Satellite-Based Remote Sensing Estimation of Precipitation for Early-Warning Systems: Strengths and Limitations”

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University of California Irvine

Union Session: Grand Challenges in Natural Hazard Research & Risk Analysis

The 25th IUGG General Assembly

June 29th 2011, Melbourne - Australia

University of California Irvine (UCI) and Arizona (UA)

CHRS & Affiliates: A truly International Team

Required Hydrometeorologic 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

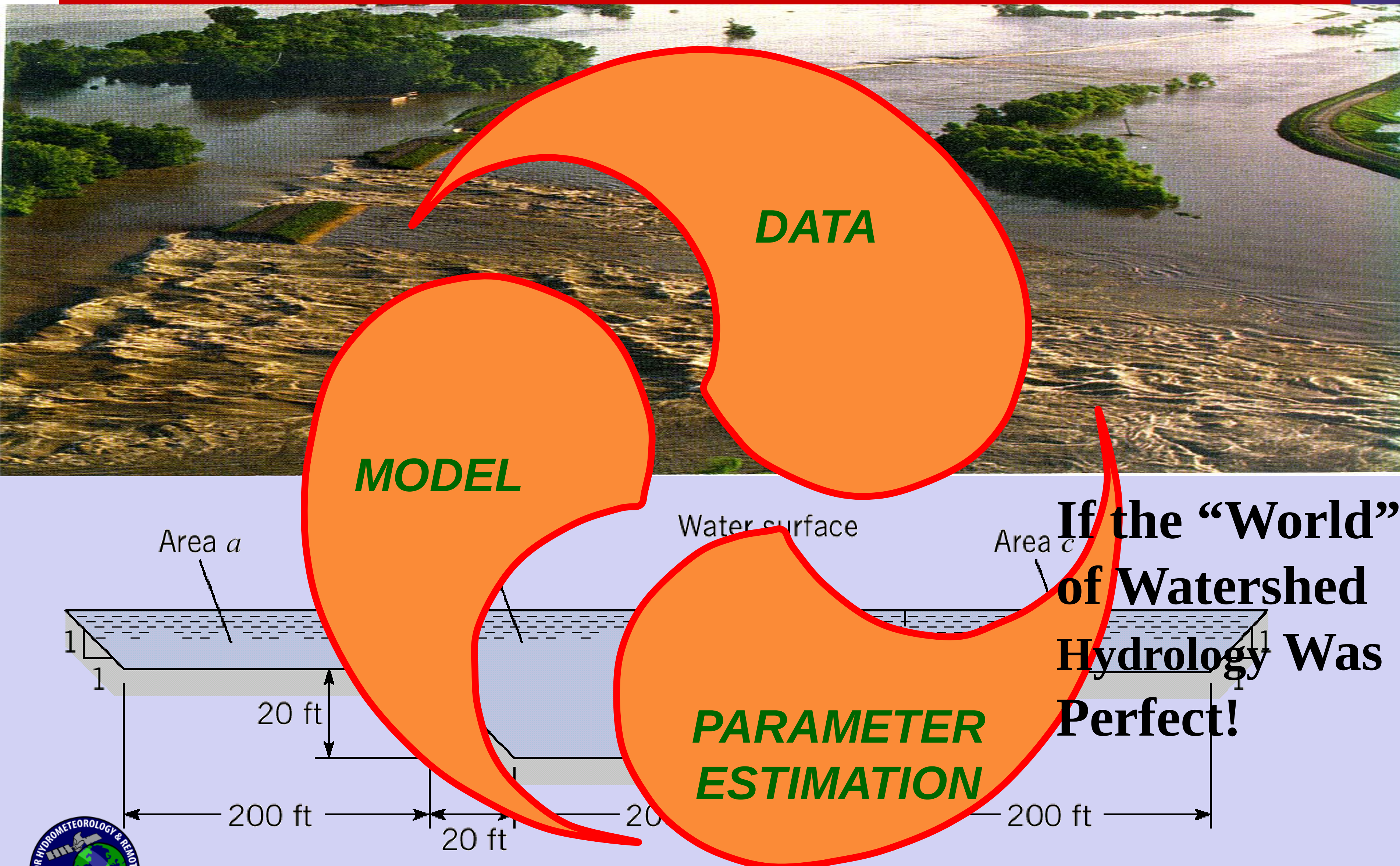
Spring Snow Melt Forecasts

Water Supply Volume

Short-range ***Mid-range*** ***Long-range***

Forecast Requirements

Hydrologic Forecasting



If the "World" of Watershed Hydrology Was Perfect!

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

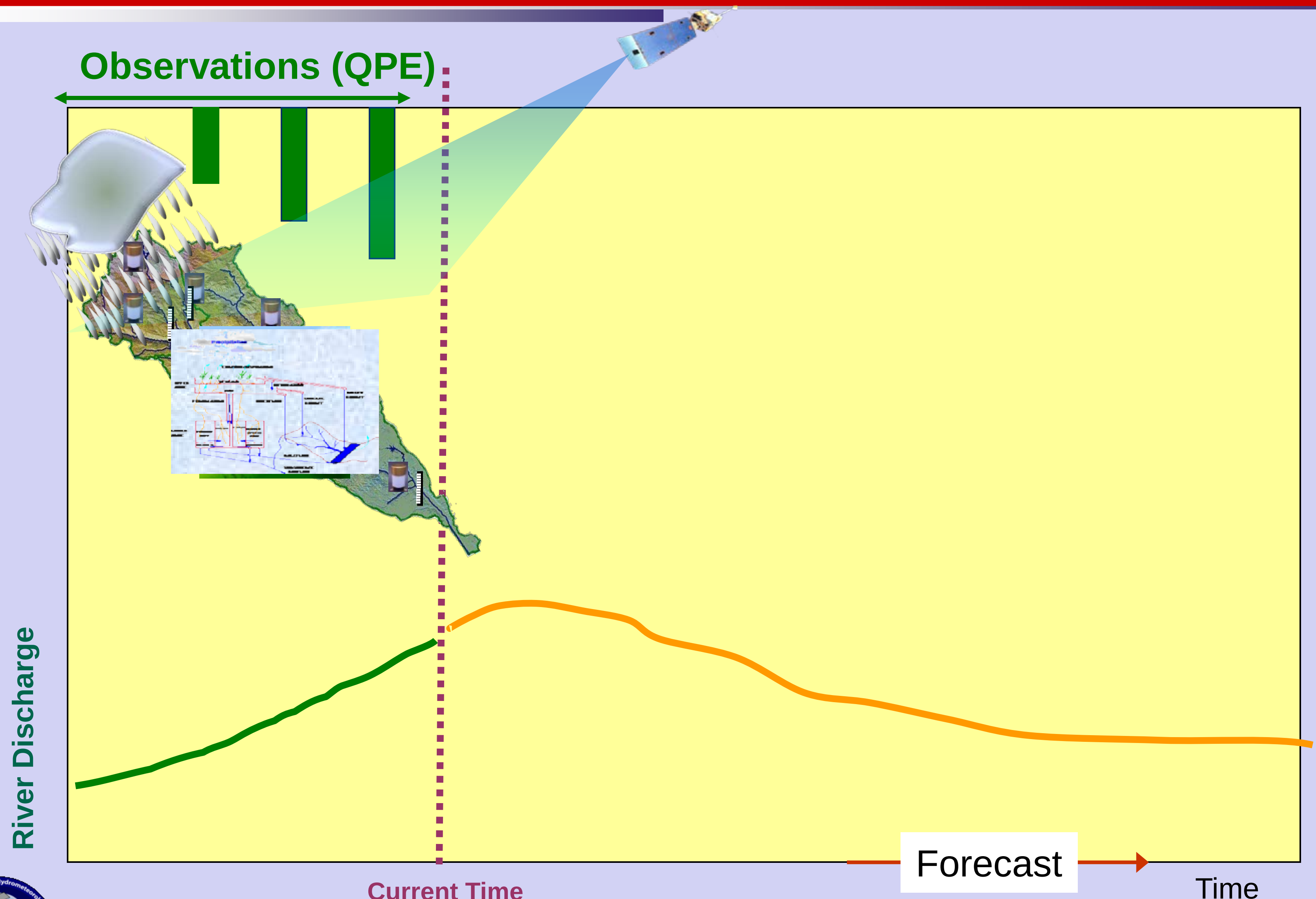
Reservoir Inflow Forecasts

Water Supply Volume

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

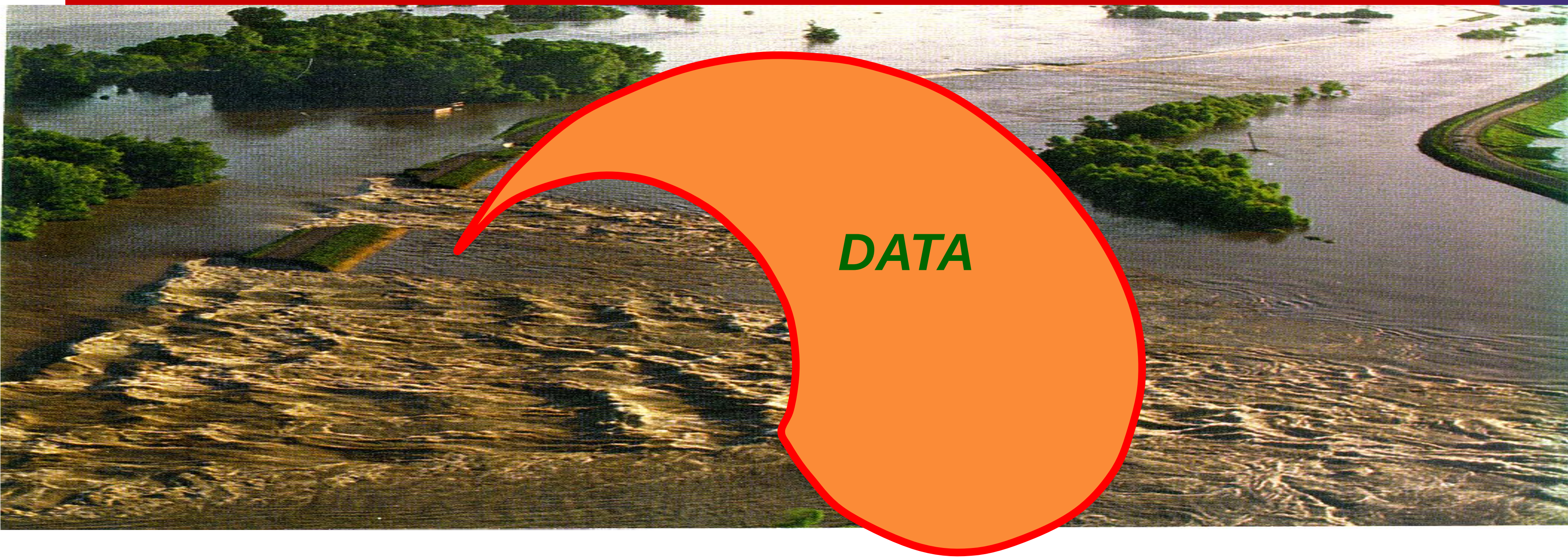
Short-range

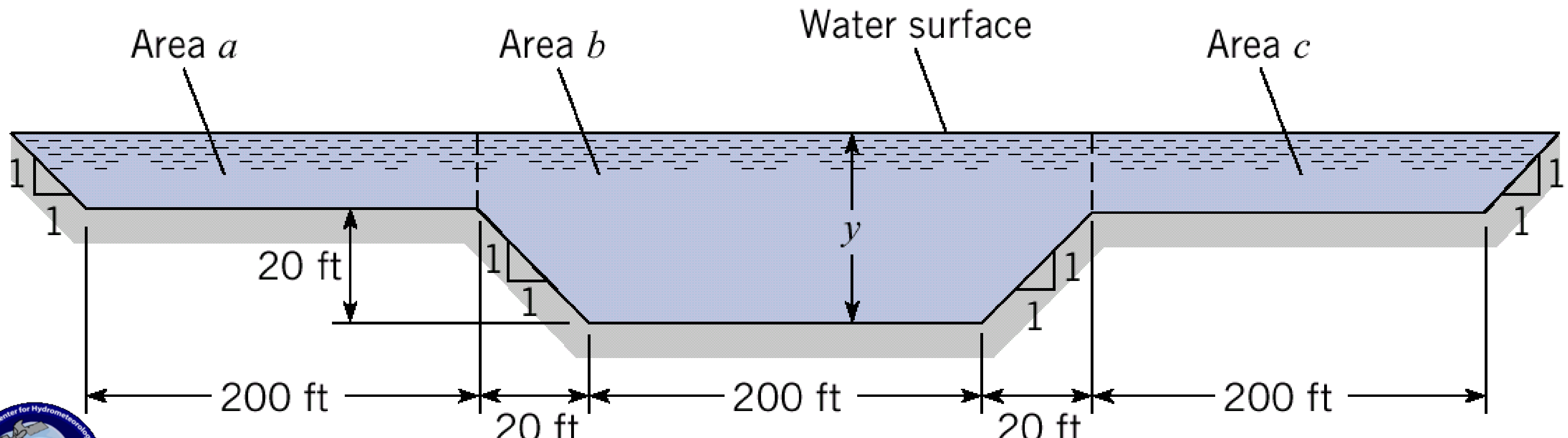
Common practice in Flood and River Flow Forecasting



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

Hydrologic Forecasting





<u>Precipitation</u>

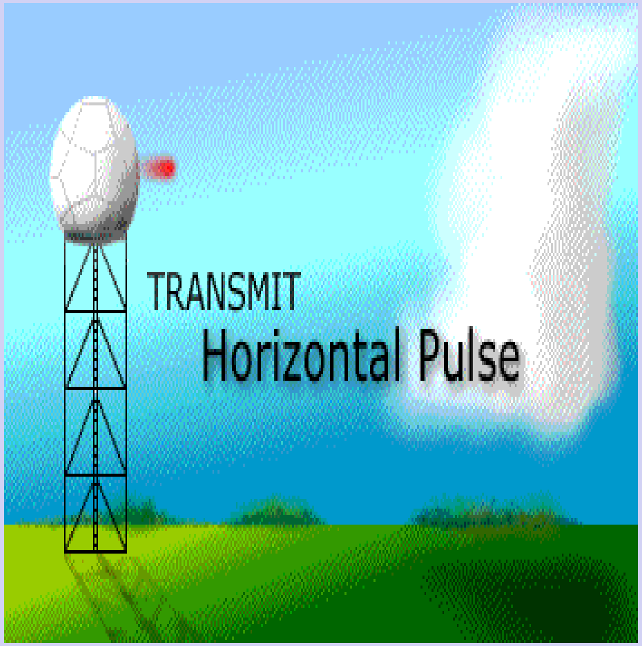
Measurement and estimation has and continues to be one of the

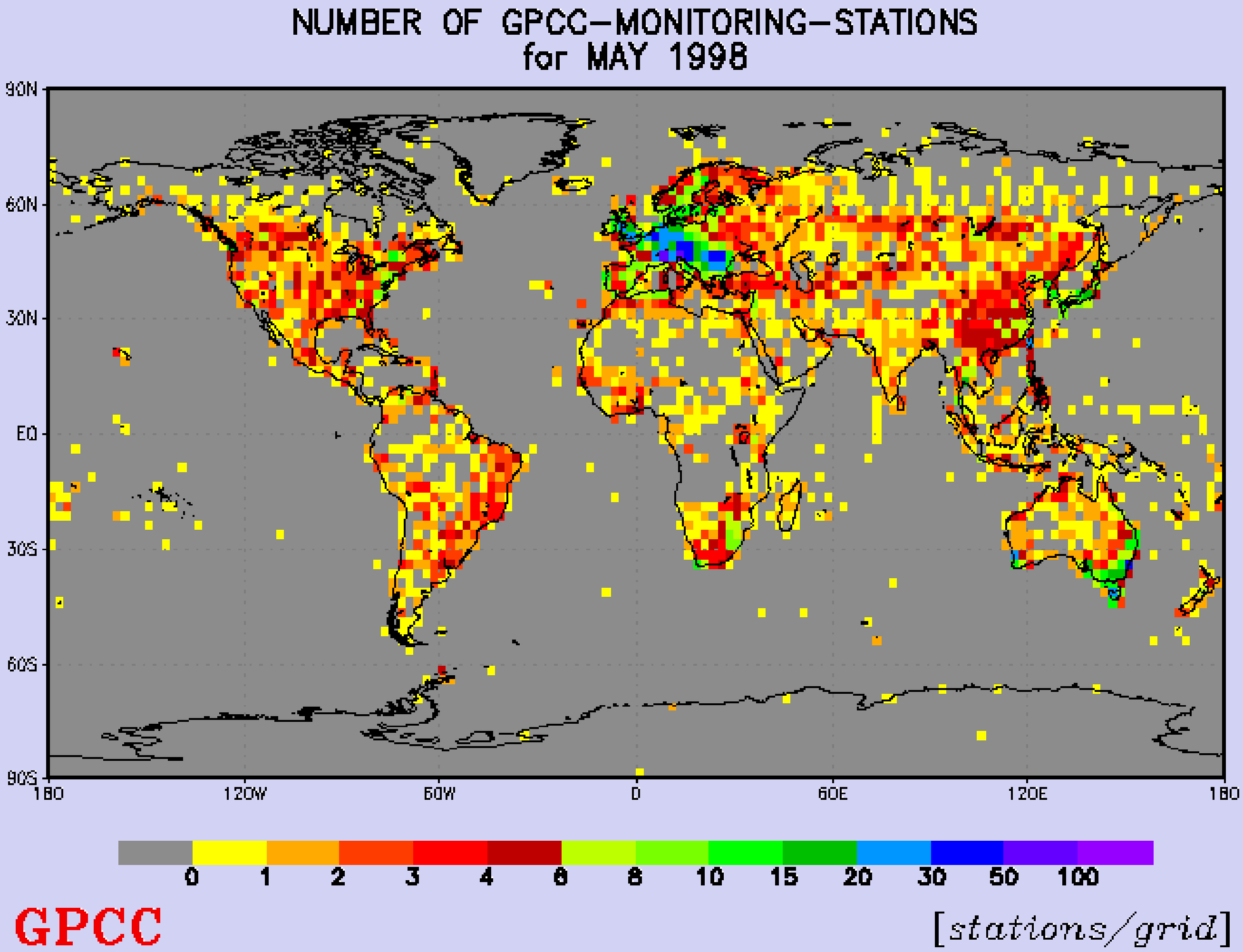
<u>KEY</u>

hydrometeorologic Challenges

Push towards High Resolution (Spatial and Temporal) Observations and Modeling

Precipitation Observations: Which to trust??

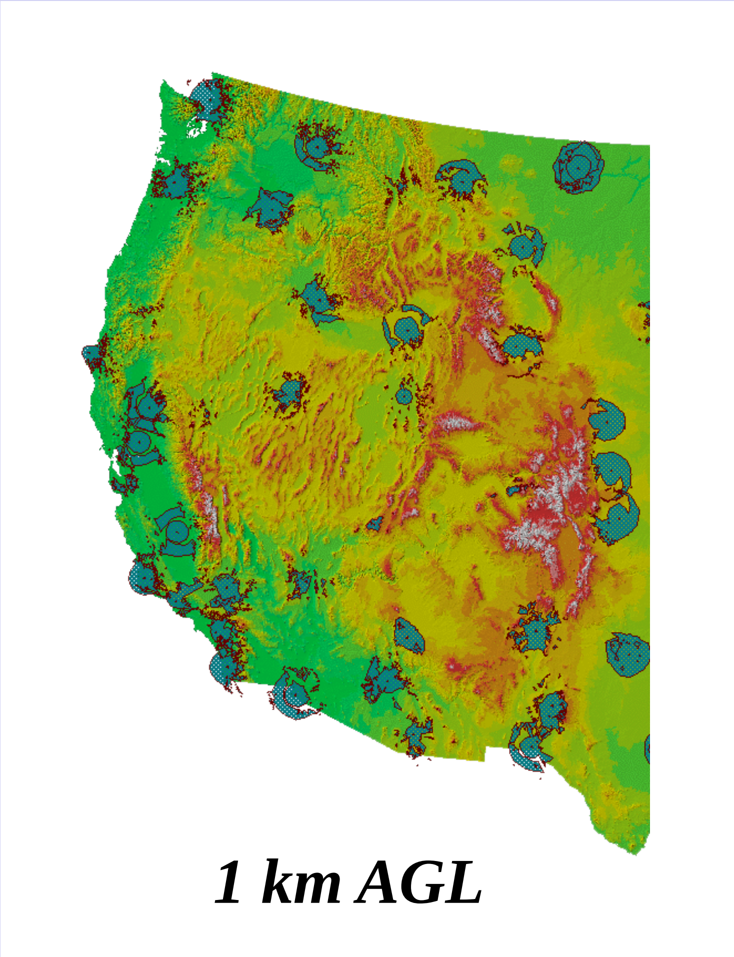




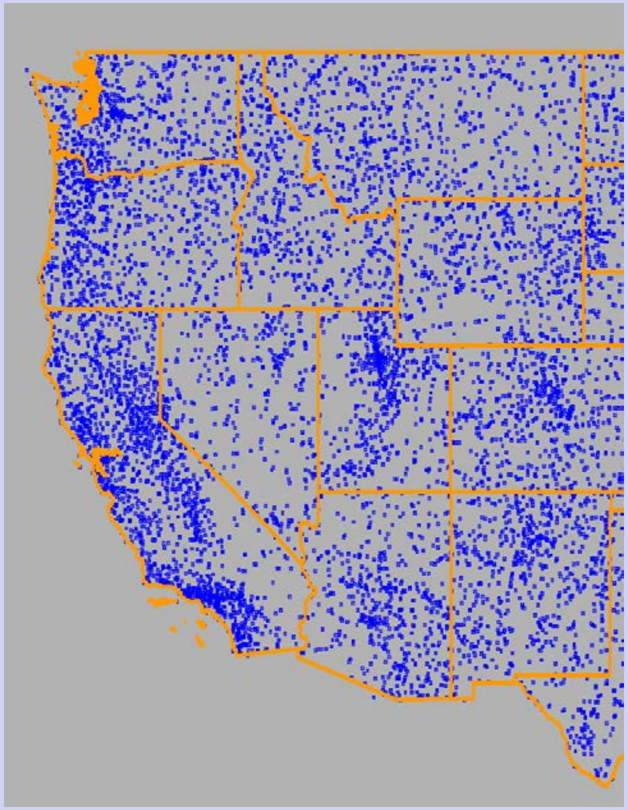
Number of range gauges per grid box. *These boxes are* ***2x2 degrees***

(Source: Global Precipitation Climatology Project)

Coverage of the WSR-88D and gauge networks



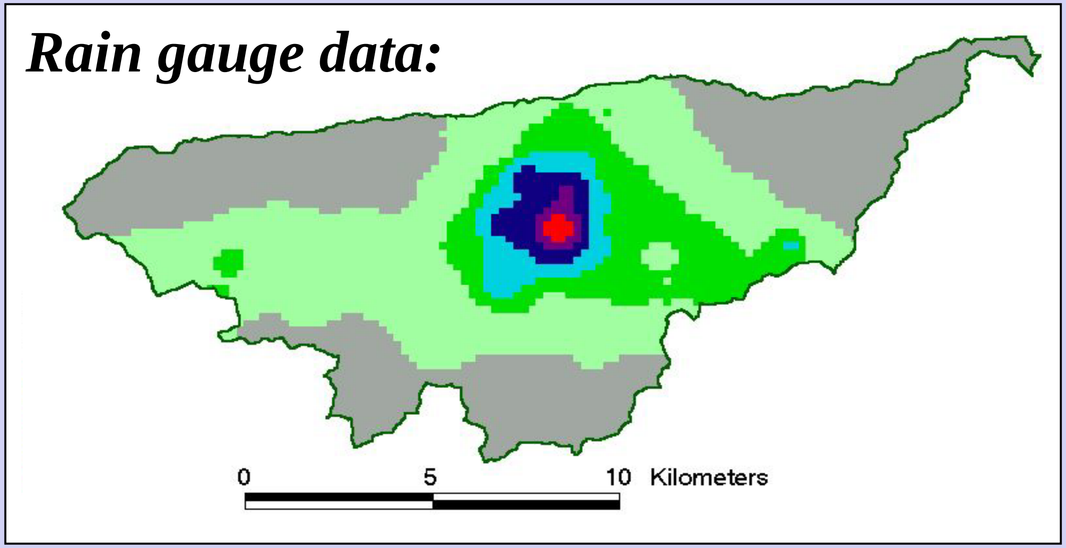
Maddox, et al., 2002

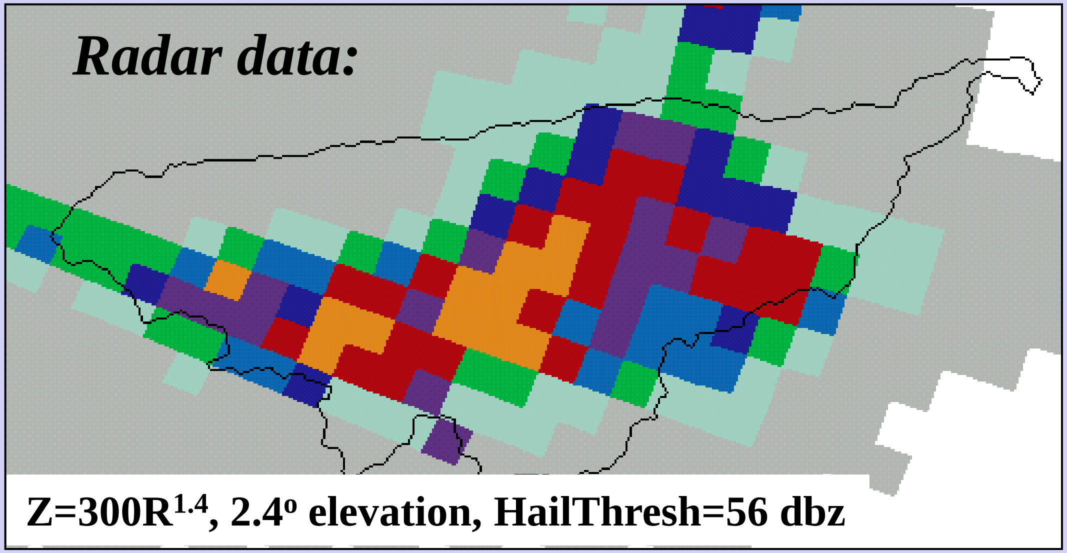


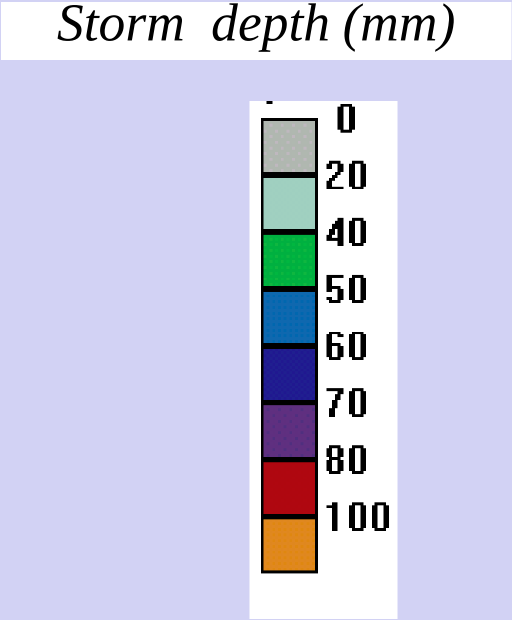
Daily precipitation gages (1 station per 600 km^2 for Colorado River basin) hourly coverage even more sparse

Radar-Gauge Comparison (Walnut Gulch, AZ)

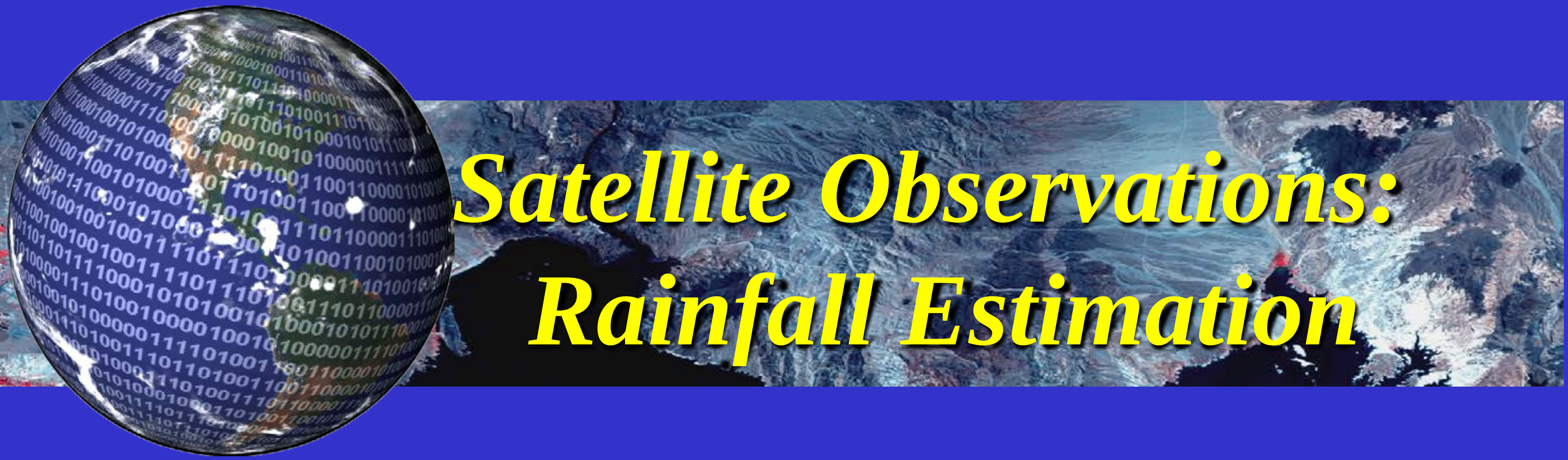
Precipitation event: Aug. 11, 2000







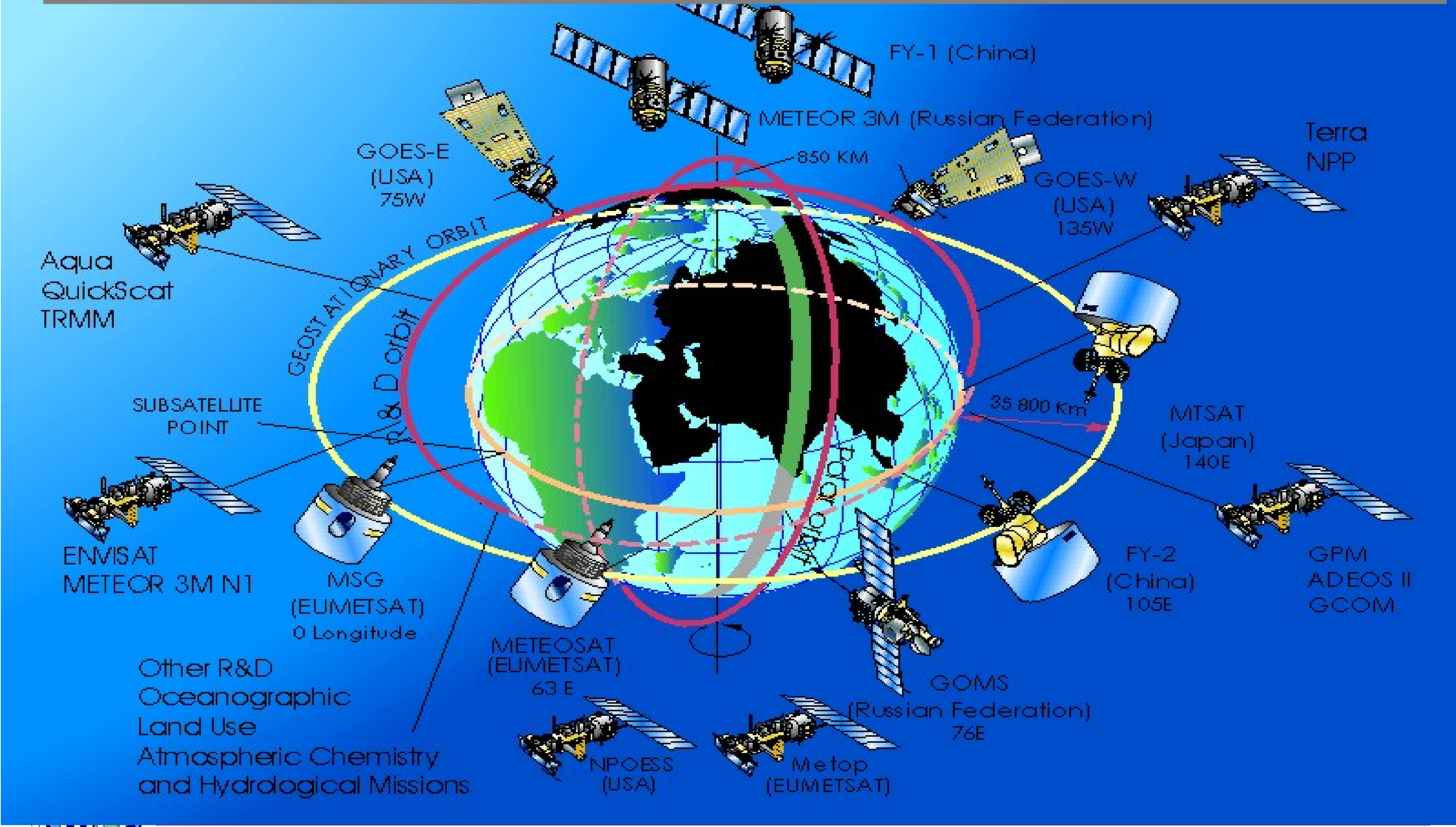
70% overestimation by the radar!



Satellite Observations: Rainfall Estimation

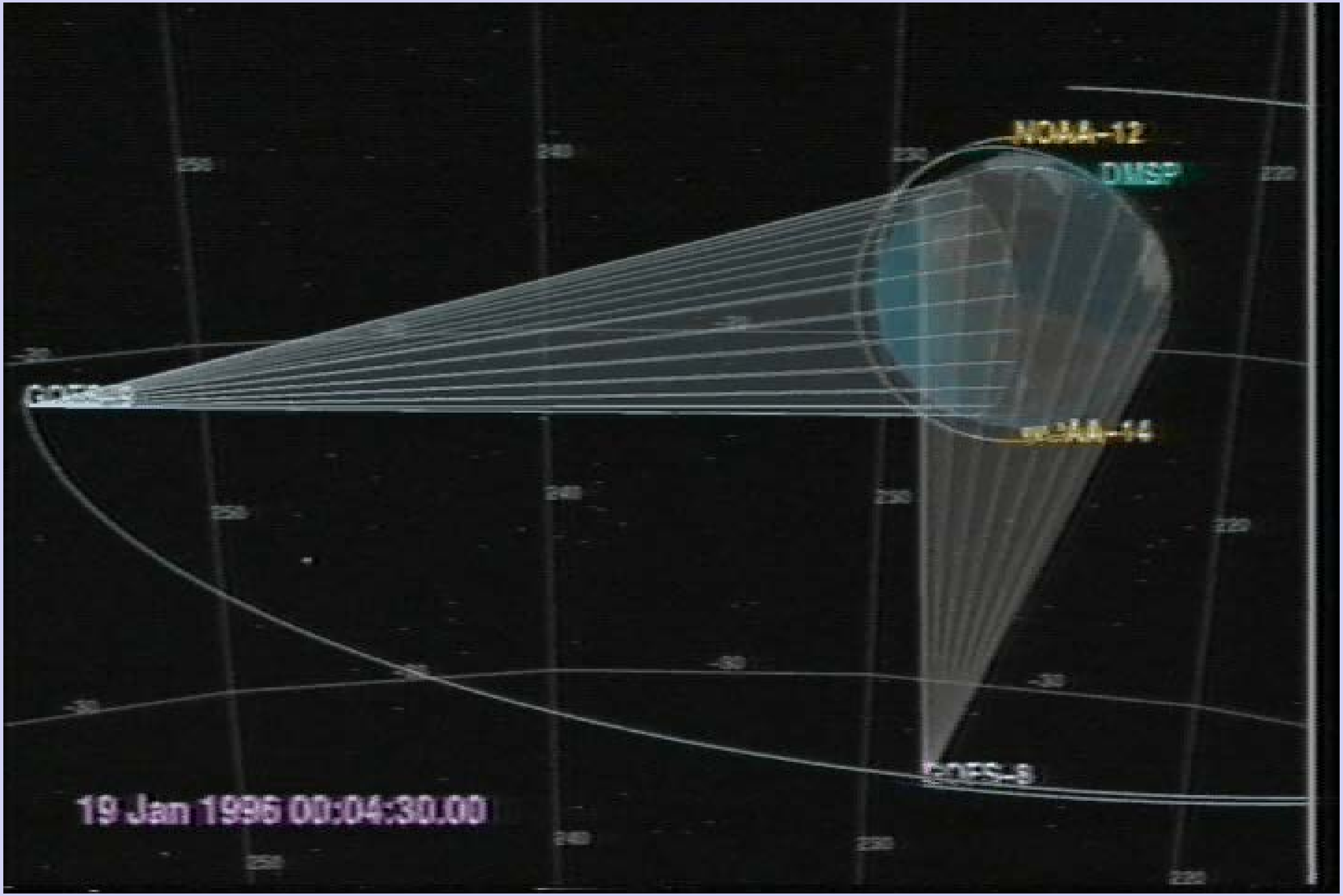
Satellite-Based Rainfall Estimation: Promising !

Observations from space: Near-continuous, global coverage,



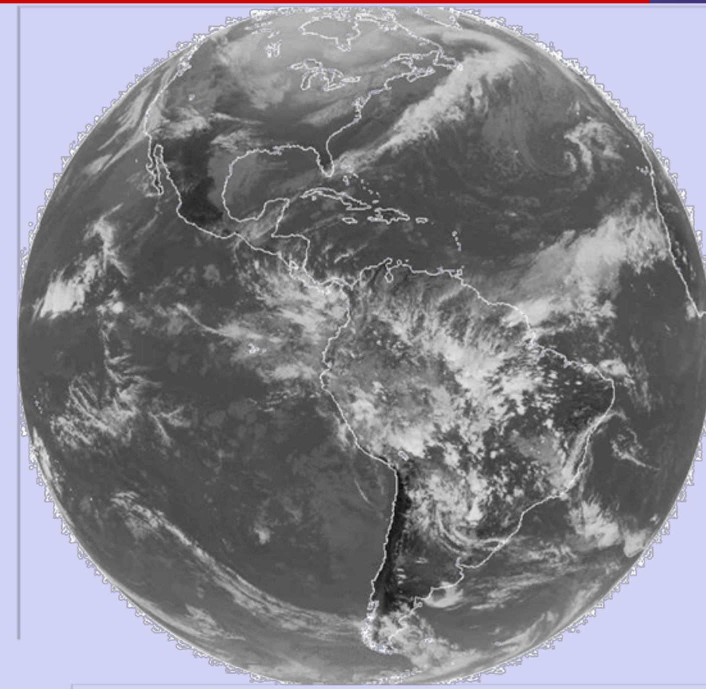
Geostationary and Polar Satellites

Courtesy: NASA's ESE



Satellite precipitation retrieval instruments

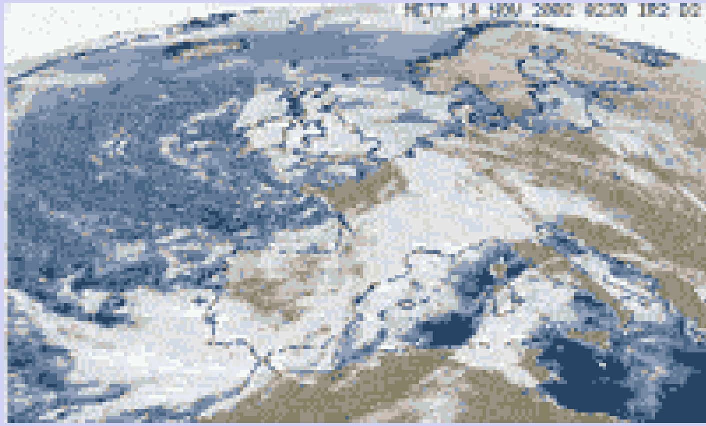
1) Using GEO satellites (Infrared/Visible channels)



***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)

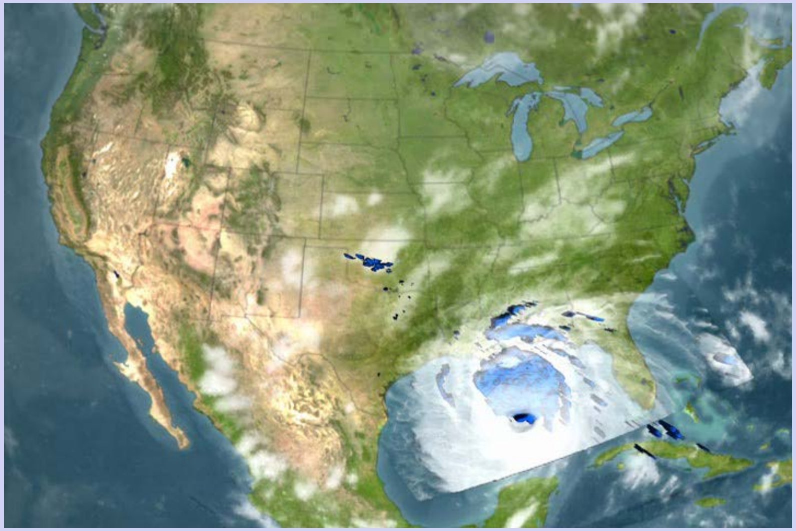
Satellite precipitation retrieval instruments

3) Active Radar

***Advantage*:**

-More accurate

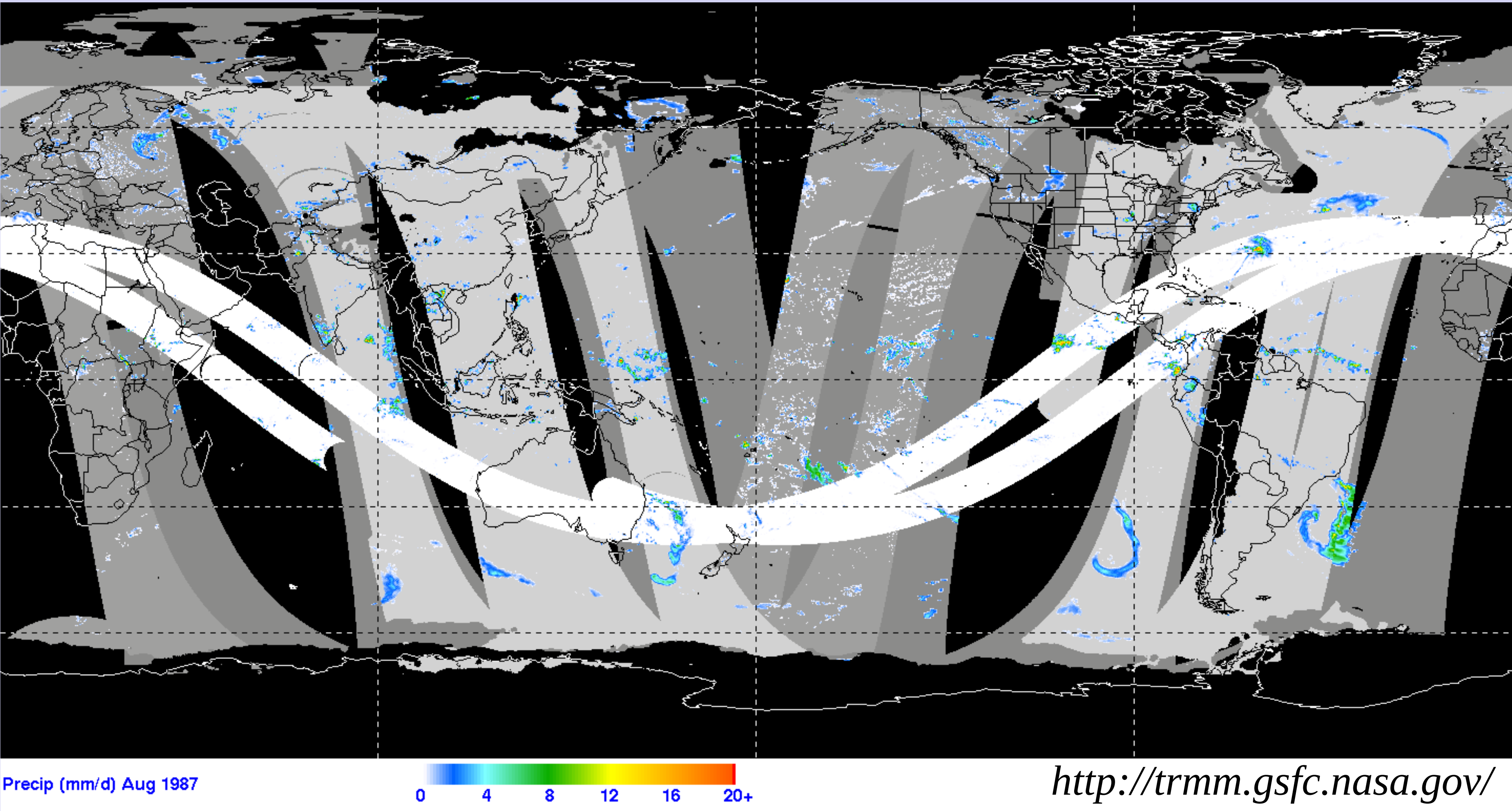
- good spatial resolution



***Disadvantage*:**

- Poor temporal resolution

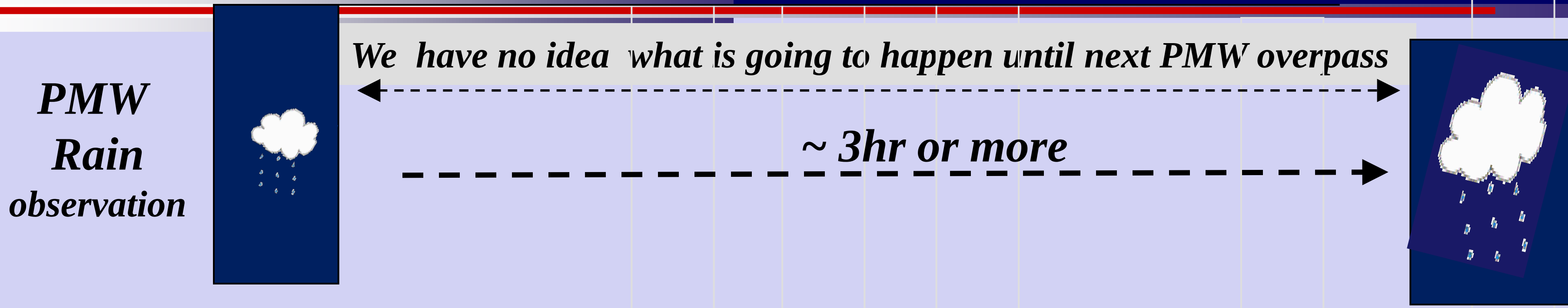
Typical Microwave Coverage in 3 Hr



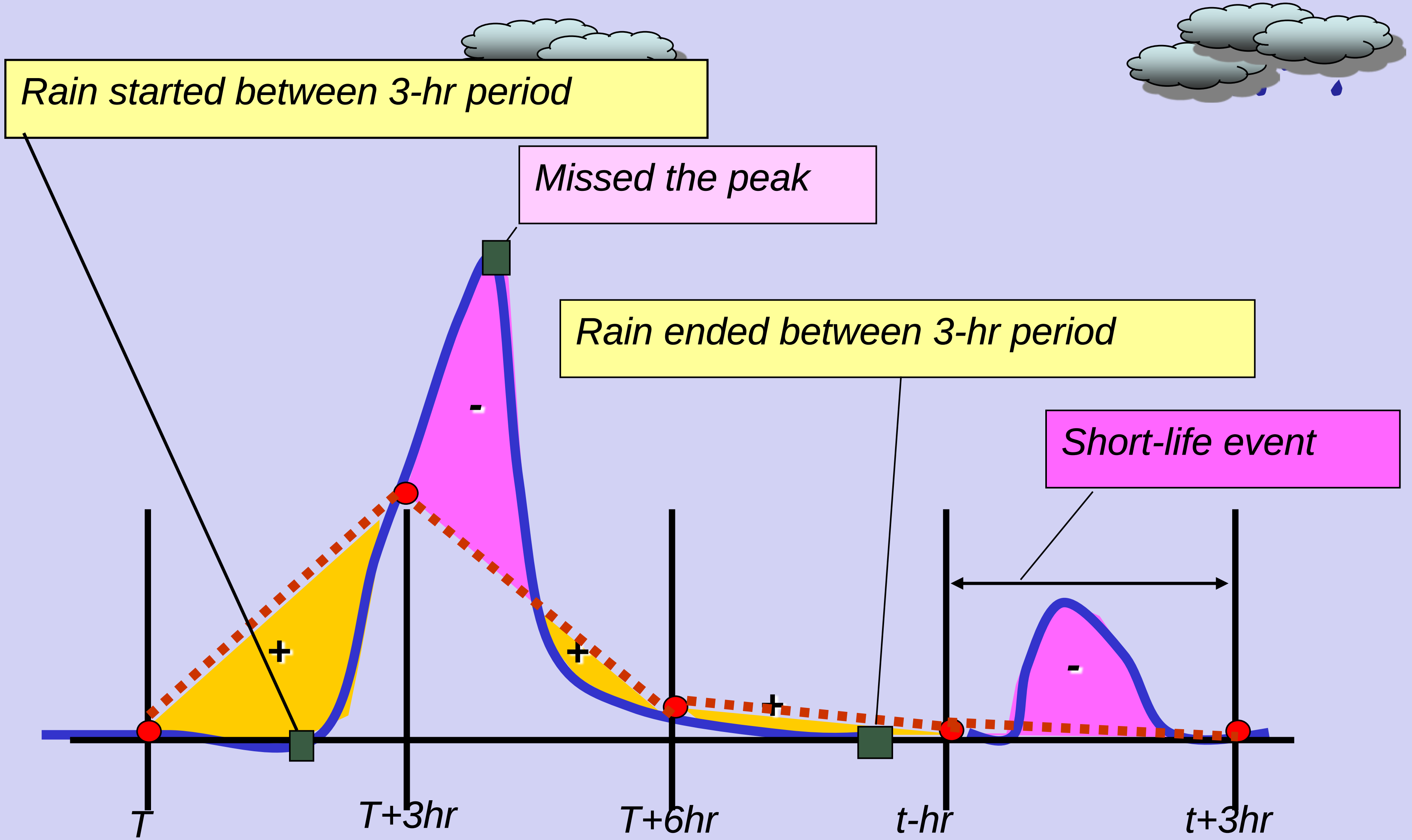
http://trmm.gsfc.nasa.gov/

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

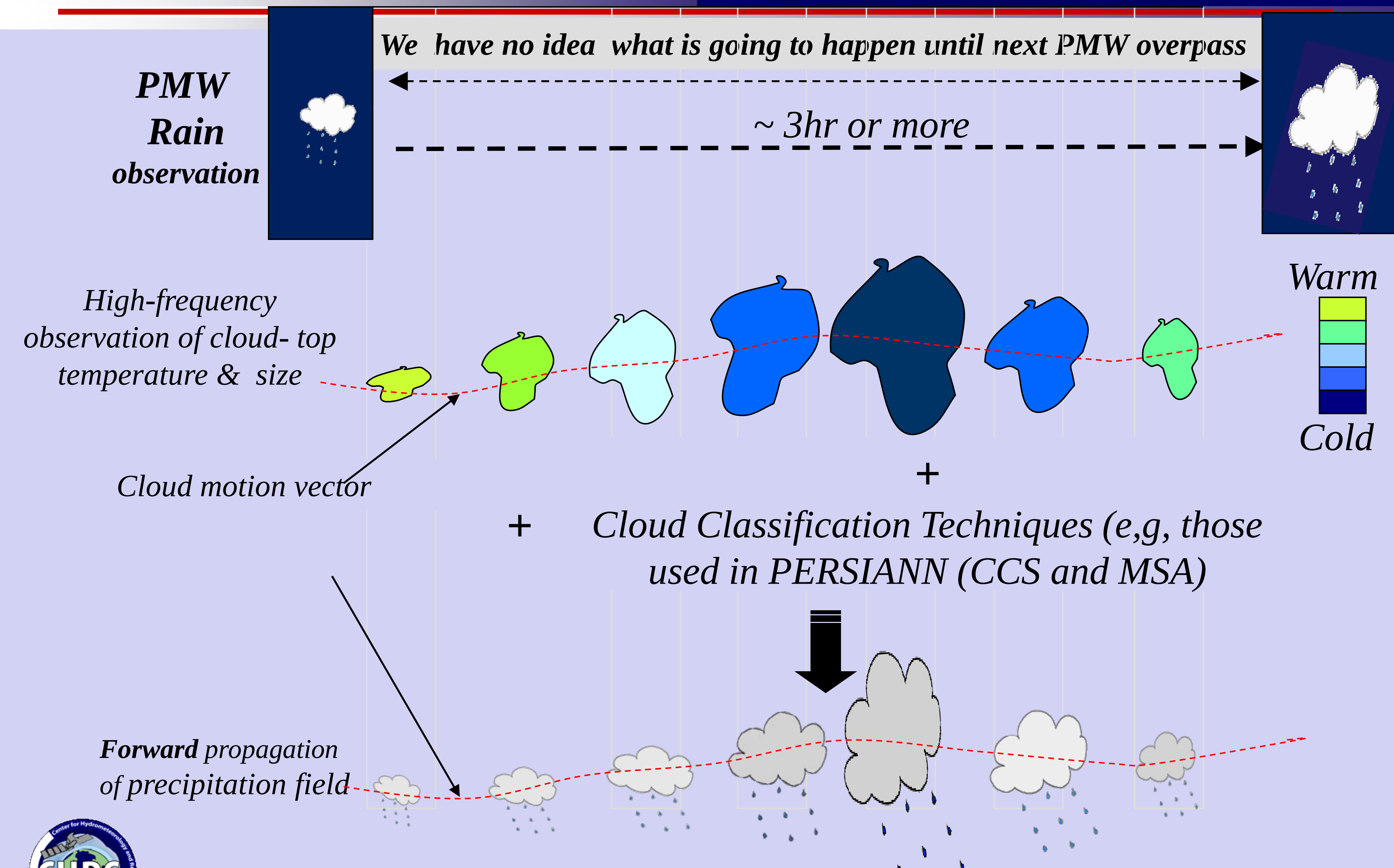
Conceptual Framework for higher resolution Precip.



Interpolation of 3-hour Precipitation

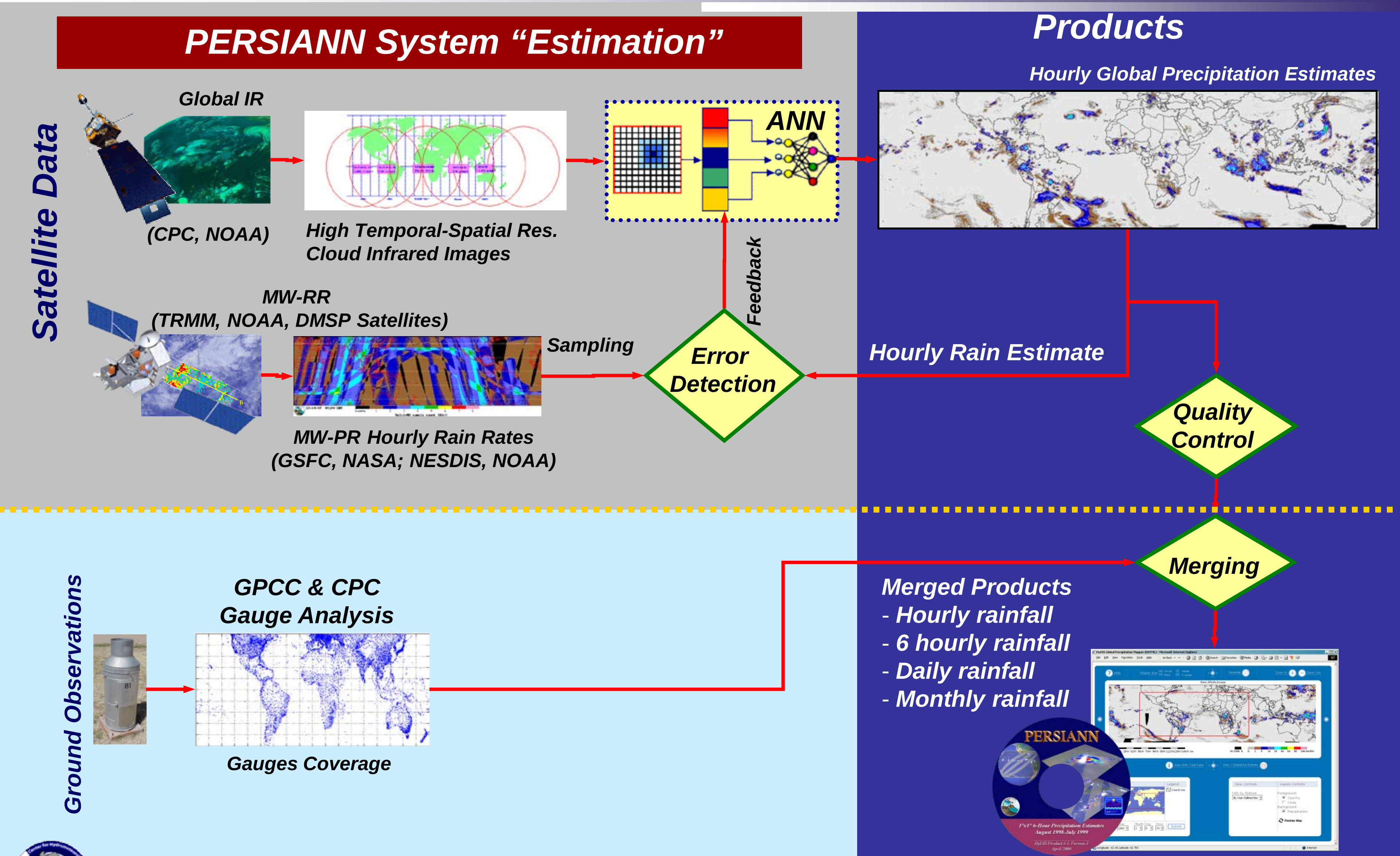


Conceptual Framework for higher resolution Precip.



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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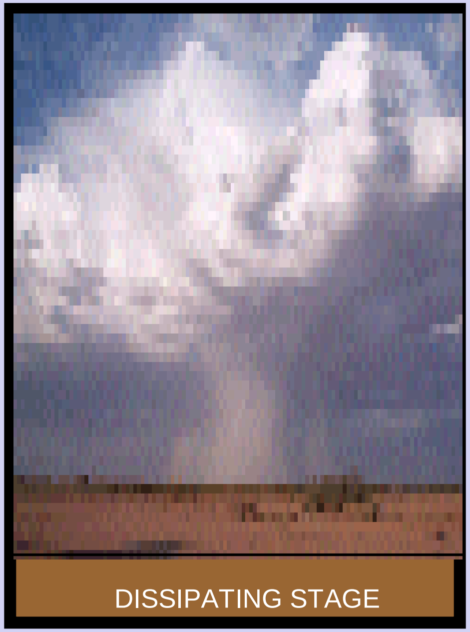
High Resolution Precipitation Estimates

PERSIANN-CCS

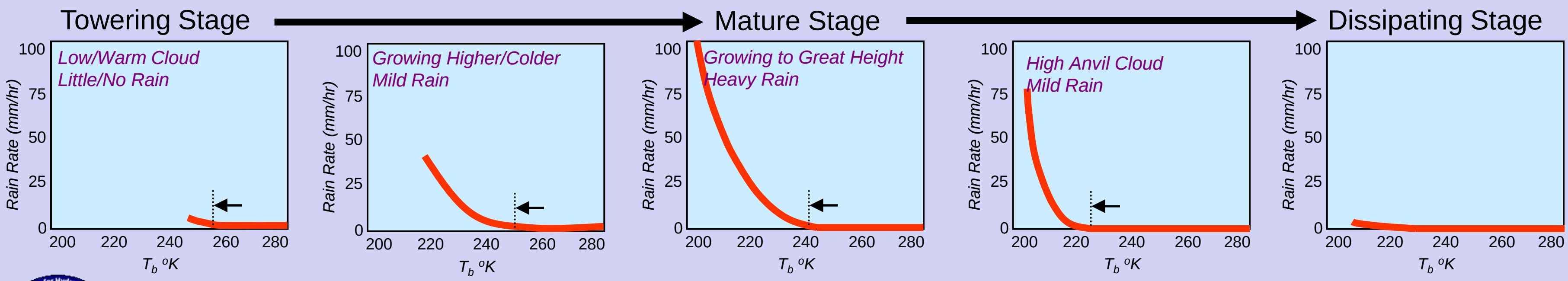
Stages of a Convective Storm and Rainfall Distribution

TOWERING CUMULUS STAGE

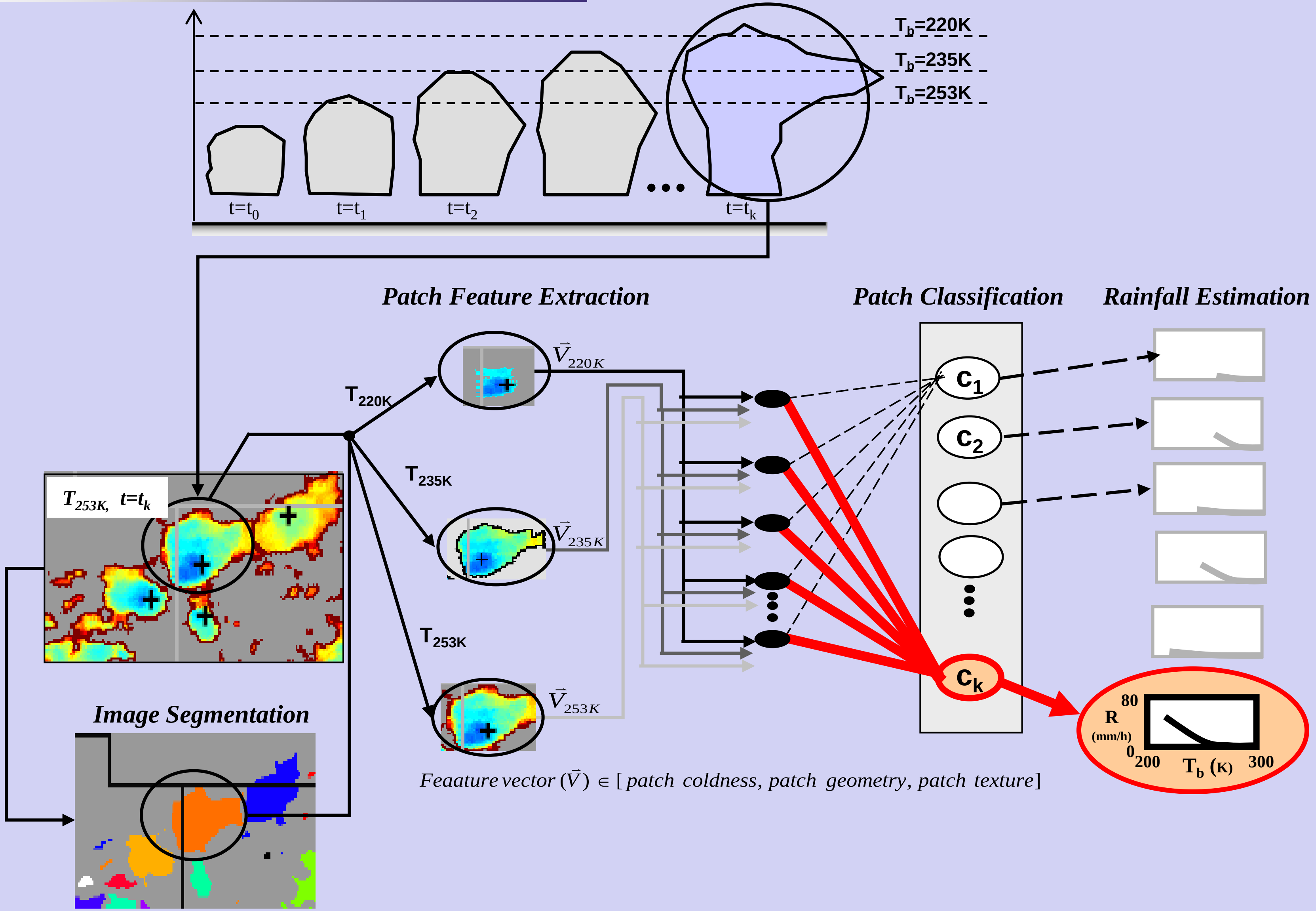
MATURE STAGE



DISSIPATING STAGE



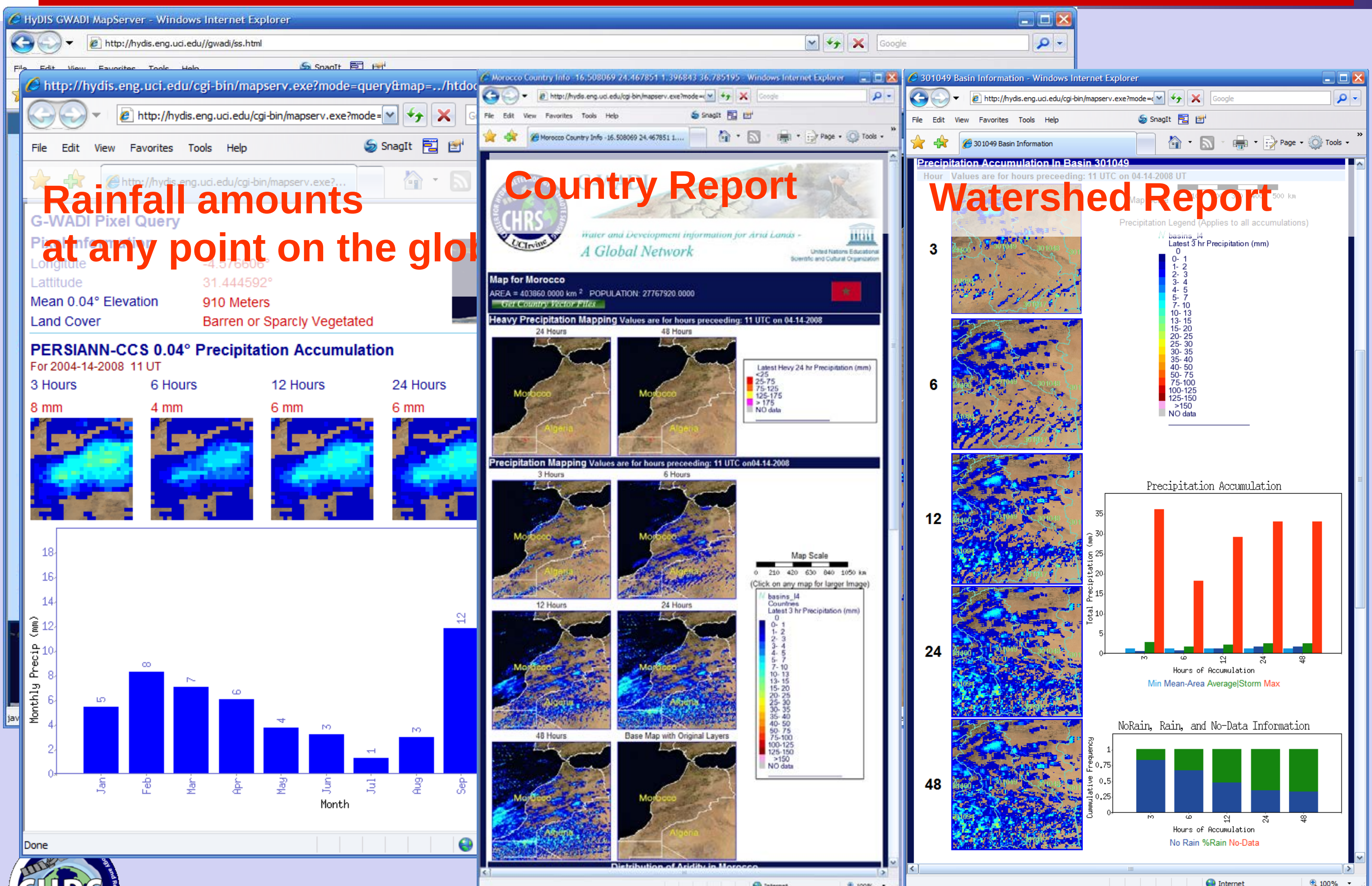
Cloud Segmentation Algorithm



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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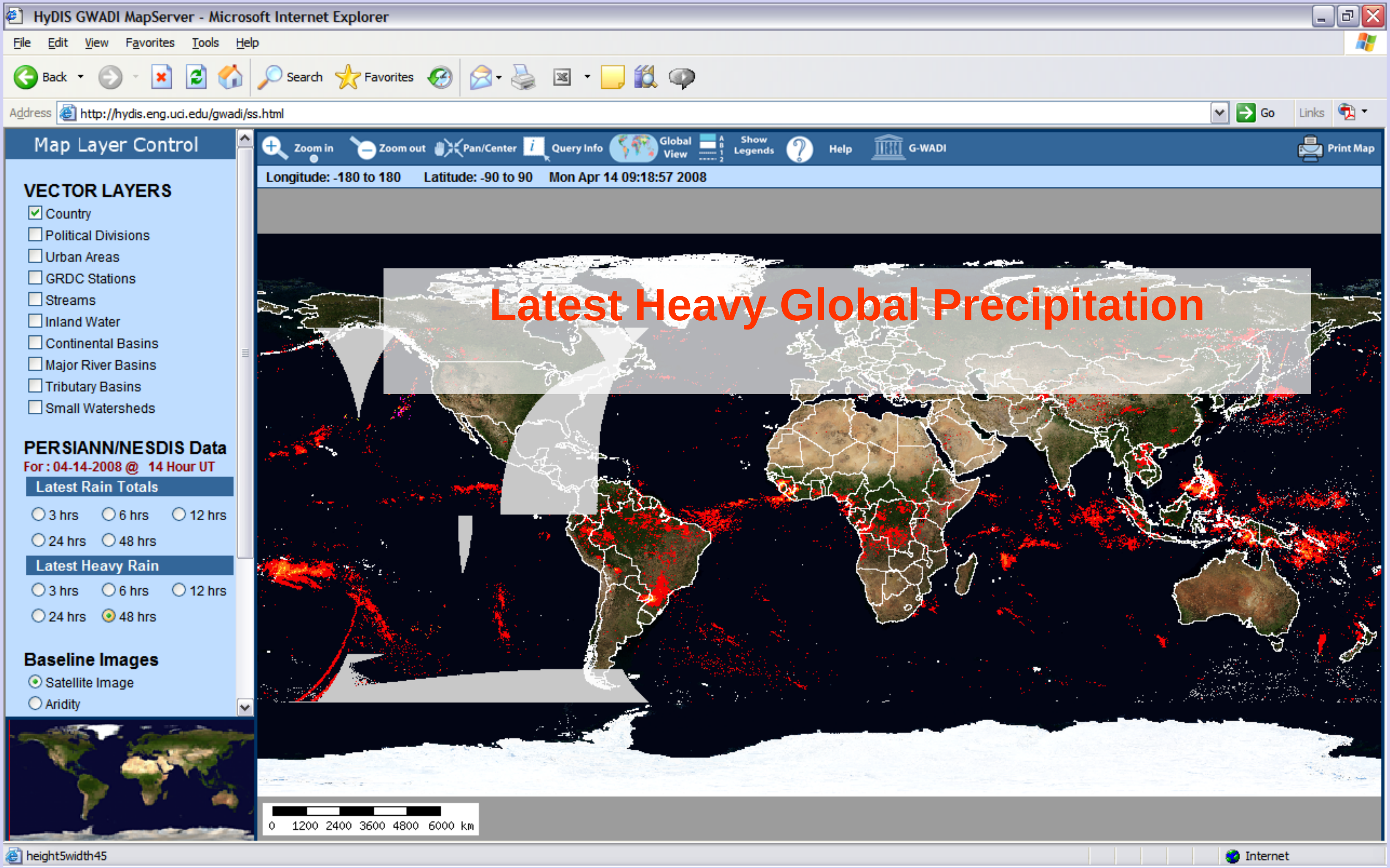
Real Time Global Data: Cooperation With UNESCO



PERSIANN Satellite Product On Google Earth

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

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Good Progress To Date, But a lot of work ahead and much to be desired!

Achieving higher resolution for Hydrologic applications

There is no debate about the importance of GEO (VIS/IR) information for hydrological applications. However,

Questions:

Can Multi–spectral images help us to improve GEO-based precipitation estimation ?

How can we extract efficient information from LEO(PMW) and GEO (VIS/IR) images ?

The ABI (Advanced Baseline Imager) on GOES-R

- *Currently many sensors provide multi-spectral images with high spatial and temporal resolution.*

- *SEVIRI is a sensor on Meteosat Second Generation (MSG) satellite that has 12 spectral bands.*

- *In Approx. 2015, ABI sensor on GOES-R will provide 16 spectral bands.*

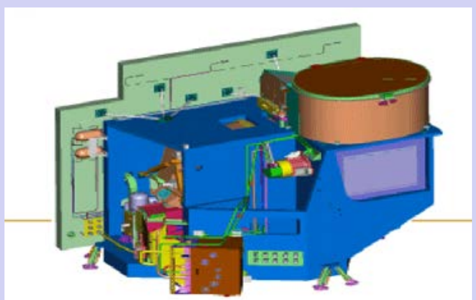
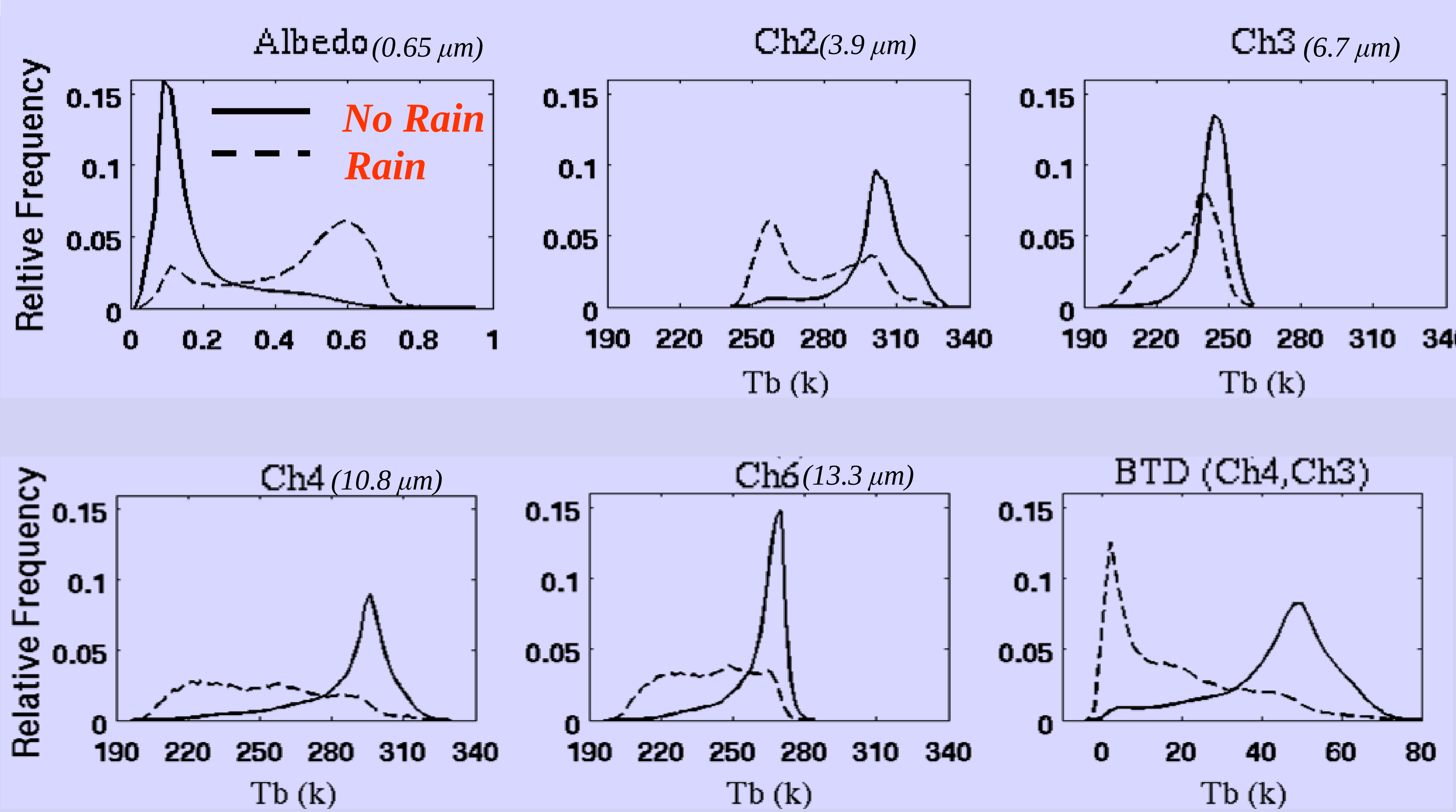


Figure courtesy of ITT Industries

•***Together a great opportunity to investigate the role of multi-spectral data for precipitation estimation***

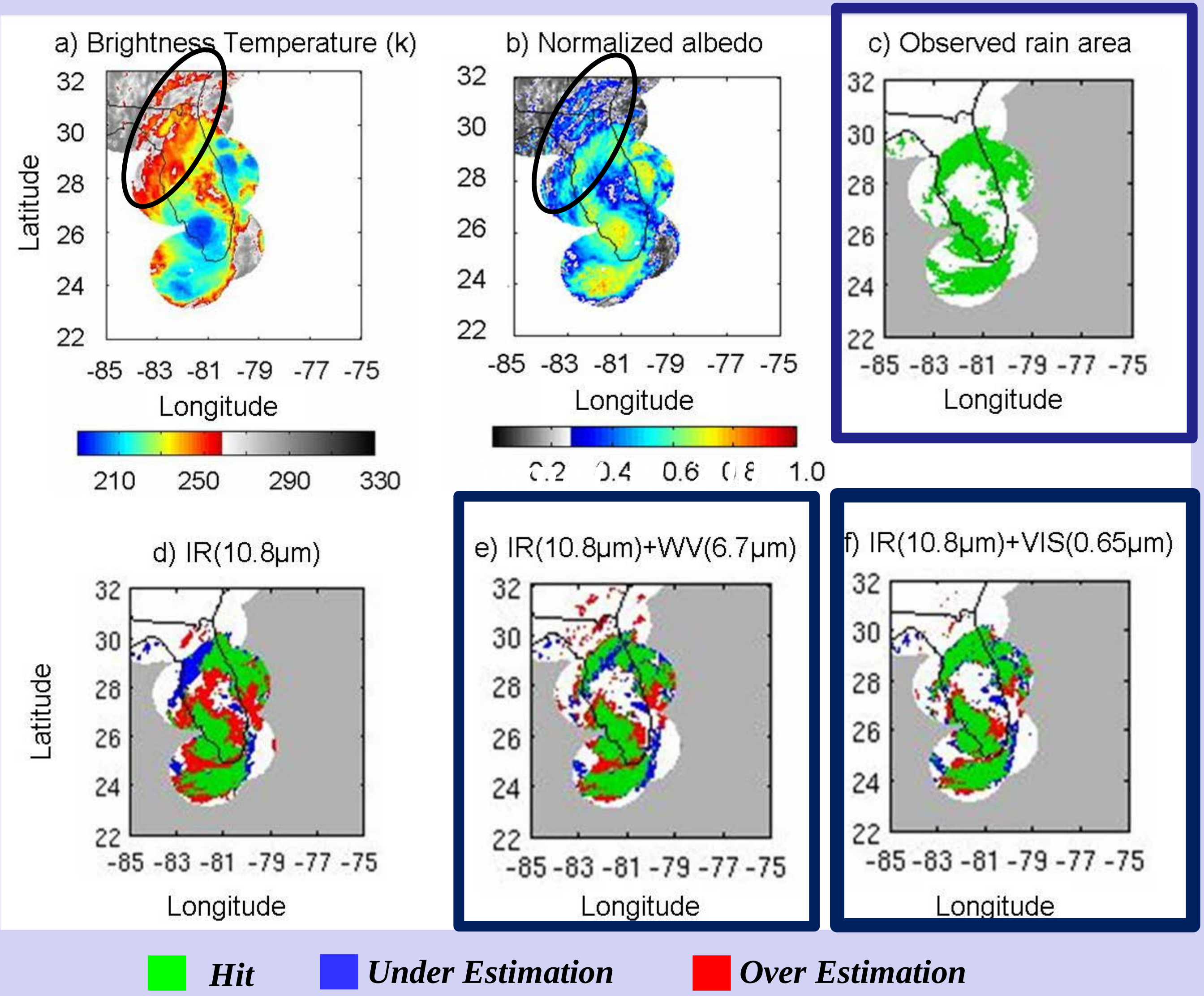
Behrangi et al (2009 a & b)

Relative-frequency dist. of different channels (rain / no-rain) conditions



By counting satellite pixels under rain and no-rain conditions we can plot the relative frequency curves for each spectral band. These curves indicate that different spectral channels show different capabilities to distinguish between rain and no-rain pixels

Case Study: Hurricane Ernesto August 30, 2006

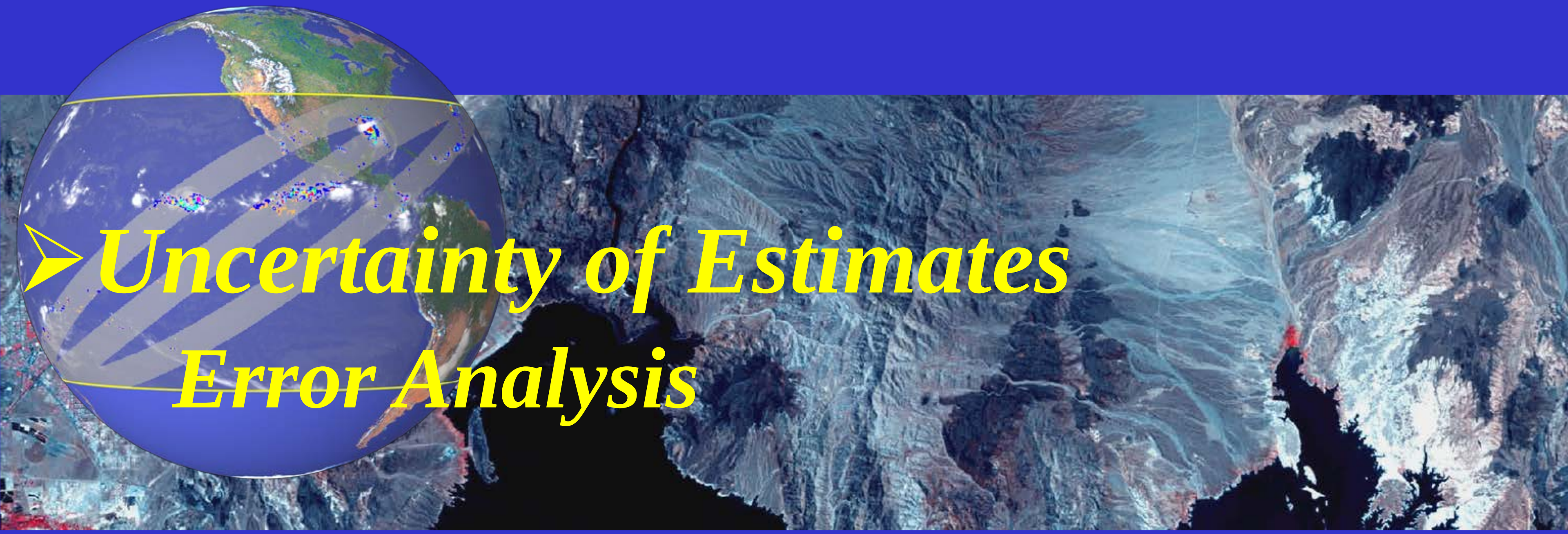


GPM Mission: Target Date 2013-1014

OBJECTIVES

- **1 Main satellite + 8 Smaller Satellites **
- **Provide sufficient global sampling to significantly reduce uncertainties in short-term rainfall accumulations**

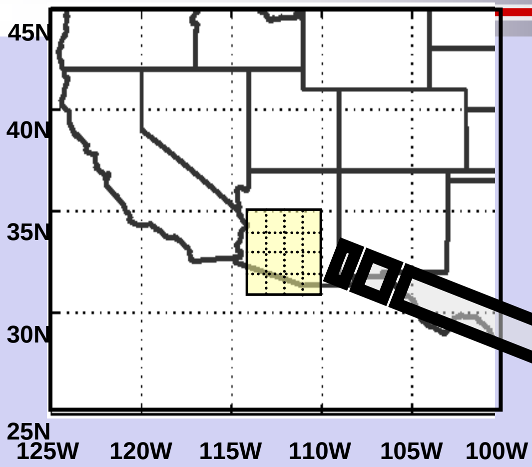
Future looks bright and will bring us more advances for precipitation Estimation

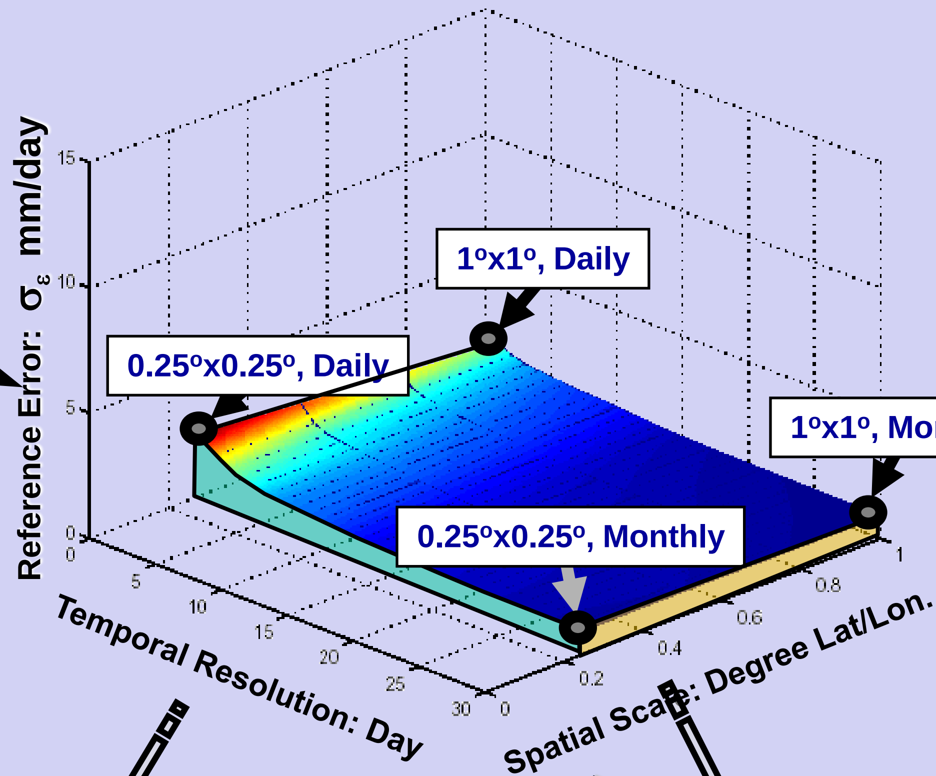


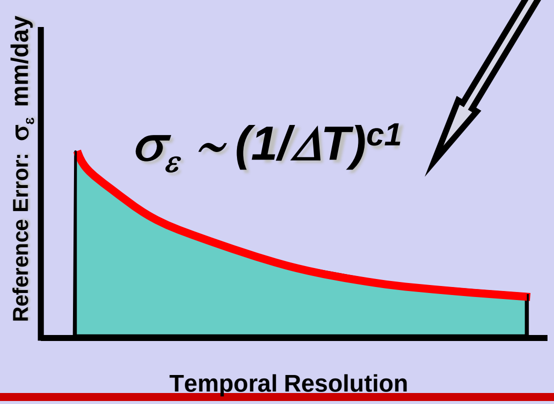
➢ *Uncertainty of Estimates*

Error Analysis

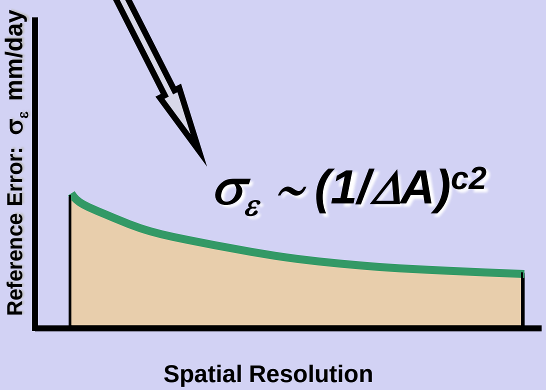
Spatial-Temporal Property of Reference Error





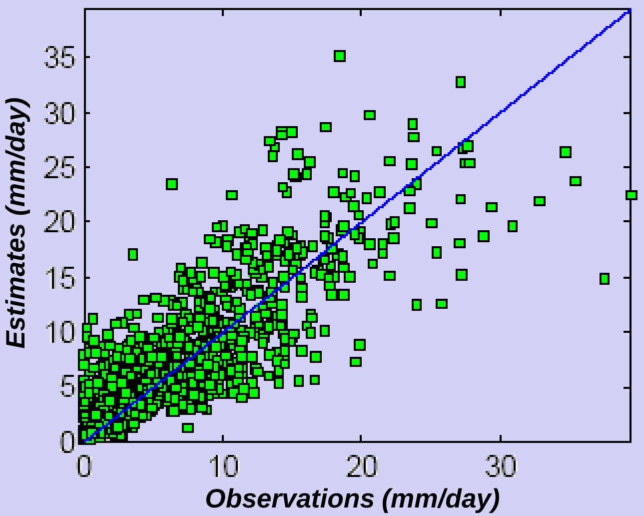


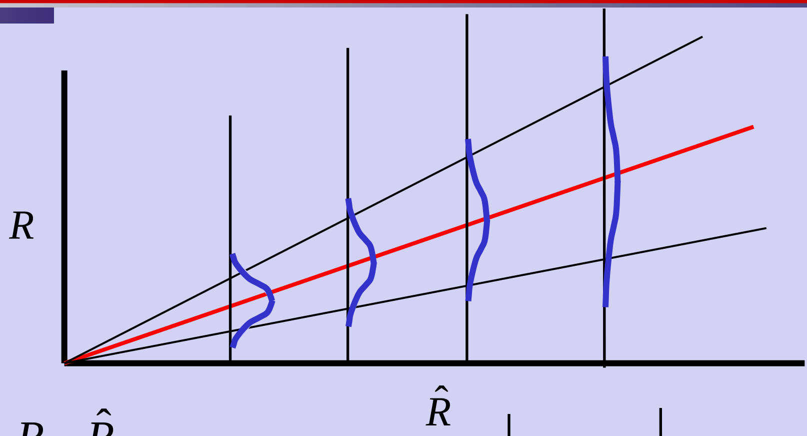
$\sigma_\varepsilon \sim (1/\Delta T)^{c1}$

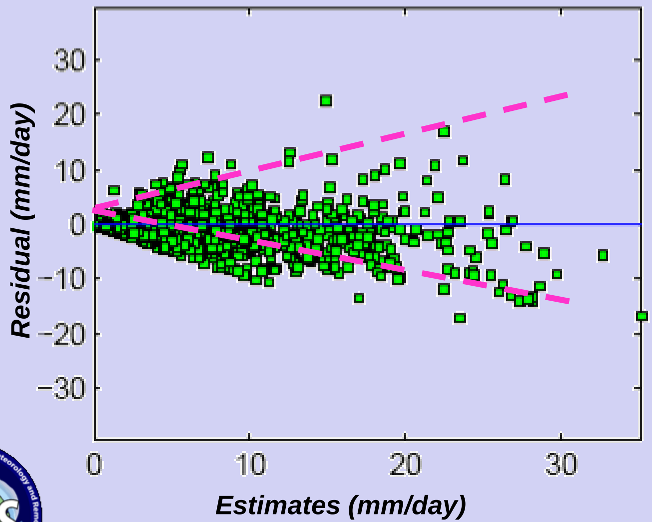


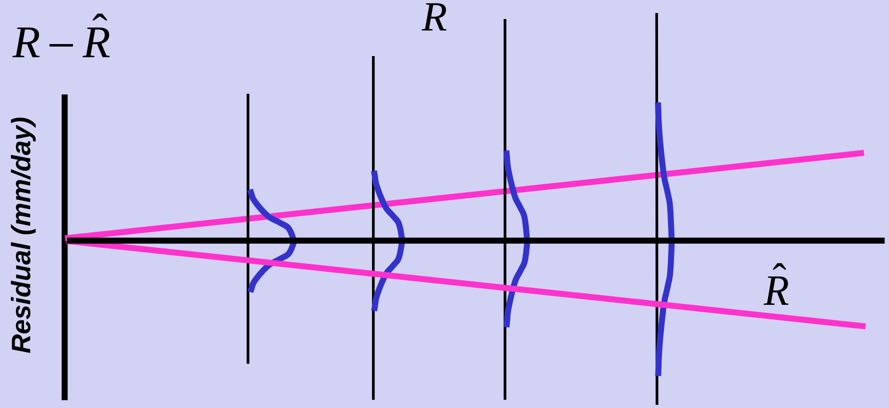
$\sigma_\varepsilon \sim (1/\Delta A)^{c2}$

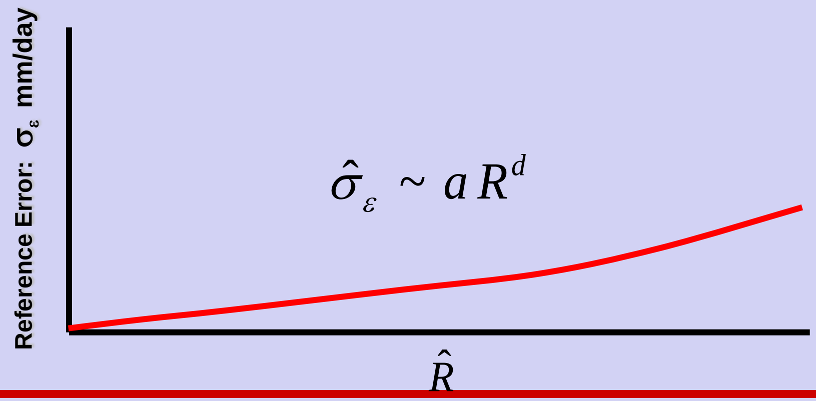
Reference Error: ΔT = 24-hour, $\Delta A = 0.25^o x 0.25^o$





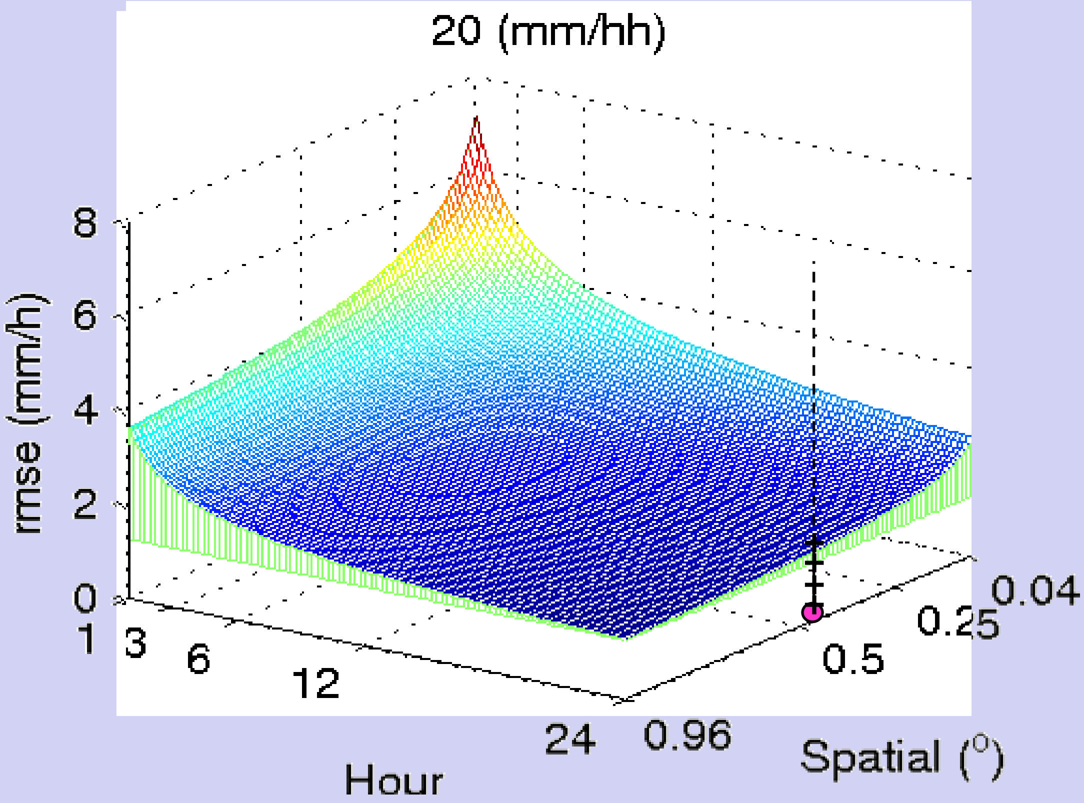






Scaling Property of PERSIANN-CCS Reference Error

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



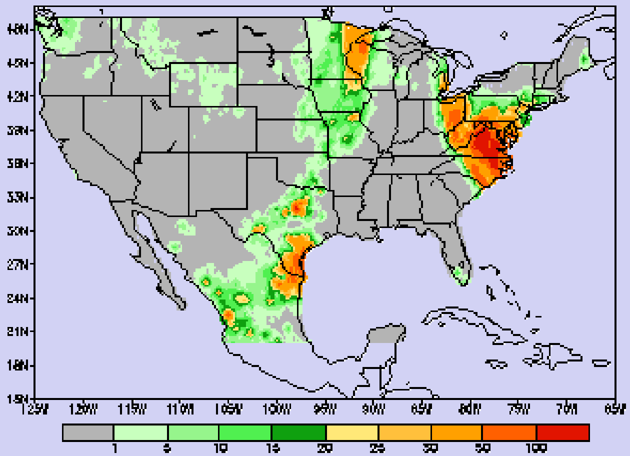
Validation and Application of Satellite Products

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



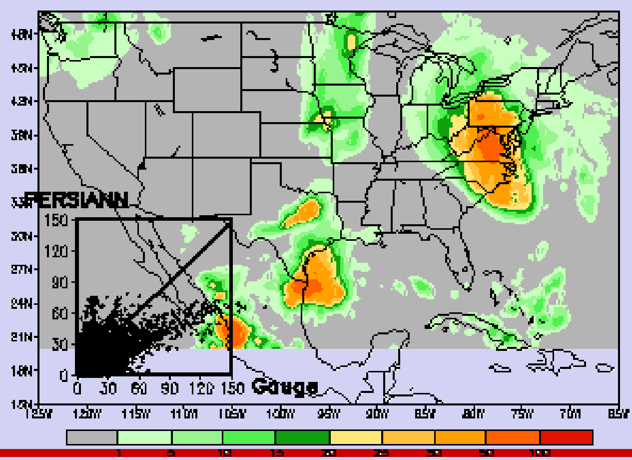
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.55	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45

	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

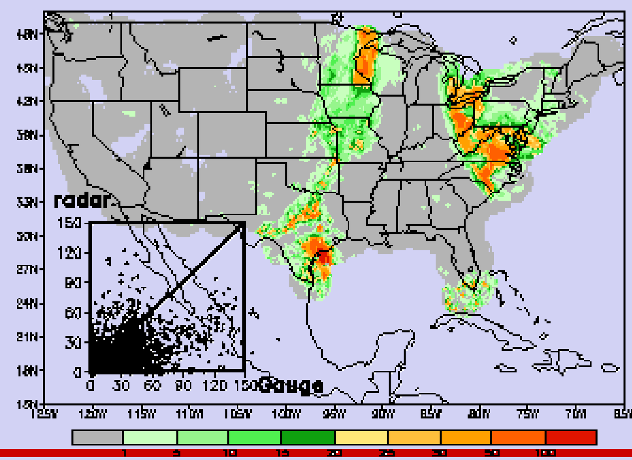
gauge	PERSIANN < 1	PERSIANN ≥ 1
< 1	8082.	1497.
≥ 1	1081.	3168.

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

PERSIANN

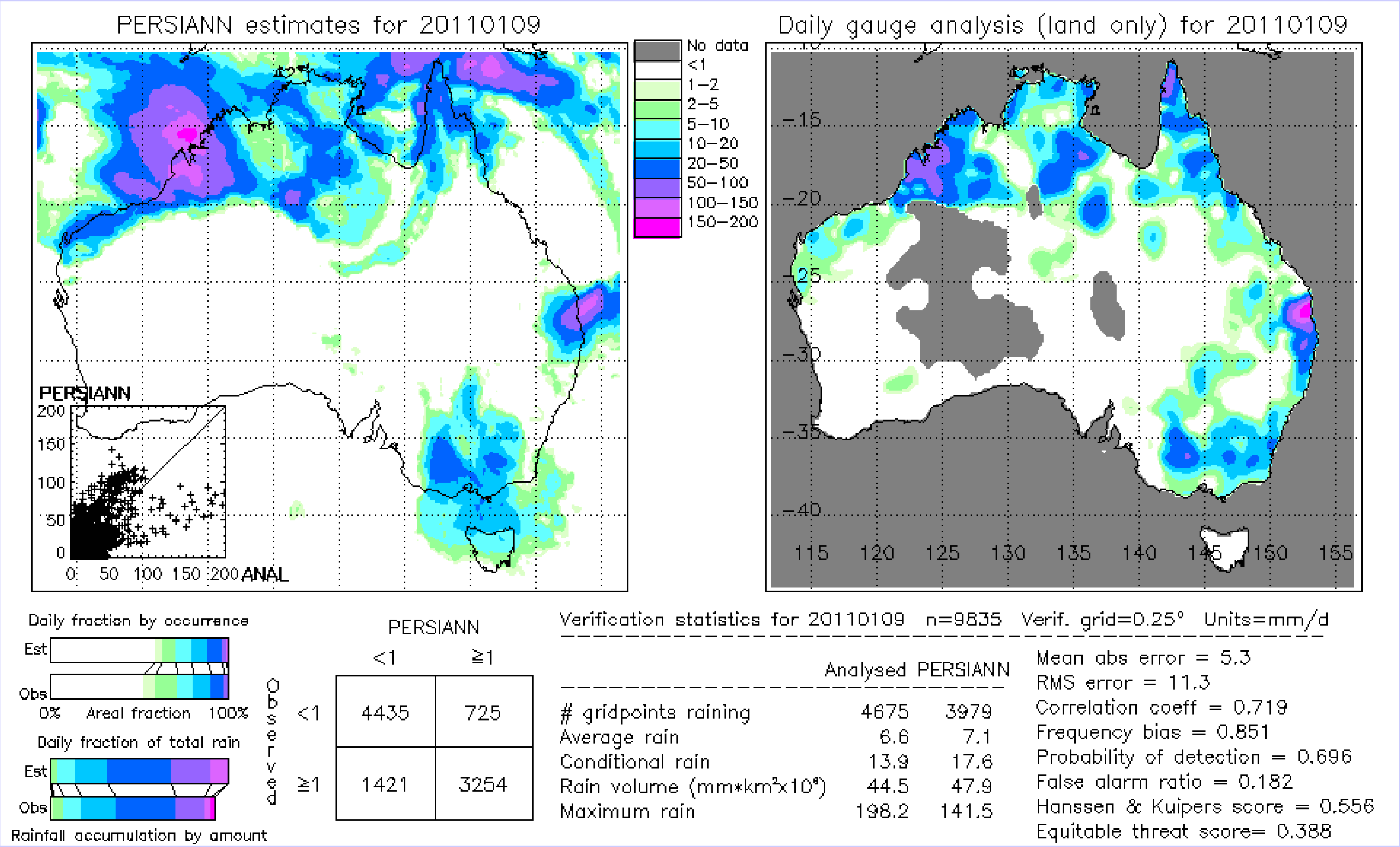


Radar



Evaluation of PERSIANN Daily Rainfall

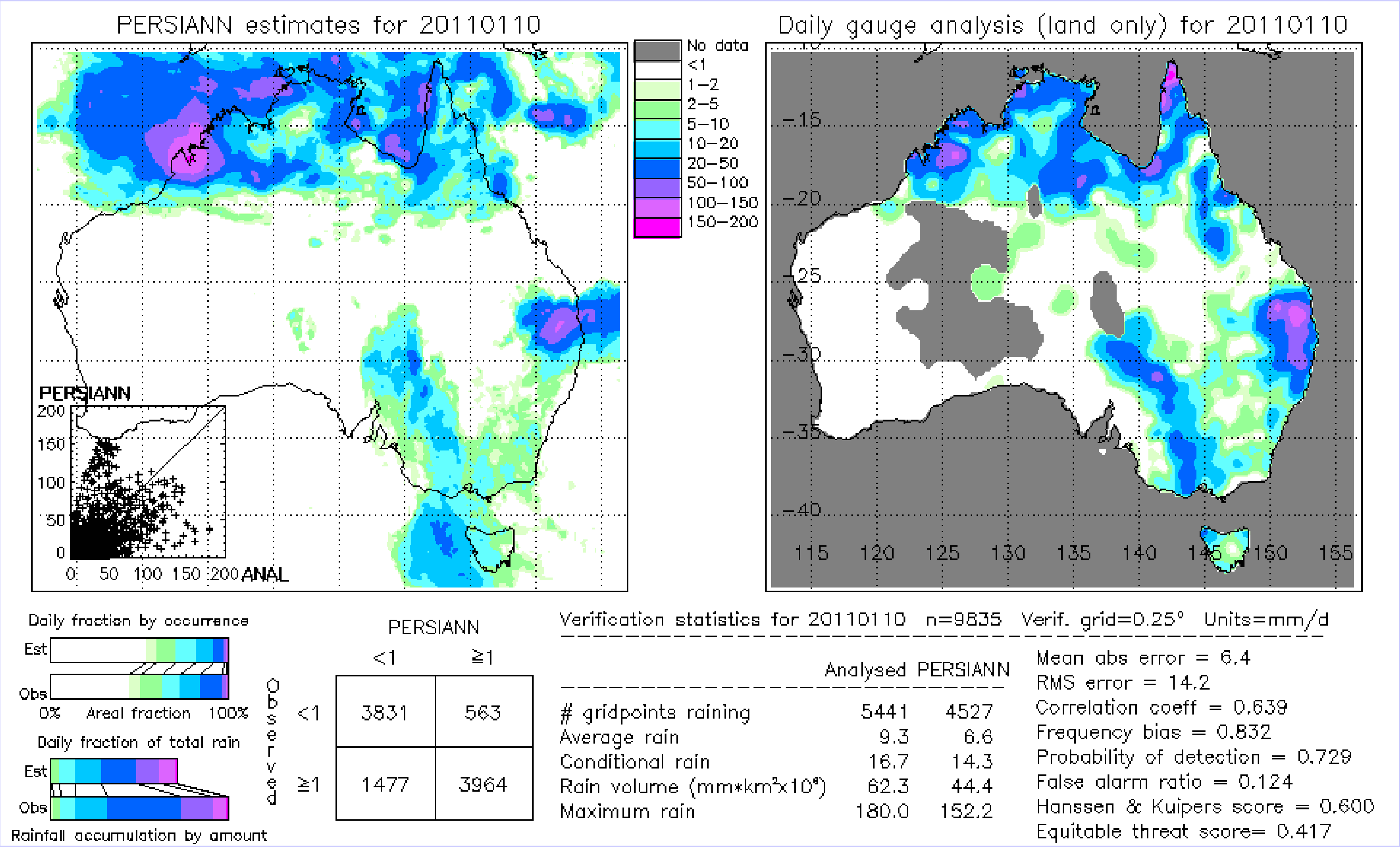
01-09-2011 (0.25-degree resolution)



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

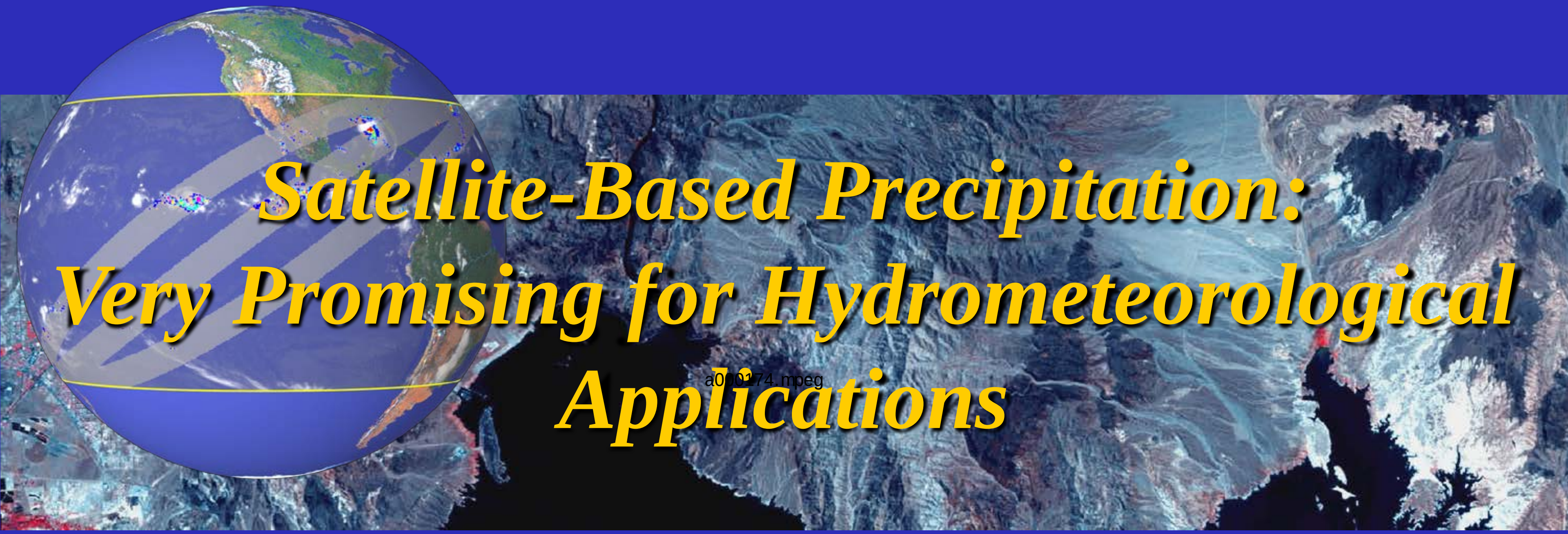
Evaluation of PERSIANN Daily Rainfall

01-10-2011 (0.25-degree resolution)



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

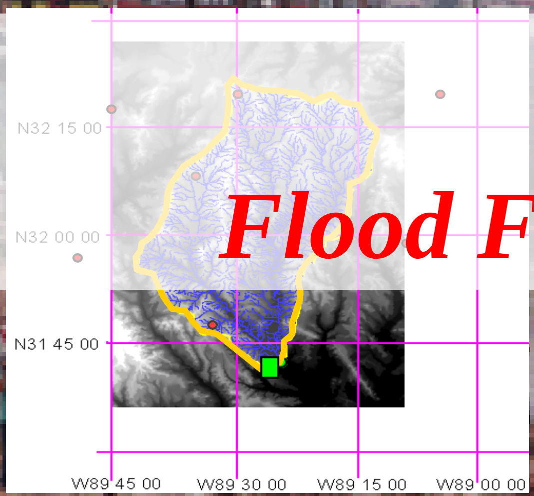
Satellite-Based Precipitation: Very Promising for Hydrometeorological Applications



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).

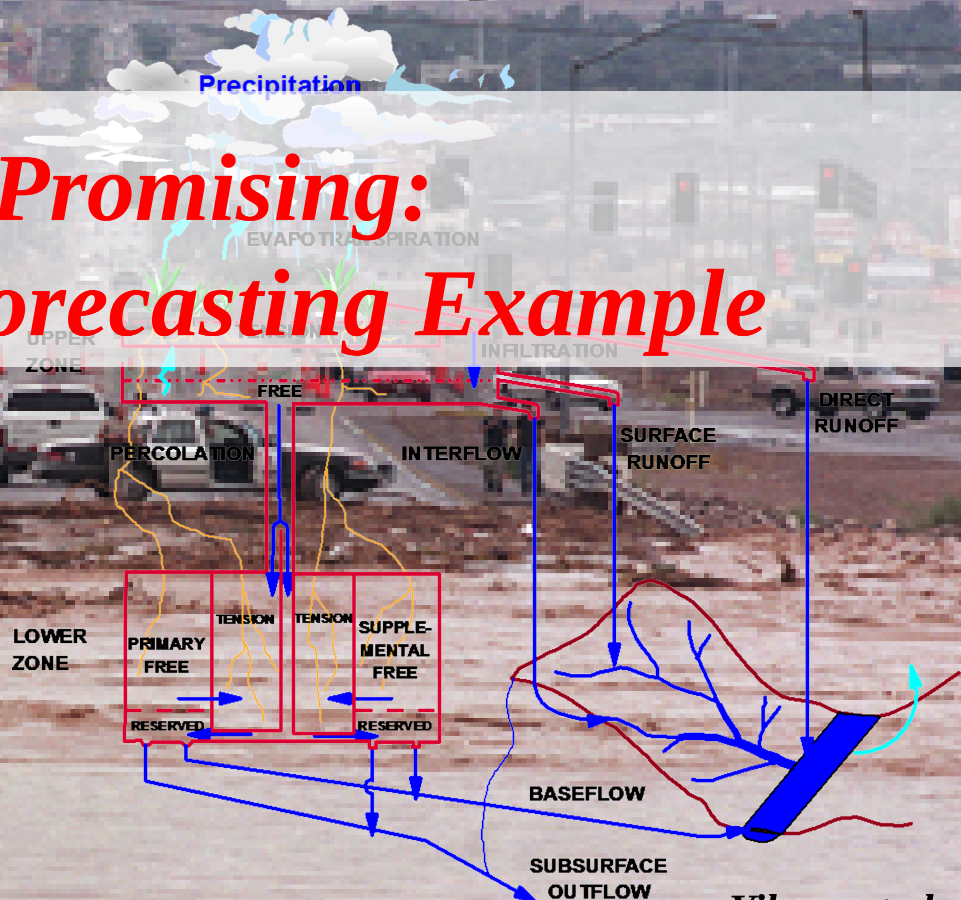
Promising:
Flood Forecasting Example



● Gages used by NWS

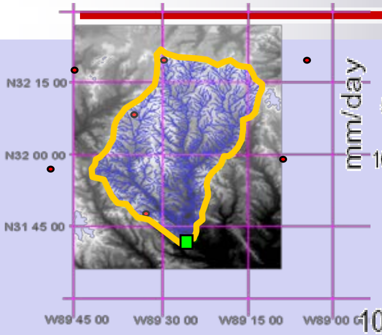
Leaf River Near Collins
Mississippi
USGS # 02472000

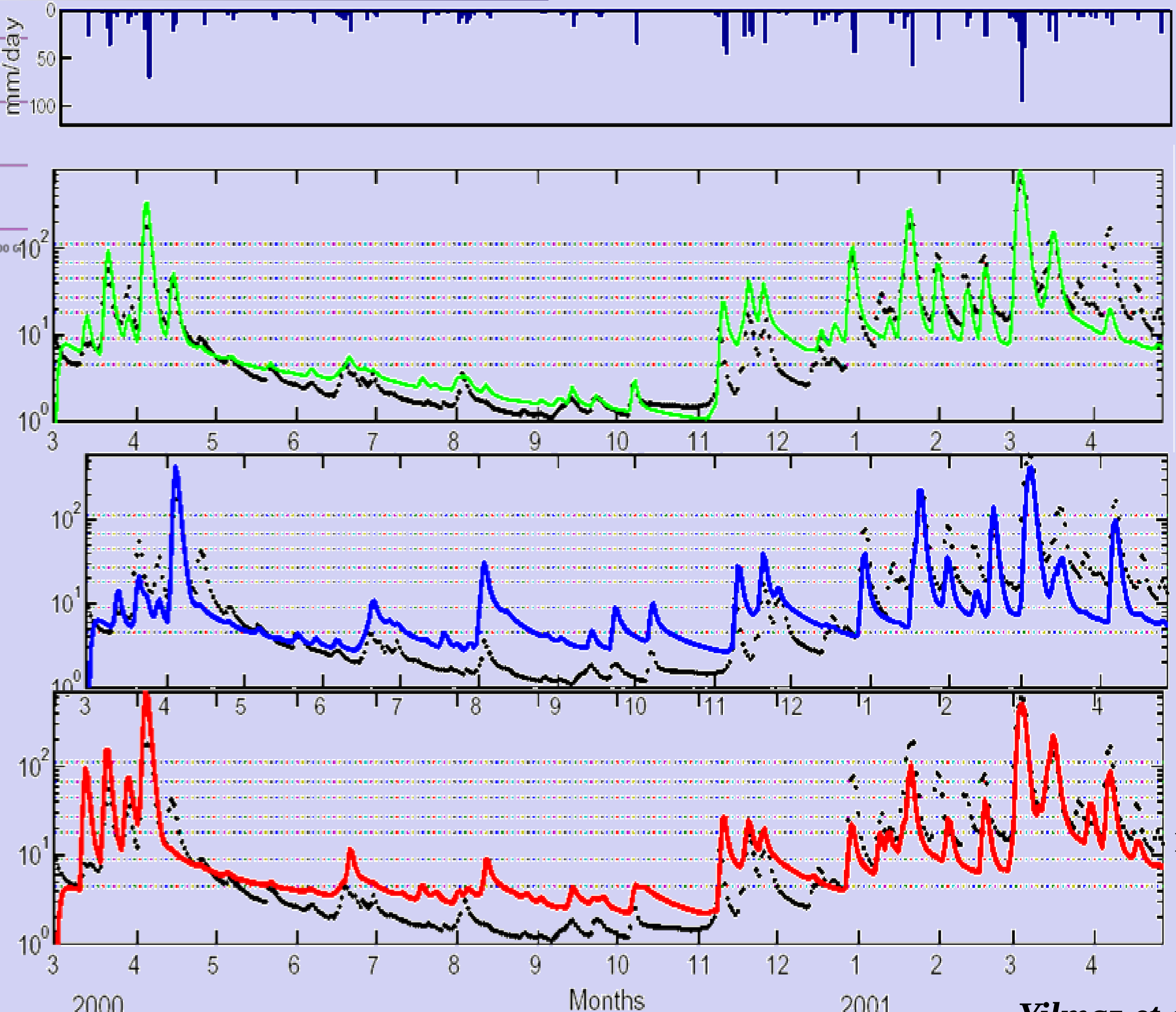
Basin Area : 753 mi²



Yilmaz et al. JHM 2005

Satellite Rainfall Estimation: Research at UC Irvine





RAINGAGE

Corr =0.95
RMS =23.9
BIAS =-1.32

RADAR

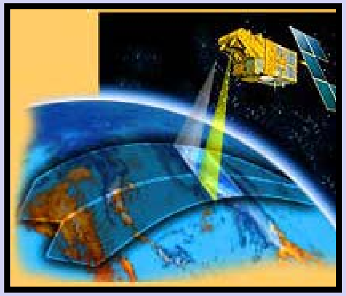
Corr =0.92
RMS =28.8
BIAS =-6.74

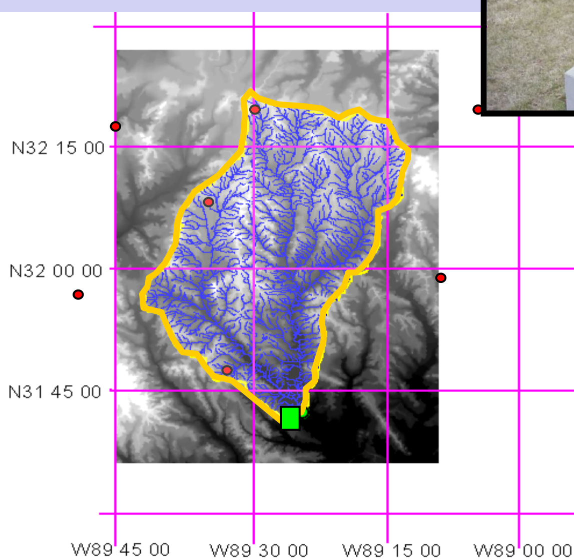
PERSIANN

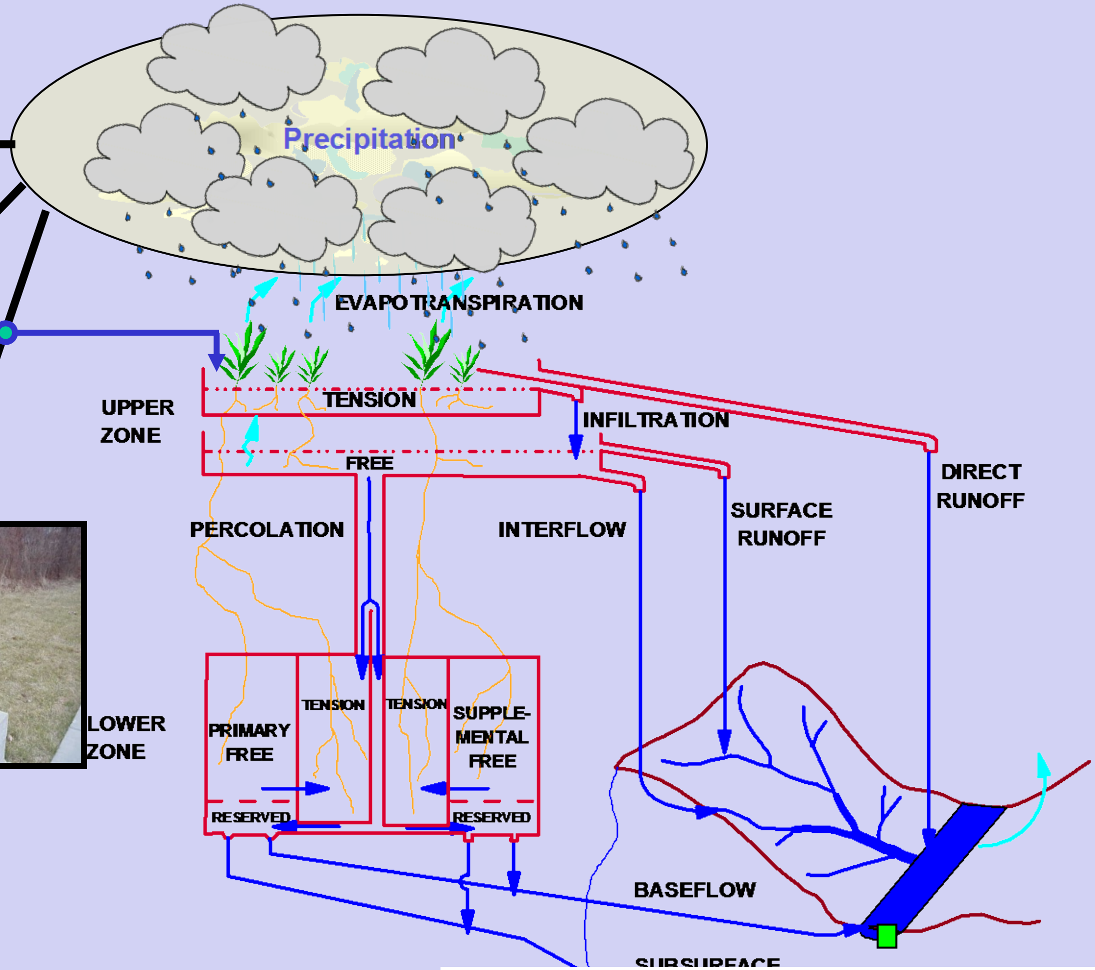
Corr =0.94
RMS =22.6
BIAS =-5.15

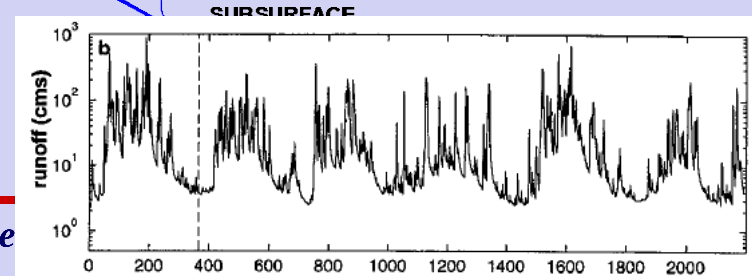
Yilmaz et al. JHM 2005

Basin Scale Precipitation Data Merging

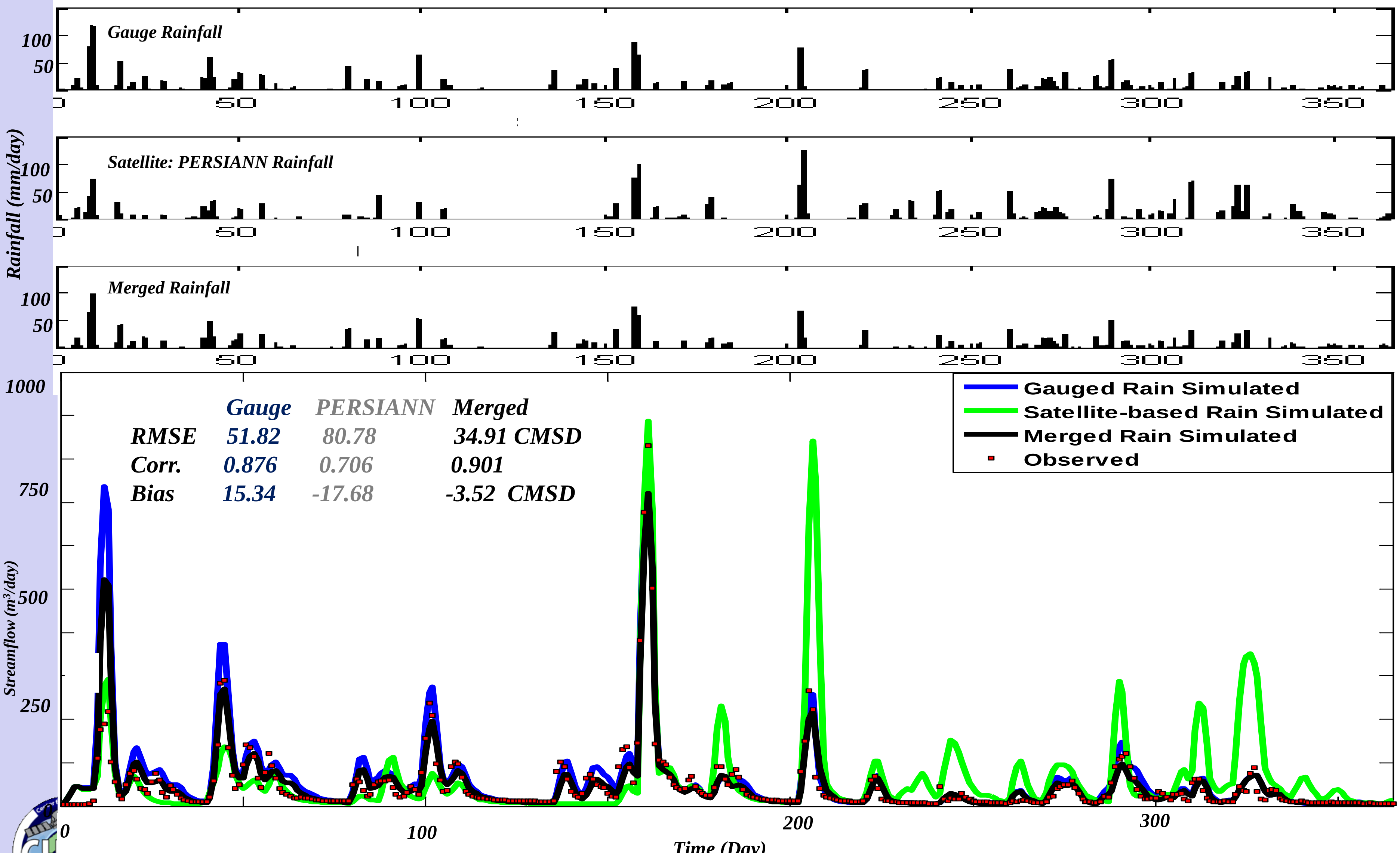








Runoff Forecasting from Gauge, PERSIANN, and Merged Rainfall

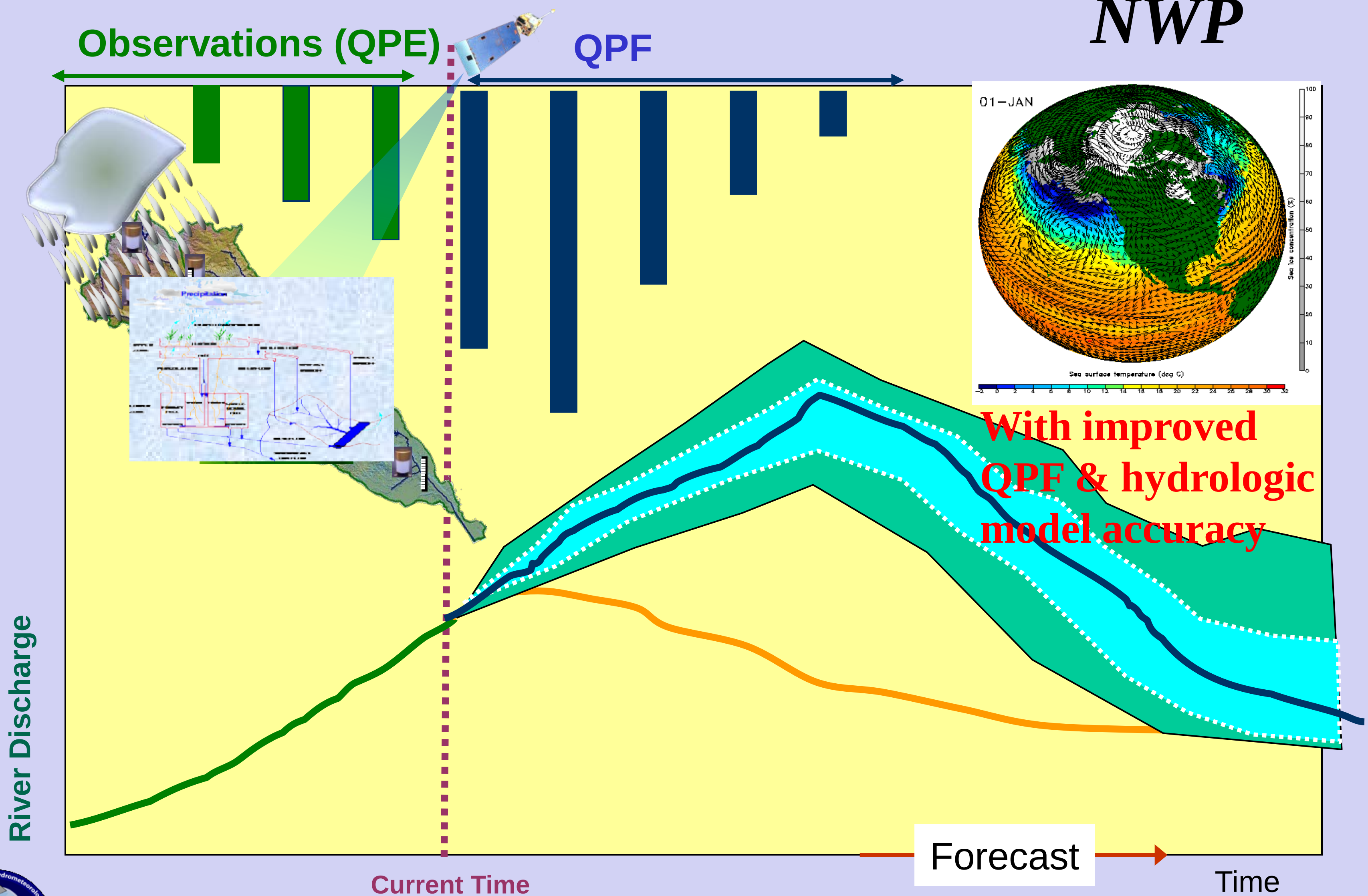


Estimating Future “Short-Term” Rainfall:

1- Models: (NWP - QPF)

2- Extrapolation-based Nowcasting

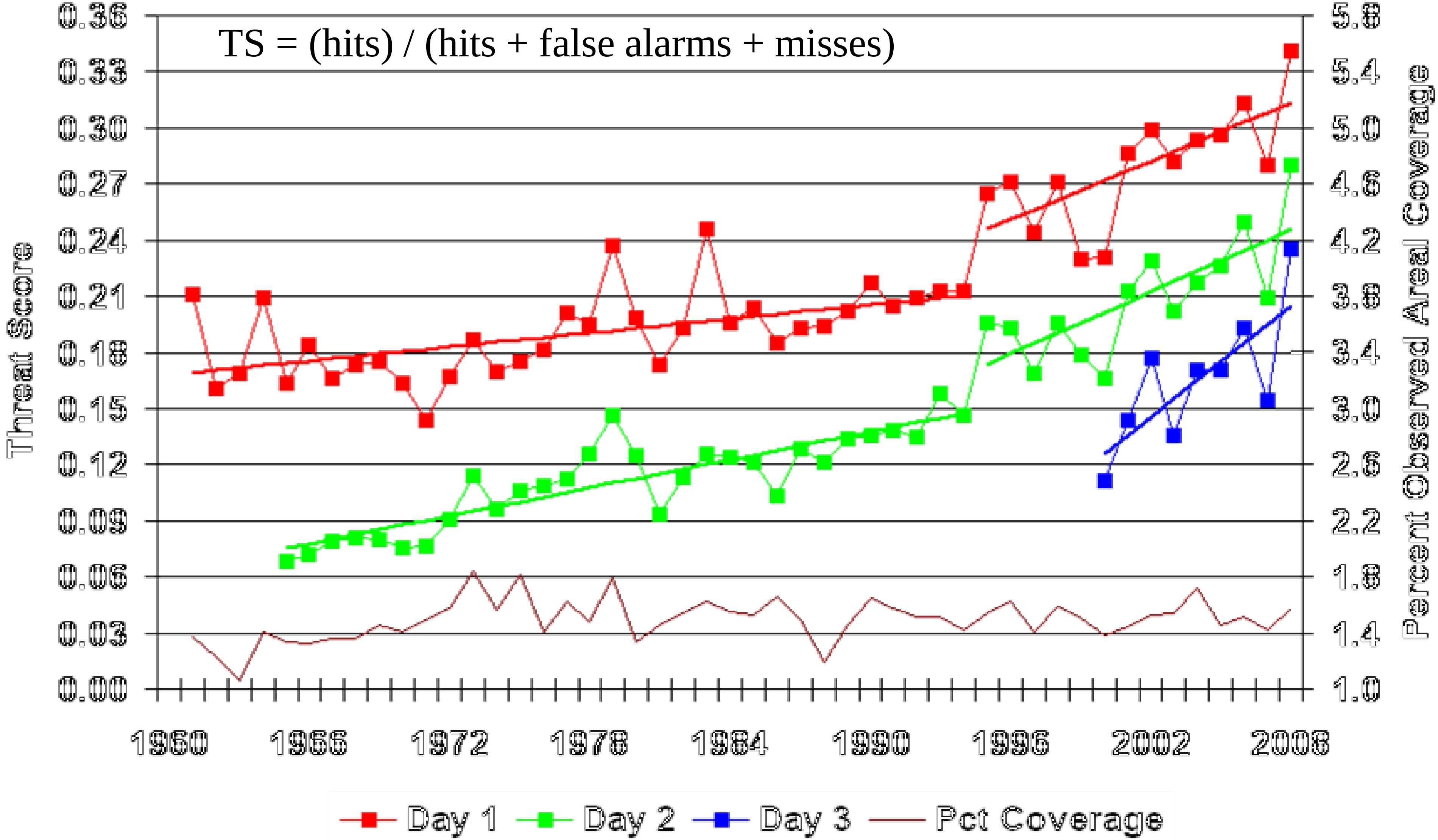
Efforts in Extending the Forecast Lead Time



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

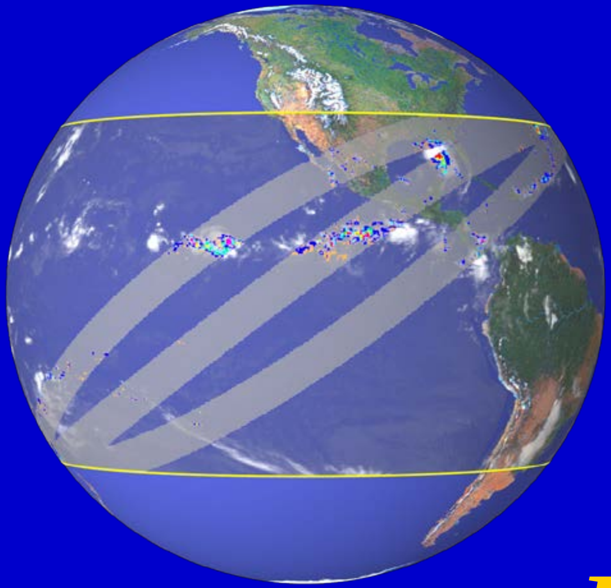
They Are Very Promising!

Center for Hydrometeorology and Remote Sensing, UCI

CHRS

Thank You For the Opportunity

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



BACK UP Material