



Lecture II

Hydrological modeling requirements for Water Resources Applications - Data Issues

Soroosh Sorooshian

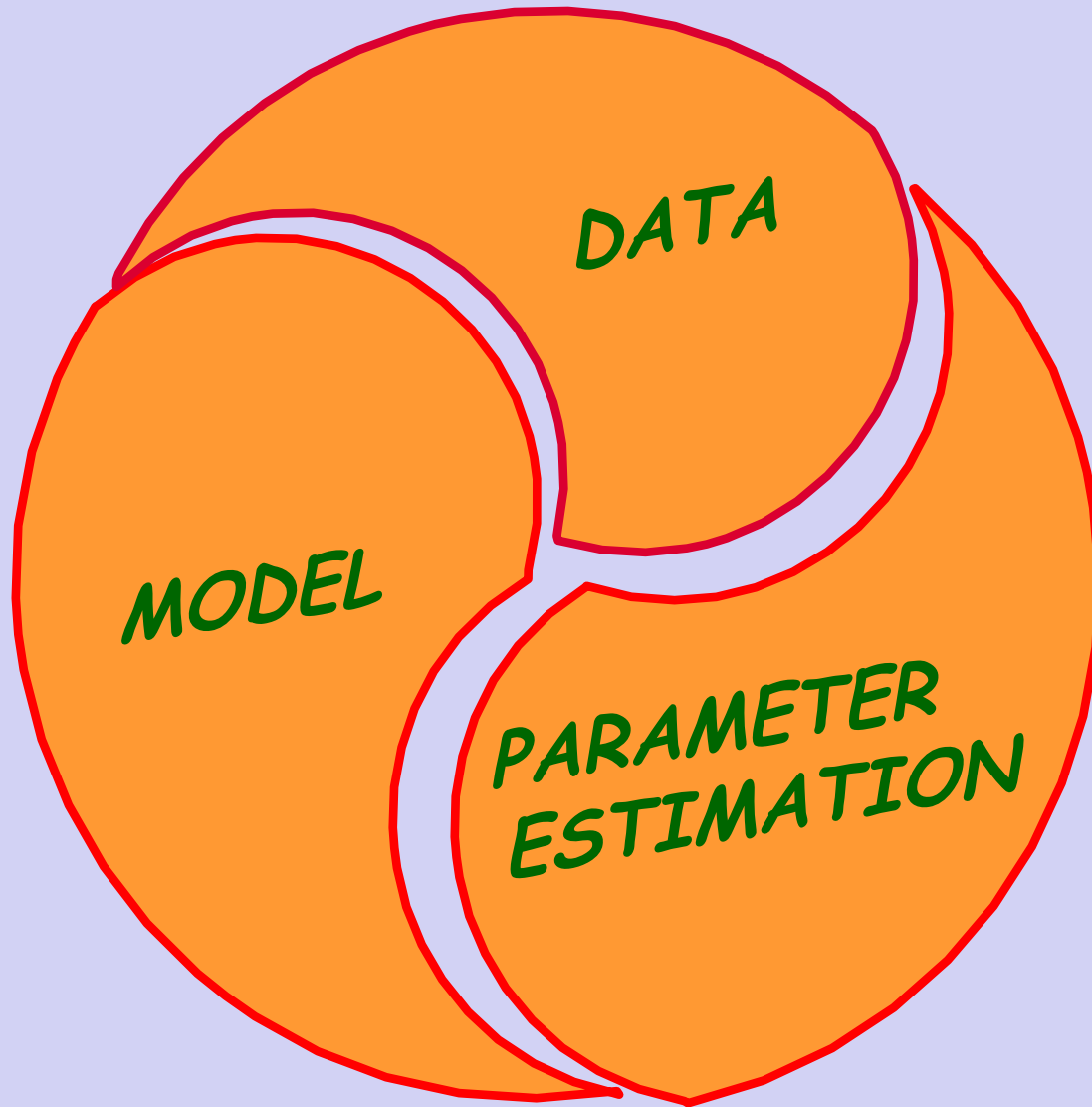
*Center for Hydrometeorology and Remote Sensing
University of California Irvine*



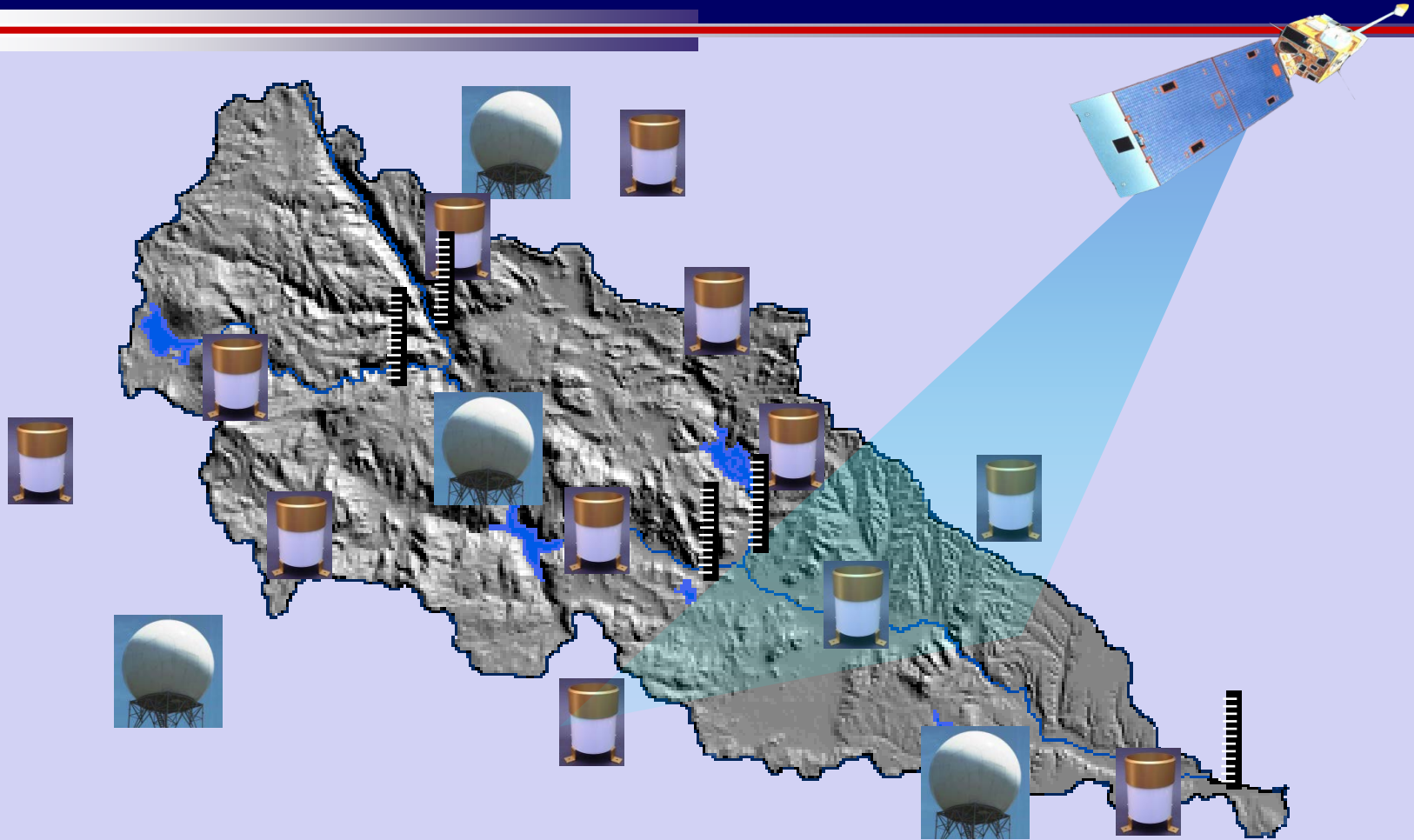
***The Abdus Salam ICTP Summer School on:
Climate Impact Modeling for Developing Countries:
Water, Agriculture & Health
Trieste, Italy: Sept. 5th – 16th 2011***



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*

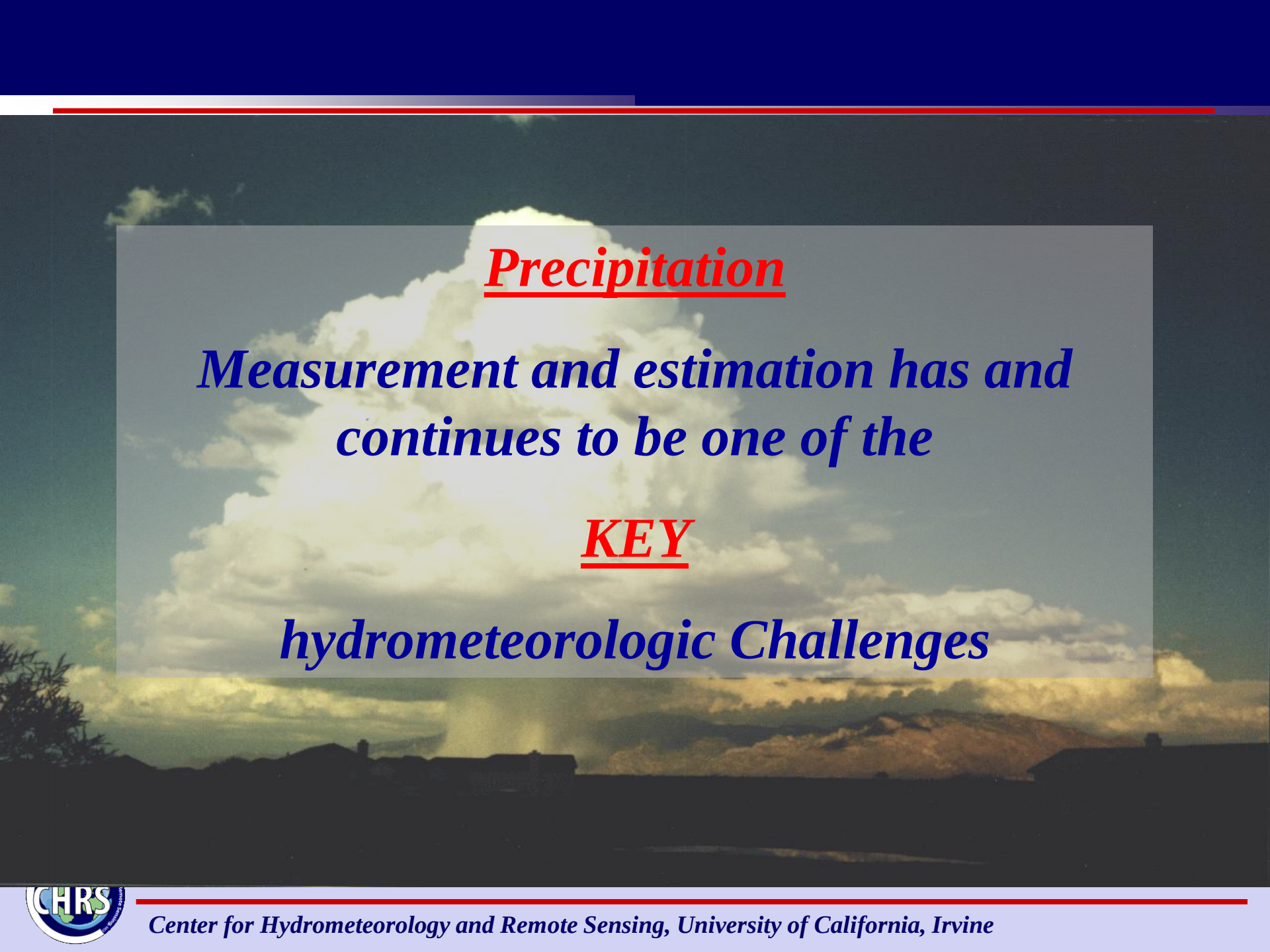
Observation of Primary Hydrologic Variables



Precipitation

Stream flow





Precipitation

*Measurement and estimation has and
continues to be one of the*

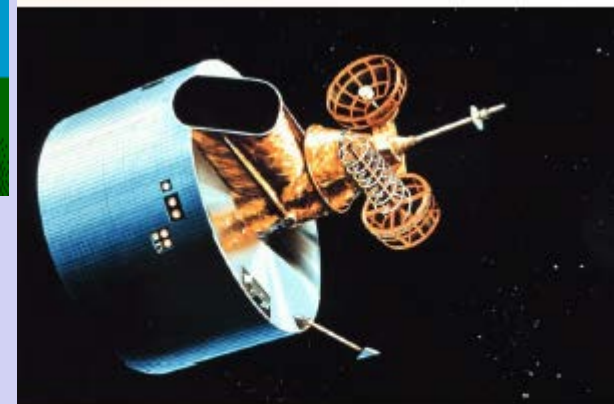
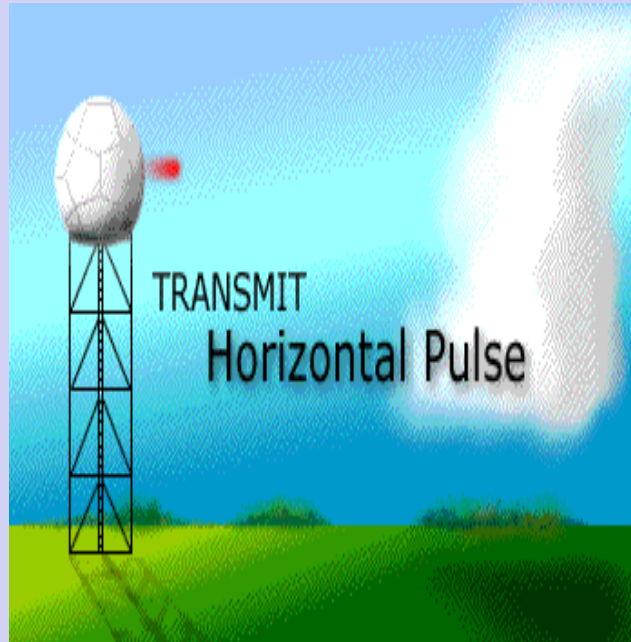
KEY

hydrometeorologic Challenges

Precipitation Observations: Which to trust??



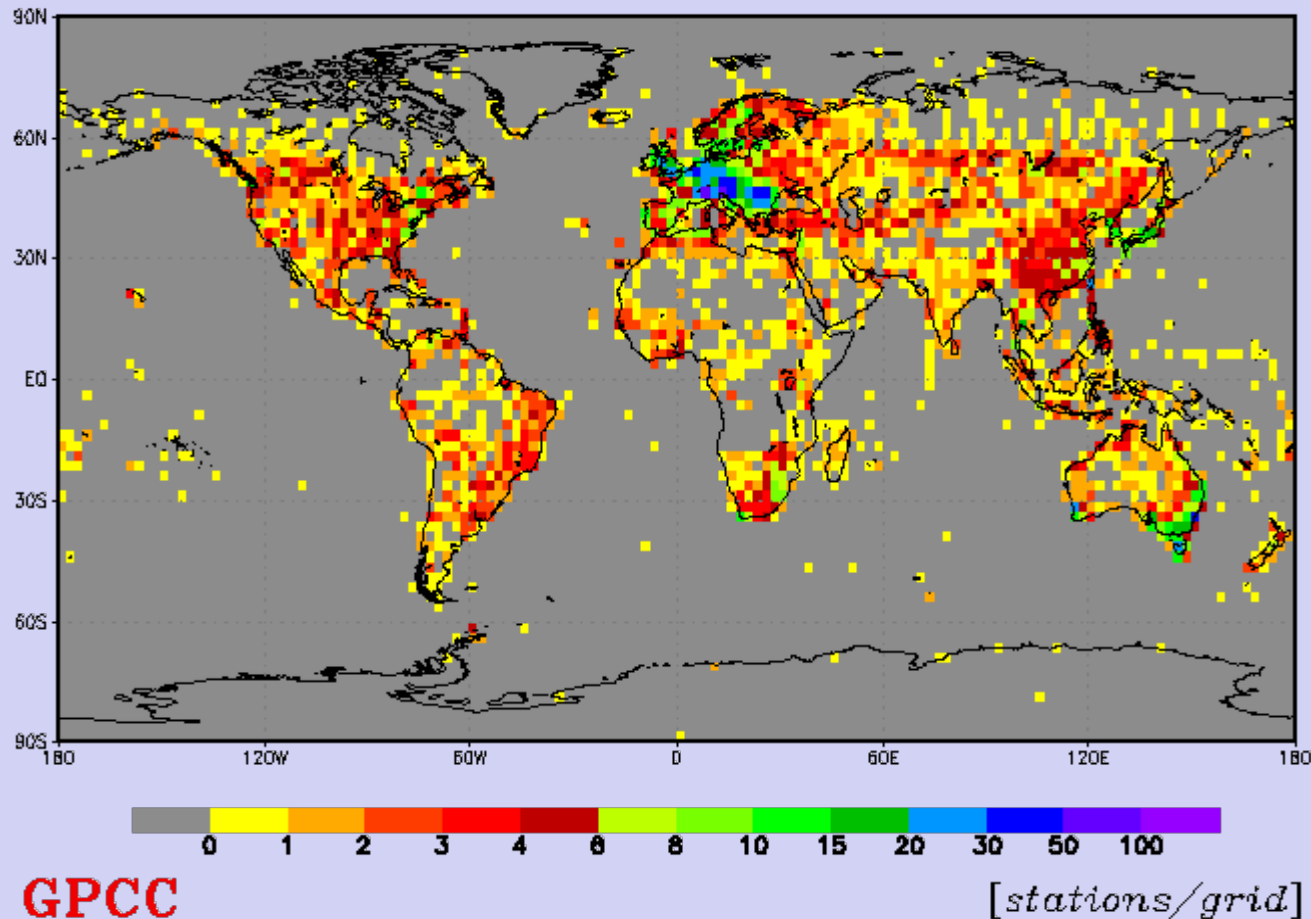
Rain Gauges



Satellite

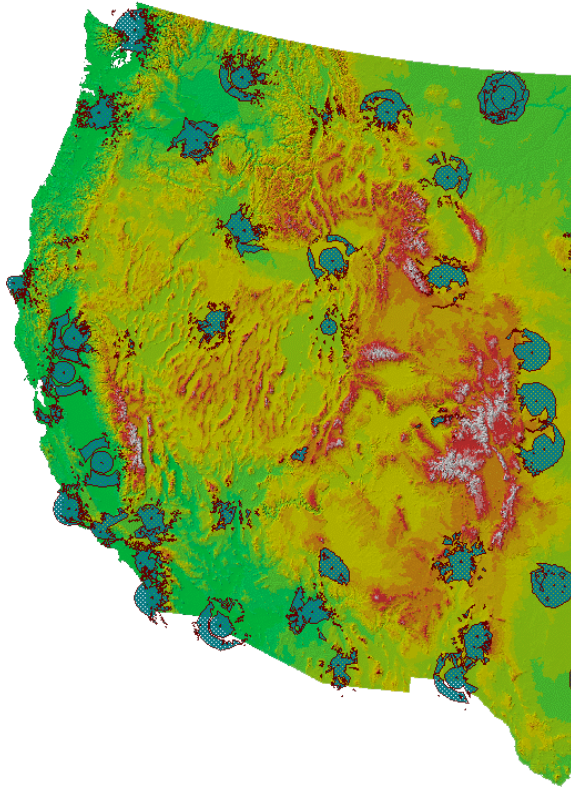


NUMBER OF GPCC-MONITORING-STATIONS
for MAY 1998



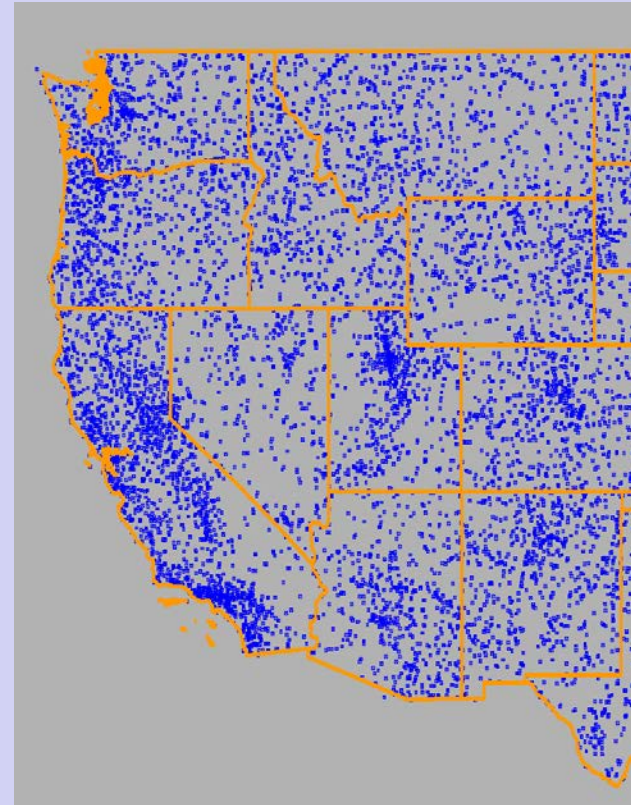
Number of range gauges per grid box. These boxes are 2x2 degrees
(Source: Global Precipitation Climatology Project)

Coverage of the WSR-88D and gauge networks



1 km AGL

Maddox, et al., 2002

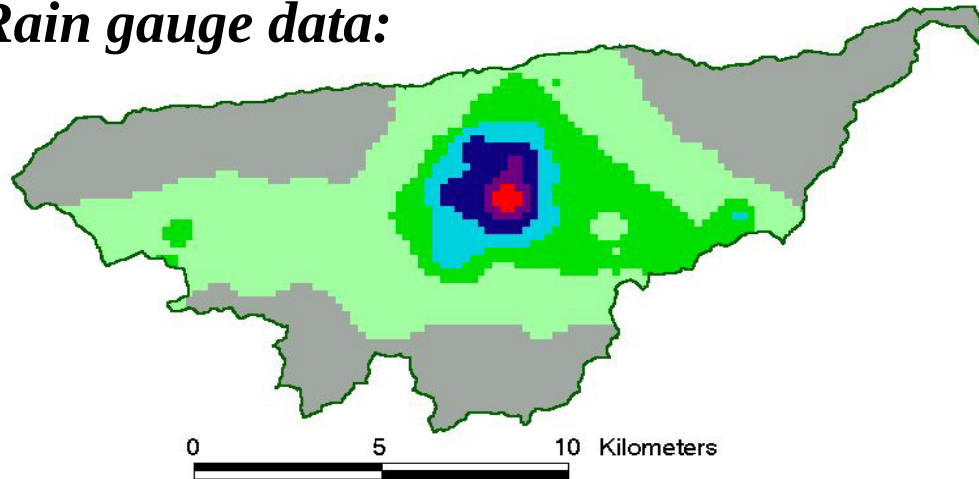


**Daily precipitation
gages (1 station per 600 km²
for Colorado River basin)
hourly coverage
even more sparse**



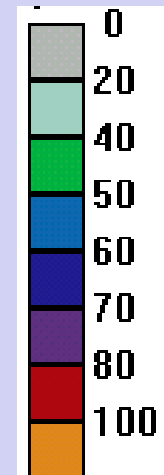
Radar-Gauge Comparison (Walnut Gulch, AZ)

Rain gauge data:

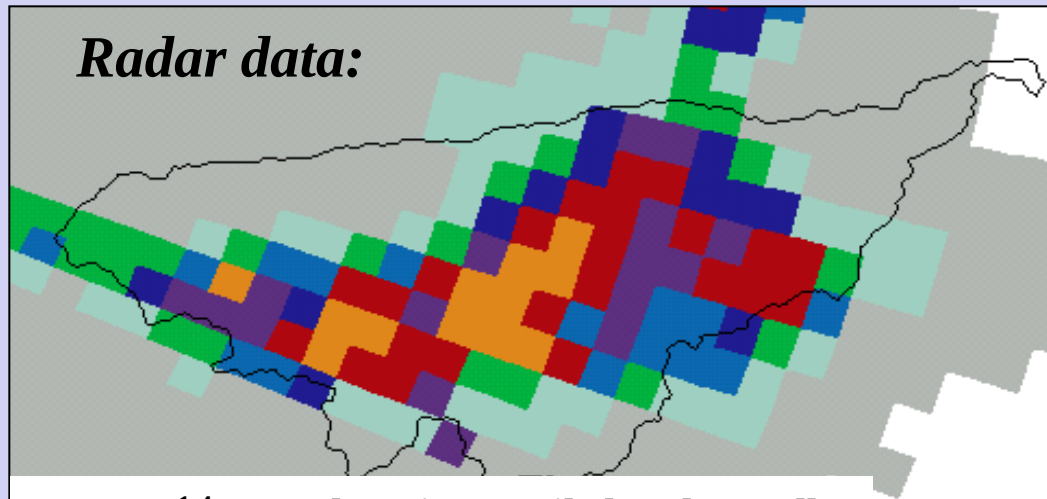


*Precipitation event:
Aug. 11, 2000*

Storm depth (mm)



Radar data:



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

*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

A



Monthly Total

100 mm

Frequency 6.7%

Intensity 50.0 mm

B



100 mm

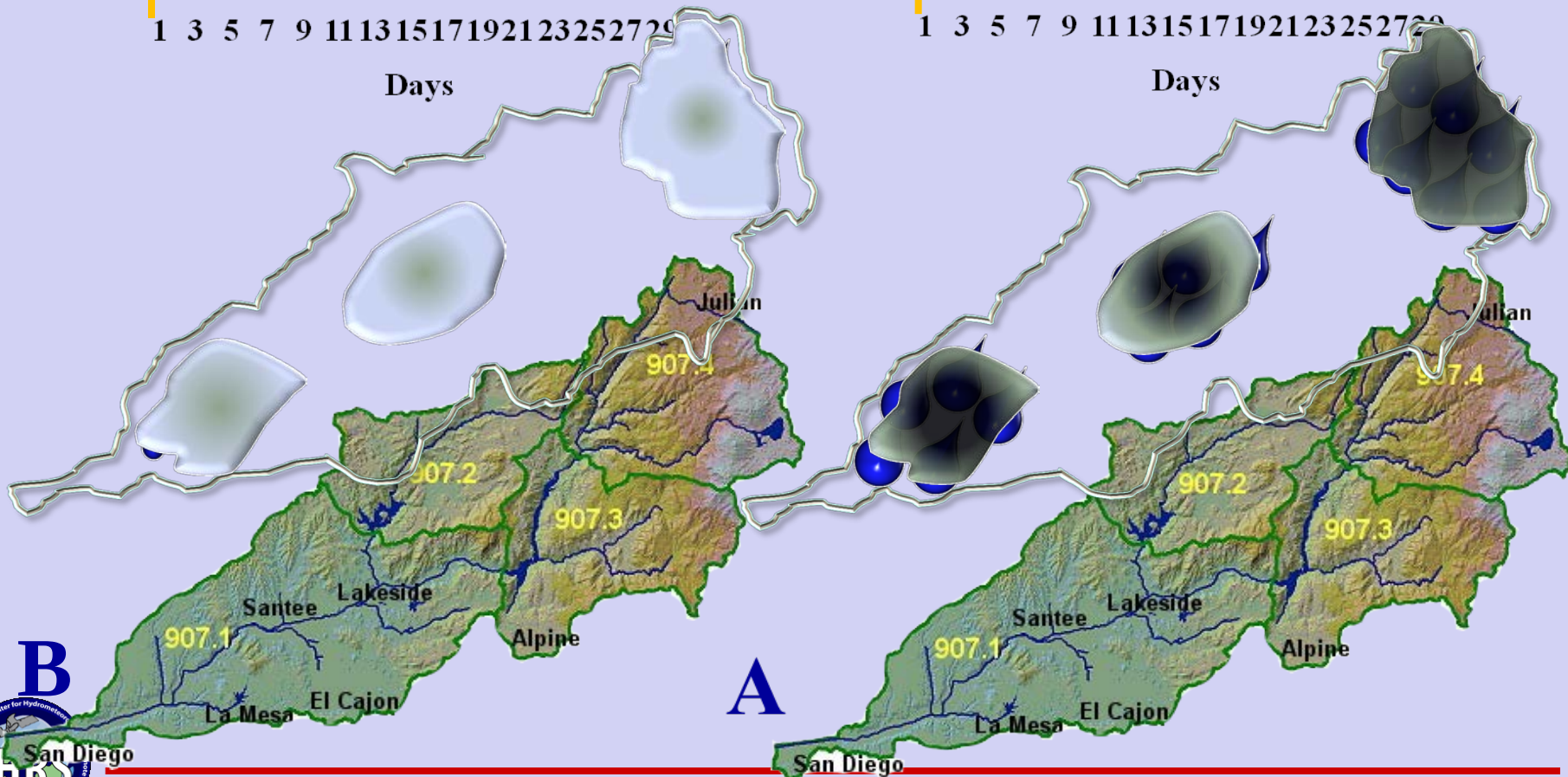
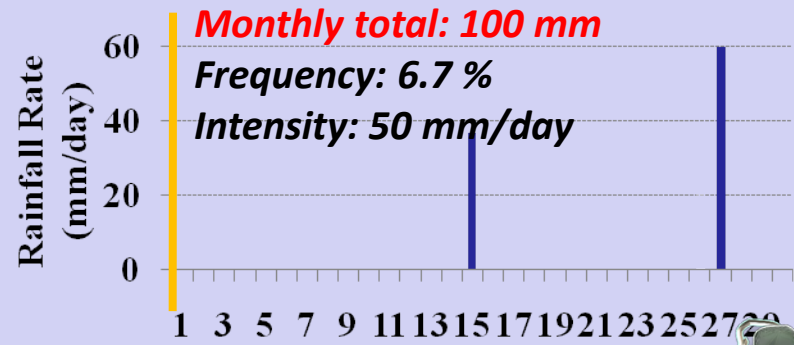
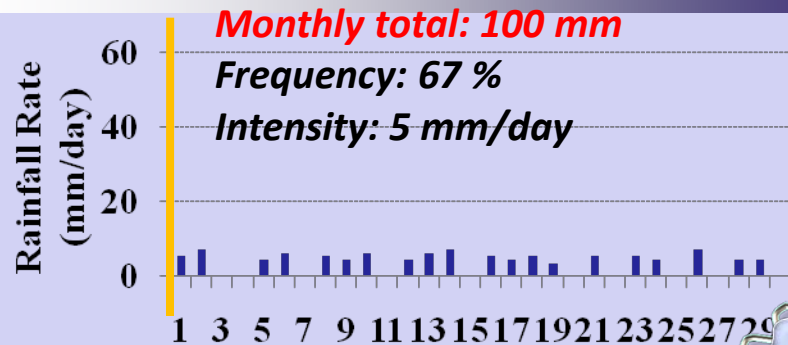
Frequency 67%

Intensity 5.0 mm



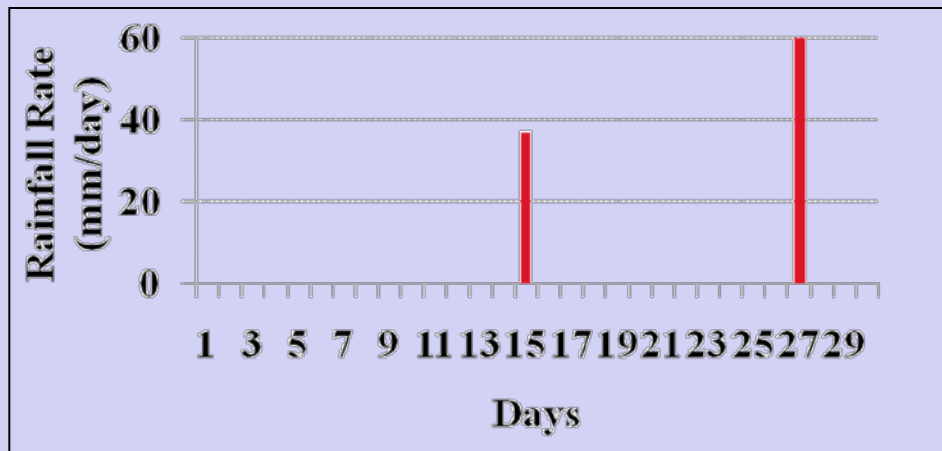
Idea from: K. Trenberth, NCAR

Temporal Scale Importance: Daily Precip. at 2 stations



Importance of Temporal Scale : Daily Precip. at 2 stations

A

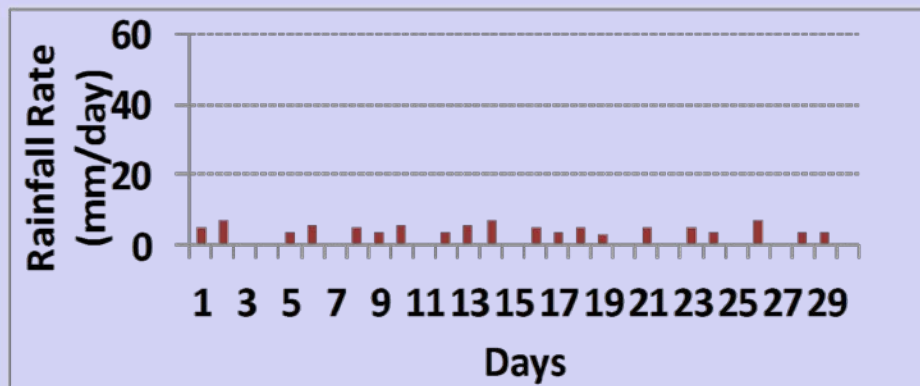


Frequency 6.7%

Intensity 50.0 mm

- *Localized Flooding*
- *Stream bed Recharge*

B



Frequency 67%

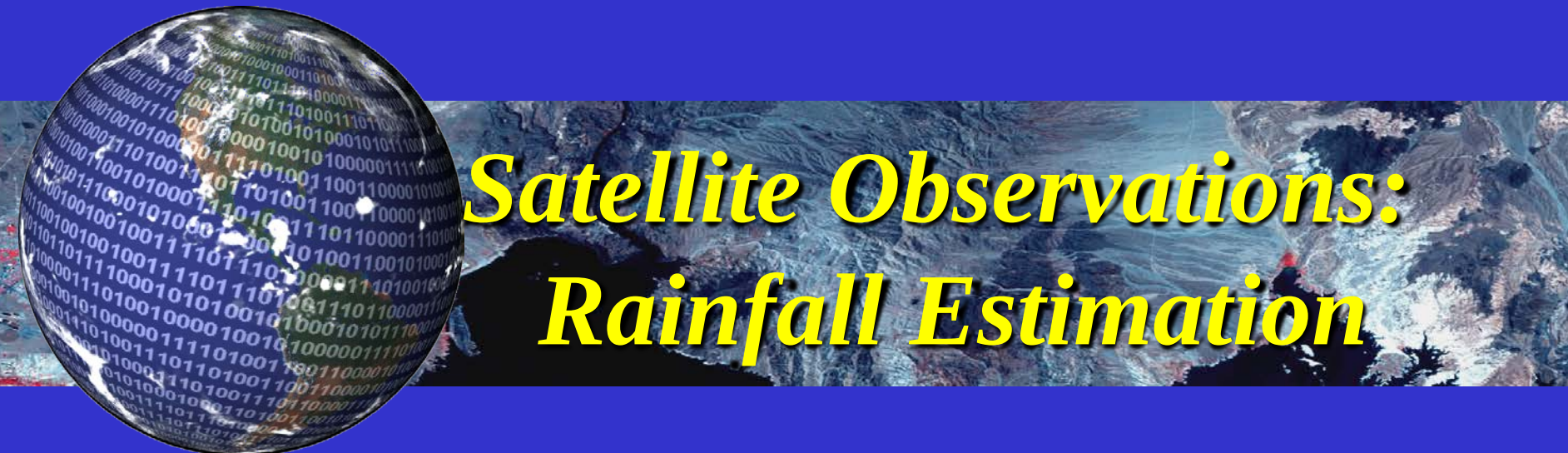
Intensity 5.0 mm

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



Idea from: K. Trenberth, NCAR

Space-Based Observations



Satellite Observations: Rainfall Estimation



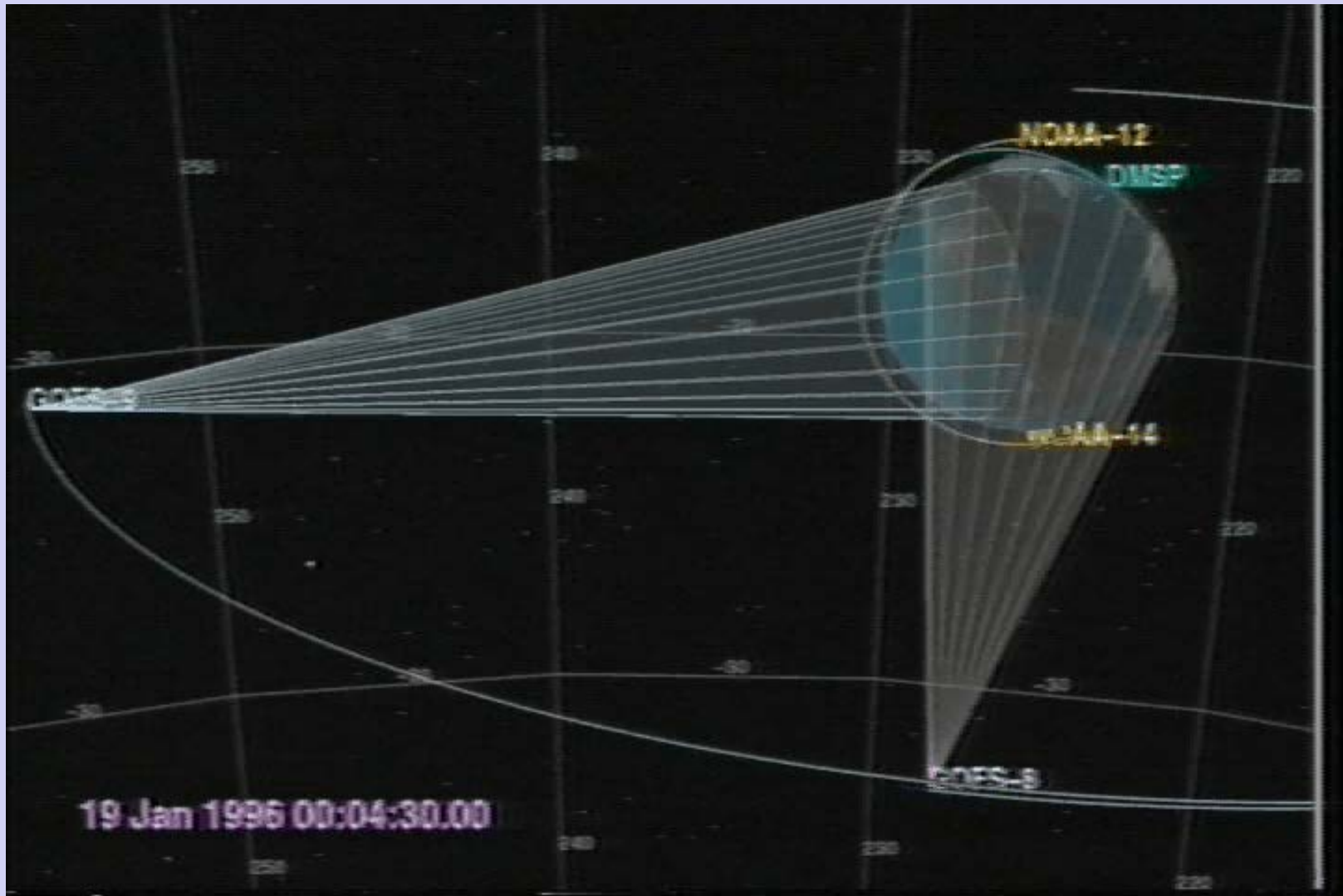
Satellite-Based Rainfall Estimation: Promising !

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



Geostationary and Polar Satellites

Courtesy: NASA's ESE



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Satellite precipitation retrieval instruments

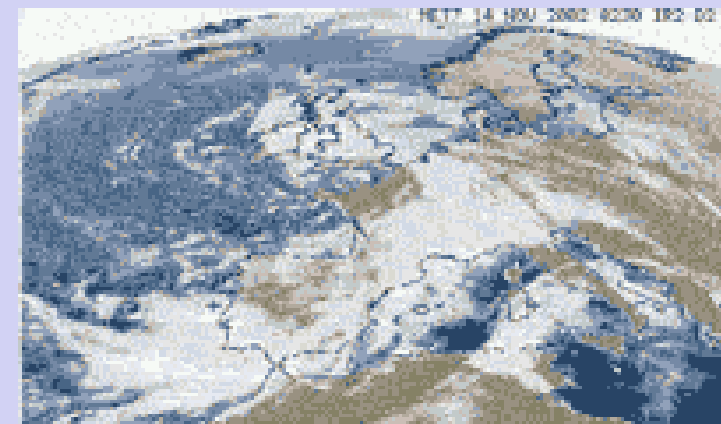
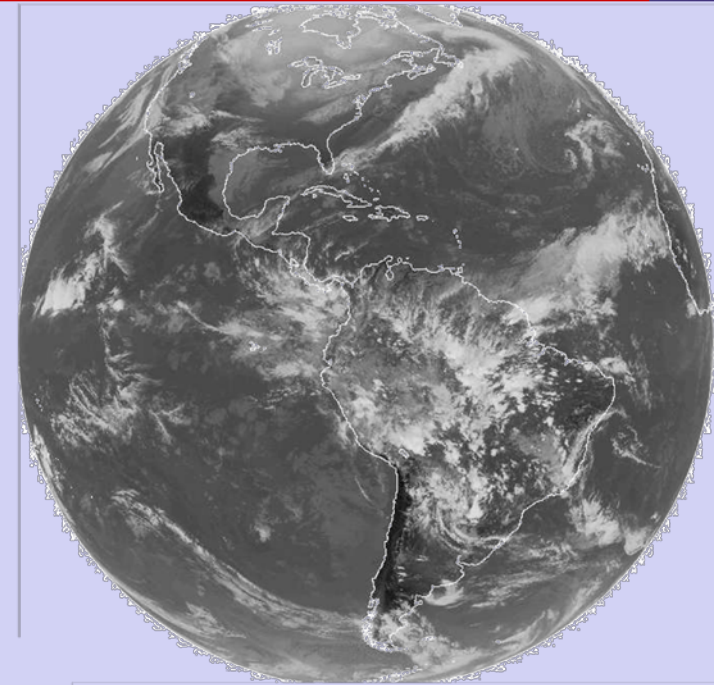
1) Using GEO satellites (Infrared/Visible channels)

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 $\rightarrow$ colder $\rightarrow$ 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 ($\sim 5\text{-}50\text{km}$)
- Heterogeneous emissivity over land:
(e.g., problem with warm rainfall over land)



Satellite precipitation retrieval instruments

3) Active Radar

Advantage:

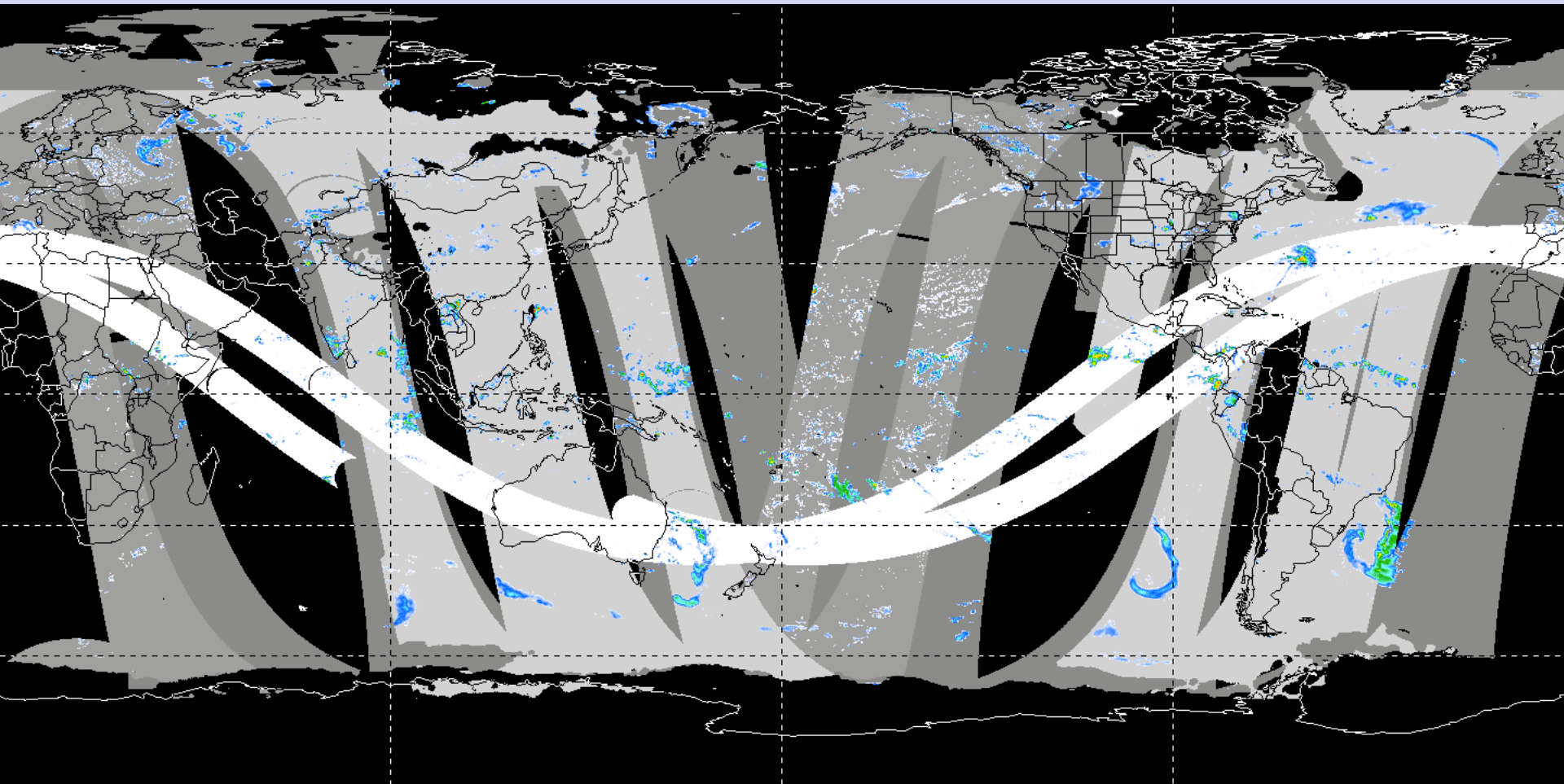
- More accurate
- good spatial resolution

Disadvantage:

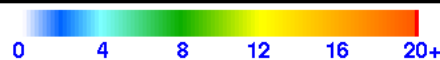
- Poor temporal resolution



Typical Microwave Coverage in 3 Hr



Precip (mm/d) Aug 1987



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

TMI – white

AMSU-E – medium grey

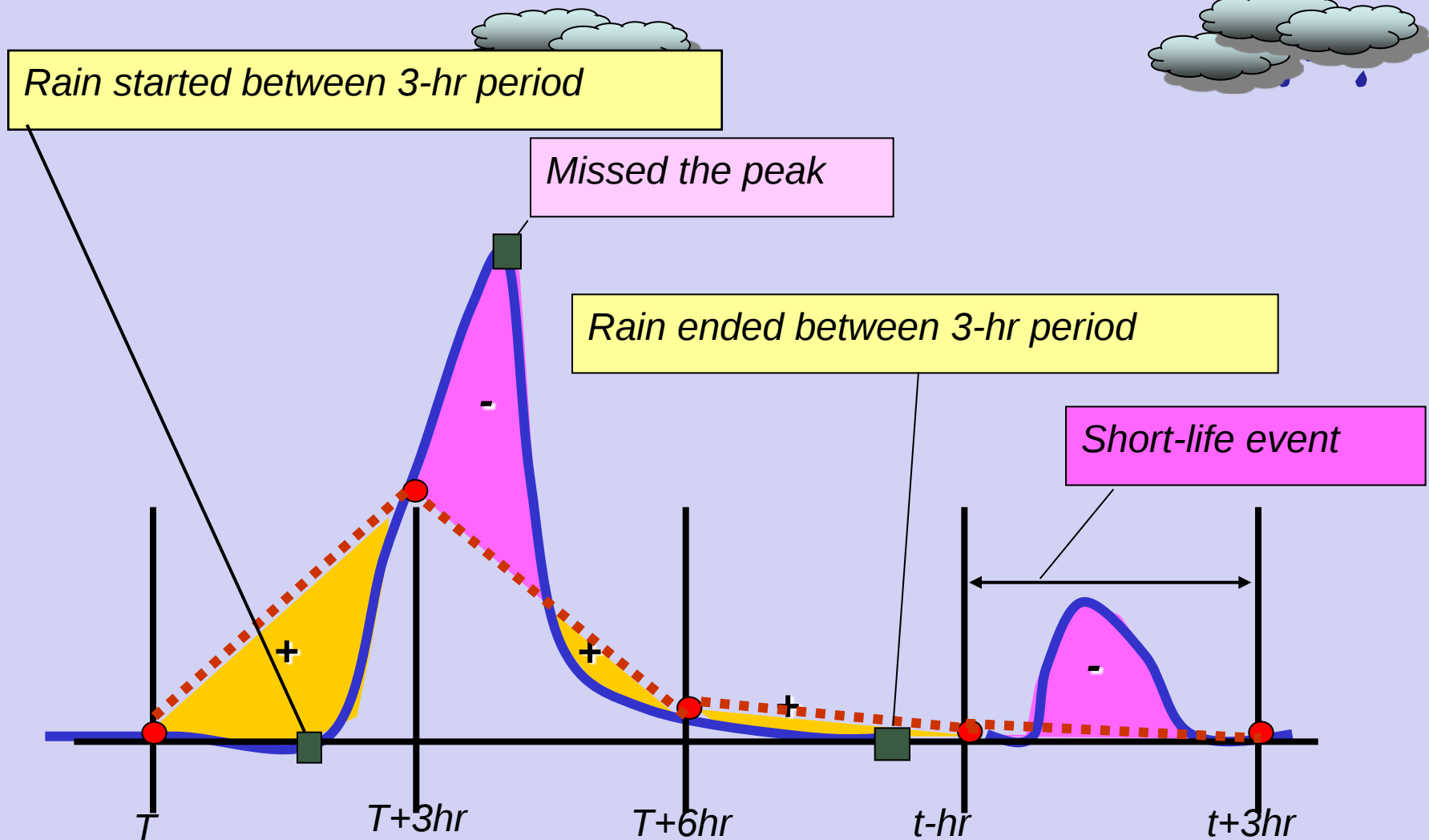
SSM/I – light grey

AMSU-B – dark grey



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Interpolation of 3-hour Precipitation



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



PERSIANN System

Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks

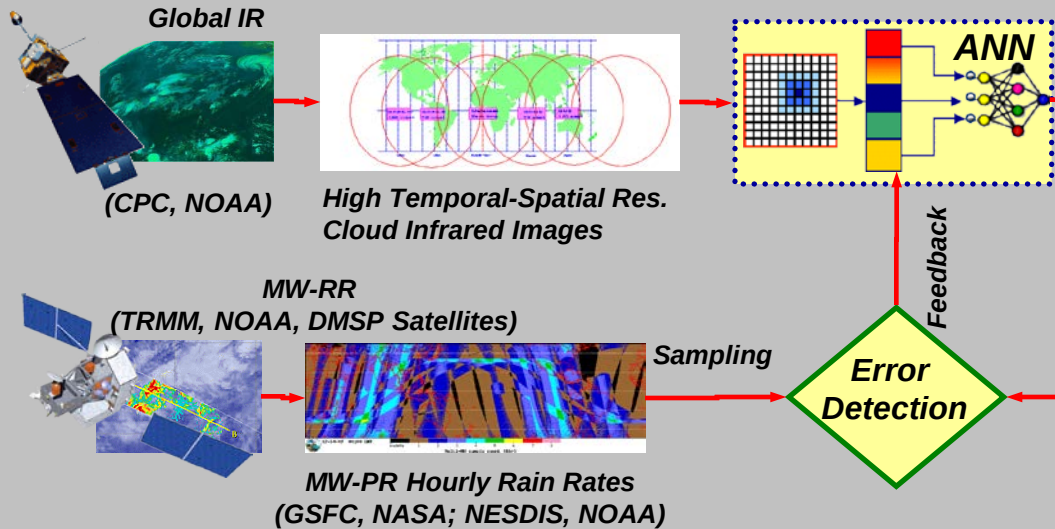


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Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)

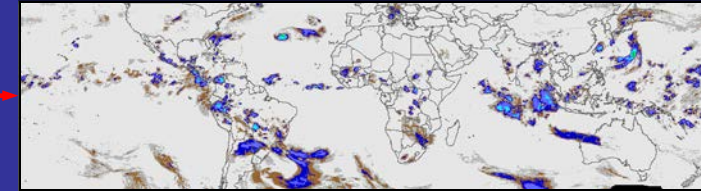
PERSIANN System "Estimation"

Satellite Data



Products

Hourly Global Precipitation Estimates



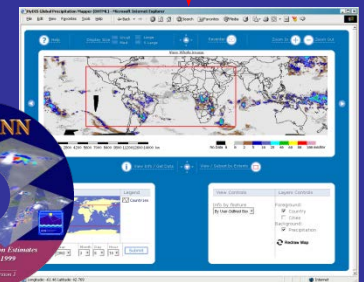
Hourly Rain Estimate

Quality Control

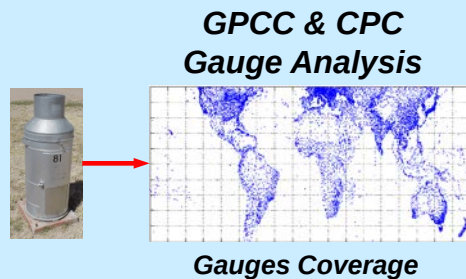
Merging

Merged Products

- Hourly rainfall
- 6 hourly rainfall
- Daily rainfall
- Monthly rainfall



Ground Observations



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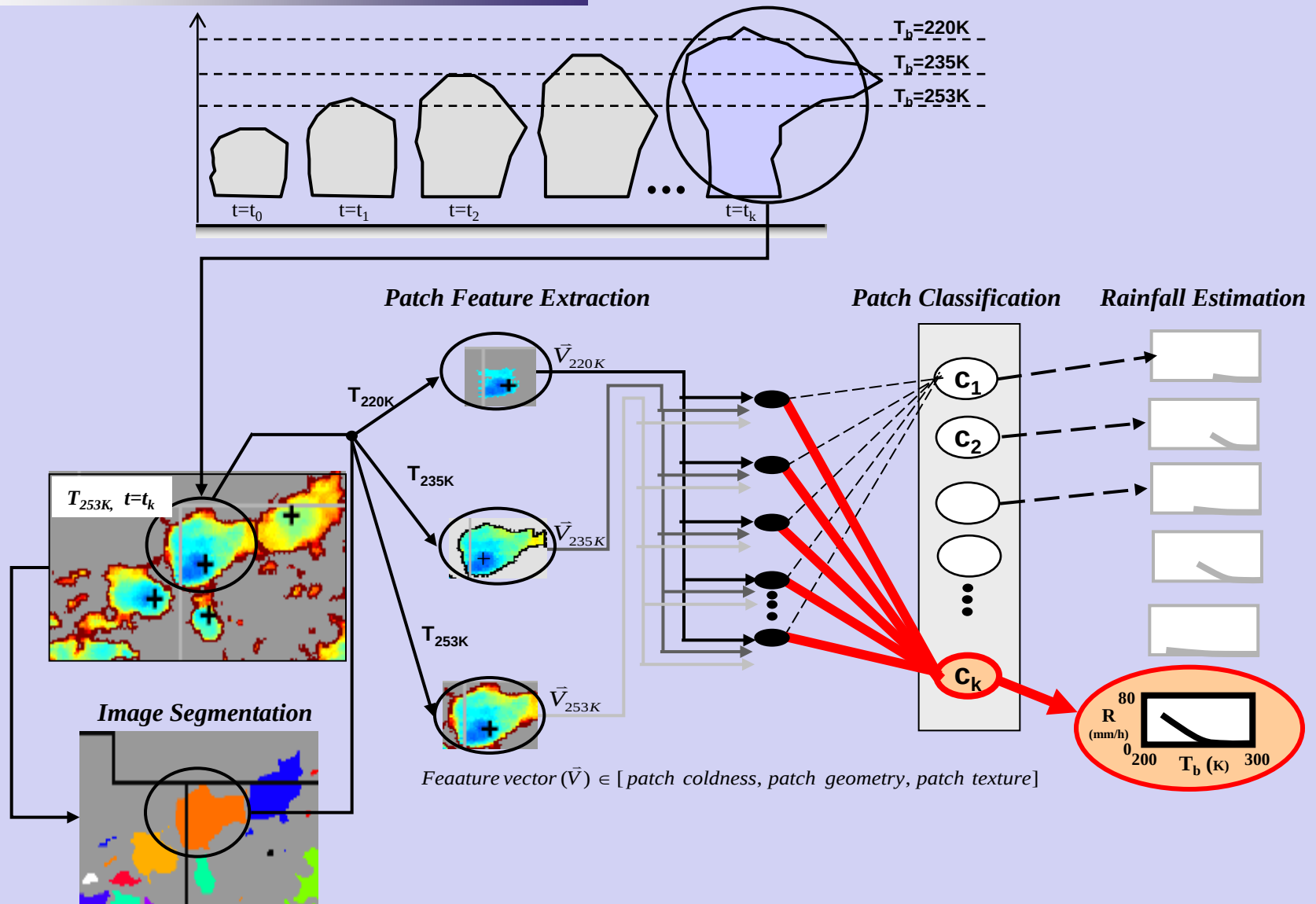
High Resolution Precipitation Estimates

PERSIANN-CCS

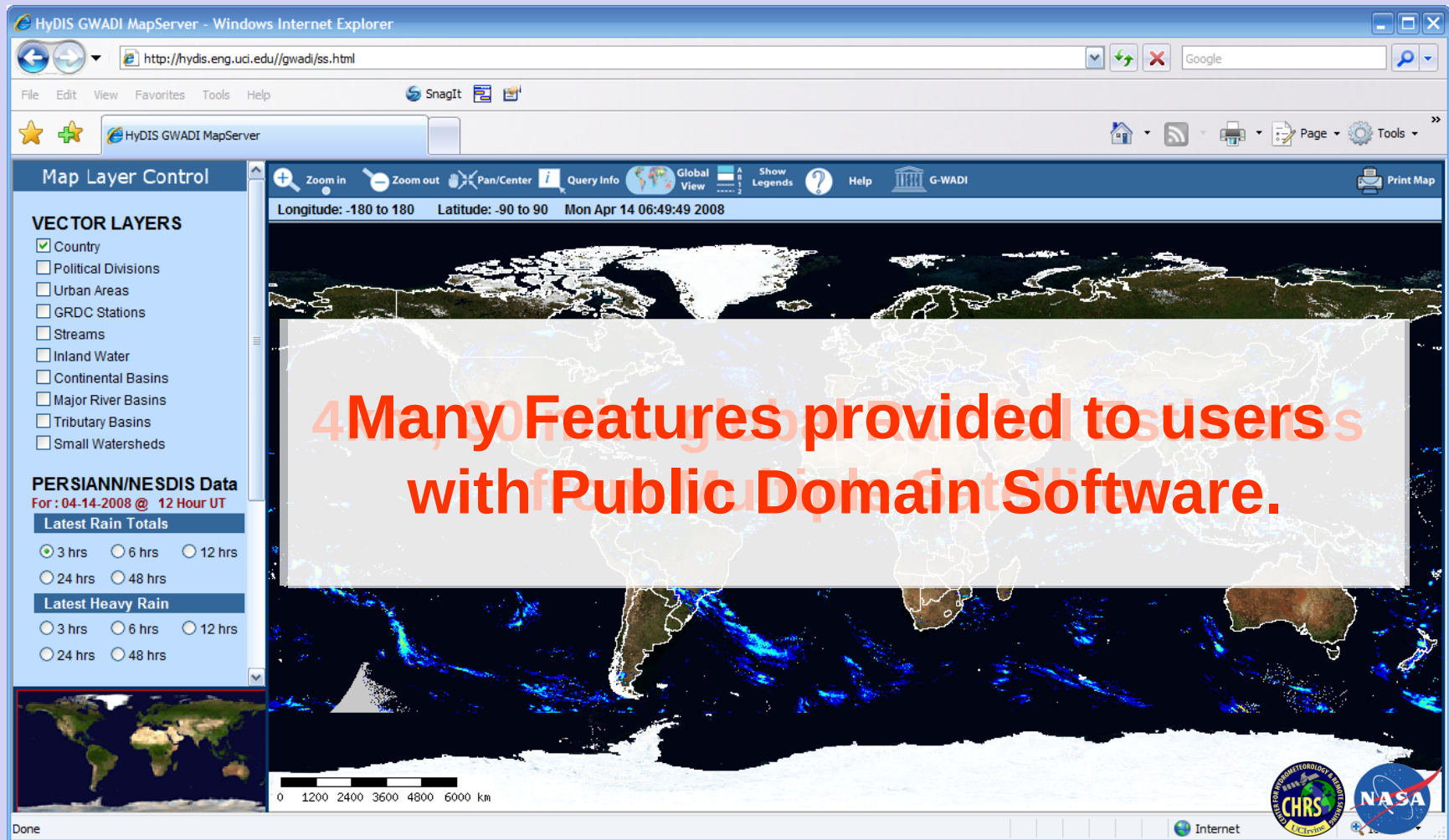


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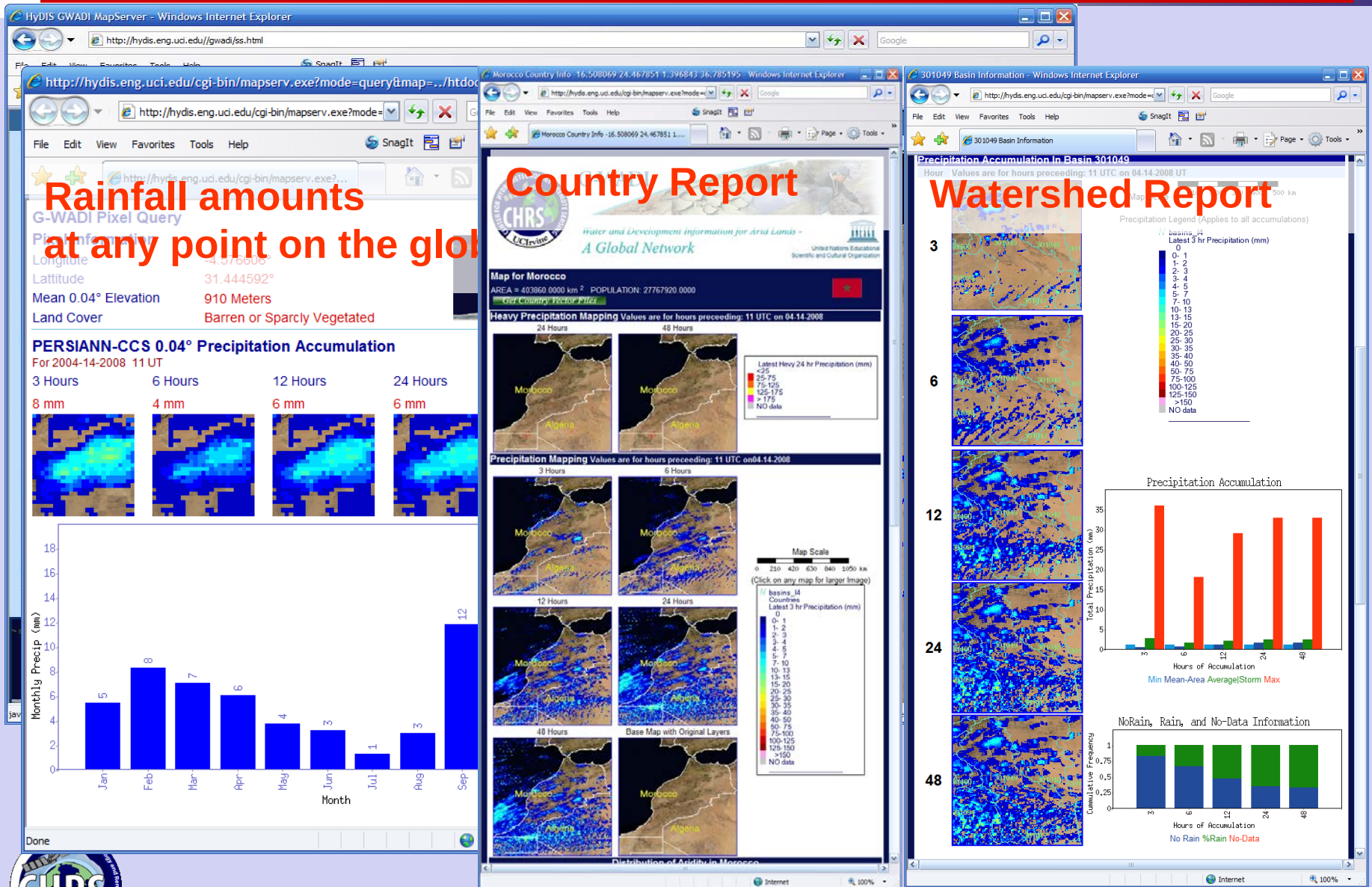
Cloud Segmentation Algorithm



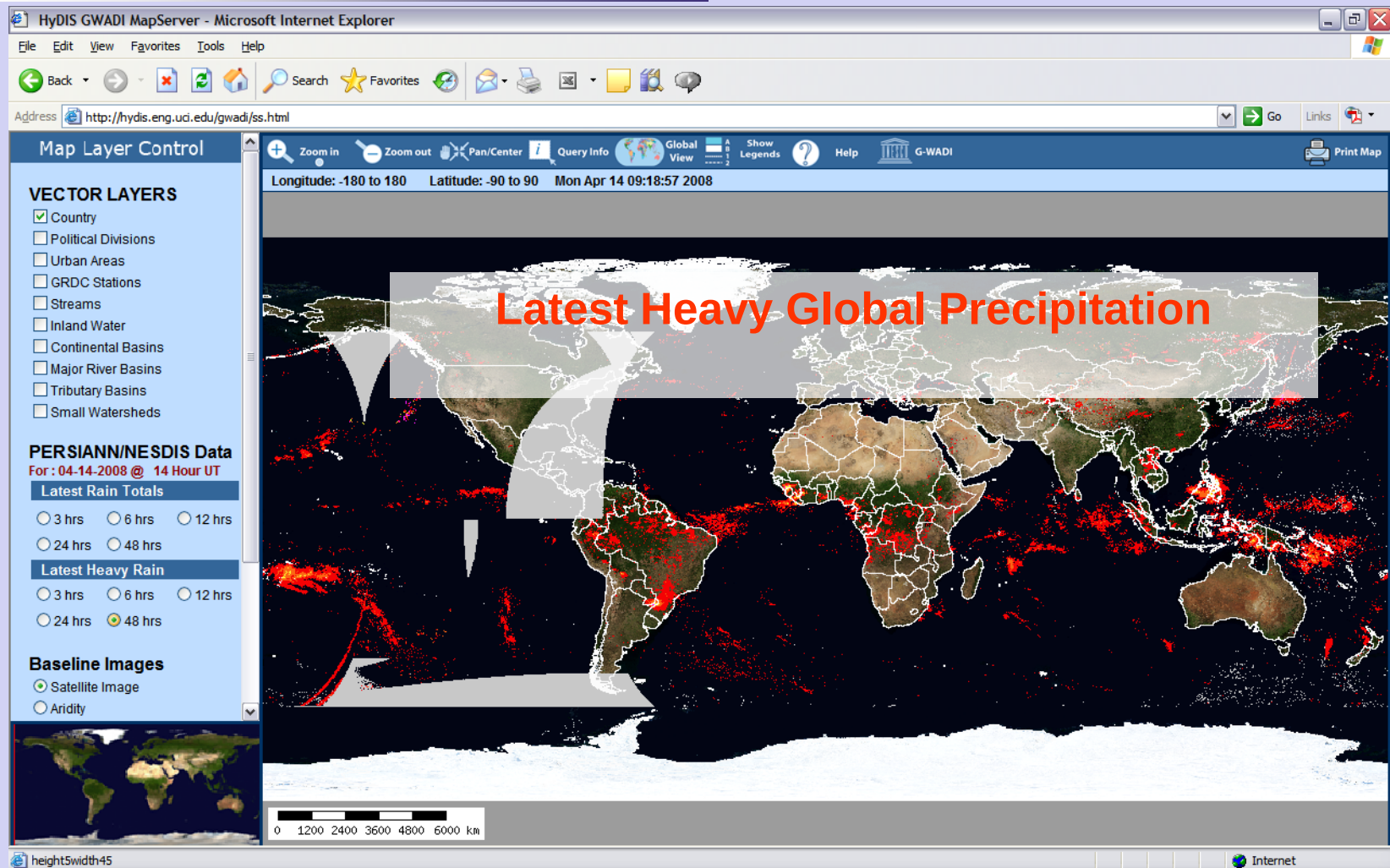
Real Time Global Data: Cooperation With UNESCO



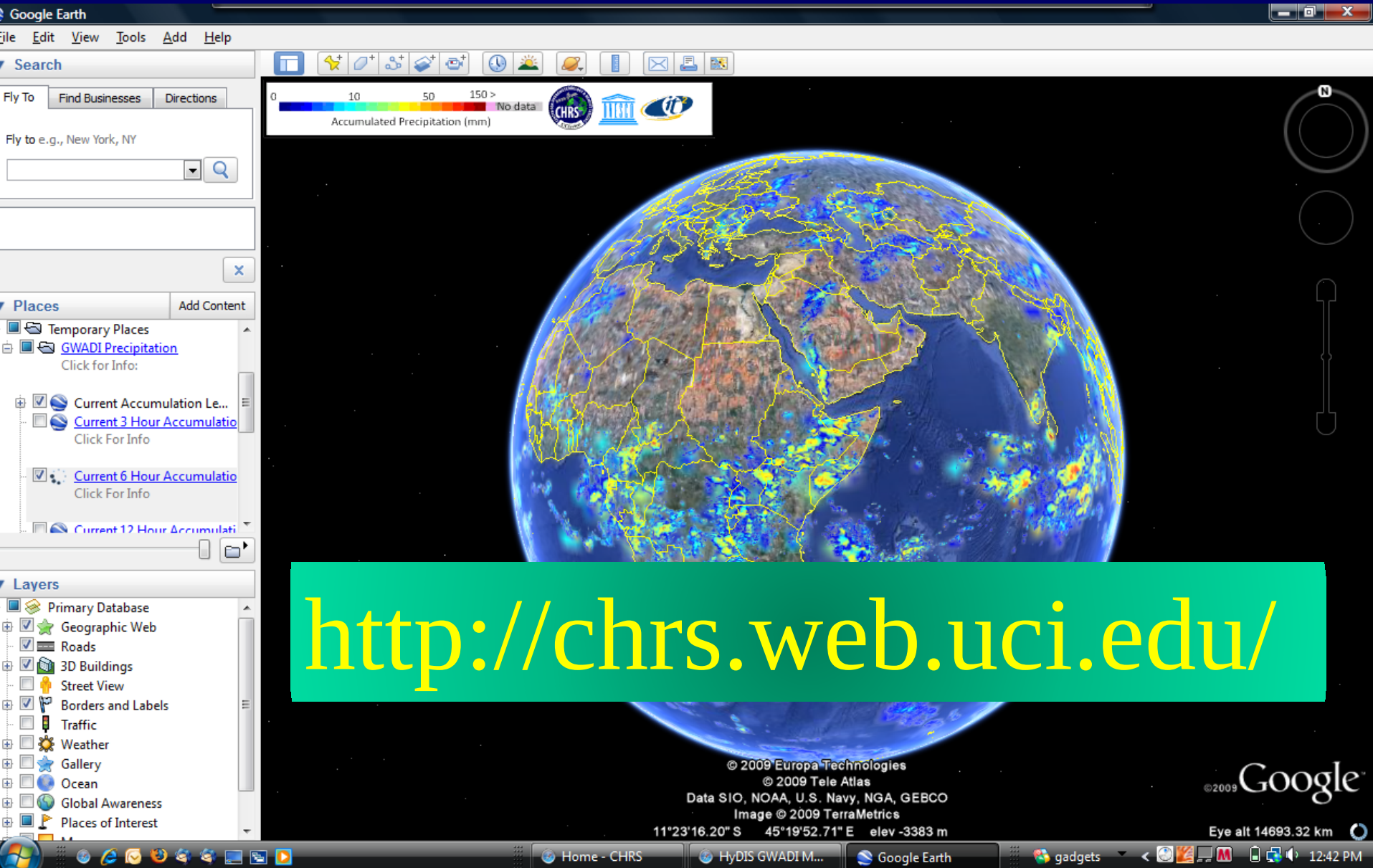
Real Time Global Data: Cooperation With UNESCO

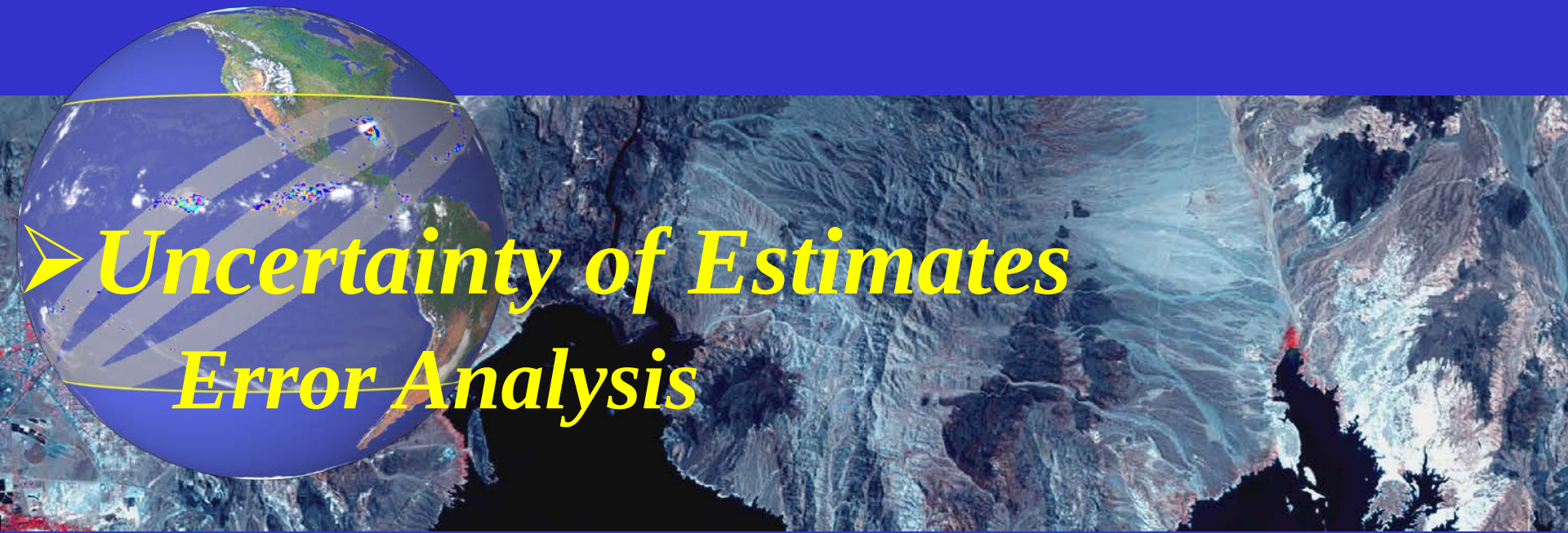


Real Time Global Data: Cooperation With UNESCO



PERSIANN Satellite Product On Google Earth

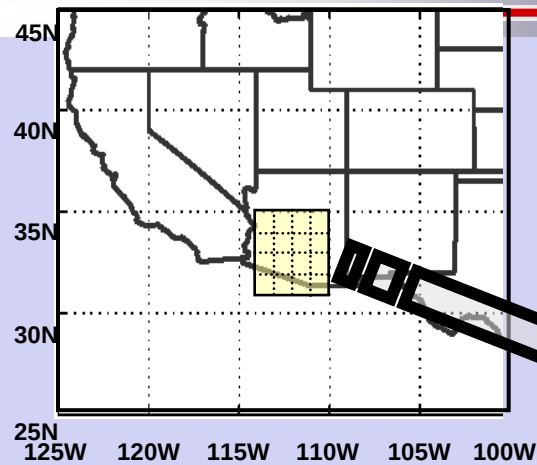




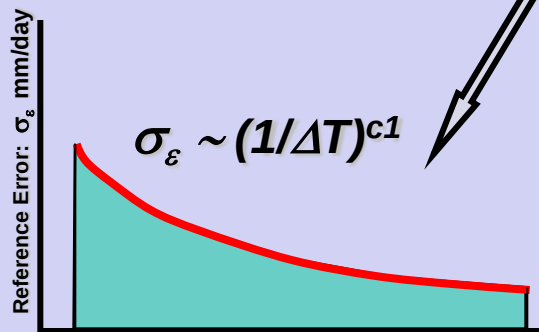
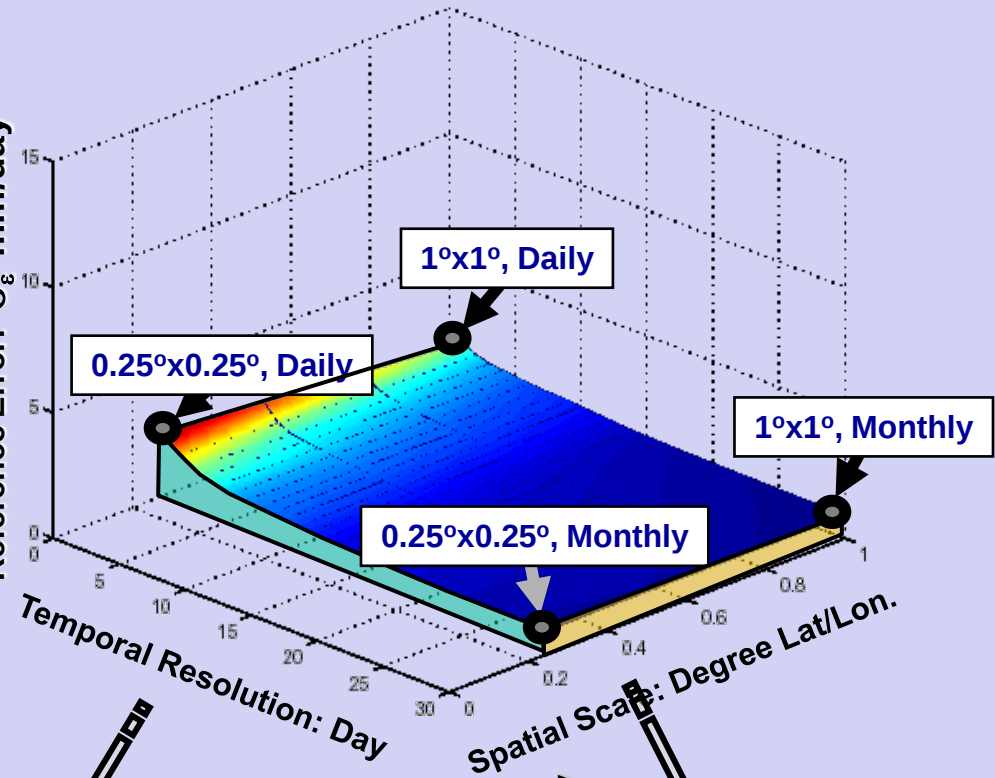
► *Uncertainty of Estimates* *Error Analysis*



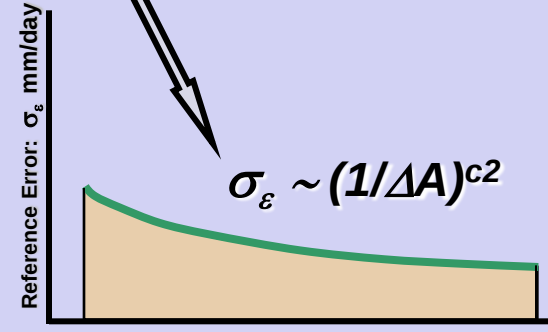
Spatial-Temporal Property of Reference Error



Reference Error: σ_ε mm/day



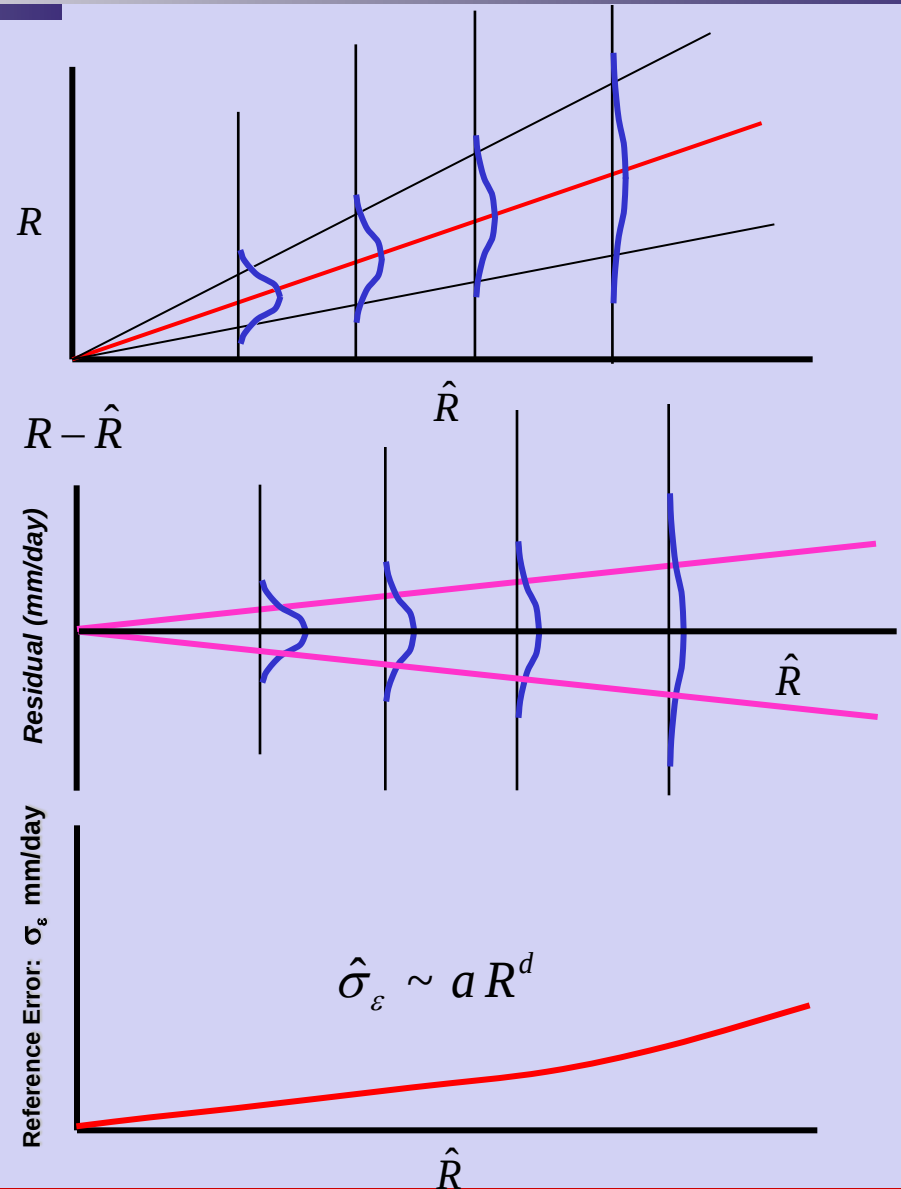
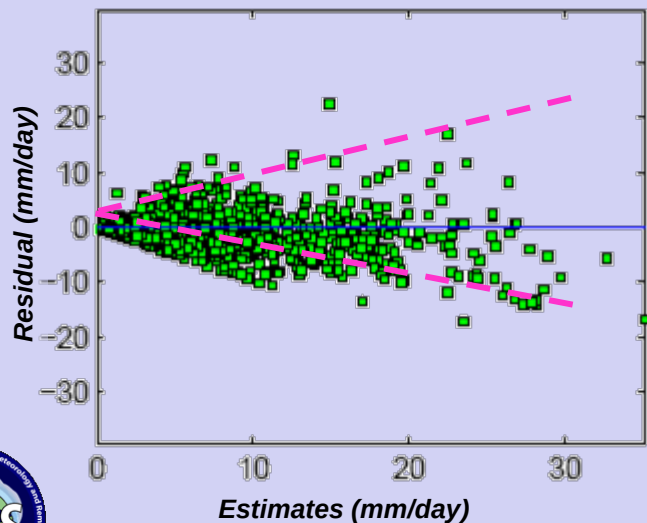
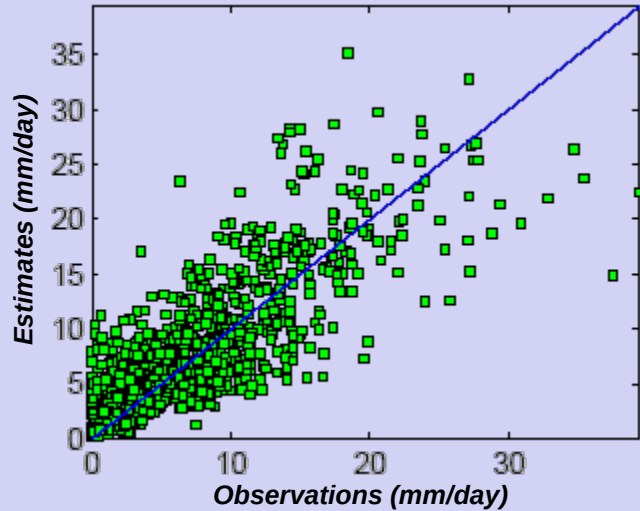
Temporal Resolution



Spatial Resolution

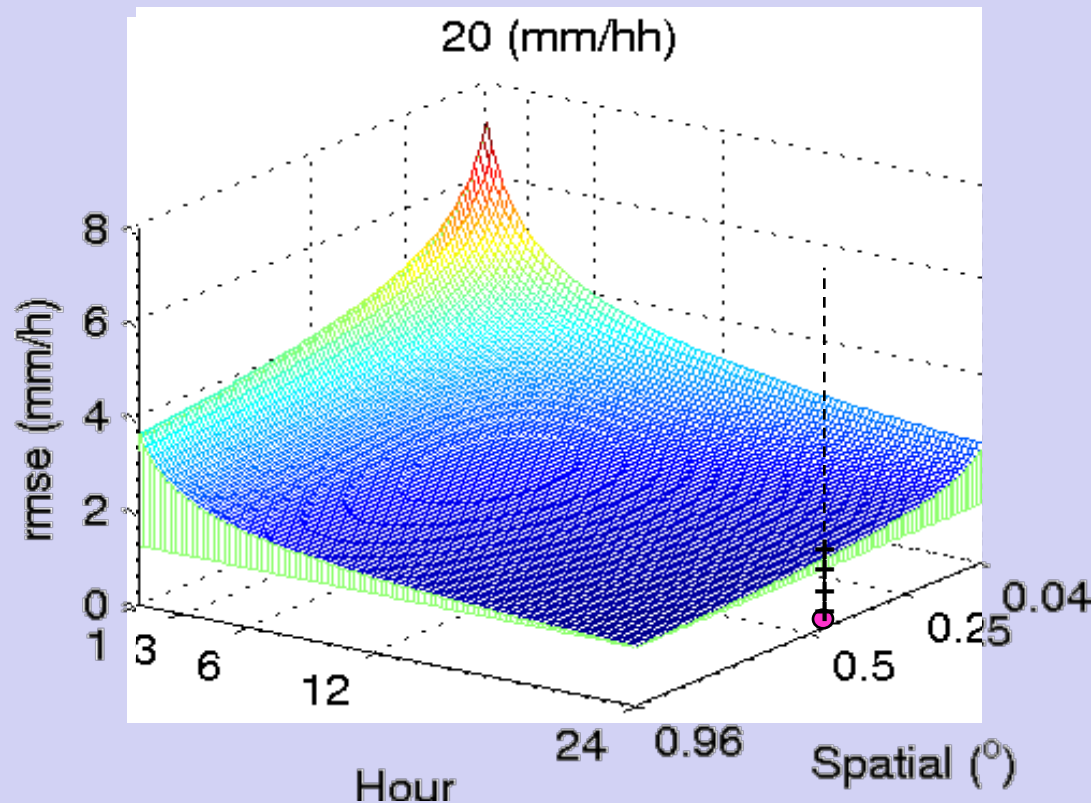


Reference Error: $\Delta T = 24\text{-hour}$, $\Delta A = 0.25^\circ \times 0.25^\circ$



Scaling Property of PERSIANN-CCS Reference Error

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





Validation and Application of Satellite Products

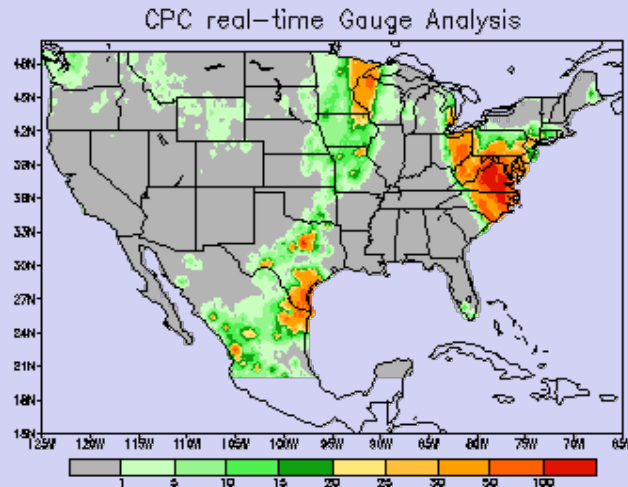


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US Daily Precipitation Validation Page

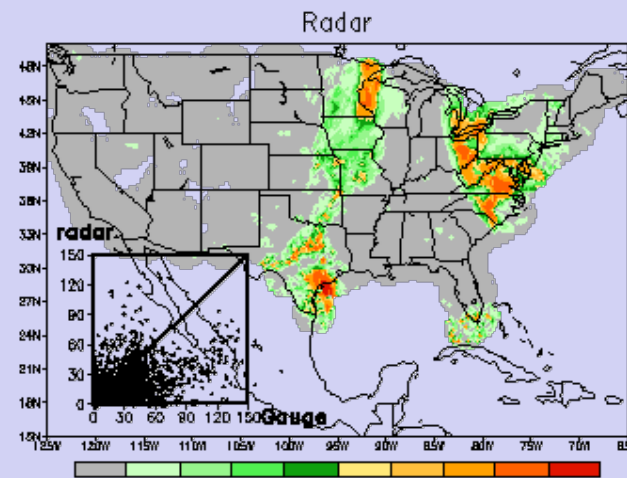
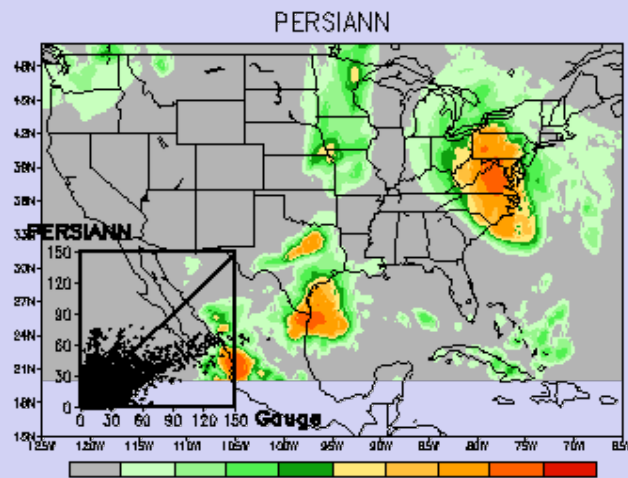
http://www.cpc.ncep.noaa.gov/products/janowiak/us_web.html

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



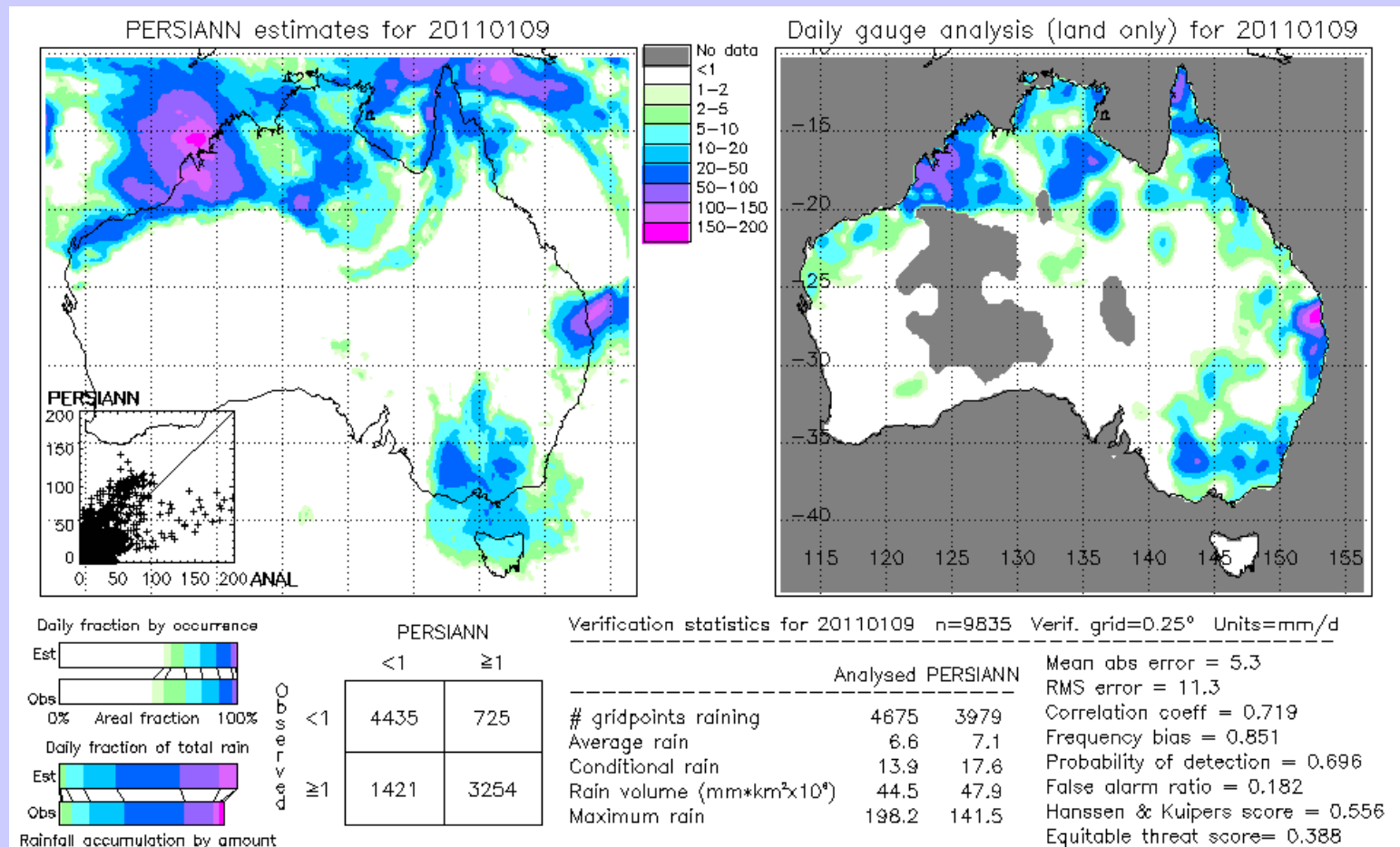
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.55	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45
Correlation:	G-S 0.827	G-R 0.726	R-S 0.606
Mean Absolute Error:	3.63	3.42	3.35
RMSE (mm/day):	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			radar	
	< 1	≥ 1		< 1	≥ 1
< 1 gauge	8082.	1497.	< 1 gauge	9386.	193.
≥ 1 gauge	1081.	3168.	≥ 1 gauge	1471.	2778.



Evaluation of PERSIANN Daily Rainfall

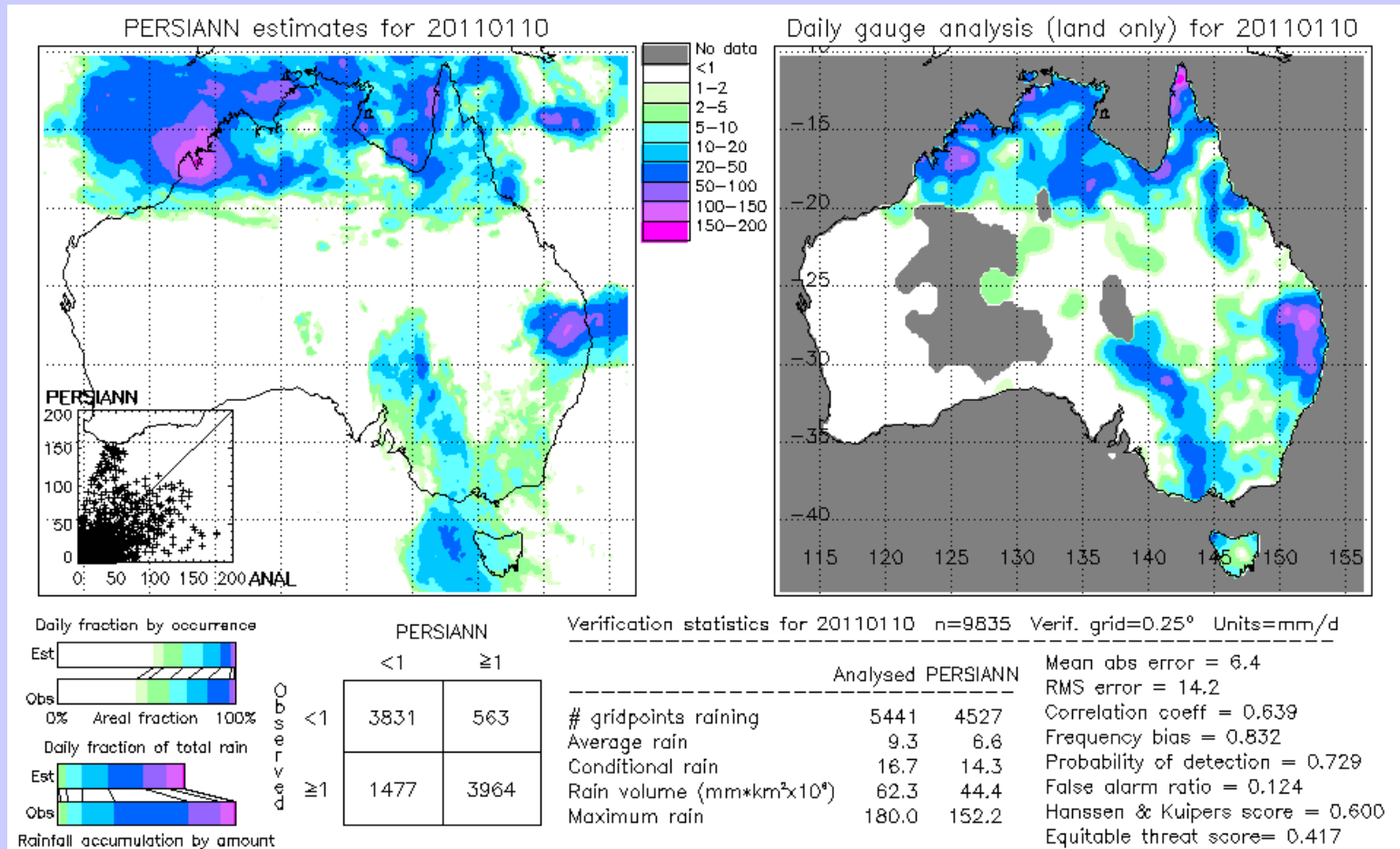
01-09-2011 (0.25-degree resolution)



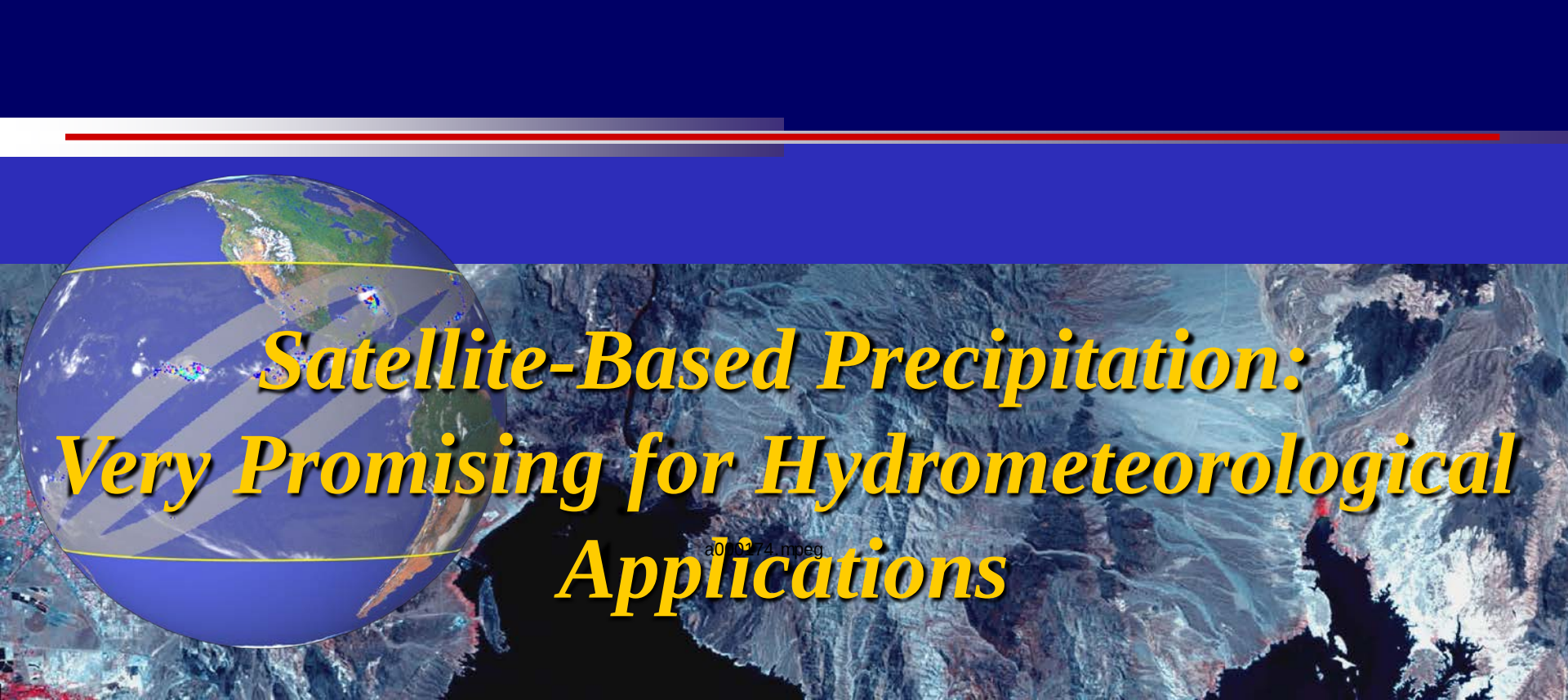
Source: IPWG Validation over Australia: http://cawcr.gov.au/projects/SatRainVal/sat_val_aus.html

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

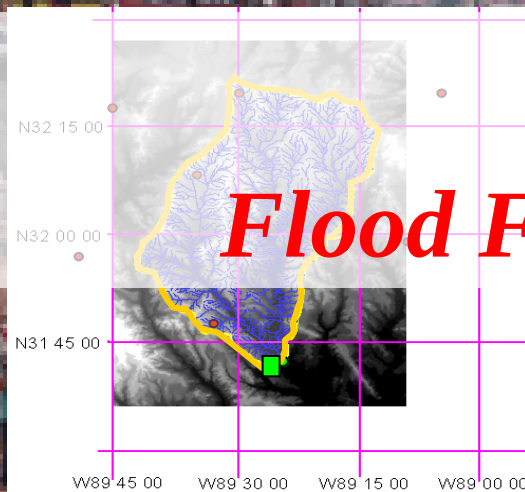


Satellite-Based Precipitation: Very Promising for Hydrometeorological Applications



Satellite Rainfall Estimation for Operational Use

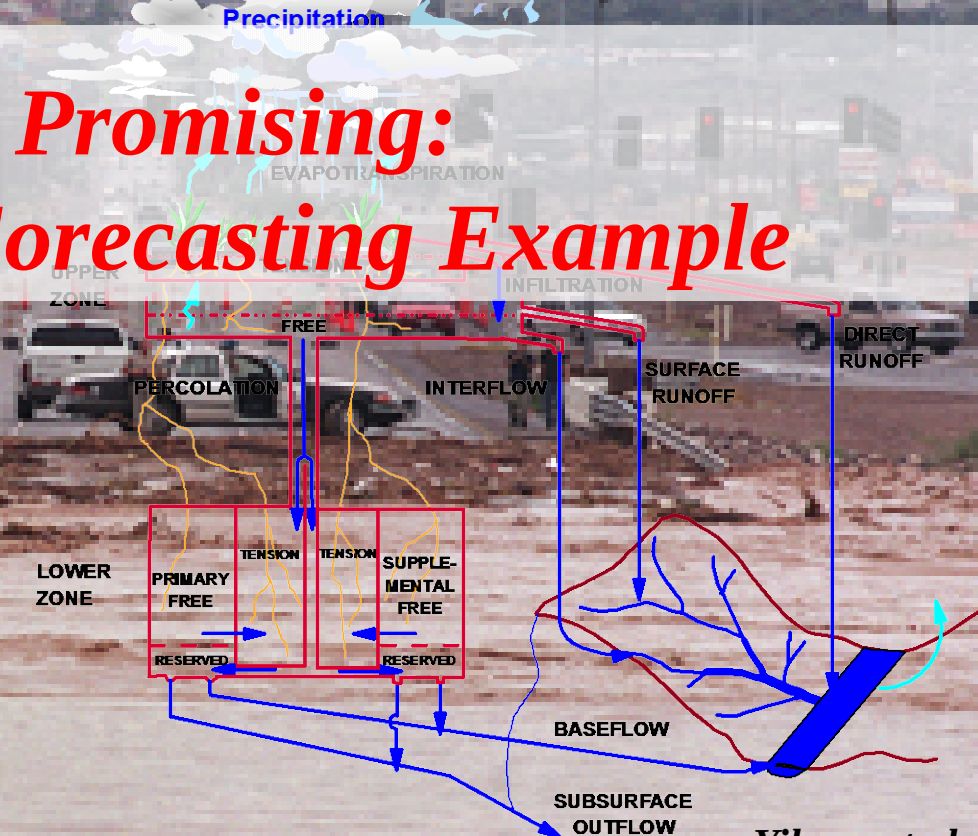
Streamflow forecasting of a catchment in US using UCI-PERSIANN rainfall Estimates for use in the US National Weather Service Runoff Forecasting System (NWSRFS).



● Gages used by NWS

Leaf River Near Collins
Mississippi
USGS # 02472000

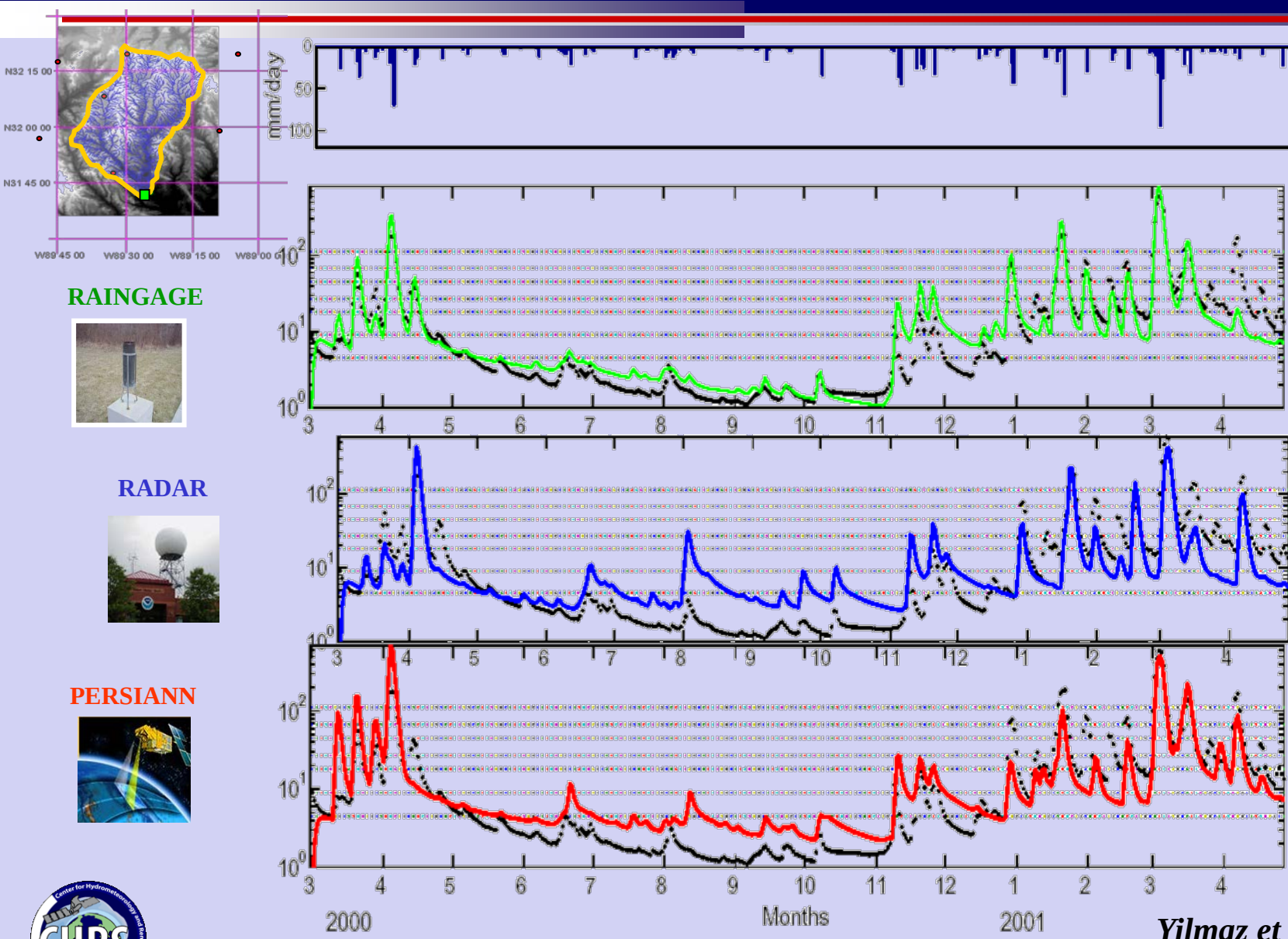
Basin Area : 753 mi²



Yilmaz et al. JHM 2005



Satellite Rainfall Estimation: Research at UC Irvine



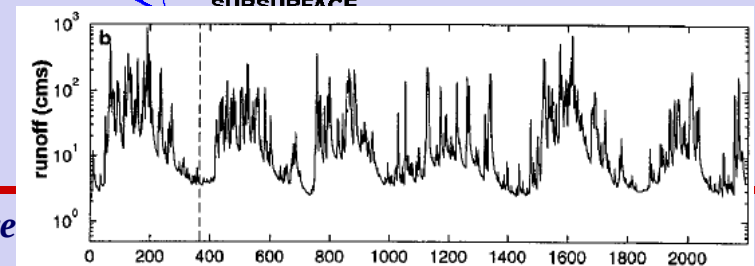
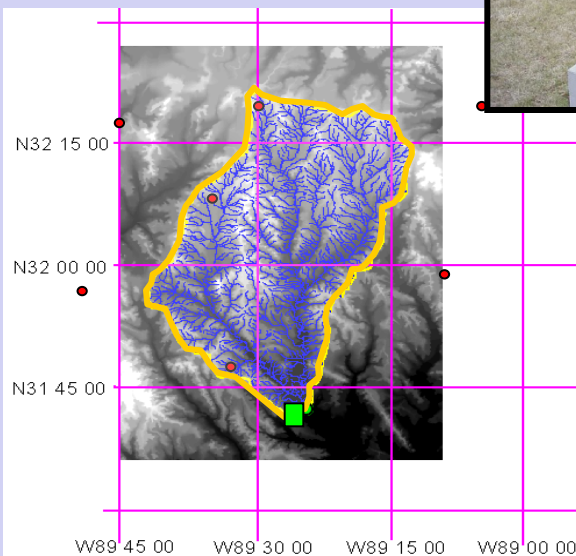
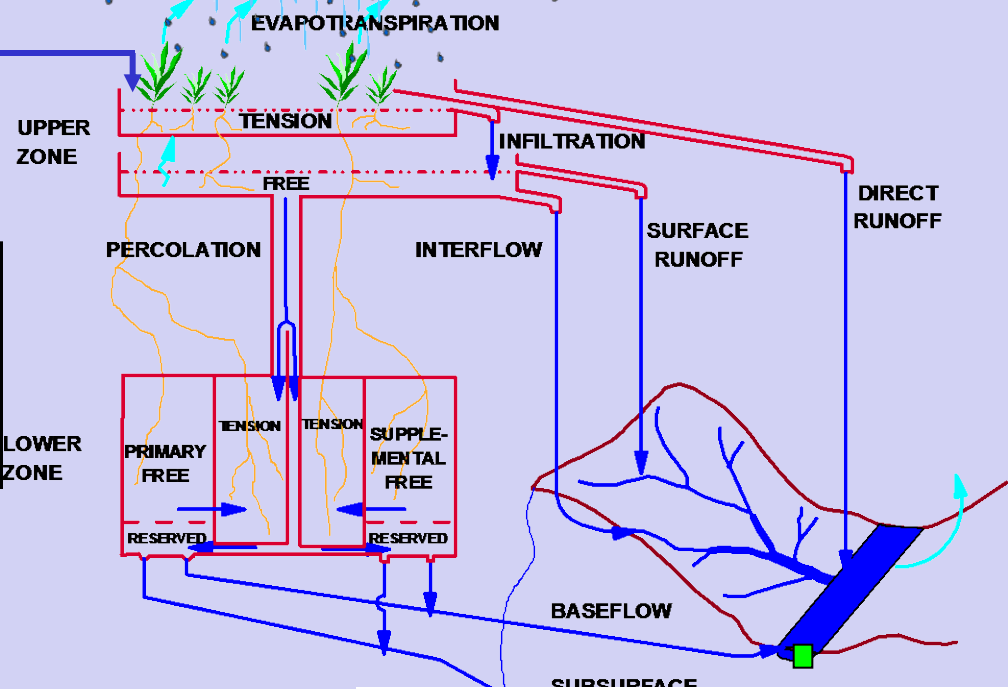
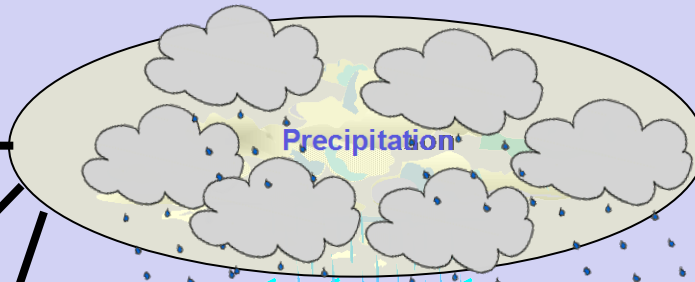
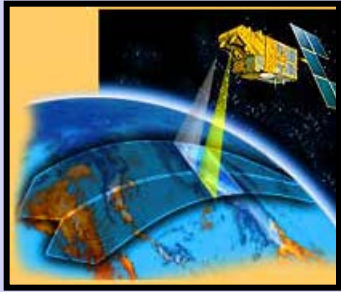
Corr =0.95
RMS =23.9
BIAS =-1.32

Corr =0.92
RMS =28.8
BIAS =-6.74

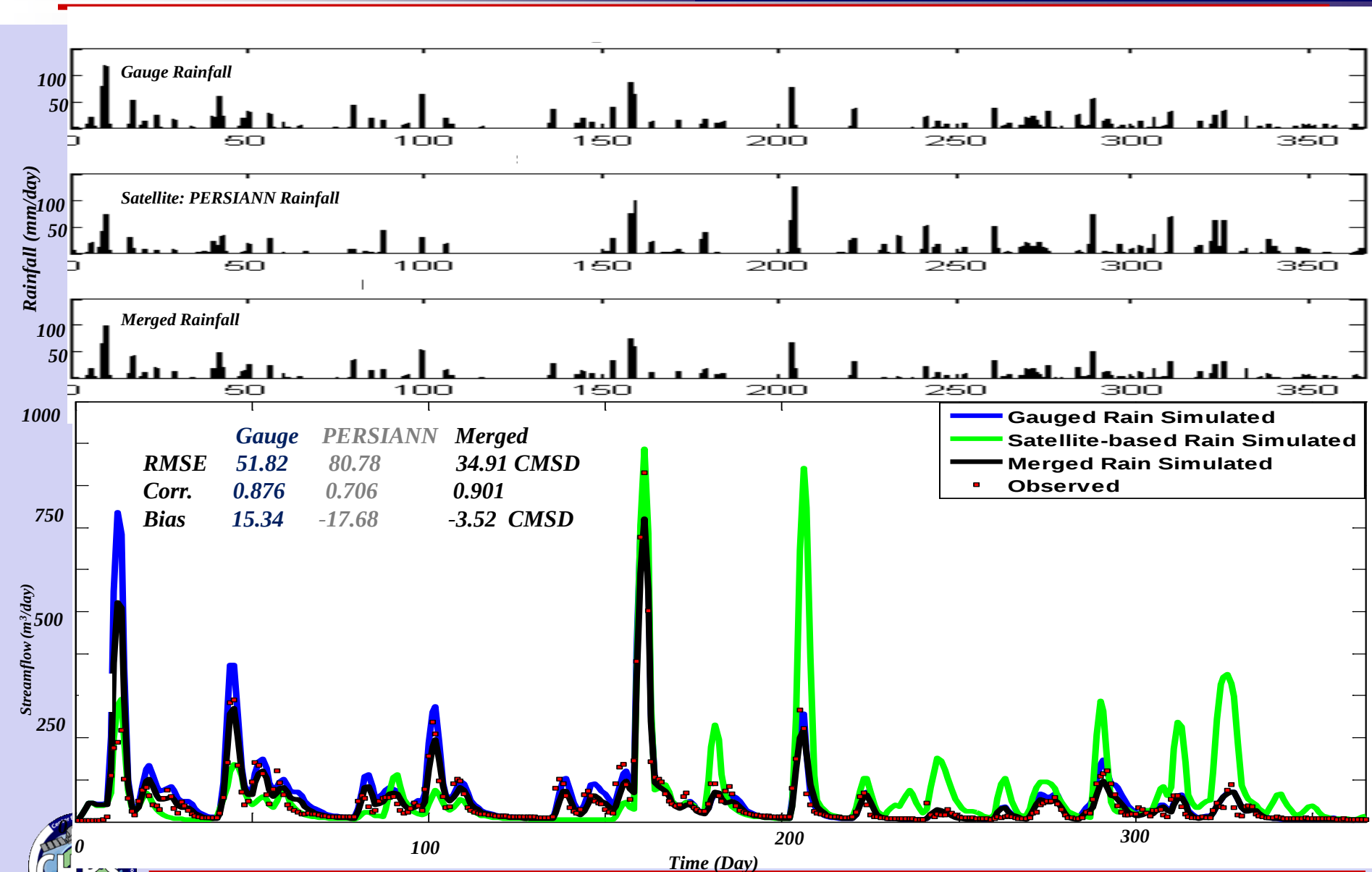
Corr =0.94
RMS =22.6
BIAS =-5.15



Basin Scale Precipitation Data Merging



Runoff Forecasting from Gauge, PERSIANN, and Merged Rainfall



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

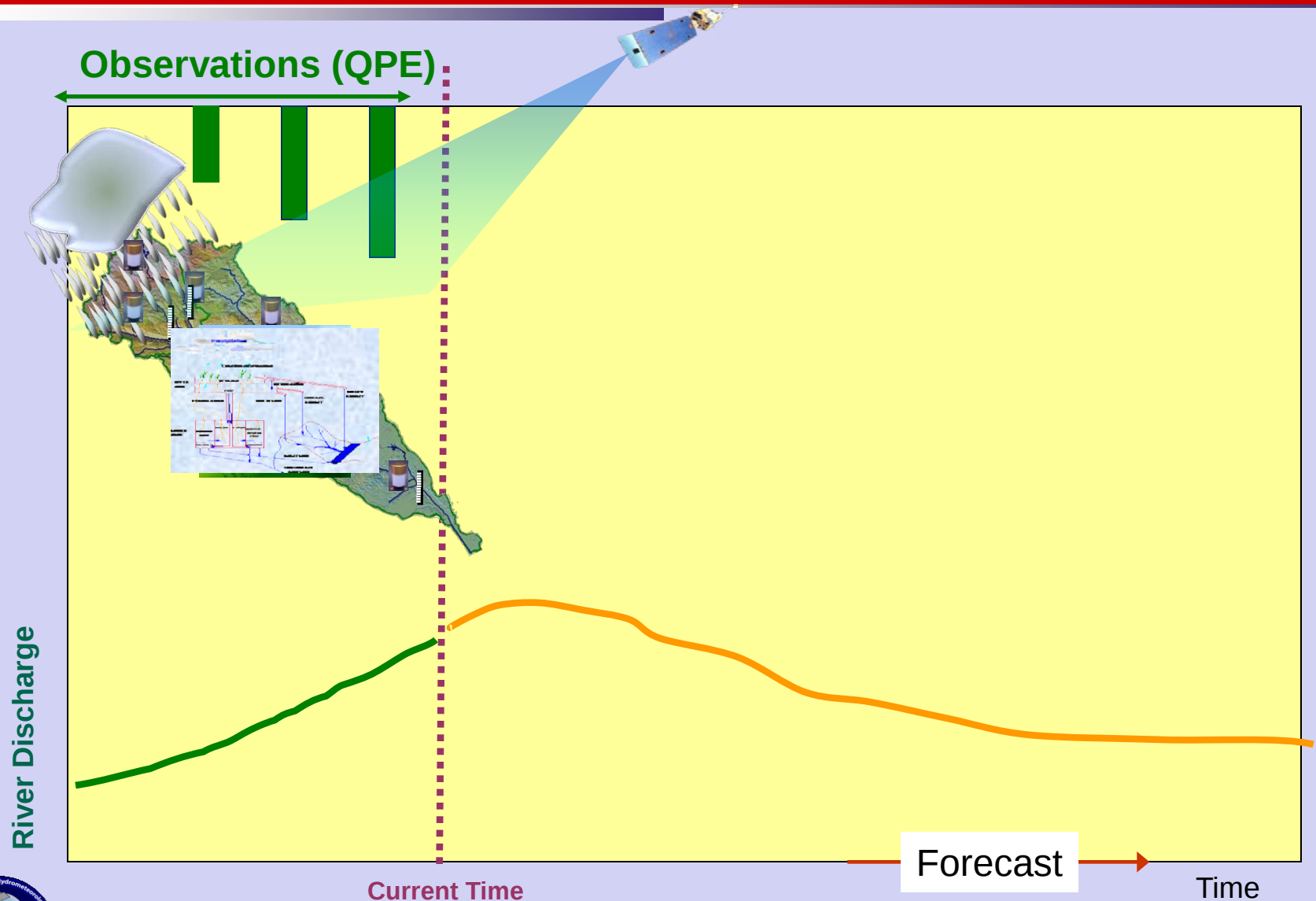
➤ **flood and River flow forecasting**

Water Supply Volume

Short-range

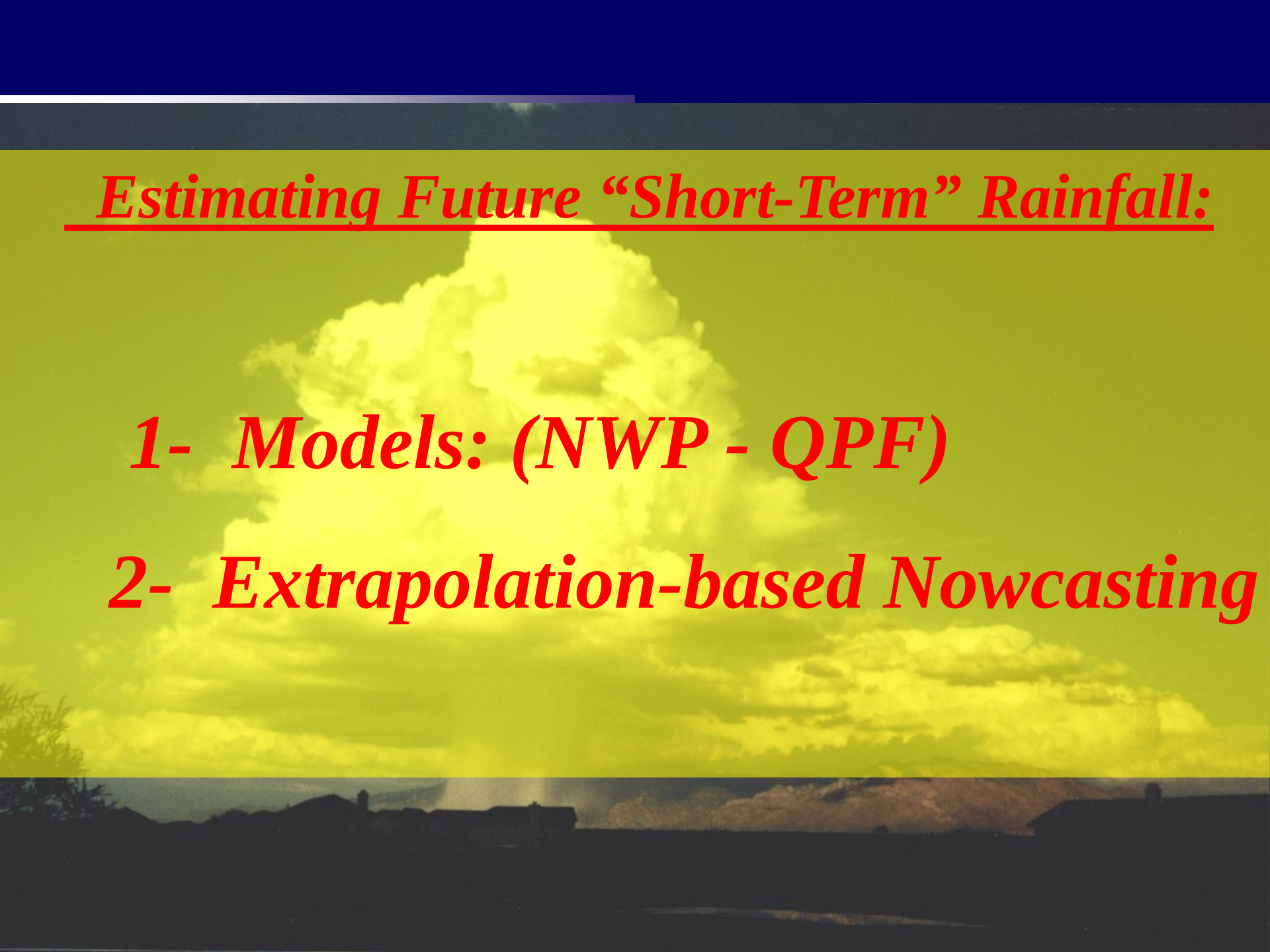


Common practice in Flood and River Flow Forecasting



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

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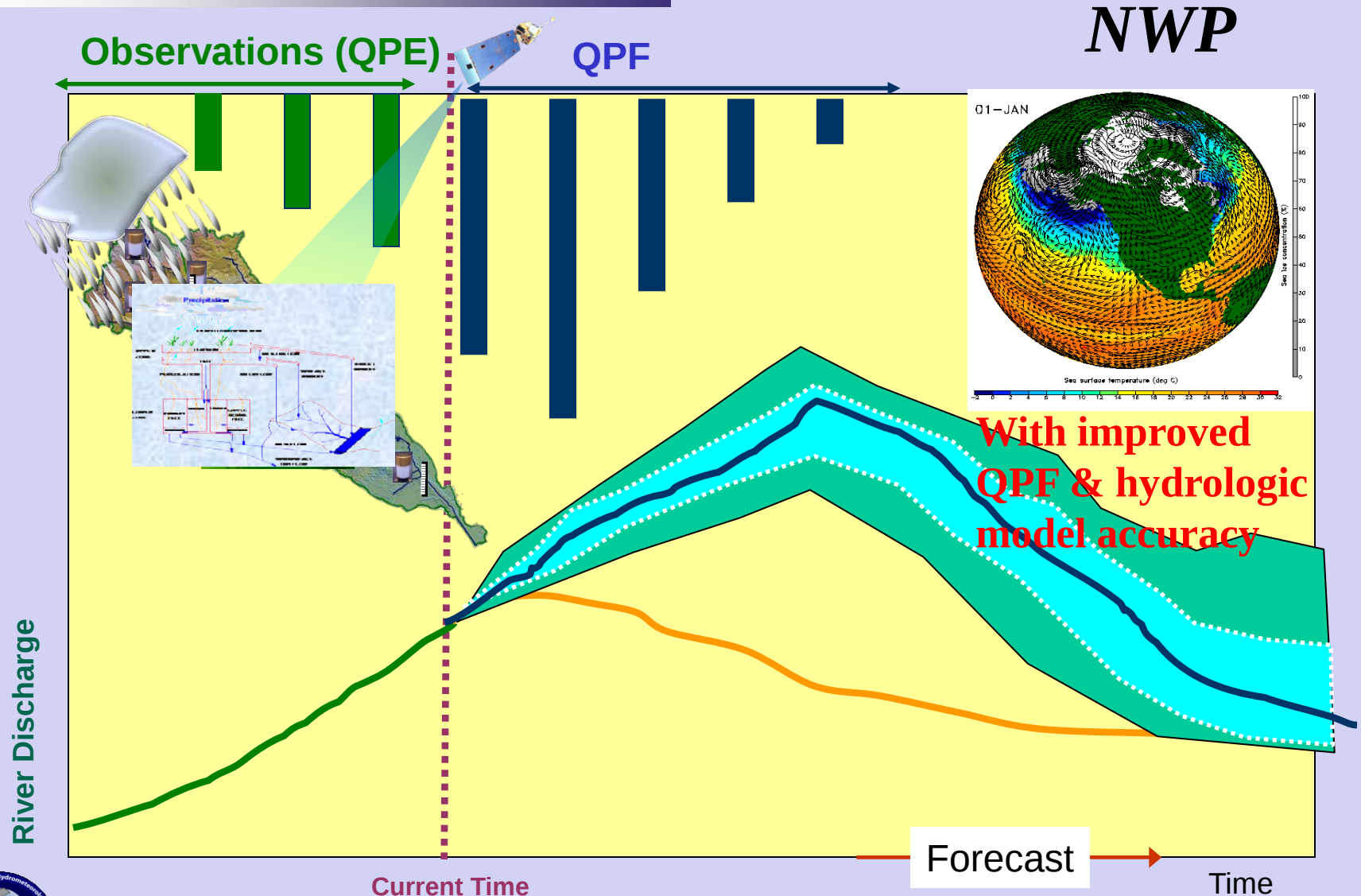


Estimating Future “Short-Term” Rainfall:

1- Models: (NWP - QPF)

2- Extrapolation-based Nowcasting

Efforts in Extending the Forecast Lead Time

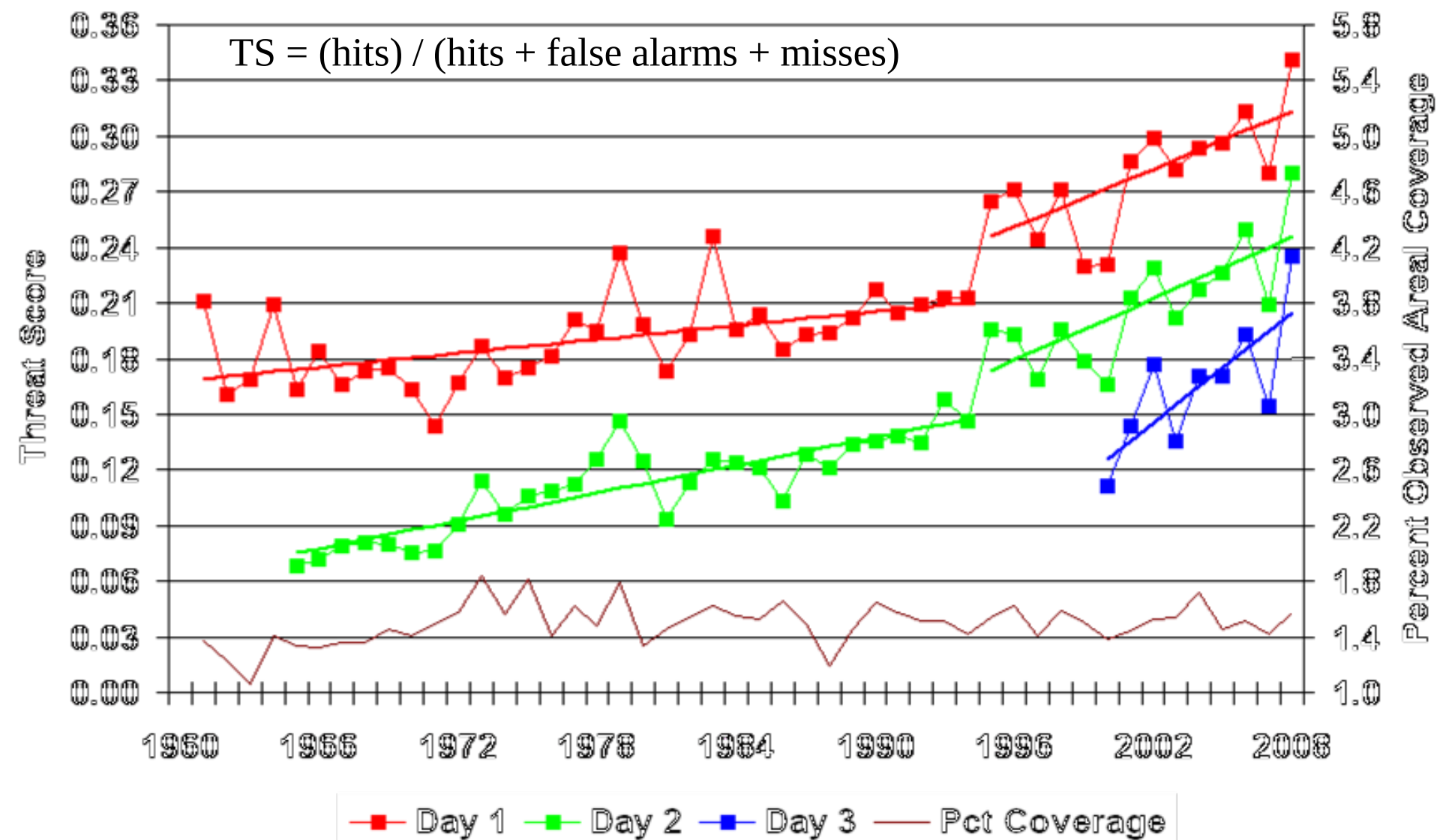


Animation Assisted by: Q. Xia, Gi-H. Park & L. Bastidas

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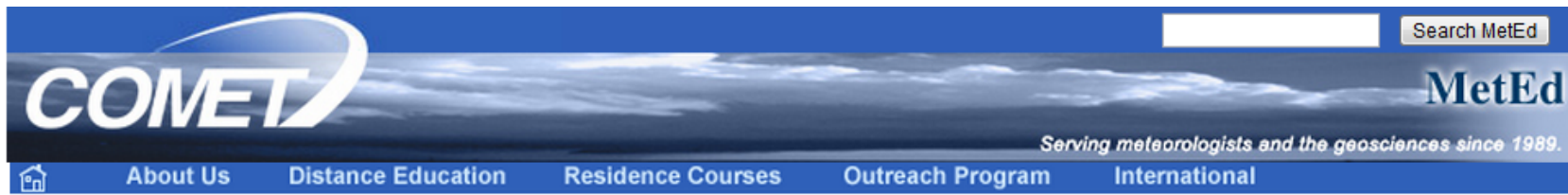
HPC QPF verification 1-inch threat score



In Brief:

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

*They Are Very
Promising!*



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[Help/Technical Support](#)

Residence and Virtual Courses →

Our state-of-the-art classroom hosts courses taught jointly by university, faculty, operational forecasters, and other leaders in our field. These classes include both lectures and hands-on exercises that simulate the forecast environment.

[Classroom Website](#)

Outreach Program →

The Outreach Program provides funding for collaborative, applied research projects conducted by universities and operational forecast offices. The National Weather Service is the primary sponsor.

[Outreach Website](#)

[Proposal Info](#)

[Supported Projects](#)

[Info for PIs](#)

[Contact Us](#)

International Projects →

In partnership with the National Weather Service and the World Meteorological Organization, we are working to improve access to weather data and training by the global meteorological community.

[MetEd en Español](#)

[Canadian Activities](#)

[SCHOTI/CO-COM](#)

[CALMet](#)

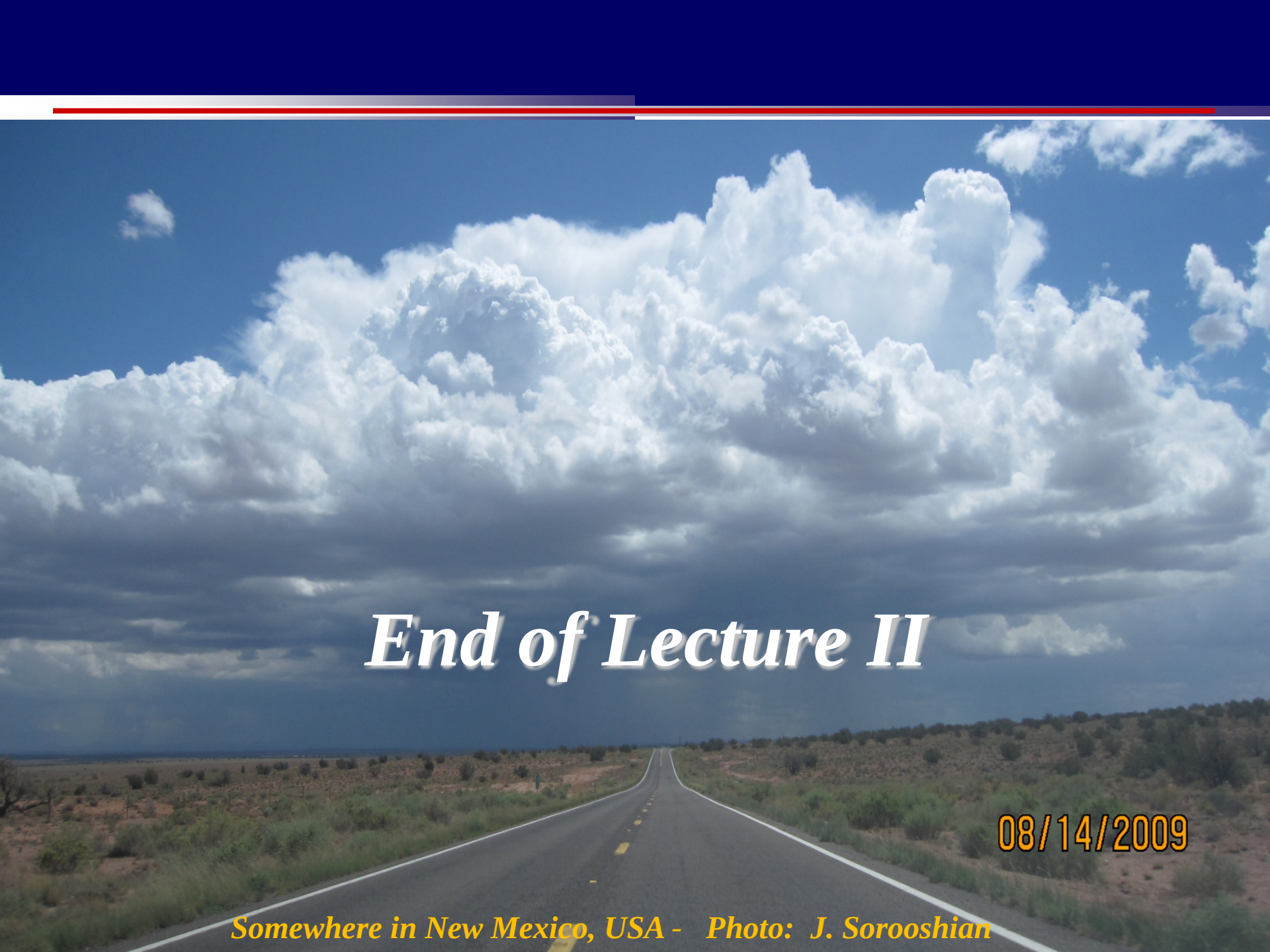


COMET Training Material



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

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



End of Lecture II

08/14/2009

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