

Ensuring Water in a Changing World

“Understanding Climate Change From Data - Perspectives from Hydroclimate Modeling and Data Assimilation.”

Soroosh Sorooshian

Center for Hydrometeorology and Remote Sensing - University of California Irvine



*NSF Expeditions in Computing:
Understanding climate Change — 2013 Annual workshop
Northwestern Univ. Evanston IL. August 16th, 2013*





and many more ...

Big Challenge

*Adequacy of Hydrologic
Observations for model input
and Validation*

A Key Requirement!

*Precipitation Measurement is one of
the KEY
hydrometeorologic Challenges*

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



2 Precipitation Scenarios with different Temporal properties

A



Monthly Total

100 mm

B

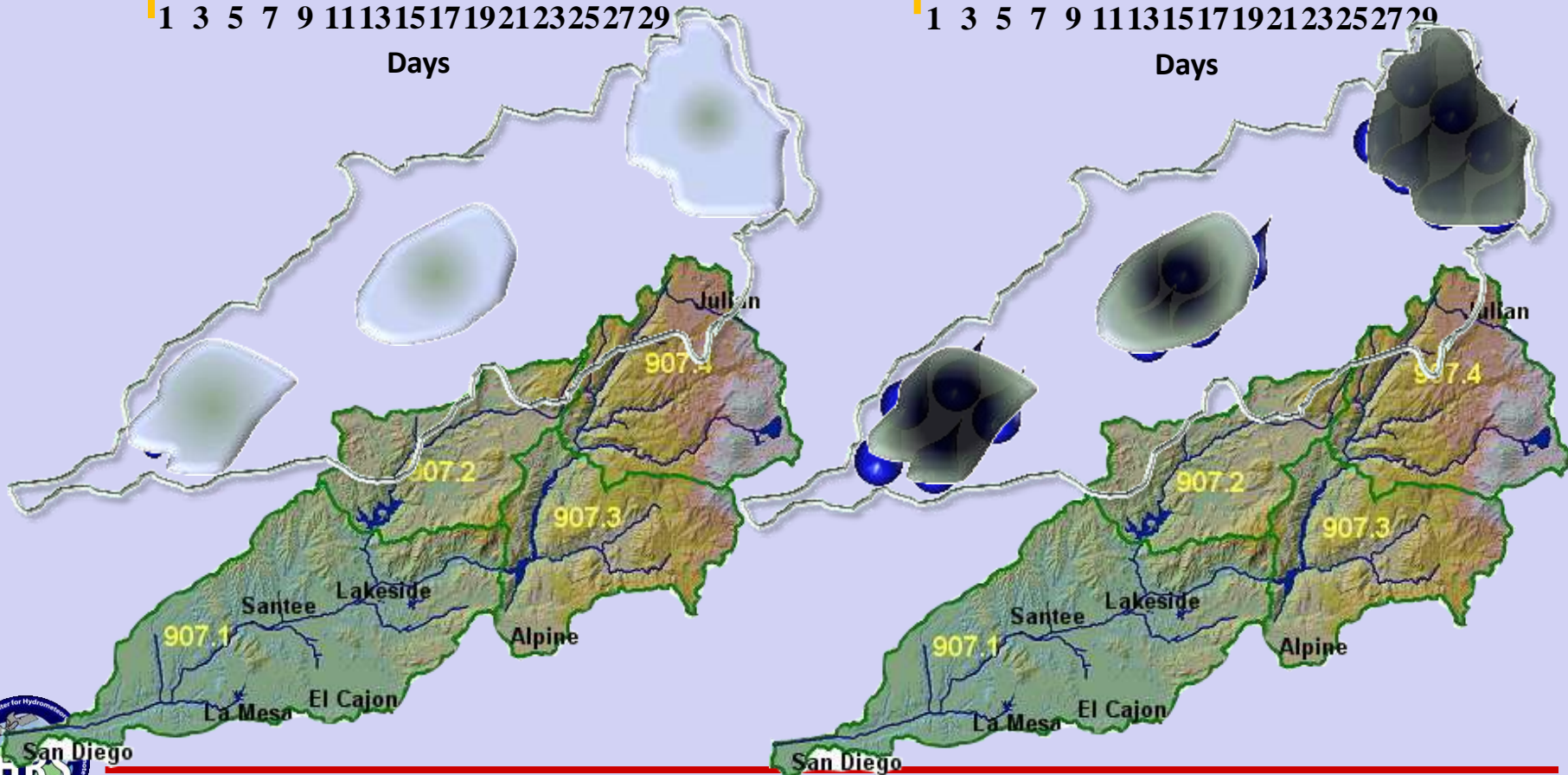
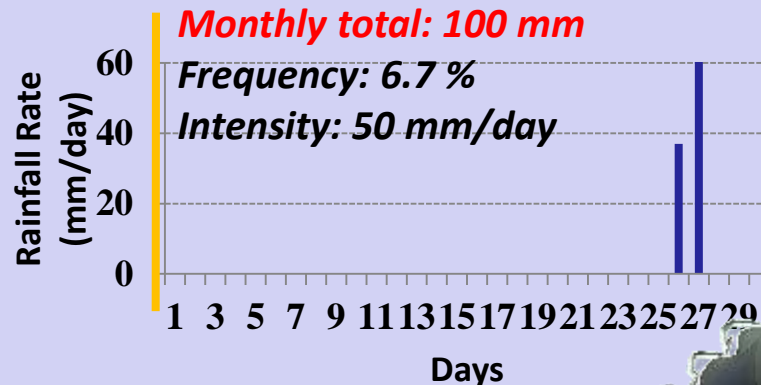
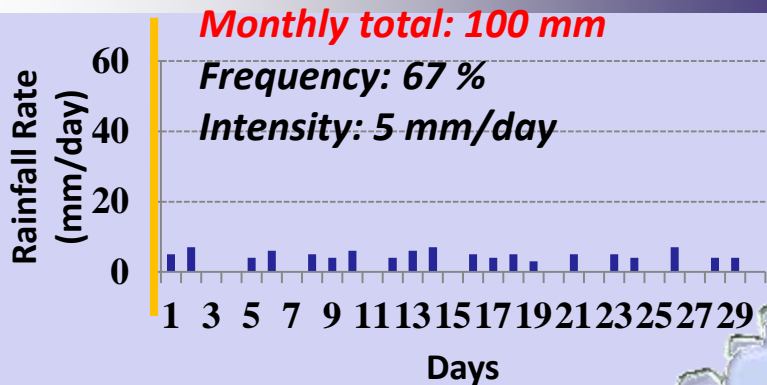


100 mm

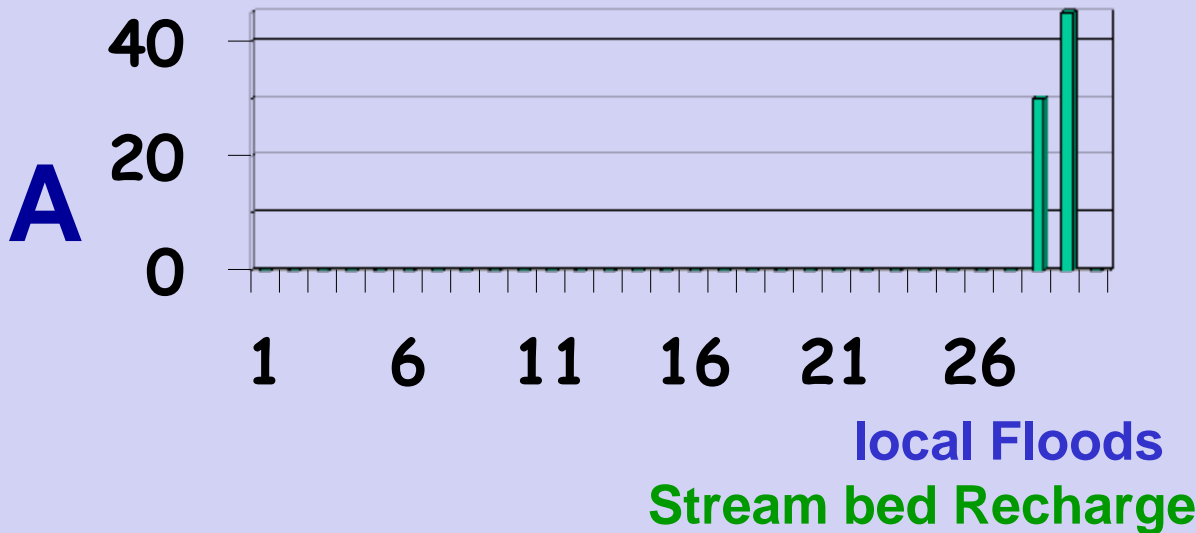


Idea from: K. Trenberth, NCAR

Temporal Scale Importance: Daily Precip. at 2 stations

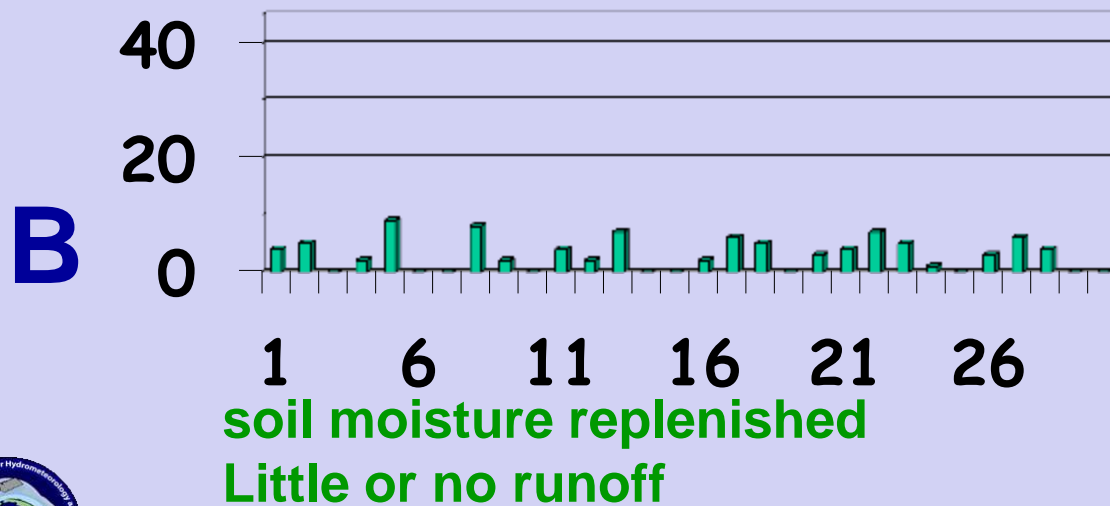


2 Rain gages with different Temporal properties



**Monthly
Amount 100 mm**

Frequency 6.7%
Intensity 50.0 mm



Amount 100 mm

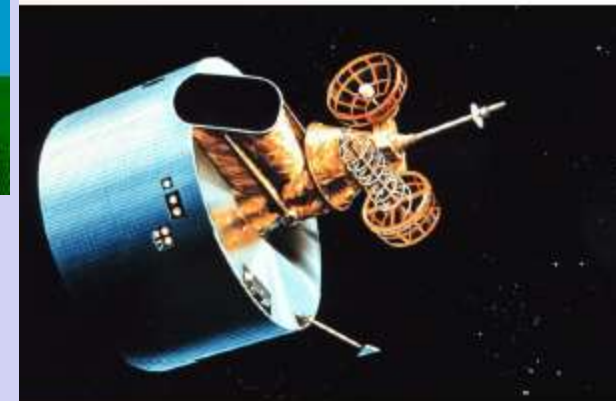
Frequency 67%
Intensity 5.0 mm



Precipitation Observations: Which to trust??



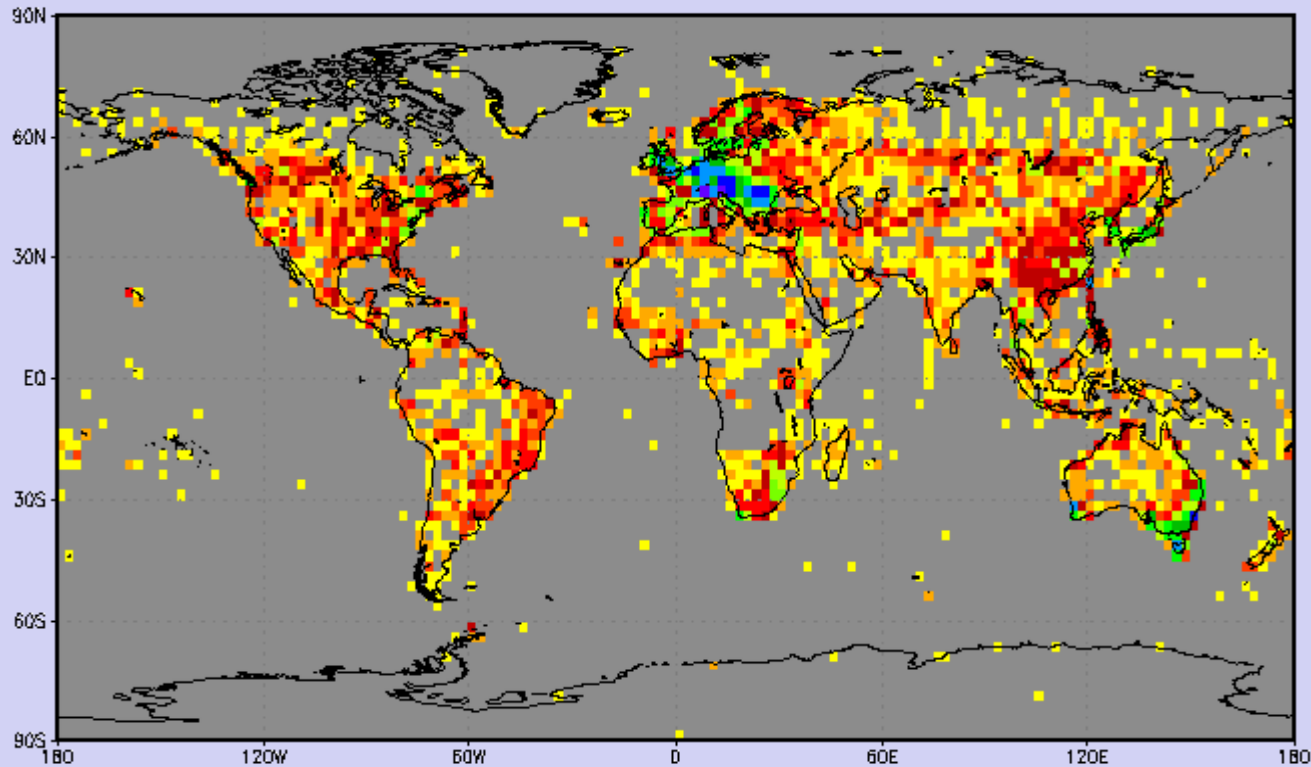
Rain Gauges



Satellite



NUMBER OF GPCC-MONITORING-STATIONS
for MAY 1998



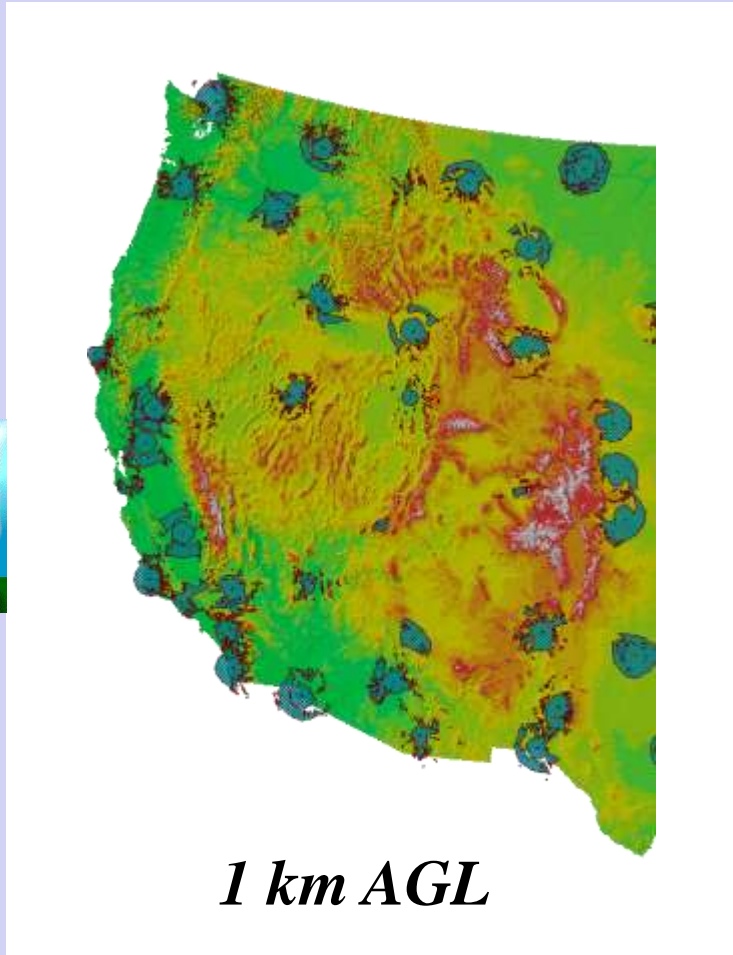
GPCC

[stations/grid]

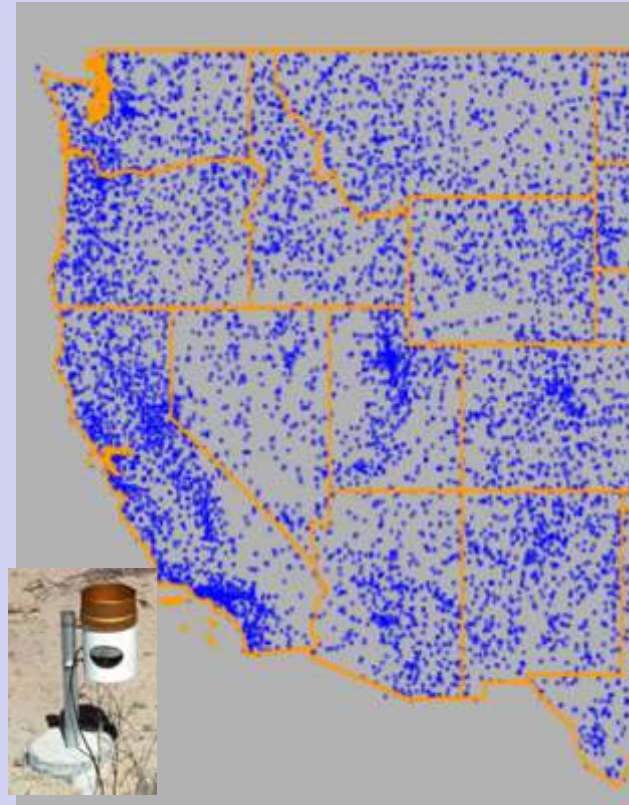
*Number of range gauges per grid box. These boxes are 2x2 degrees
(Source: Global Precipitation Climatology Project)*



Coverage of the WSR-88D and gauge networks



Maddox, et al., 2002



- *Daily precipitation*
- *Gages (1 station per 600 km²)*
- *Hourly coverage even more sparse*





Satellite-Based Precipitation:

a000174.mpeg



Satellite-Based Rainfall Estimation: Promising !

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



Satellite precipitation retrieval instruments

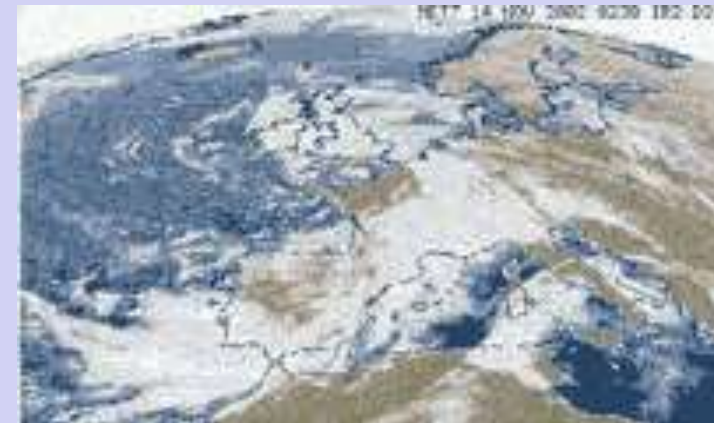
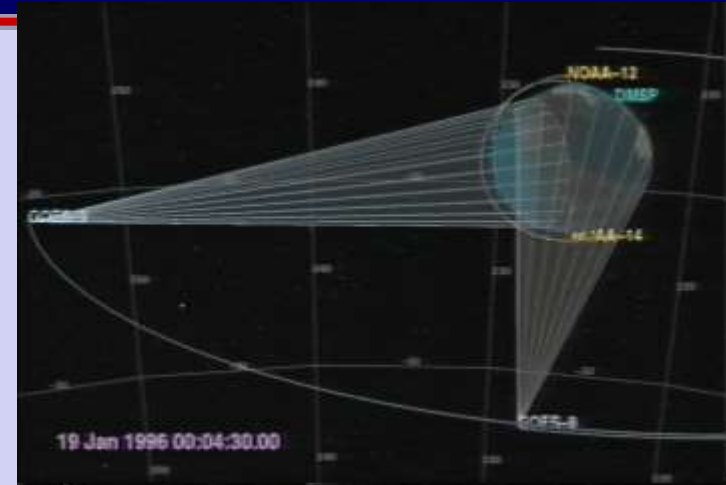
1) Using GEO satellites (Infrared/Visible channels)

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 (~5-50km)
- Heterogeneous emissivity over land:
(e.g., problem with warm rainfall over land)



Satellite precipitation retrieval instruments

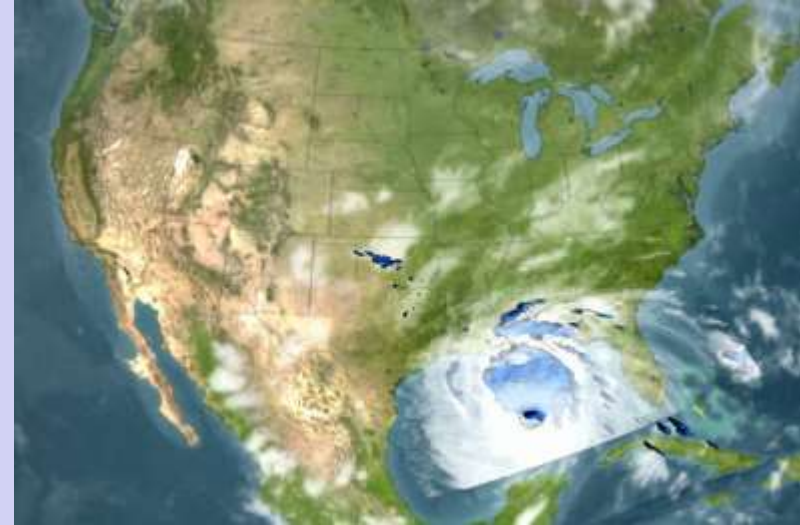
3) Active Radar

Advantage:

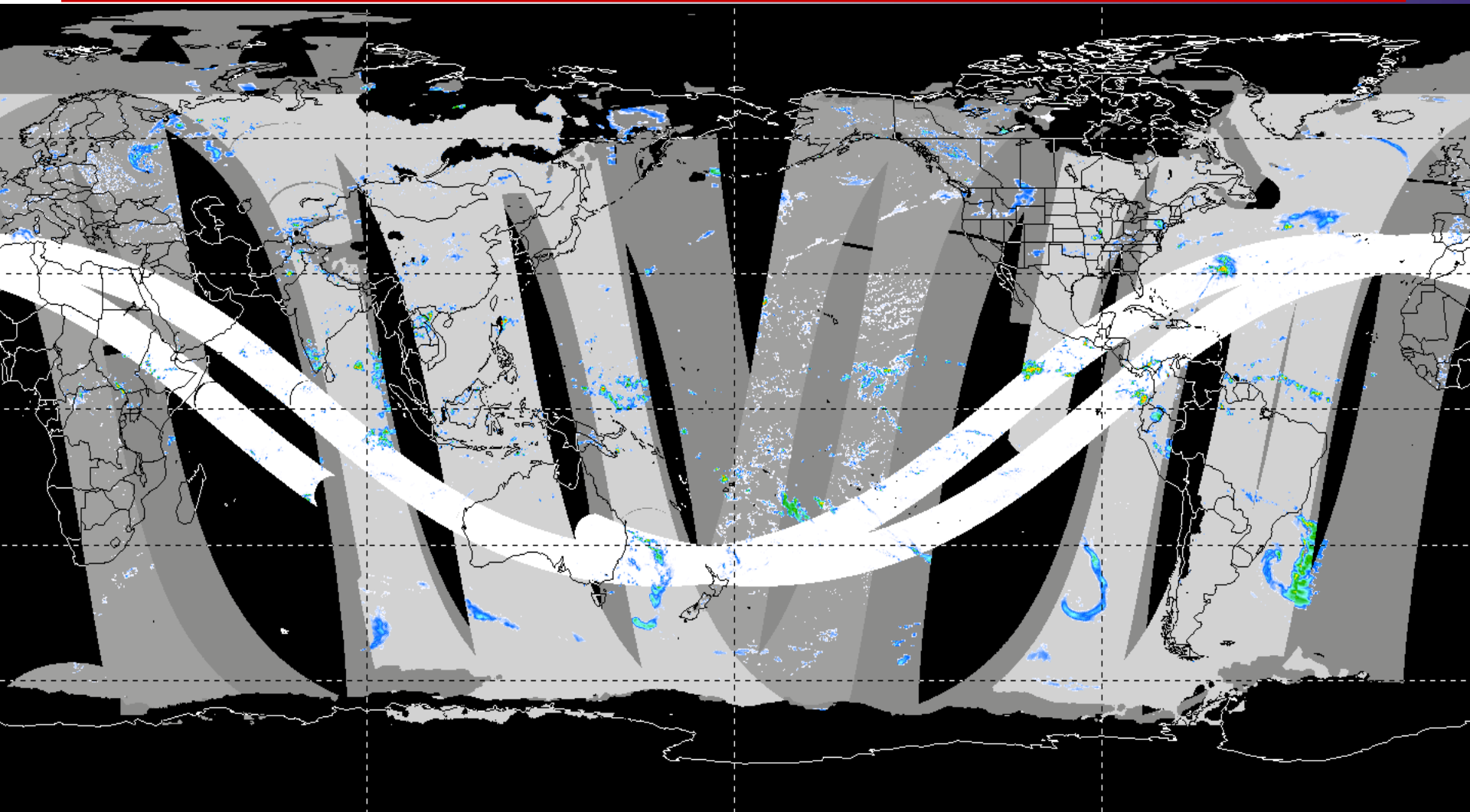
- More accurate*
- good spatial resolution*

Disadvantage:

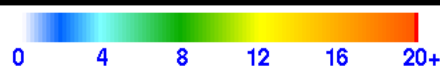
- Poor temporal resolution*



Current Microwave Satellite Configurations



Precip (mm/d) Aug 1987



Source: Huffman et al. 2007

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



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



PERSIANN System

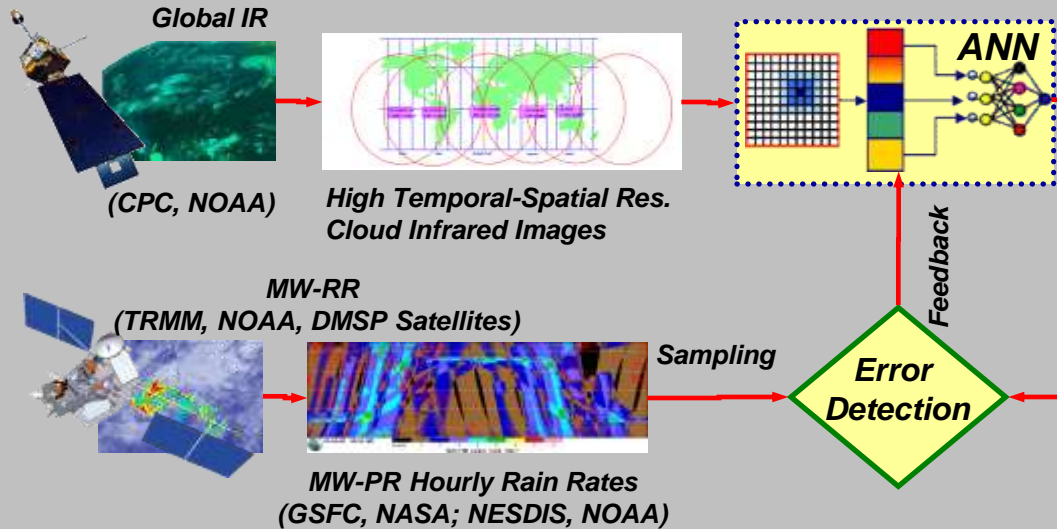
*Precipitation **E**stimation from **R**emotely **S**ensed **I**nformation using **A**rtificial **N**eural **N**etworks*



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

PERSIANN System "Estimation"

Satellite Data



Products

Hourly Global Precipitation Estimates



Hourly Rain Estimate

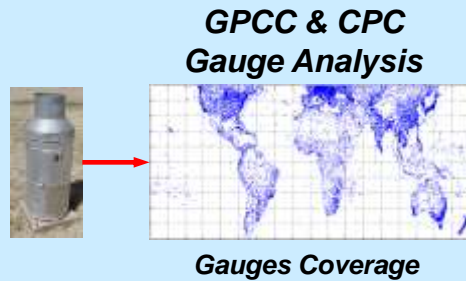
Quality Control

Merging

- Merged Products
- Hourly rainfall
 - 6 hourly rainfall
 - Daily rainfall
 - Monthly rainfall



Ground Observations

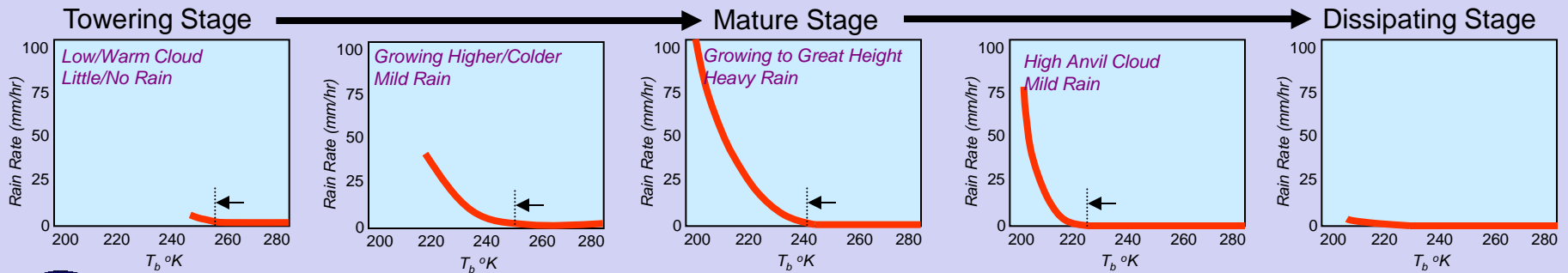




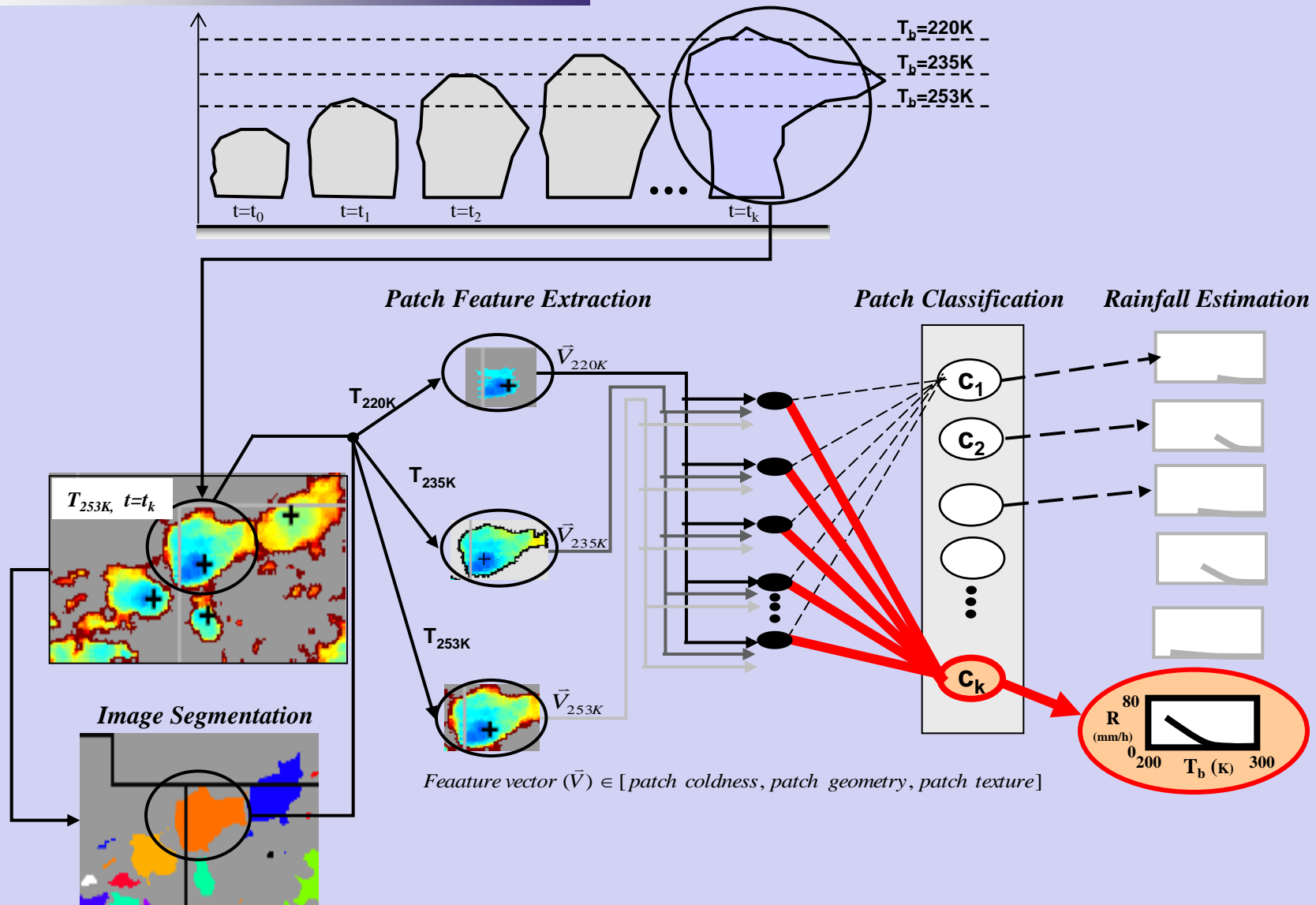
High Resolution Precipitation Estimates
PERSIANN-CCS



Stages of a Convective Storm and Rainfall Distribution

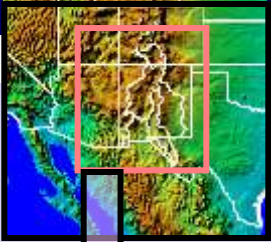


Cloud Segmentation Algorithm



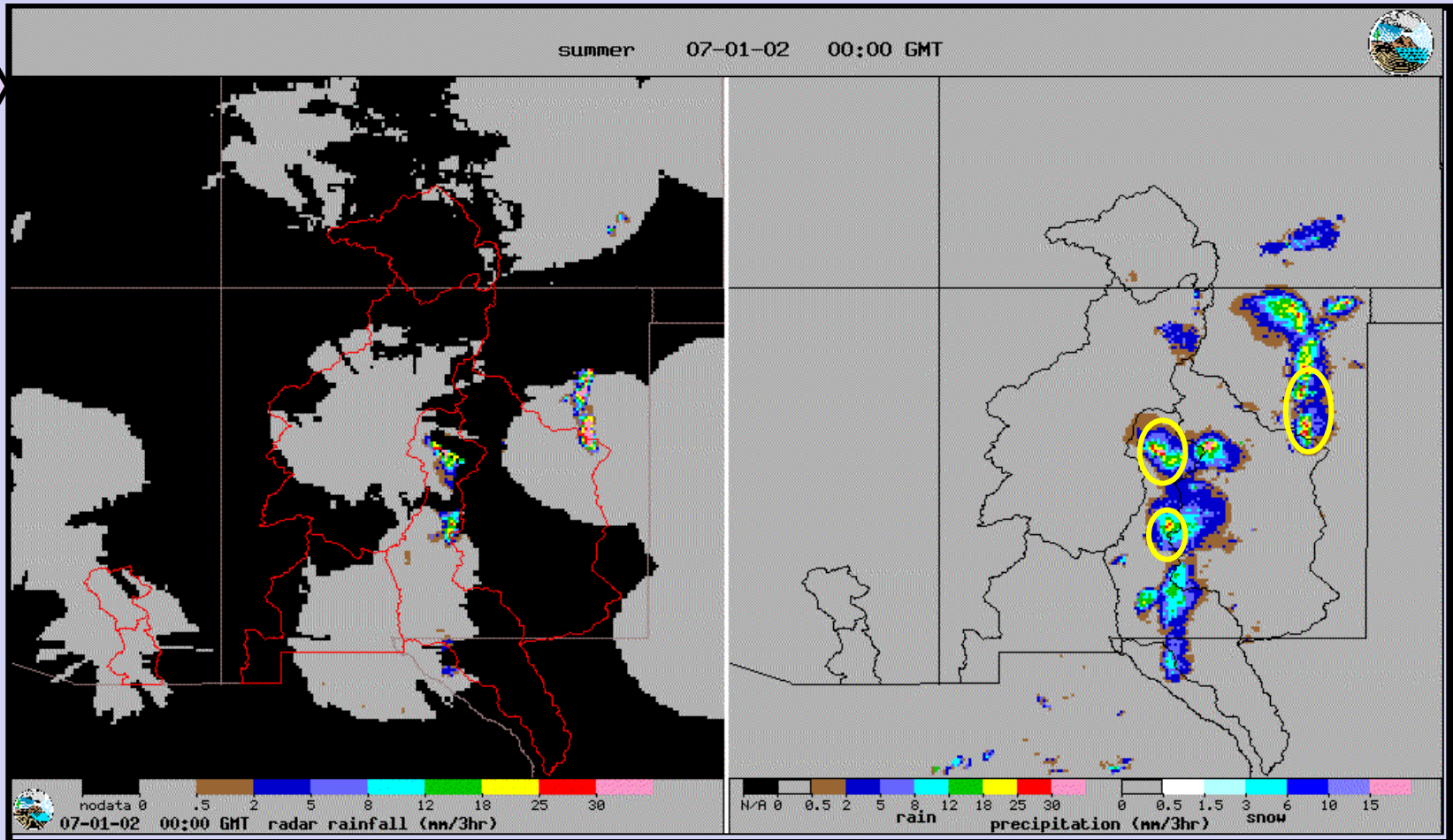
High Resolution Precipitation Estimates from PERSIANN-Cloud Classification System

Study Area



Radar Observation (2 km AGL)

PERSIANN-CCS Estimates



4km x 4km, 3-hour accumulated precipitation



Real Time Global Data: Cooperation With UNESCO

The screenshot shows a web browser window titled "HyDIS GWADI MapServer - Windows Internet Explorer". The address bar contains "http://hydis.eng.uci.edu/gwadi/ss.html". The browser's menu bar includes "File", "Edit", "View", "Favorites", "Tools", and "Help". The toolbar shows "SnagIt" and "Google". The page title is "HyDIS GWADI MapServer".

The main content area features a "Map Layer Control" panel on the left. Under "VECTOR LAYERS", the following options are listed with checkboxes: Country (checked), Political Divisions, Urban Areas, GRDC Stations, Streams, Inland Water, Continental Basins, Major River Basins, Tributary Basins, and Small Watersheds. Below this, "PERSIANN/NESDIS Data" is shown for "04-14-2008 @ 12 Hour UT". There are two sections: "Latest Rain Totals" with radio buttons for 3 hrs (selected), 6 hrs, and 12 hrs; and "Latest Heavy Rain" with radio buttons for 3 hrs, 6 hrs, 12 hrs, 24 hrs, and 48 hrs. A small globe icon is at the bottom of the panel.

The main map area displays a global map with a white outline of the world's continents and a blue overlay representing rain data. The map is titled "Map Layer Control" and includes navigation tools: "Zoom in", "Zoom out", "Pan/Center", "Query Info", "Global View", "Show Legends", "Help", and "G-WADI". The status bar shows "Longitude: -180 to 180", "Latitude: -90 to 90", and "Mon Apr 14 06:49:49 2008". A scale bar at the bottom indicates distances from 0 to 6000 km. Logos for "CHRS" and "NASA" are visible in the bottom right corner.

Overlaid on the map is a large red text box containing the text: "4 Many Features provided to users with Public Domain Software."



PERSIANN Satellite Product On Google Earth

Google Earth

File Edit View Tools Add Help

Search

Fly To Find Businesses Directions

Fly to e.g., New York, NY

Places

- Temporary Places
- GWADI Precipitation
Click for Info:
- Current Accumulation Le...
Click For Info
- Current 3 Hour Accumulatio
Click For Info
- Current 6 Hour Accumulatio
Click For Info
- Current 12 Hour Accumulatio

Layers

- Primary Database
- Geographic Web
- Roads
- 3D Buildings
- Street View
- Borders and Labels
- Traffic
- Weather
- Gallery
- Ocean
- Global Awareness
- Places of Interest

Accumulated Precipitation (mm)

0 10 50 150 > No data

CHRS

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

© 2009 Europa Technologies
© 2009 Tele Atlas
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2009 TerraMetrics

11°23'16.20" S 45°19'52.71" E elev -3383 m

© 2009 Google

Eye alt 14693.32 km

Home - CHRS HyDIS GWADI M... Google Earth gadgets 12:42 PM



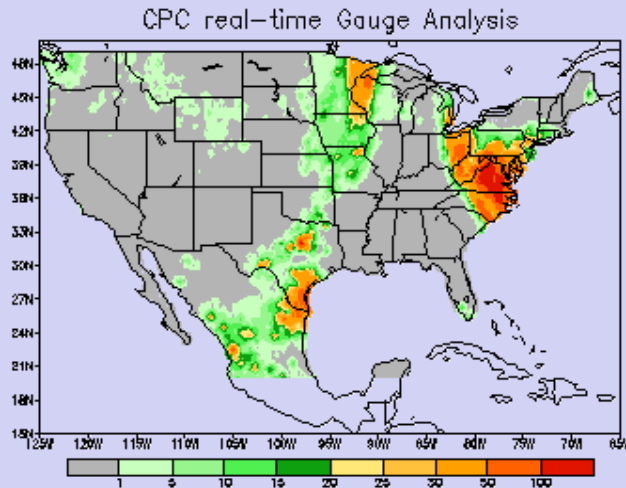
Validation and Application of Satellite Products



US Daily Precipitation Validation Page

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

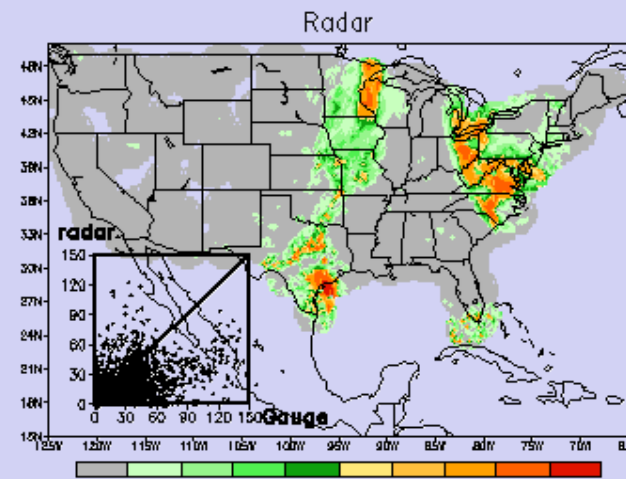
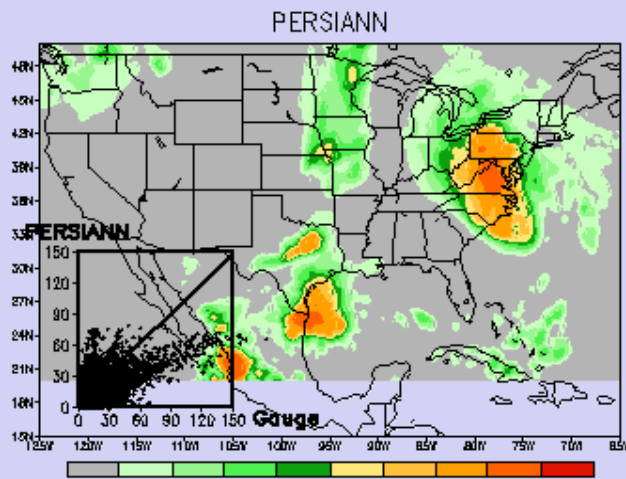
13Z 19Sep2003 thru 12Z 19Sep2003
Data on 0.25 deg grid (UNITS are mm/day)

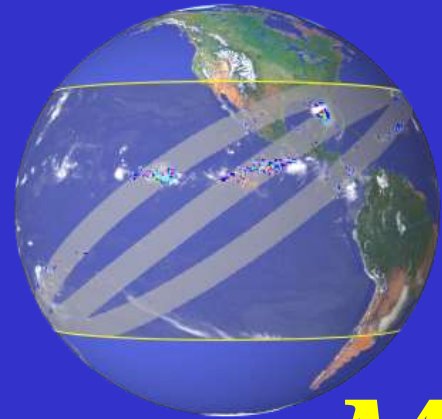


	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.55	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45

	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):	1.096	0.699	1.570
Heidke Skill Score:	0.574	0.692	0.546
Hansen-Kuipers Score:	0.589	0.634	0.660
Equitable Threat Score:	0.402	0.528	0.376

		PERSIANN		radar	
		< 1	≥ 1	< 1	≥ 1
gauge	< 1	8082.	1497.	9386.	193.
	≥ 1	1081.	3168.	1471.	2778.





Multi-spectral images:

Will combining LEO(PMW) and GEO (VIS/IR) Satellite Imagery improve Precipitation Estimates?



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.*

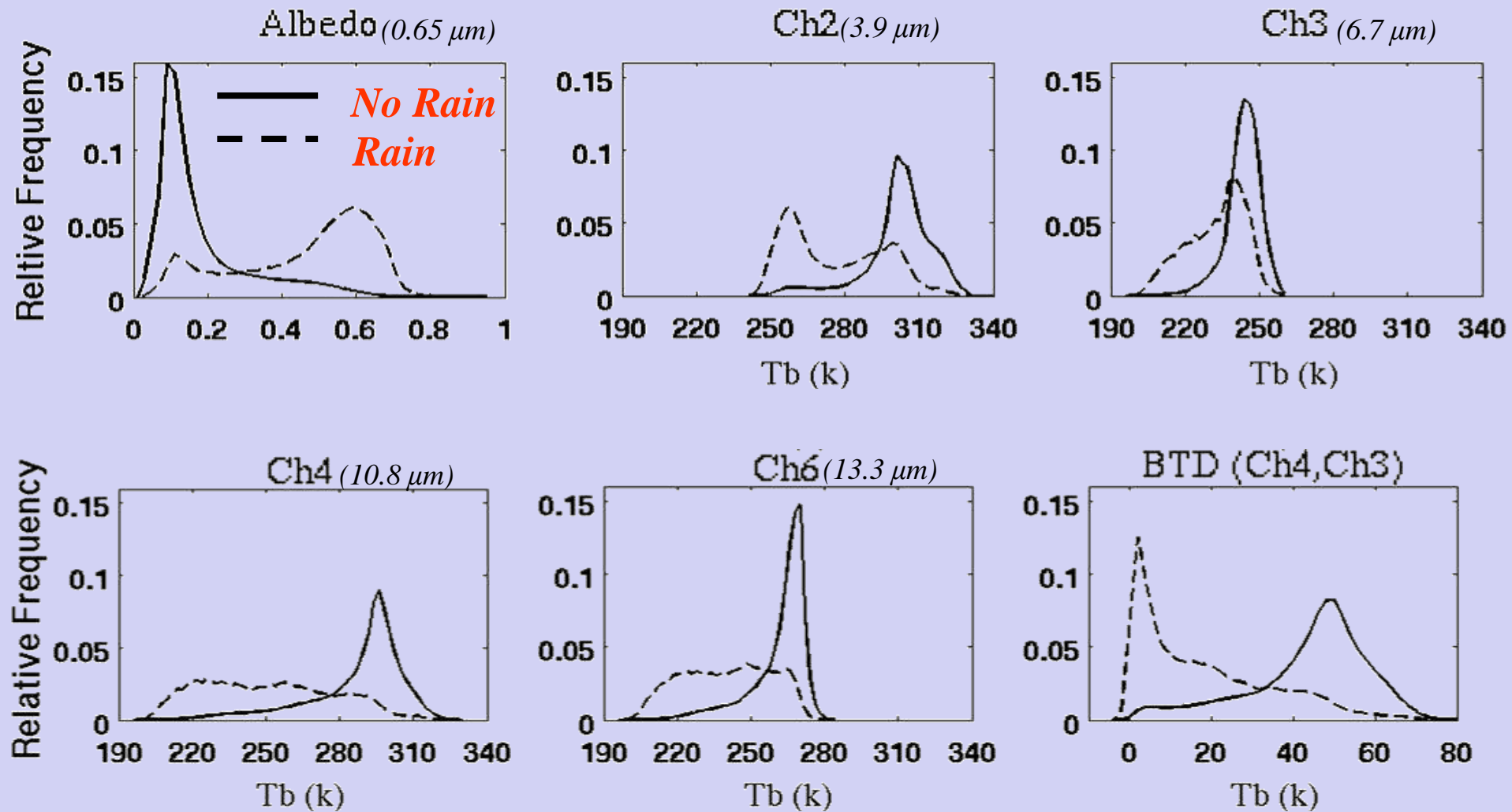


Figure courtesy of ITT Industries



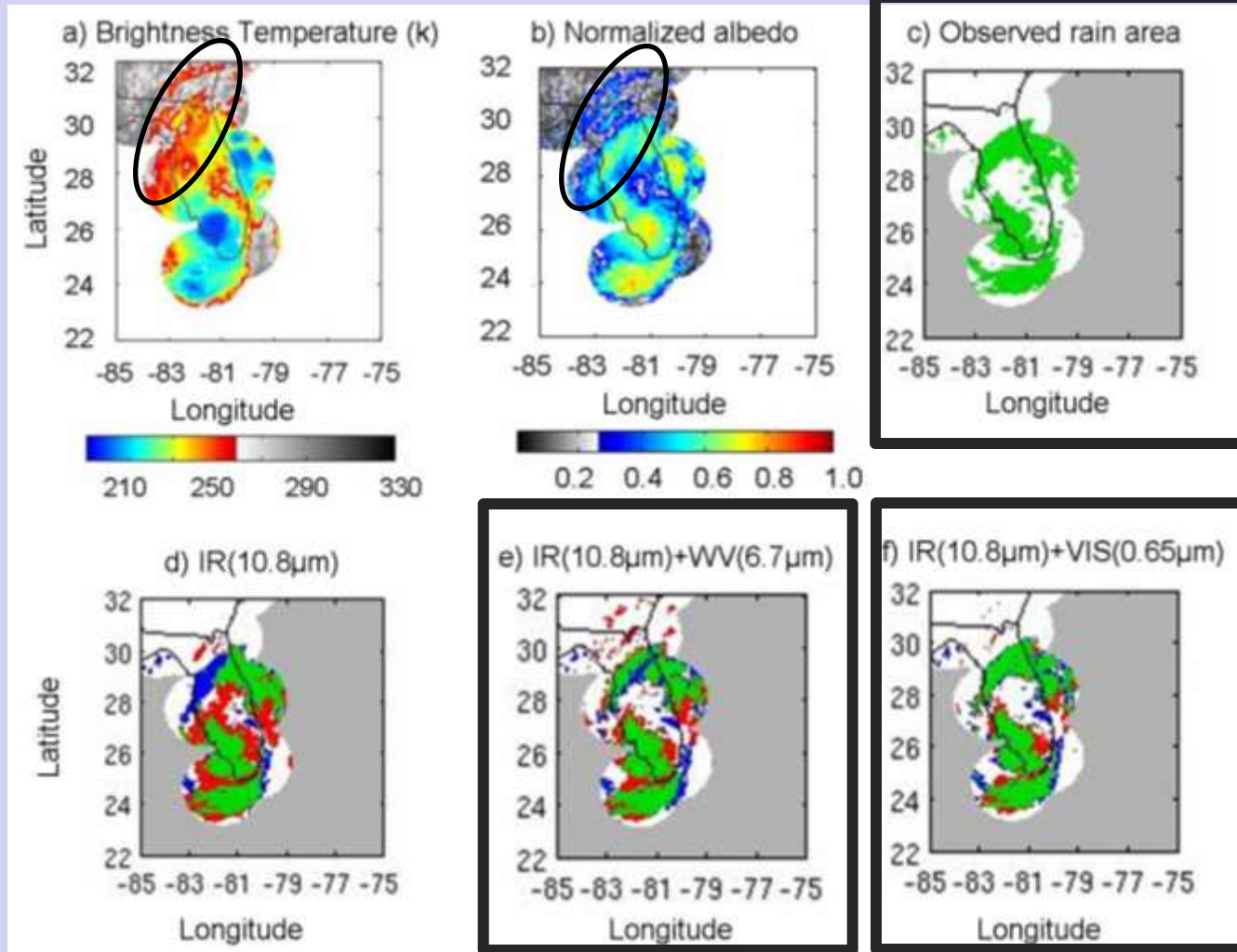
- Together a great opportunity to investigate the role of multi-spectral data for precipitation estimation*

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



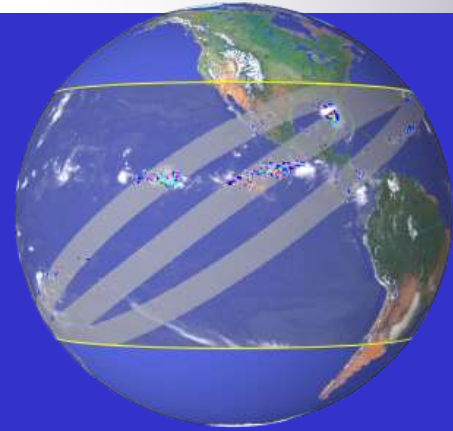
Hit

Under Estimation

Over Estimation

Behrangi et al (2009 a & b)



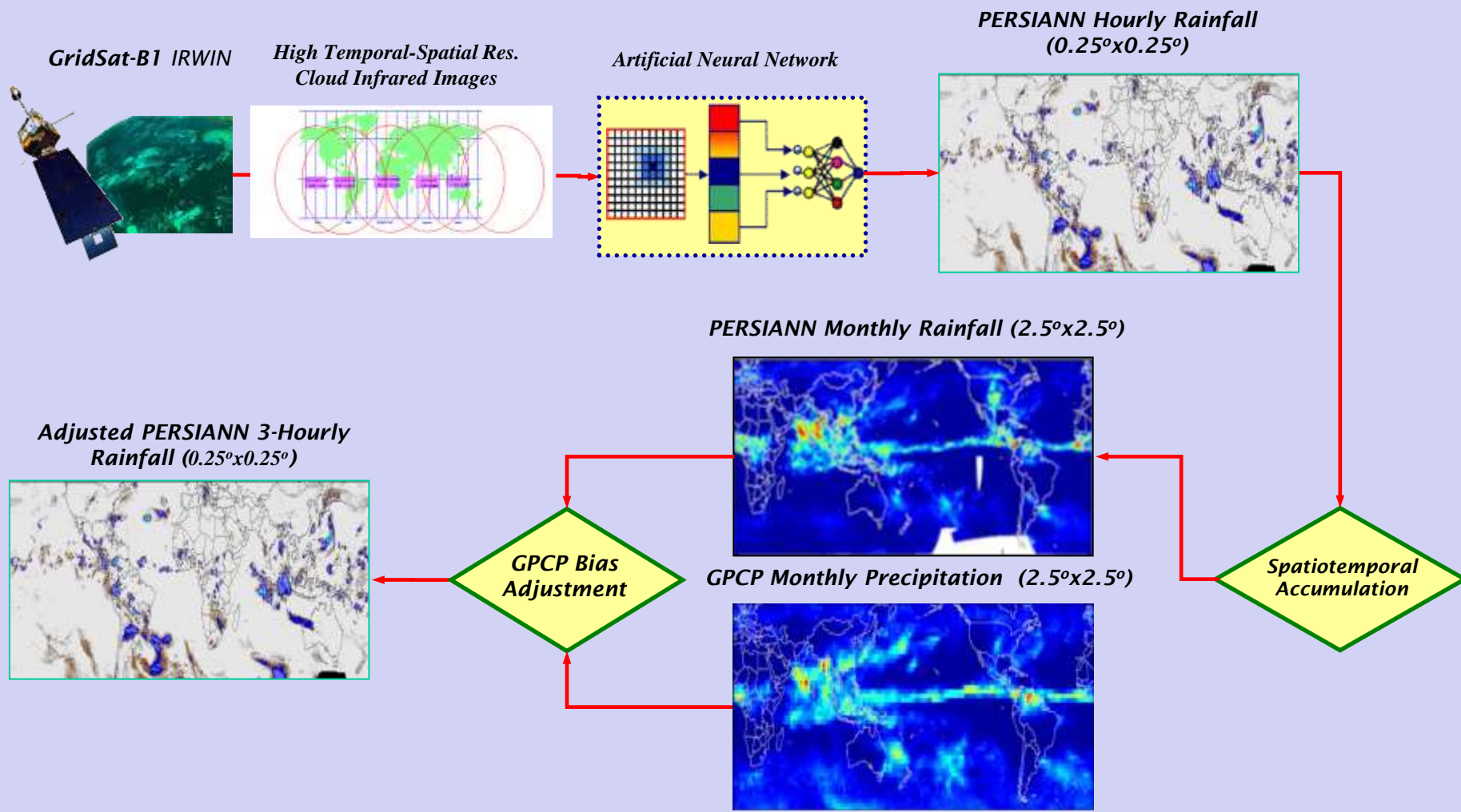


PERSIANN Climate Data Record (PERSIANN-CDR)

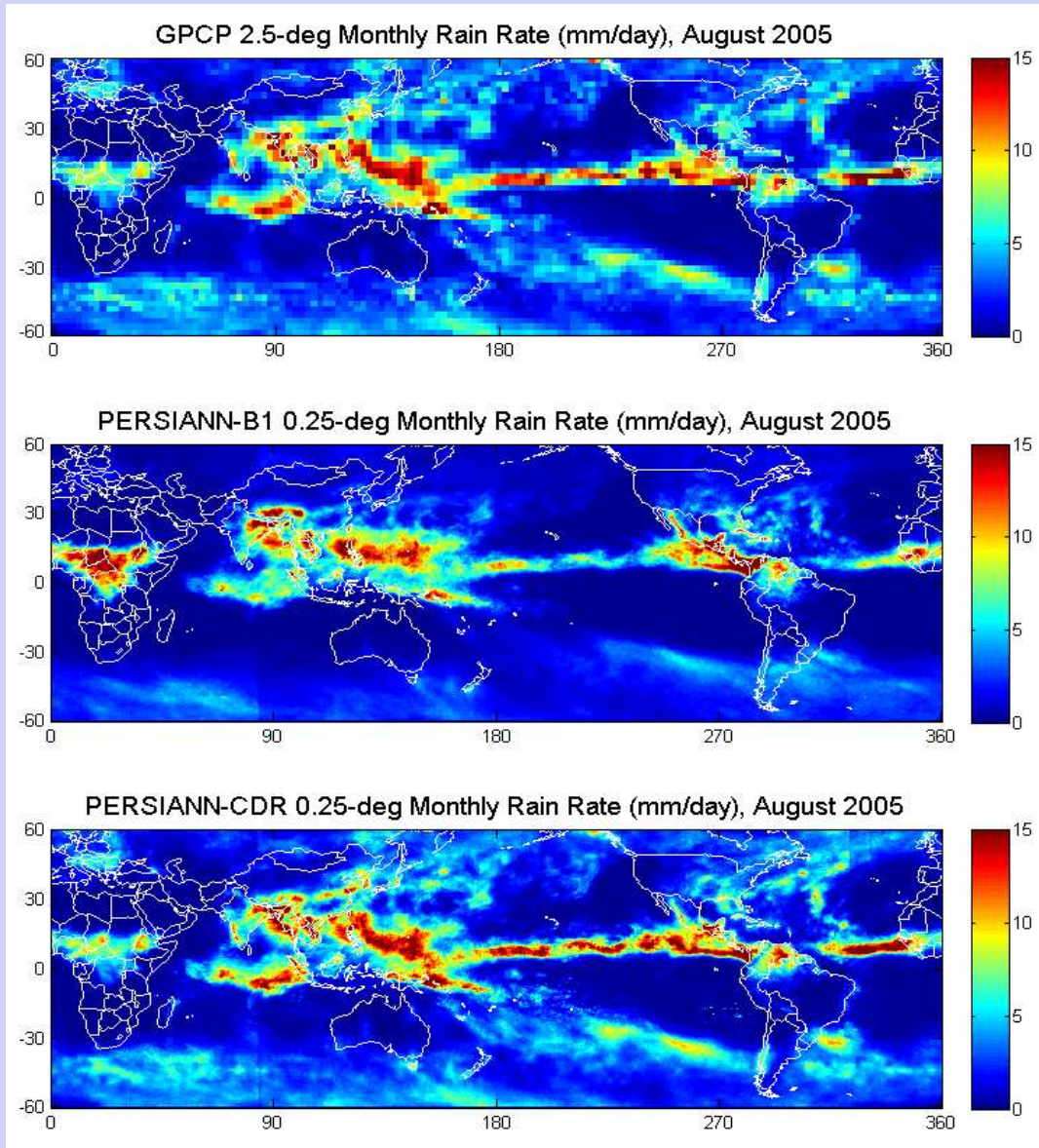
*33 Years of Multi-Satellite, High-Resolution, Near-Global, Daily
Precipitation Data Record*



PERSIANN-CDR Algorithm

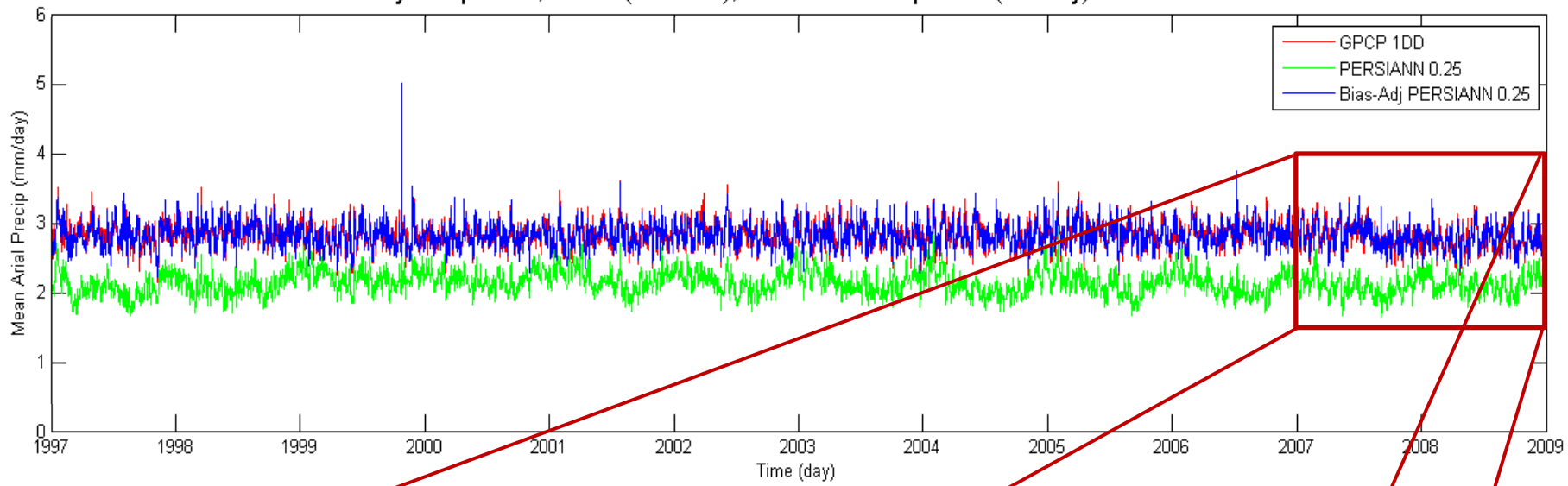


Preliminary Tests (Aug. 2013)

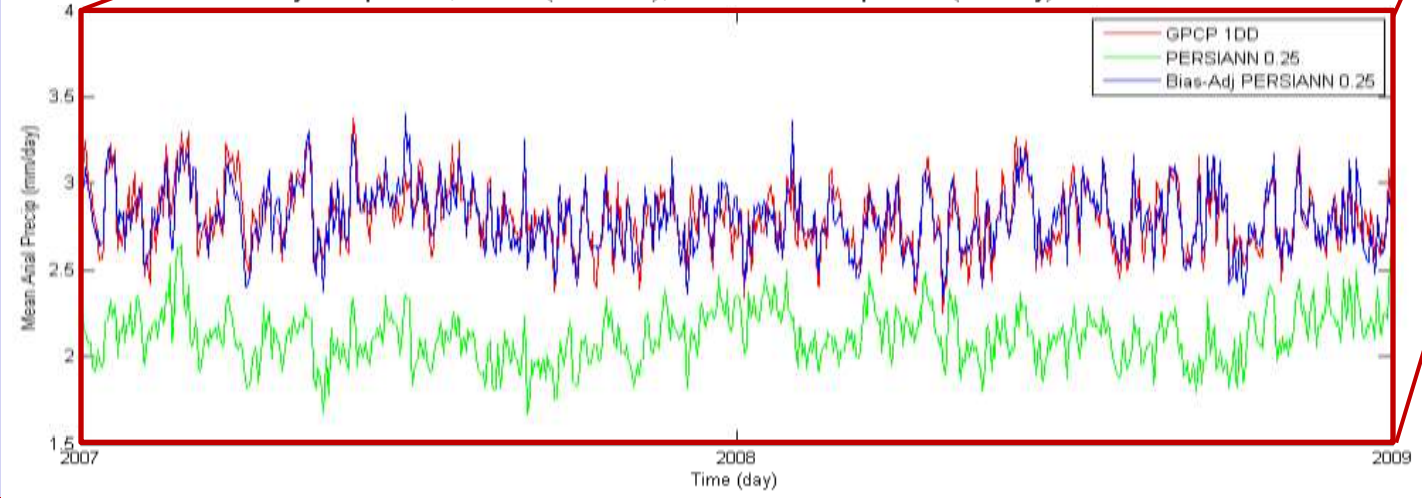


Daily Comparisons

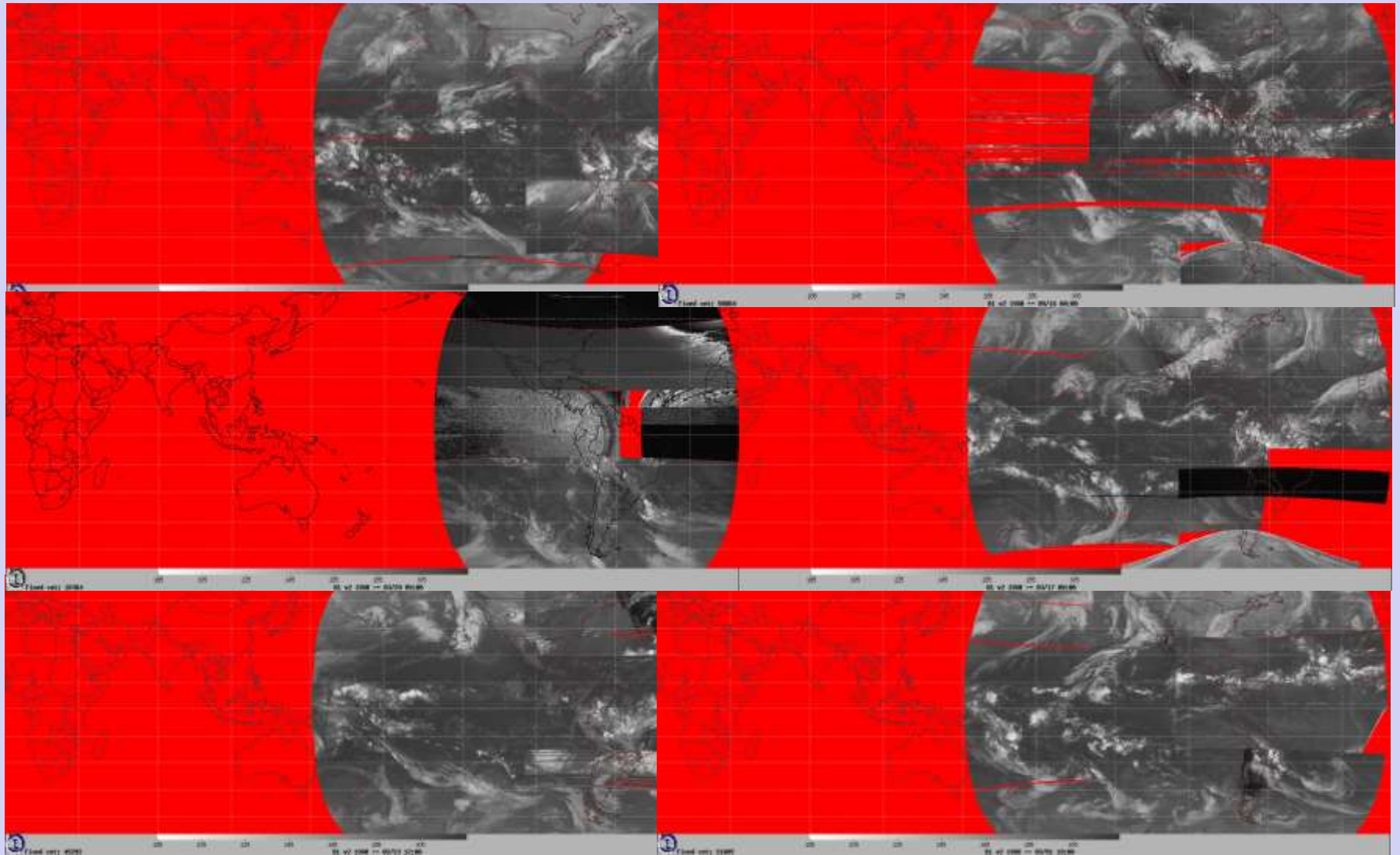
Daily Comparison, Global (60S-60N), Mean Arial Precipitation (mm/day) for 1997-2009

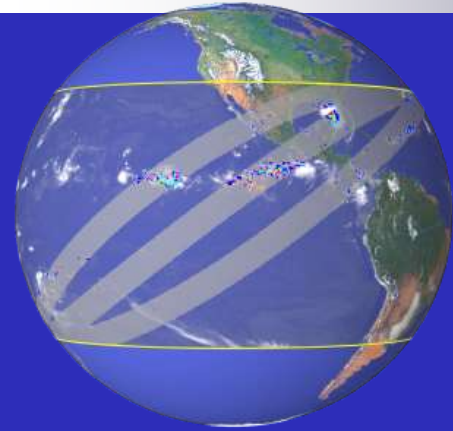


Daily Comparison, Global (60S-60N), Mean Arial Precipitation (mm/day) for 2007-2009



Devils are in details ...





PERSIANN-CONNECT

8-13-2013

University of California, Irvine



EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 94 NUMBER 32 6 AUGUST 2013

Last Chance: Present at the 2013 Fall Meeting Exploration Station.
Deadline 12 Aug. <http://bit.ly/FMExplore>

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Computational Earth Science: Big Data Transformed Into Insight

More than ever in the history of science, researchers have at their fingertips an unprecedented wealth of data from continuously orbiting satellites, weather monitoring instruments, ecological observatories, seismic stations, moored buoys, floats, and even model simulations and forecasts. With just an internet connection, scientists and engineers can access atmospheric and oceanic gridded data and time series observations, seismographs from around the world, minute-by-minute conditions of the near-Earth space environment, and other data streams that provide information on events across local, regional, and global scales. These data sets have become essential for monitoring and understanding the associated impacts of geological and environmental phenomena on society.

This increasing amount of data has led us

If such algorithms are run in a computer environment designed to home in on characteristics of objects or events of interest, then the data can be crunched even more efficiently, allowing insights from big data to be revealed at a quicker pace. Such machine learning evolved from artificial intelligence research and focuses on developing models that are based on the behaviors and characteristics of empirical data. Capturing the behaviors and characteristics from data and determining their underlying probability distributions can provide new knowledge regarding the object or characteristic of interest. Typically, the properties or "true" underlying probability distributions of the observed variable of interest are not explicitly known. However, by seeking to define or describe these underlying probability distributions, data mining can help scientists

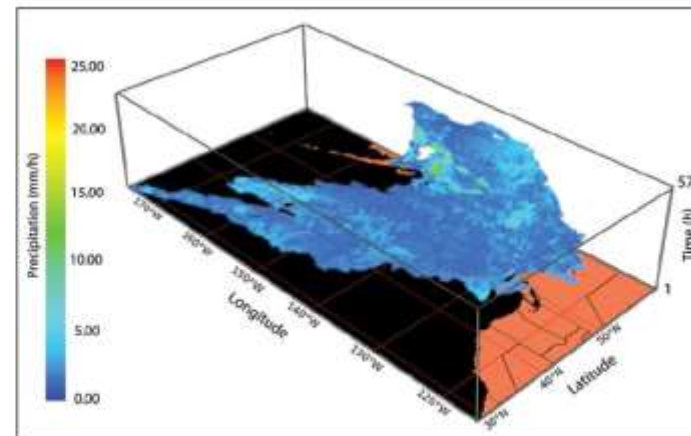


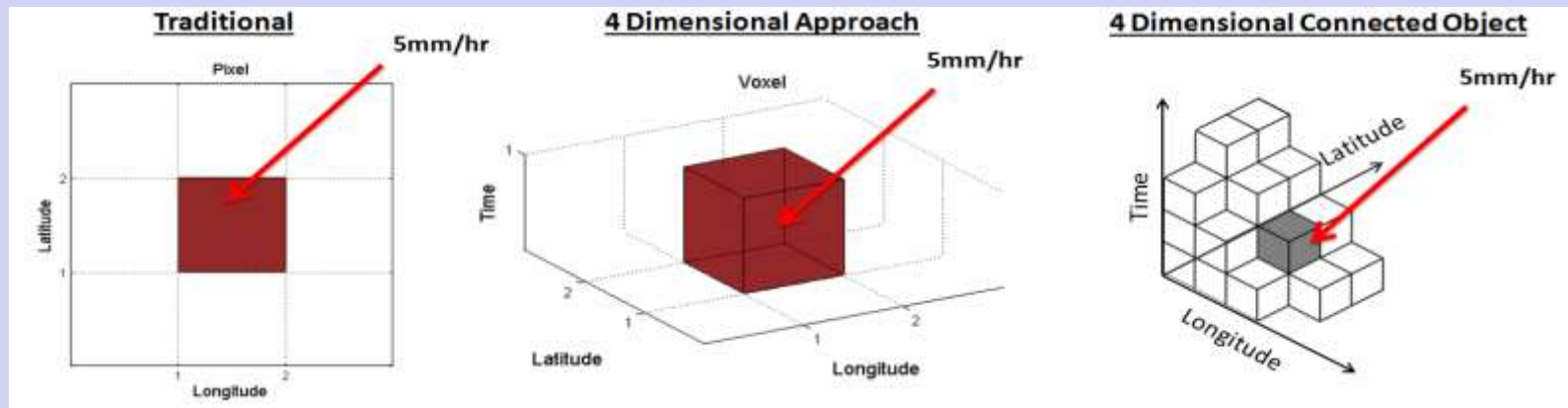
Fig. 1. A connected four-dimensional atmospheric river, or "precipitation object," extracted from the PostgreSQL database. The atmospheric river originated in the eastern Pacific and affected the western United States from 28 to 30 December 2005.

*Sellars, S., P. Nguyen, W. Chu, X. Gao, K. Hsu, and S. Sorooshian (2013),
Computational Earth Science: Big Data Transformed Into Insight, EOS Trans. AGU, 94(32),277



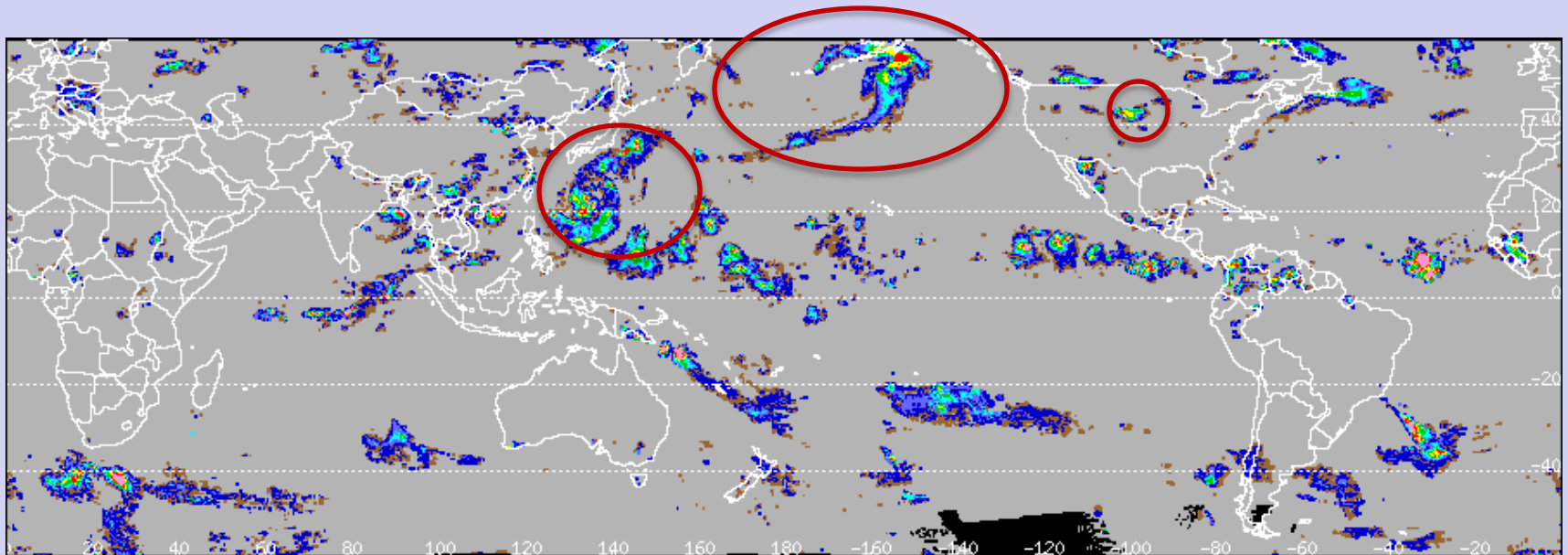
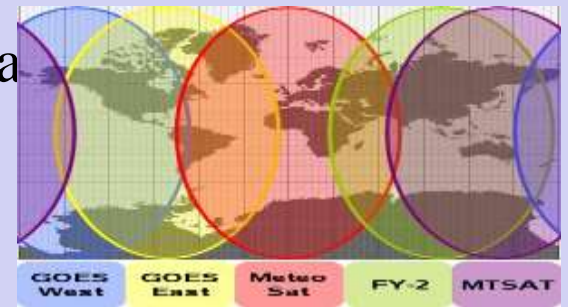
Transforming Big Data Into Insight

- PERSIANN **CONN**ected precipitation obj**ECT**
 - PERSIANN-**CONNECT**
- Connectivity algorithm transforms data into 4D “objects” in time and space
 - Latitude, Longitude, Time and Intensity
- Allows “object” population statistics to be discovered and analyzed – Teleconnections with Climate Indices?



PERSIANN

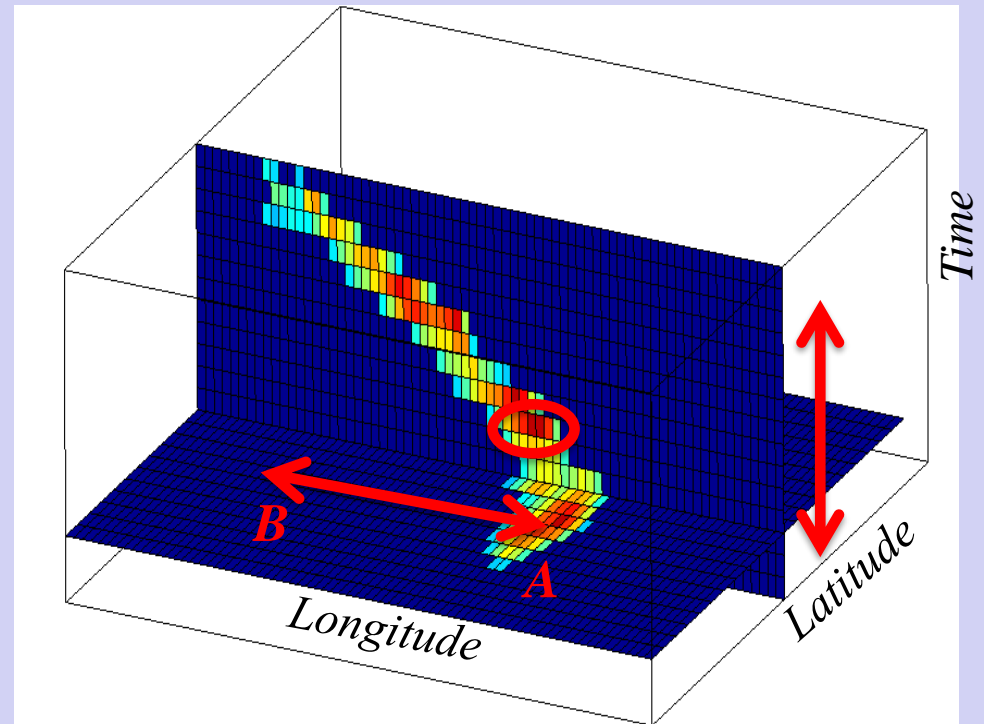
- Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)
- Hourly bias corrected PERSIANN w/GPCP data
- 0.25 degree
- 60⁰ North - 60⁰ South
- 01 March 2000 – 1st January 2011



4D Object Characteristics

Physical Based Characteristics:

- Duration (hr)
- Max Intensity (mm/hr)
- Speed (km/hr)
- Centroid (lat/lon)
- Volume (m^3)
- and many more...



Online *PERSIANN-CONNECT* Database Access

- All objects and characteristics are stored in a publically available PostgreSQL database
 - <http://chrs.web.uci.edu/research/voxel/index.html>

Center for Hydrometeorology & Remote Sensing
University of California, Irvine

CHRS Mission Statement

Building Global Capacity for Forecast and Mitigation of Hydrologic Systems through the development of means to extend the benefits of space enabled agencies' vast technological resources, which are unappreciated, into applications that assist hydrologists and water resource managers worldwide and through equitable access to relevant information.

Objectives

- Improve hydrologic prediction through development and refinement of hydrologic models and use of advanced observations, particularly from remote sensing sources
- Develop mathematical algorithms capable of estimating precipitation both from space-based and in-situ observations of spatial and temporal resolutions relevant to hydrologic applications, particularly in the semi- and arid environments.
- Develop decision support tools for generalist and hydro-climatologic information needed by the water resources managers community.
- Contribute to the education of well trained hydrologists and water resources engineers responsive to the growing needs of public and private sectors at the state, national and international levels.

CHRS will pursue this mission through interdisciplinary research and education involving faculty and students from Engineering, Physical Sciences, and Social Science as well as in collaboration with a number of other universities and national laboratories.

Our Sponsors

Logos for NASA, NOAA, and other sponsors are displayed at the bottom.

Selection Tool - High volume of database queries may slow response time

Although we always try to optimize the performance of the database, a specific query will search objects within 1.2 billion rows of data.

This database search tool is meant to search specific objects in time and space. **Please notice that a smaller geographical areas and shorter durations will result in faster processing of your request.** If you need a longer duration data for a large area, we recommend obtaining the data from the ftp site listed above. Start by selecting a desired geographic box.

Then select the duration (Start-End) of the required data. Lastly, set minimum and maximum intensity value bounds and click the submit button.

Location

North
60

West 0 East 360

South
-60

Time

Please define the start and end period (YYYY-MM-DD HH:MM:SS):

Start Date:

End Date:

Intensity

Please set minimum and maximum precipitation intensity criteria (mm/hr):

Min Intensity:

Max Intensity:

Download Options:

Download raw object data

Download statistics data





Impact of Irrigation

Modeling the effects of irrigation on regional hydroclimate

Previous studies:

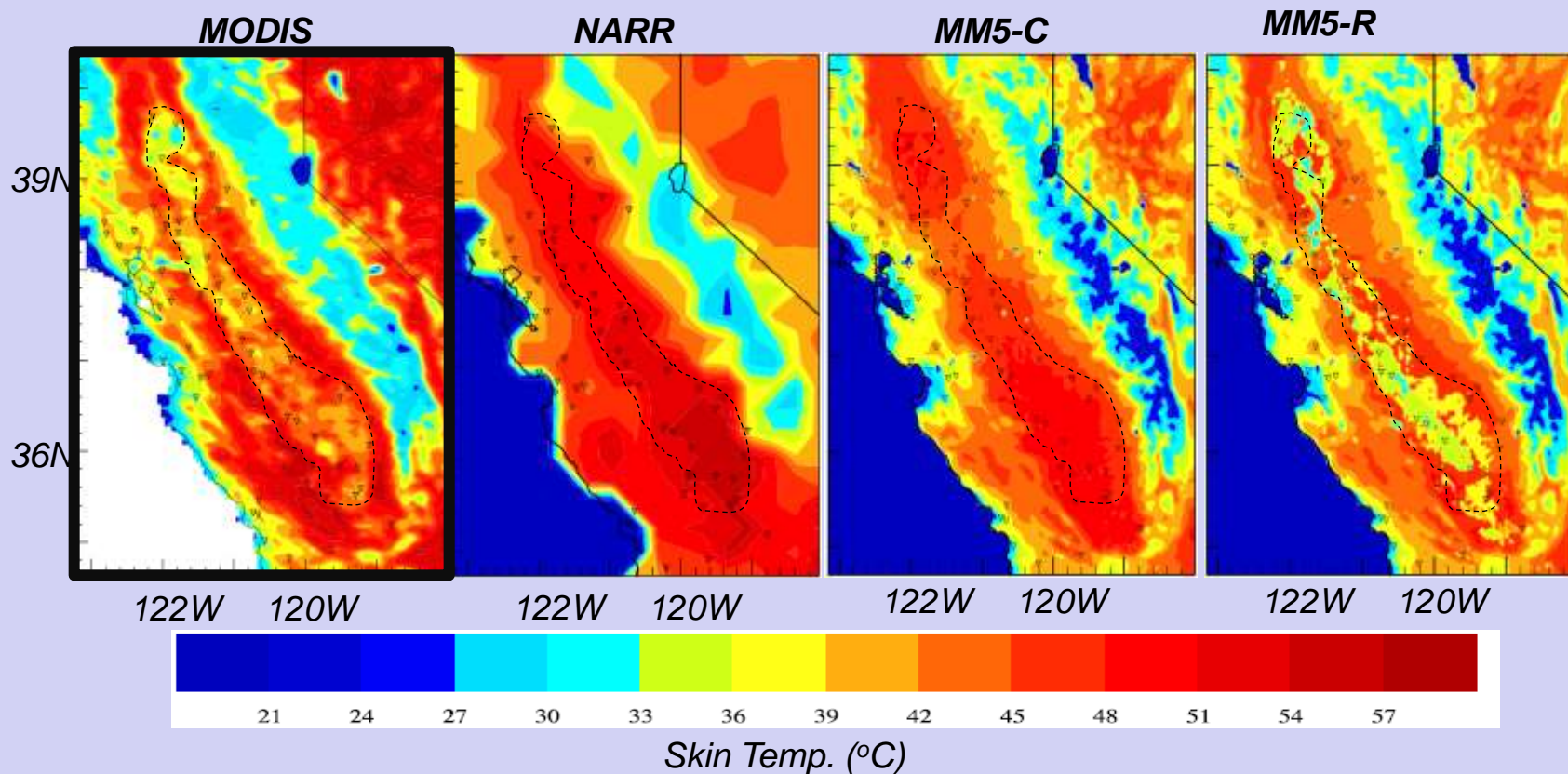
- 1) Based on temperature variation*
- 2) Assuming soil water at field capacity (saturation)*
 - the modeled soil layers are kept at field capacity or at full saturation during the simulation runs (e.g. Adegoke, et al. 2003; Haddad et al. 2006; Kueppers et al. 2007)*

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.

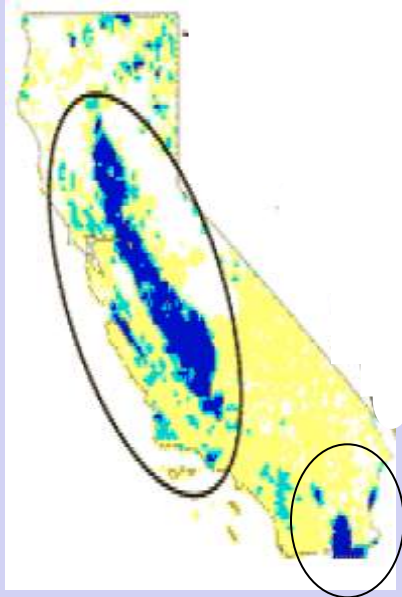


Adding irrigation into RCM (MM5), Improves the model's ability to simulate, more closely, the temperature patterns observed by MODIS

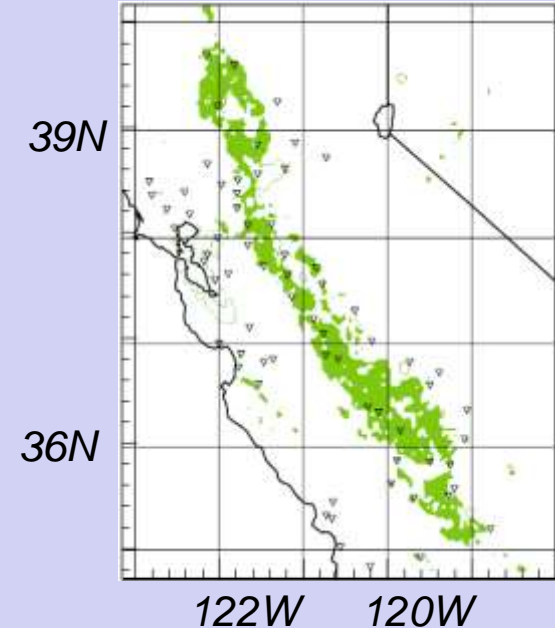


“Observed” vs “Model-Generated” Data

Irrigation areas



CIMIS stations

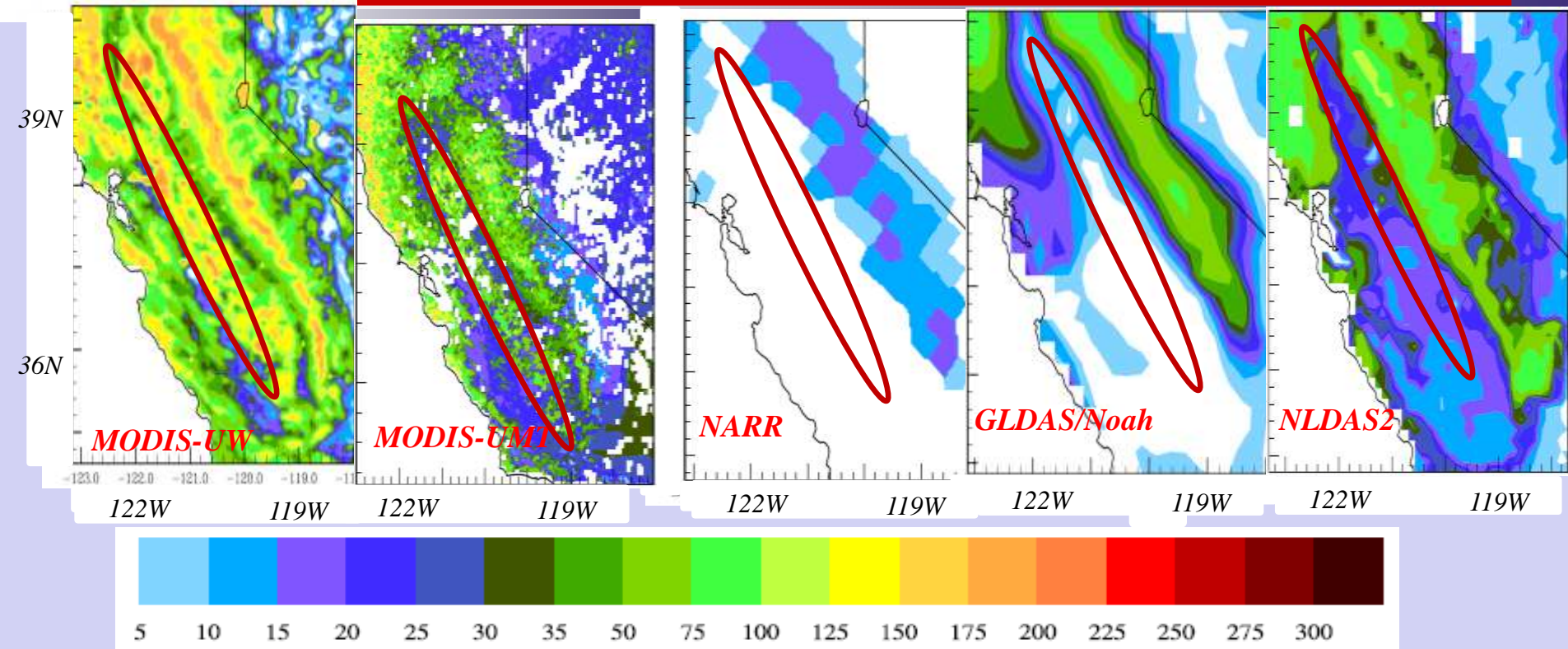


Studies over California's Central Valley Irrigation Region

Sorooshian et al. 2011 & 2012



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.





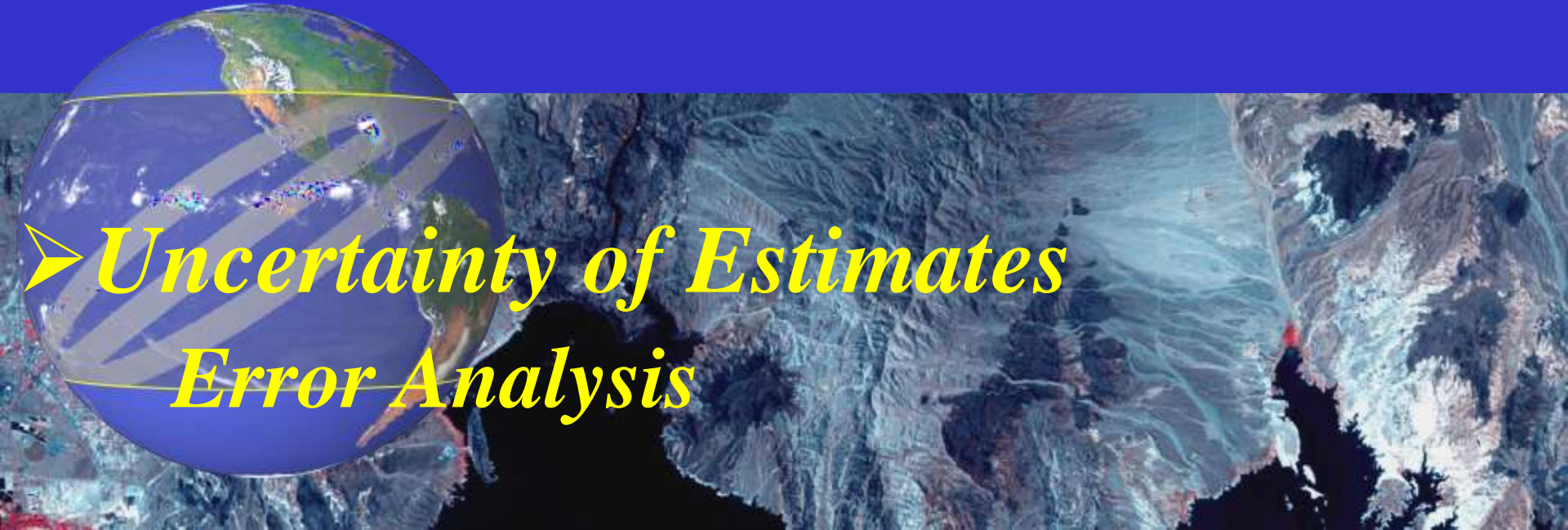
Thank You For the Invitation

08/14/2009

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

Back Up

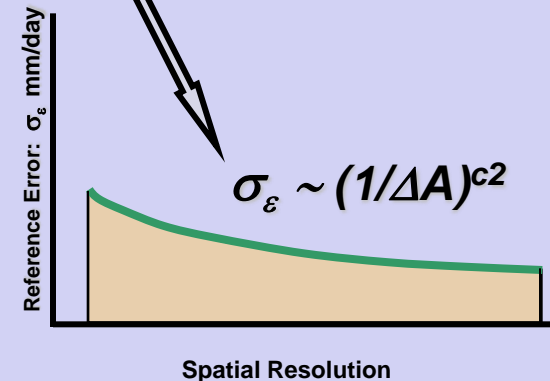
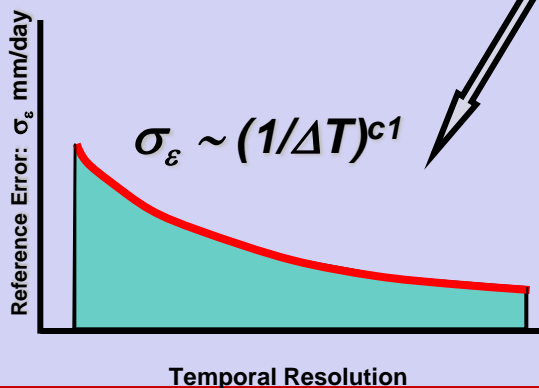
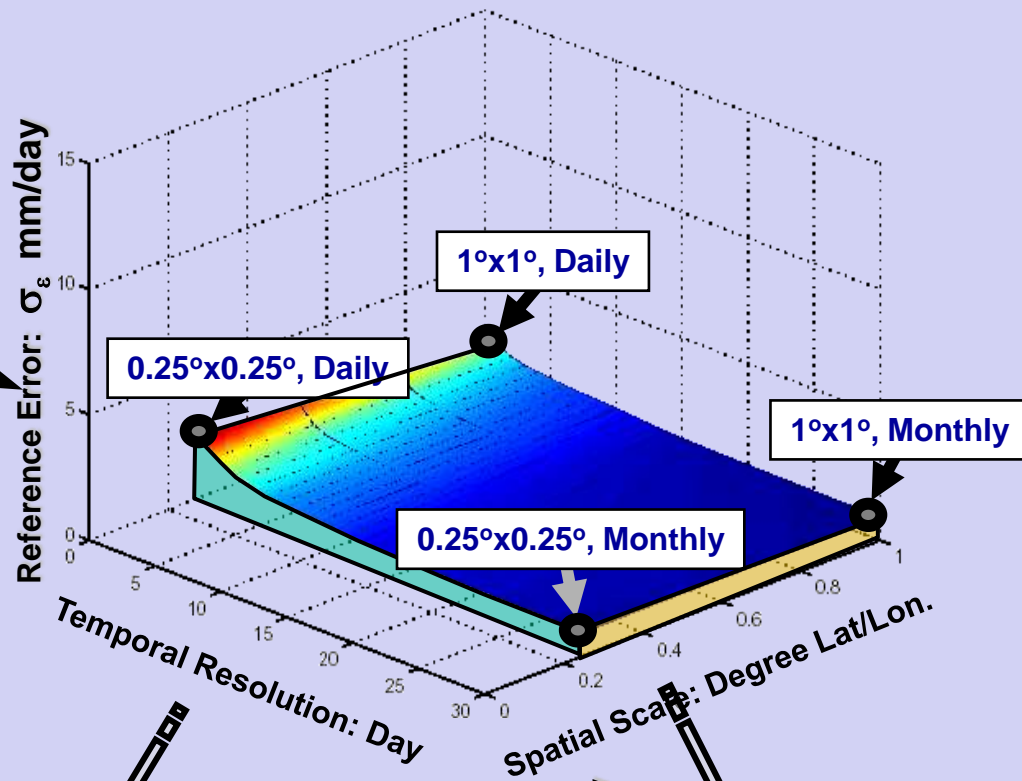
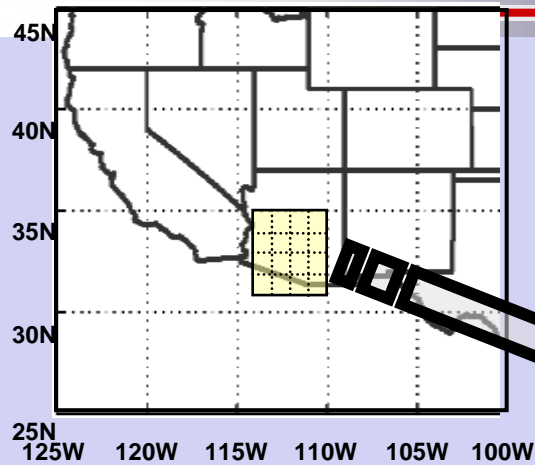




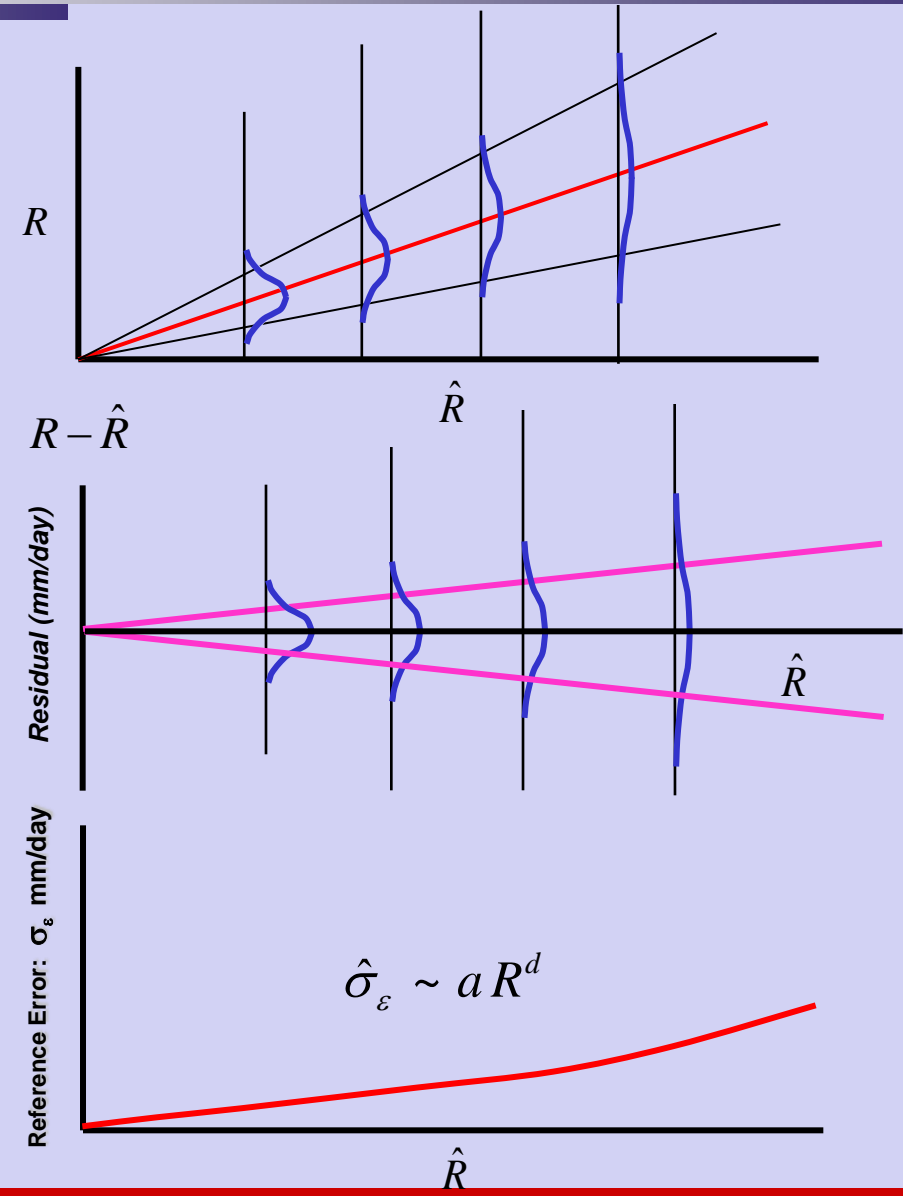
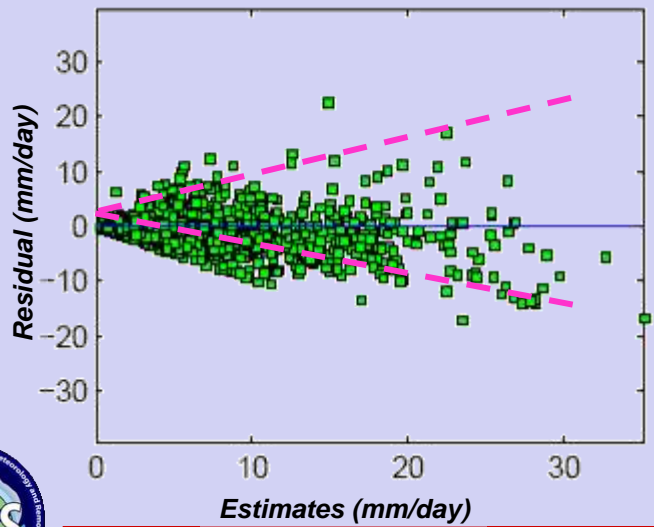
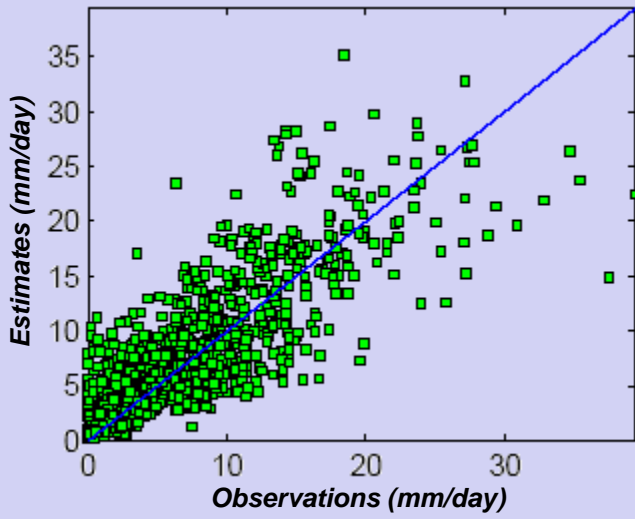
➤ *Uncertainty of Estimates*
Error Analysis



Spatial-Temporal Property of Reference Error

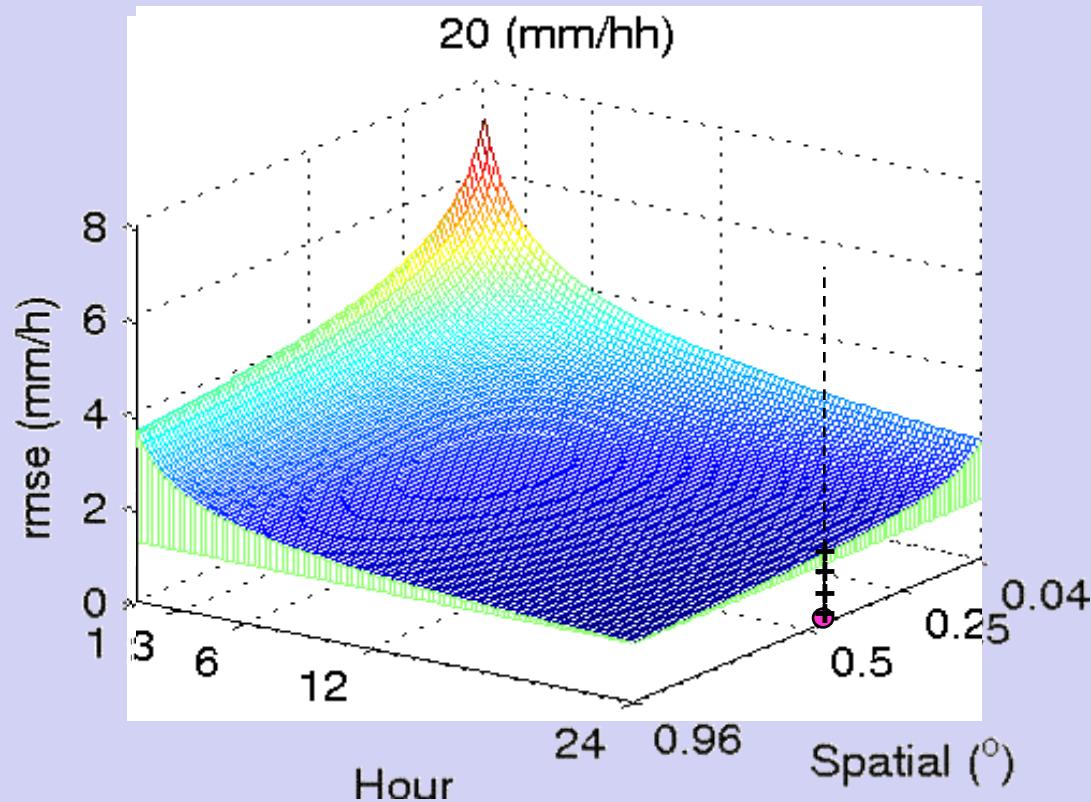


Reference Error: $\Delta T = 24\text{-hour}$, $\Delta A = 0.25^\circ \times 0.25^\circ$



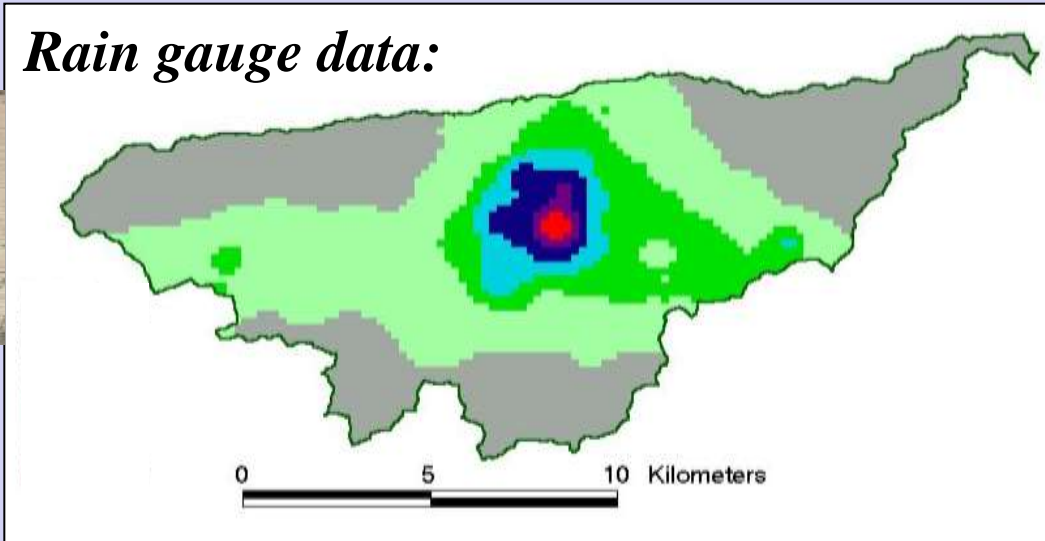
Scaling Property of PERSIANN-CCS Reference Error

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



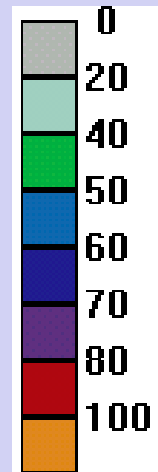
Radar-Gauge Comparison (Walnut Gulch, AZ)

Rain gauge data:

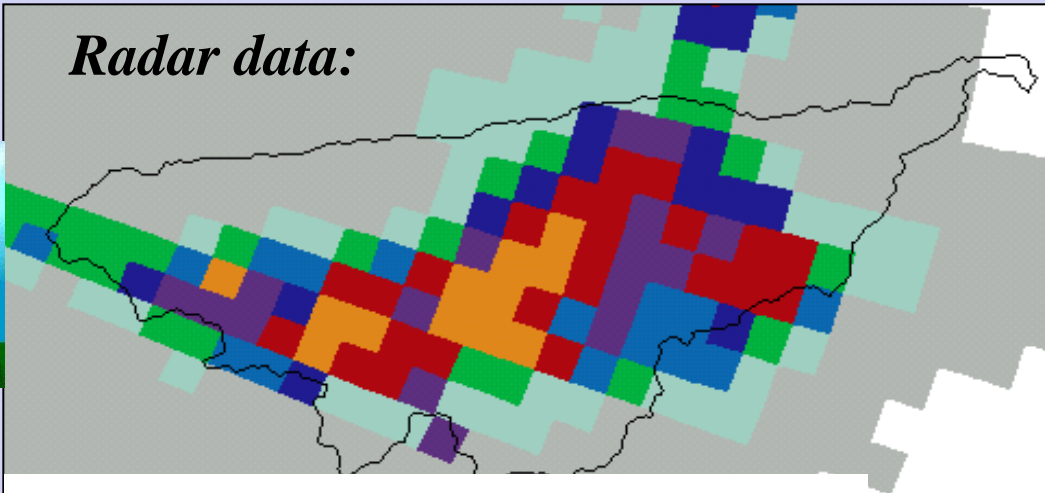


*Precipitation event:
Aug. 11, 2000*

Storm depth (mm)



Radar data:

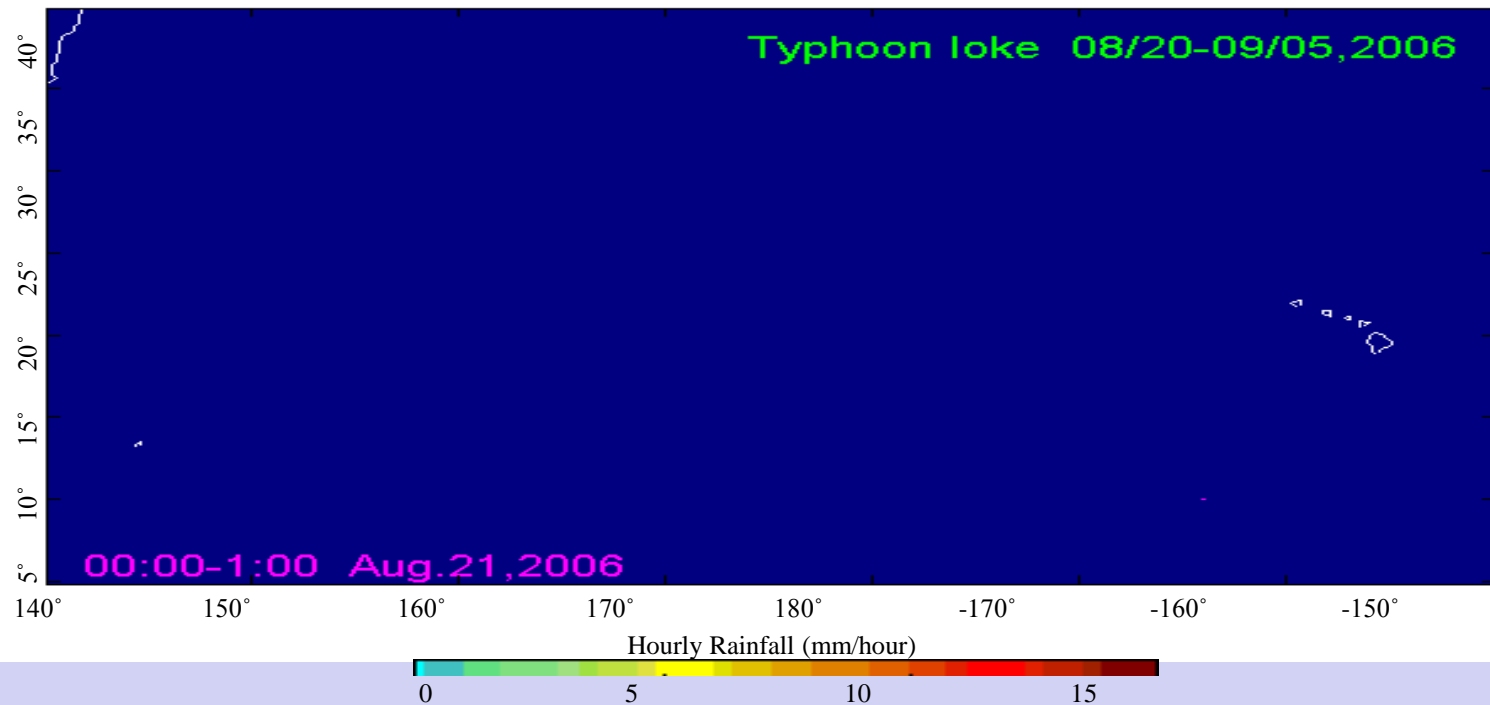


*70% overestimation
by the radar!*

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

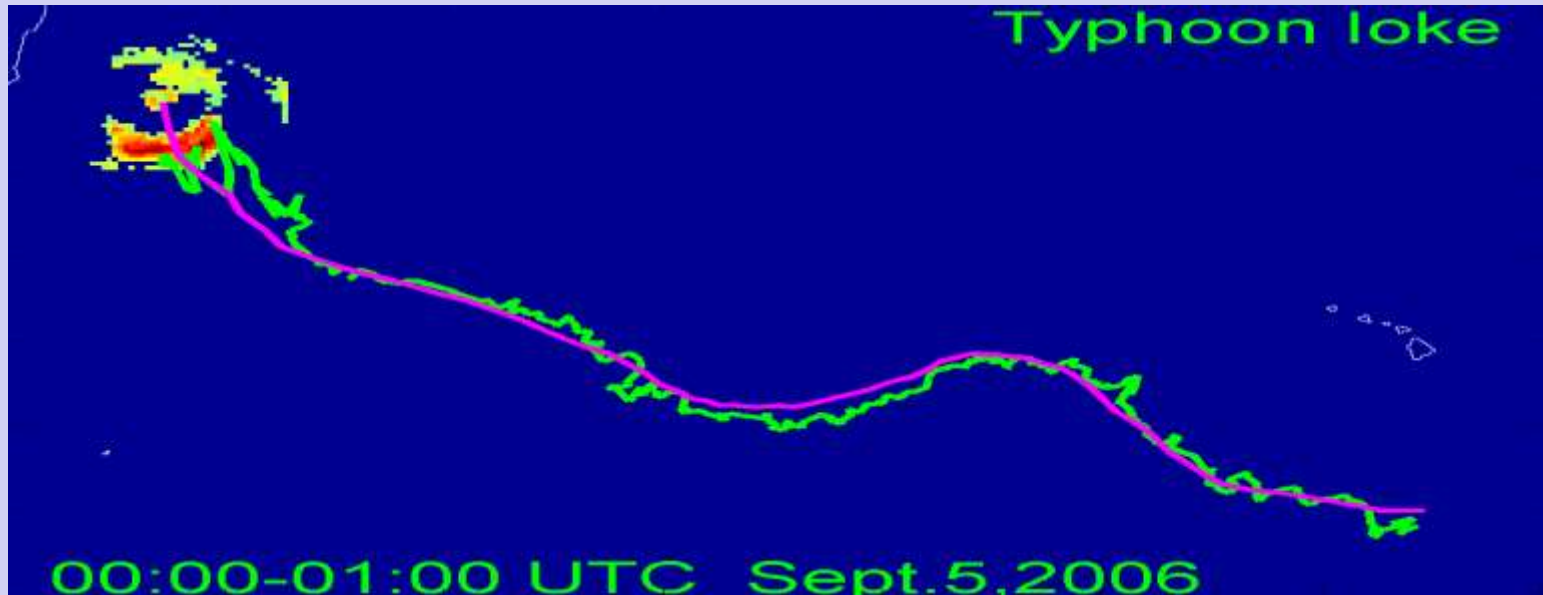
Morin et al ADWR 2005





— Magenta line: Tracks of the location of the peak rainfall rate pixel





Green line: the 6-hourly track of rainfall volume centroid

Magenta line: the 6-hourly track of the typhoon provided by IBTrACS.



Interpolation of 3-hour Precipitation

