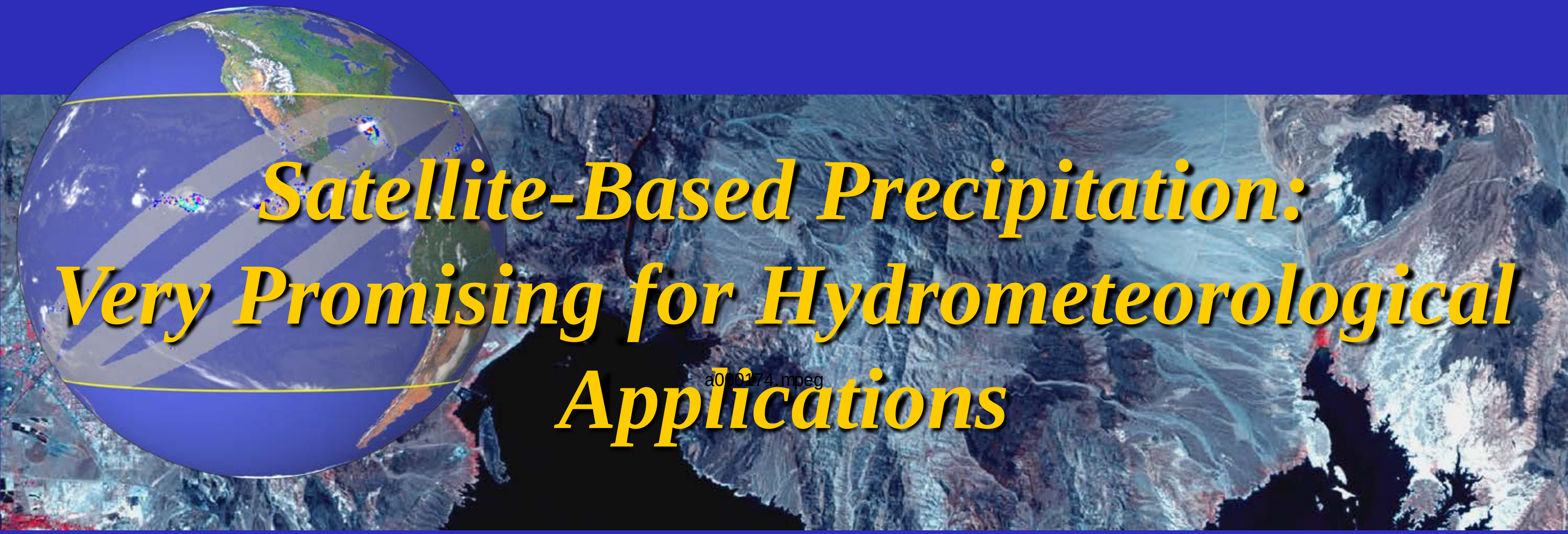
Evaluation of PERSIANN Daily Rainfall

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

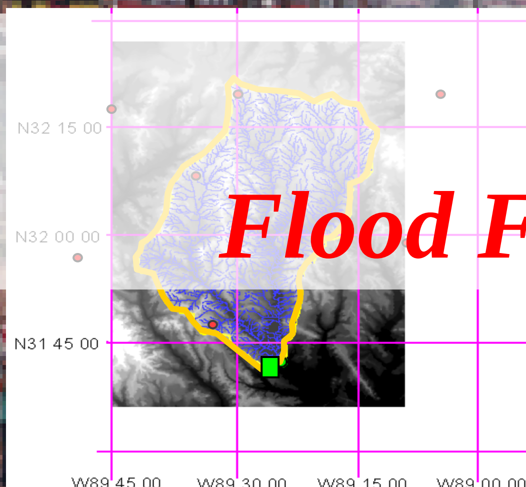


Satellite Rainfall Estimation for Operational Use

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:

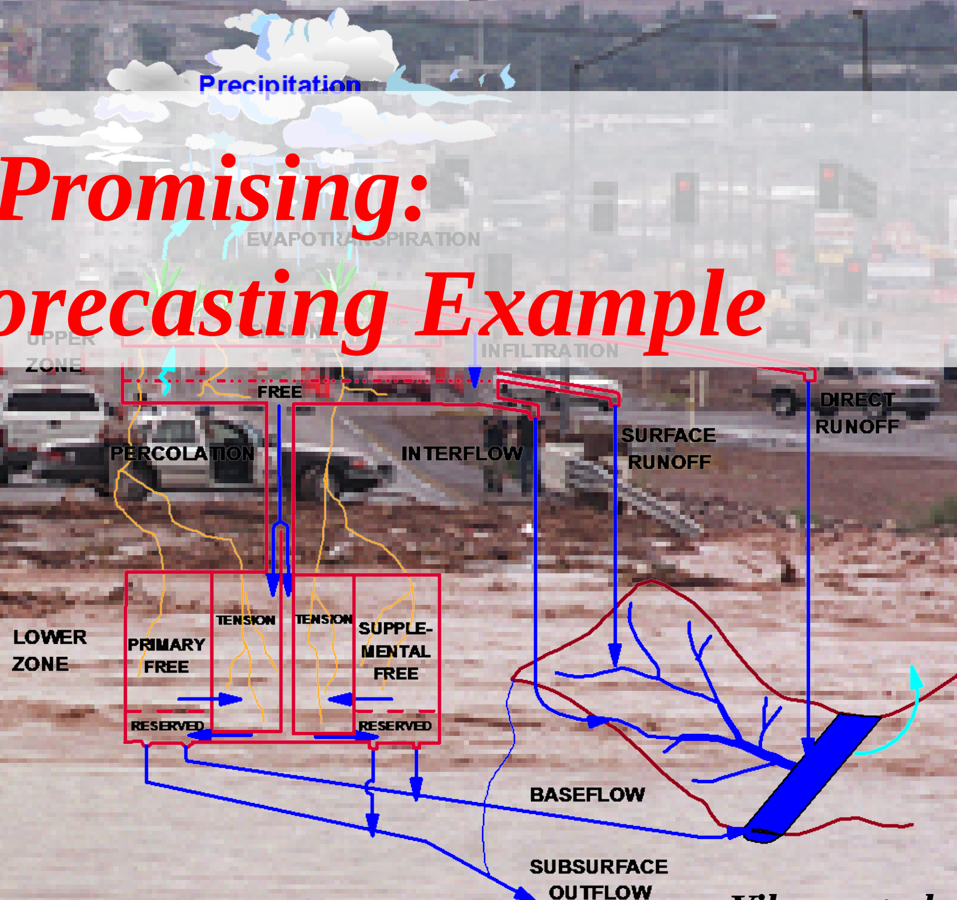
Flood Forecasting Example



Gages used by NWS

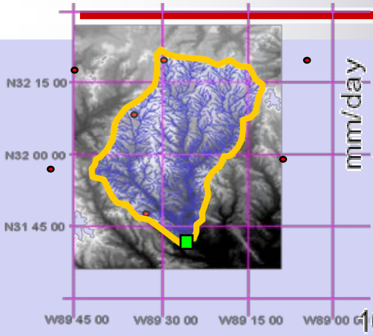
Leaf River Near Collins
Mississippi
USGS # 02472000

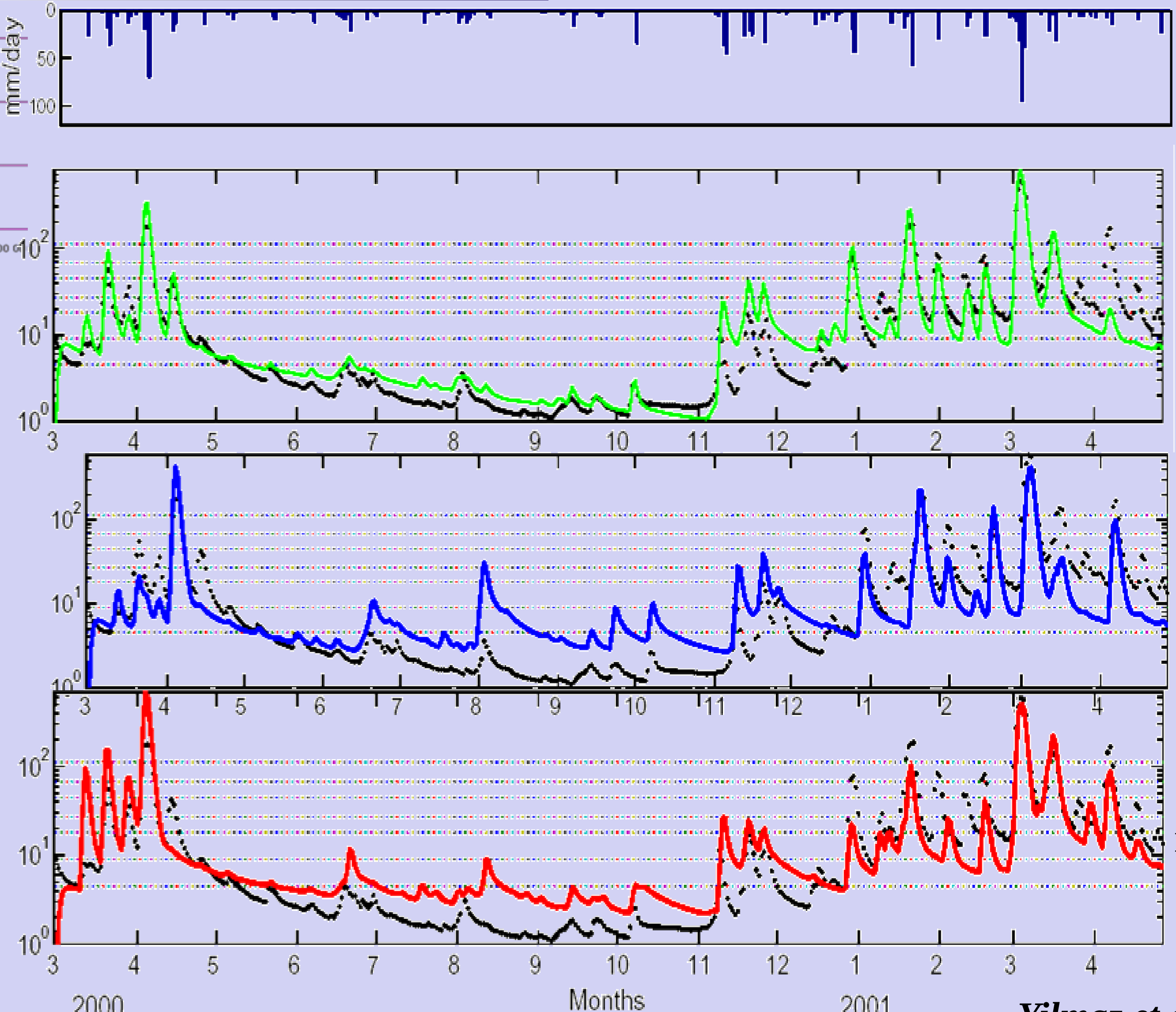
Basin Area : 753 mi^2



Yilmaz et al. JHM 2005

Satellite Rainfall Estimation: Research at UC Irvine





RAINGAGE

Corr =0.95
RMS =23.9
BIAS =-1.32

RADAR

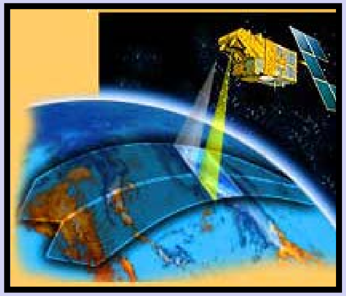
Corr =0.92
RMS =28.8
BIAS =-6.74

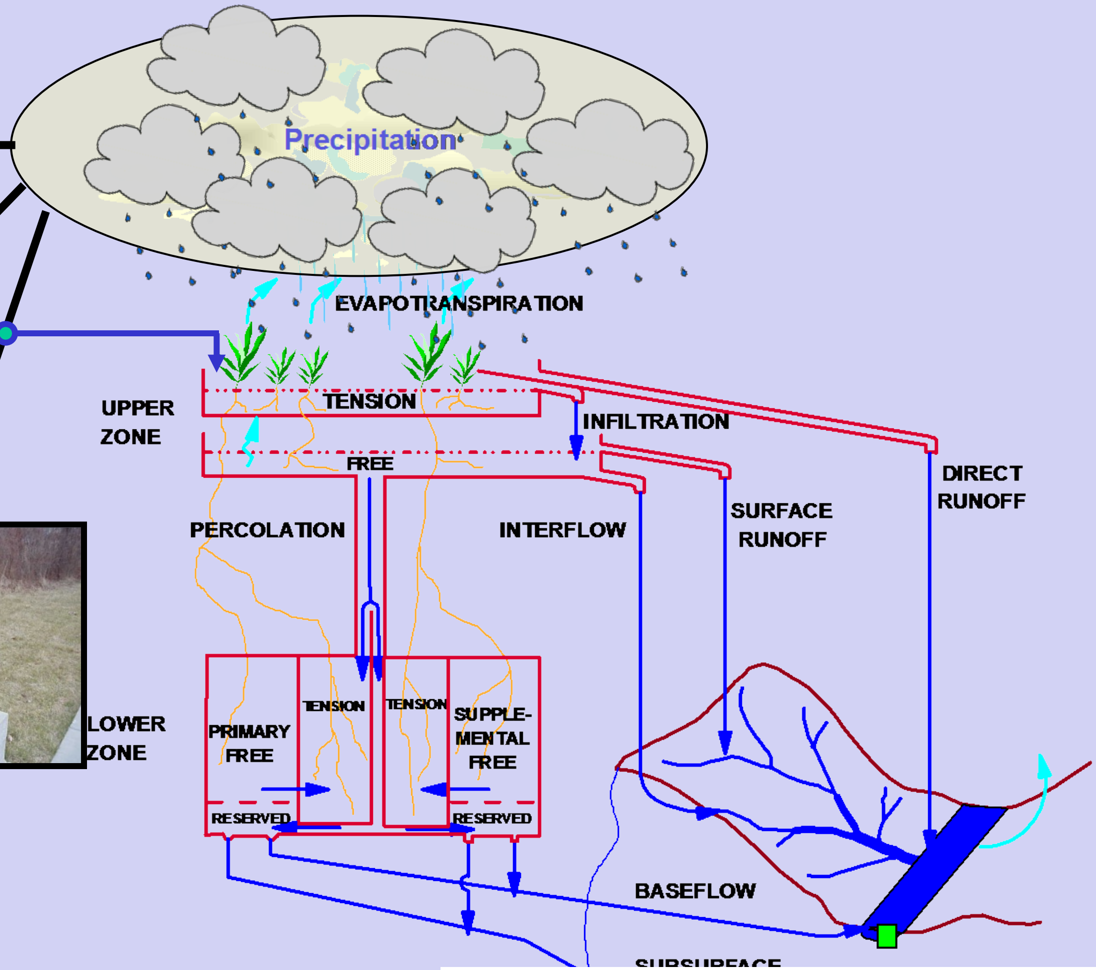
PERSIANN

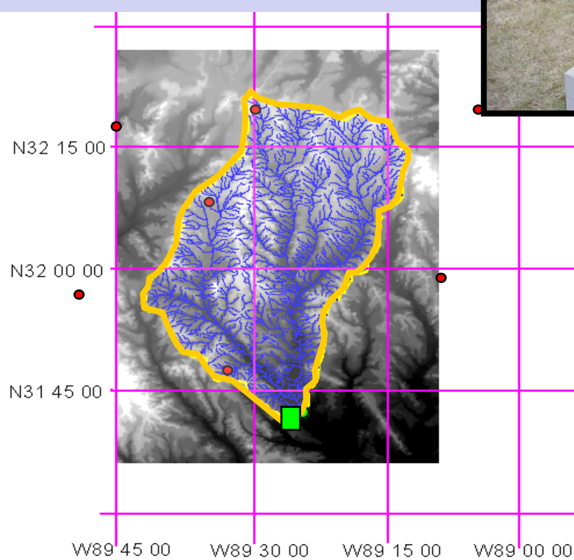
Corr =0.94
RMS =22.6
BIAS =-5.15

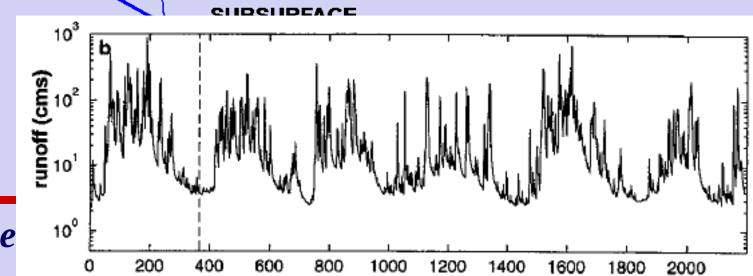
Yilmaz et al. JHM 2005

Basin Scale Precipitation Data Merging

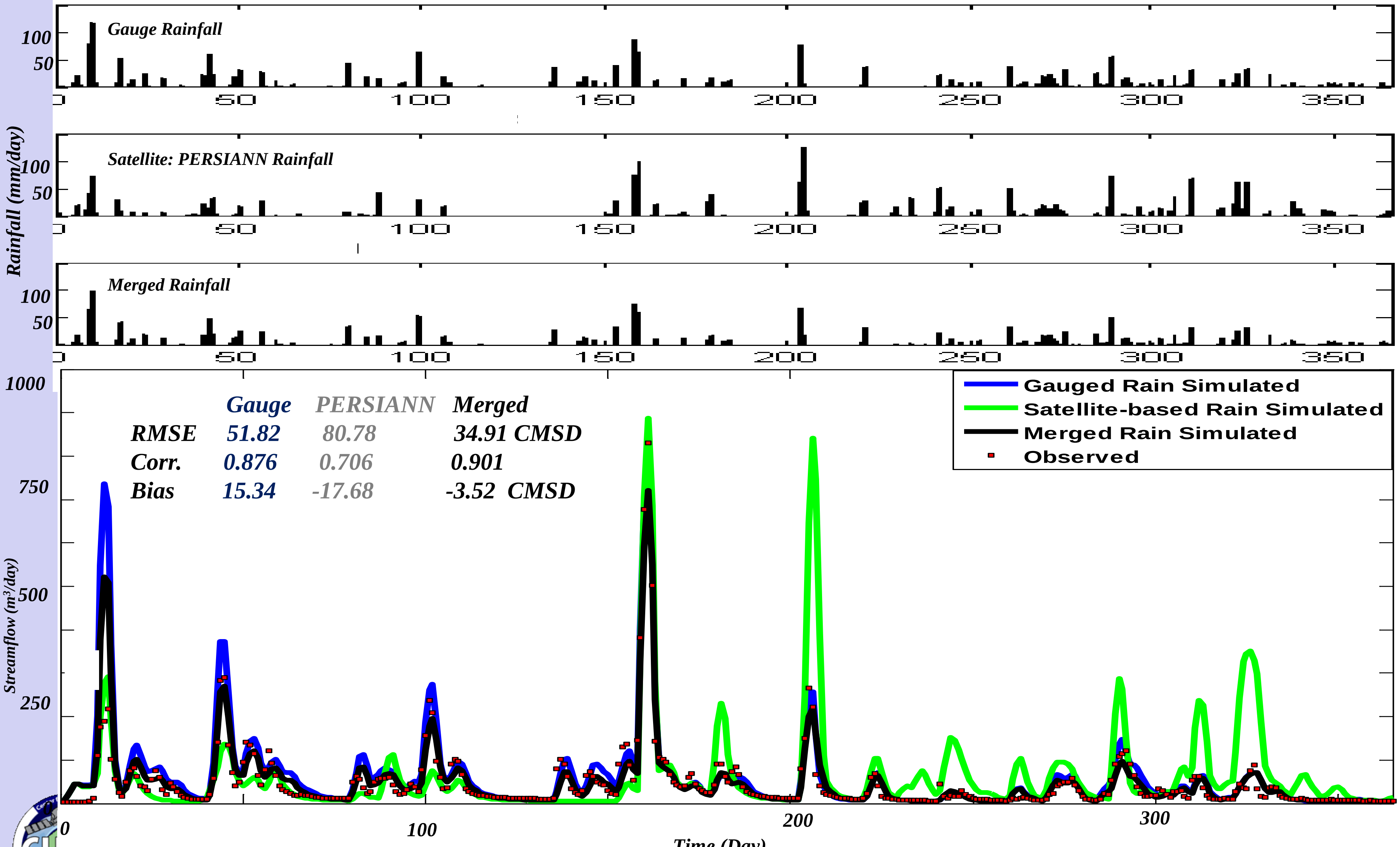








Runoff Forecasting from Gauge, PERSIANN, and Merged Rainfall



	Gauge	PERSIANN	Merged
RMSE	51.82	80.78	34.91 CMSD
Corr.	0.876	0.706	0.901
Bias	15.34	-17.68	-3.52 CMSD

Required Hydrometeorological 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

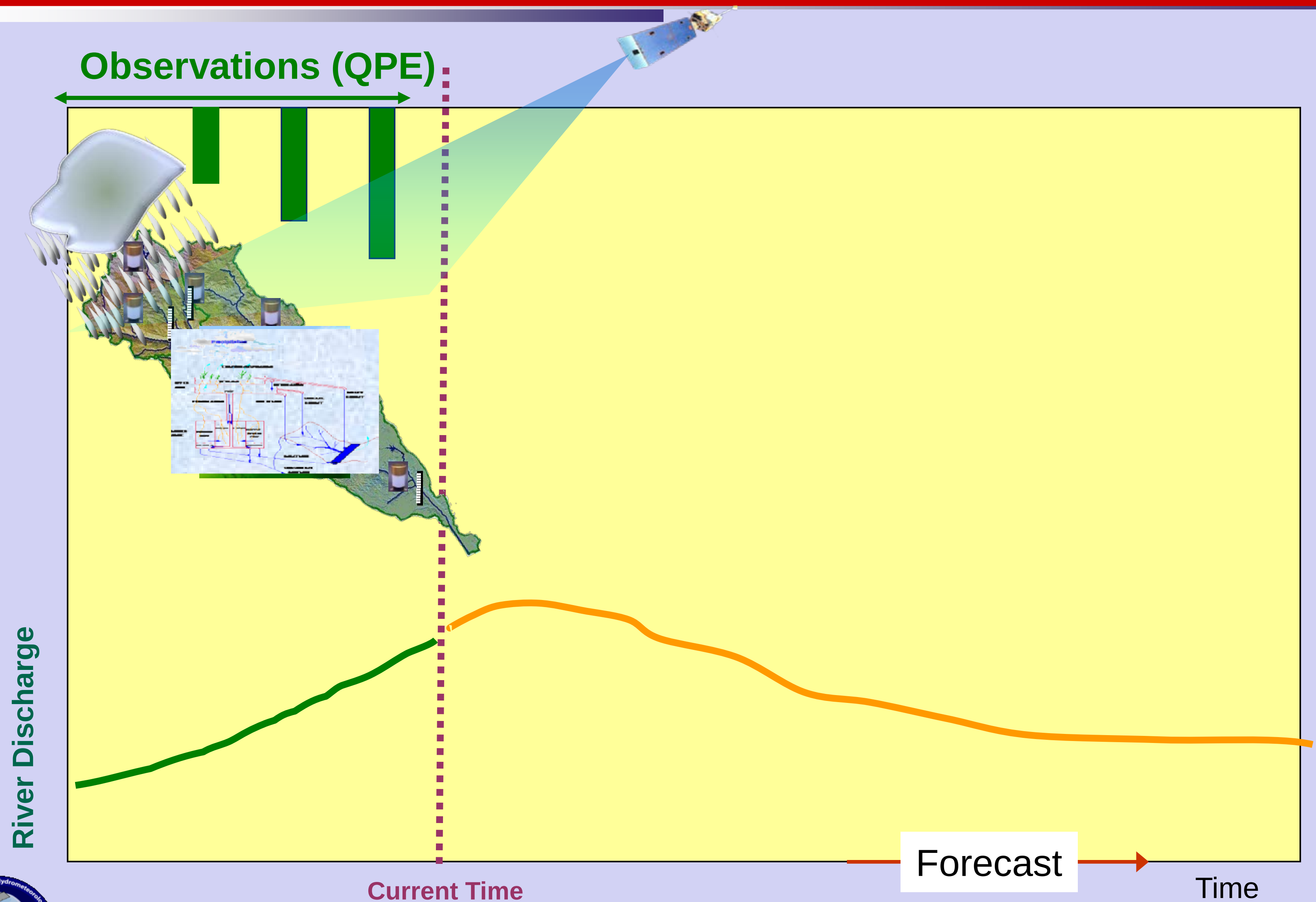
Spring Snowmelt Forecasts

Water Supply Volume

- ***Weather Scale:***
  - ***flood and River flow forecasting***

Short-range

Common practice in Flood and River Flow Forecasting



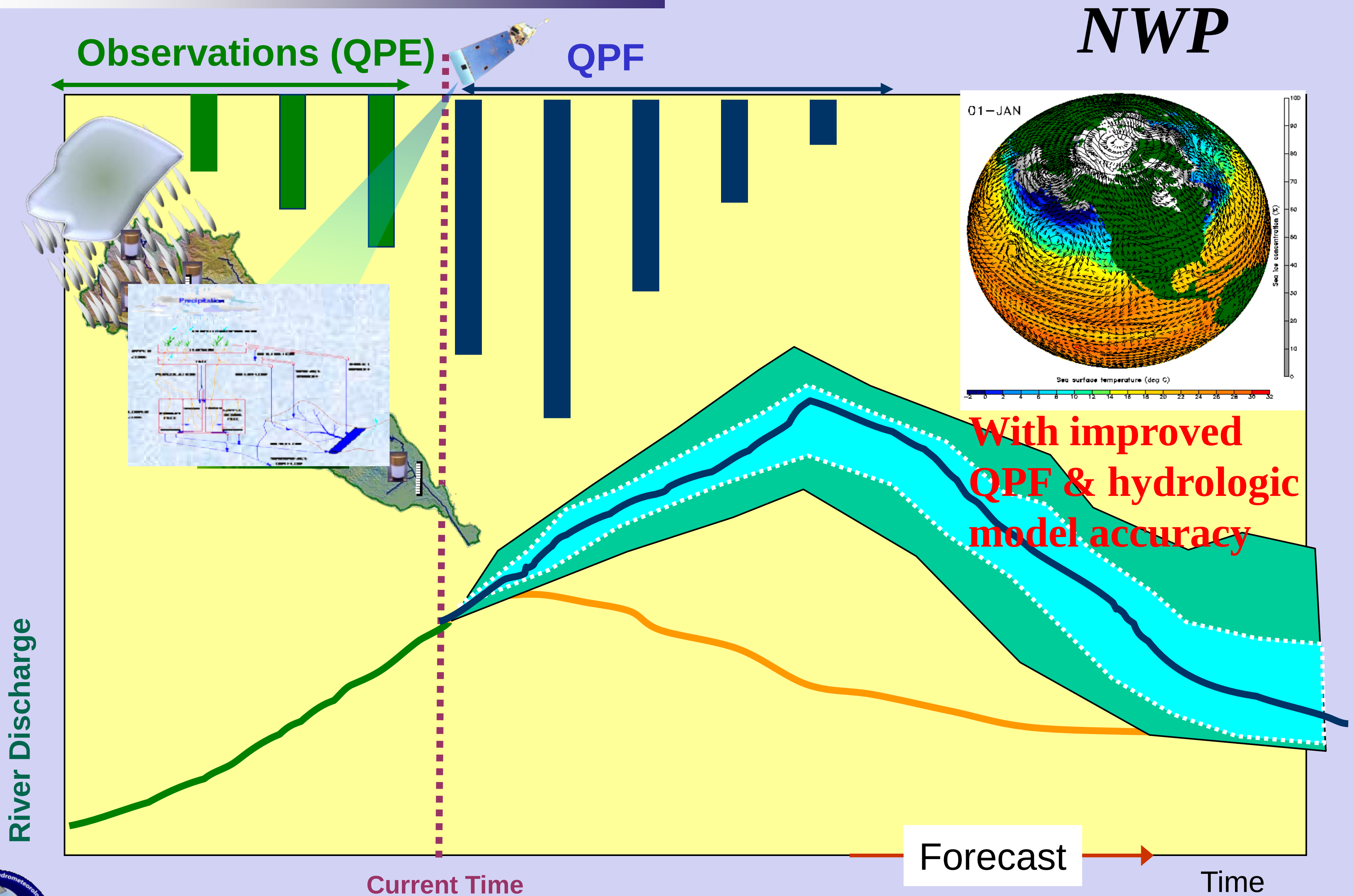
Animation Assisted by: Q. Xia & Gi-H. Park

Estimating Future "Short-Term" Rainfall:

1- Models: (NWP - QPF)

2- Extrapolation-based Nowcasting

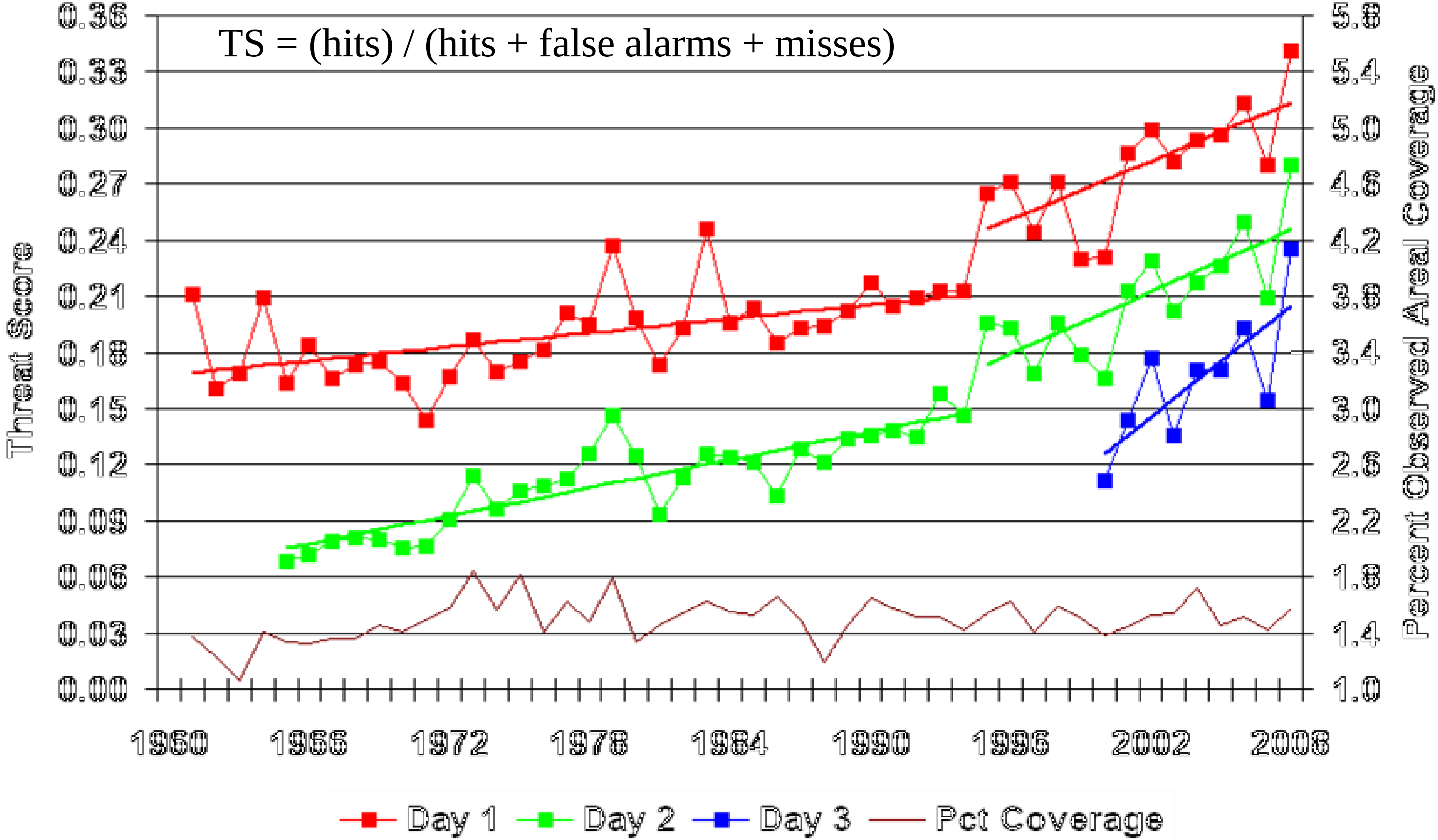
Efforts in Extending the Forecast Lead Time



Animation Assisted by: Q. Xia, Gi-H. Park & L. Bastidas

Provided by: J. Hoke

HPC QPF verification
1-inch threat score



In Brief:

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

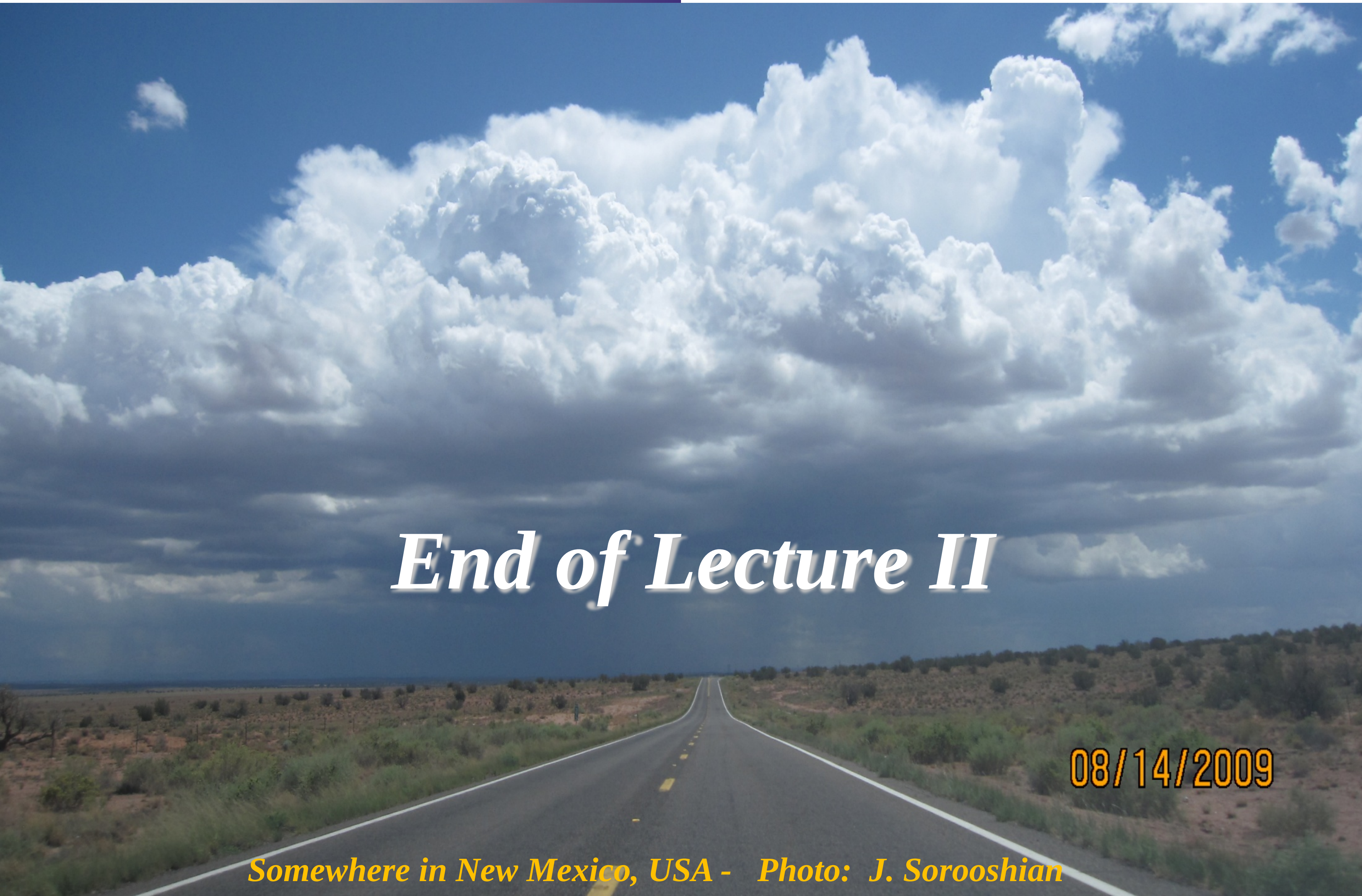
They Are Very Promising!

http://www.comet.ucar.edu/

COMET Training Material

http://www.comet.ucar.edu/

End of Lecture II



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