Task Assigned to Professors Takeuchi, Kundzewicz and I:

Lessons from Hydrology in the 20th Century, and Messages to the Next Generation

International Symposium on:

Hydrology delivering Earth System Science to Society

Tsukuba, Japan, Feb. 28 - Mar. 2 2007

Personal View on Hydrometeorologic Forecasting Progress to date and what strategy to follow into the future?

Soroosh Sorooshian

Center for Hydrometeorology and Remote Sensing
University of California Irvine

International Symposium on:

Hydrology delivering Earth System Science to Society

Tsukuba, Japan, Feb. 28 - Mar. 2 2007

CHRS & Affiliates: A Truly International Team

and many more…

Two Primary Water Resources/Hydrology Challenges:

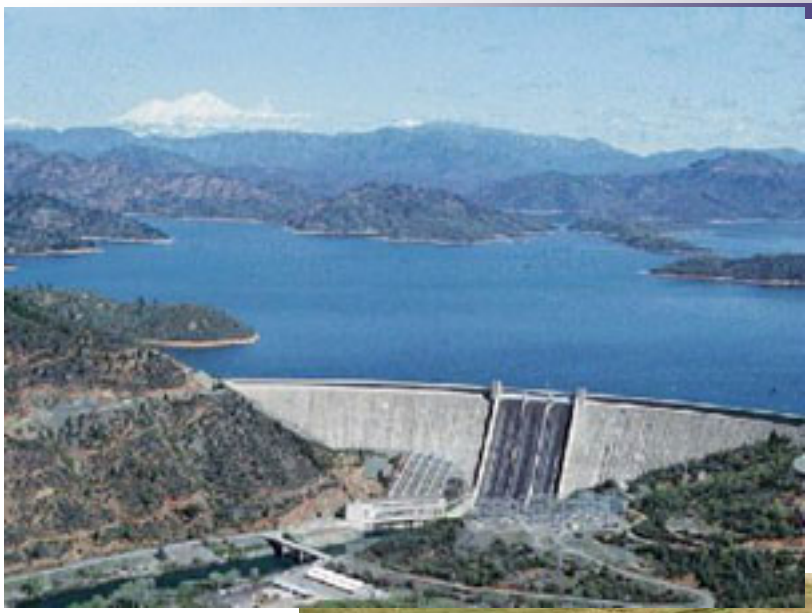
- ***Hydrologic Hazards (Floods and Droughts)***

- ***Water Supply Requirements (Quantity and Quality)***

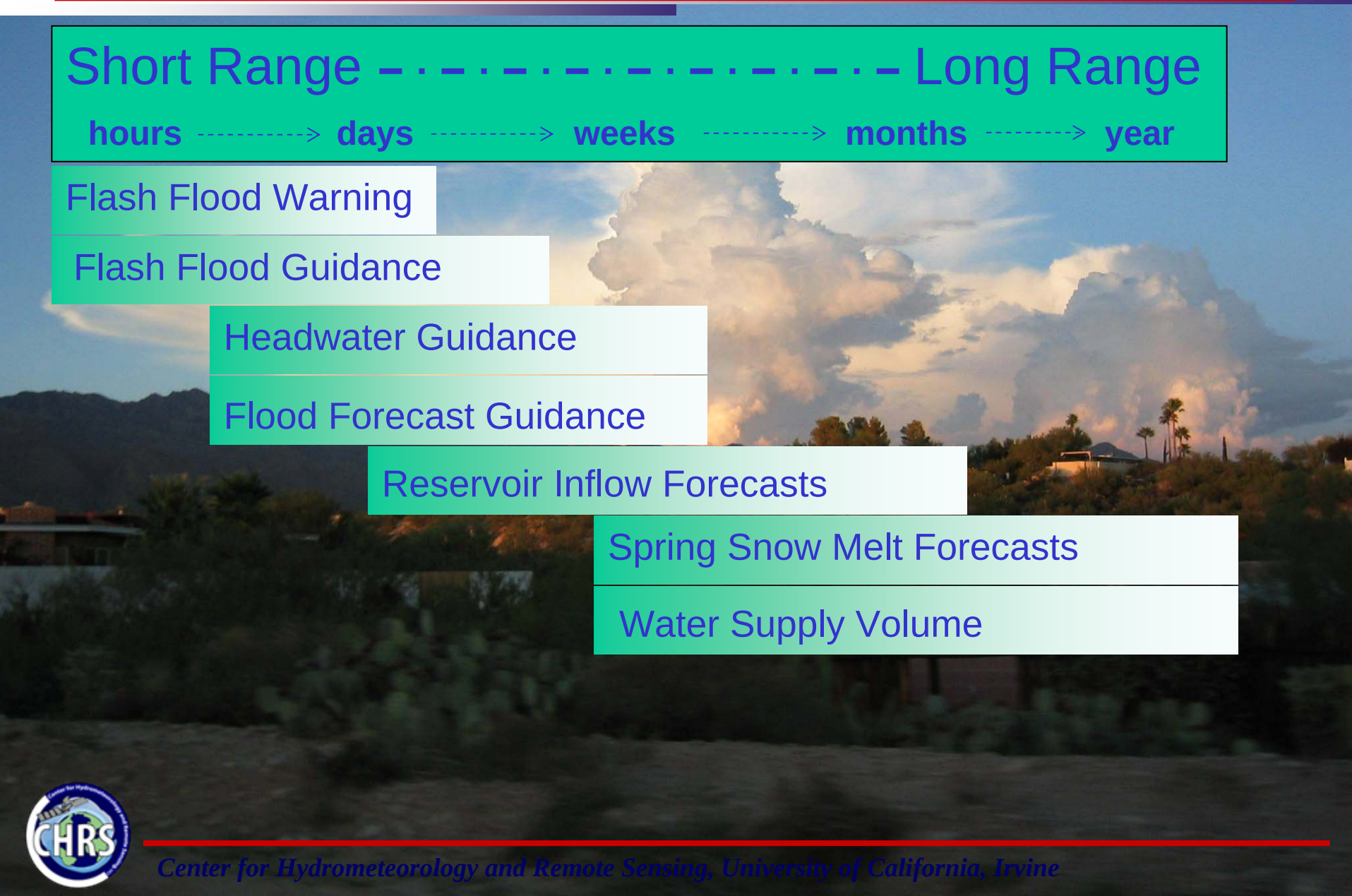
Primary Solution To Meet Hydrologic Extreme and Water Resources Needs

Engineering Approach: Control, Store, Pump and Transfer

A Century of Water Resources Development: Engineering success



Hydrometeorologic Predictions Are Critical



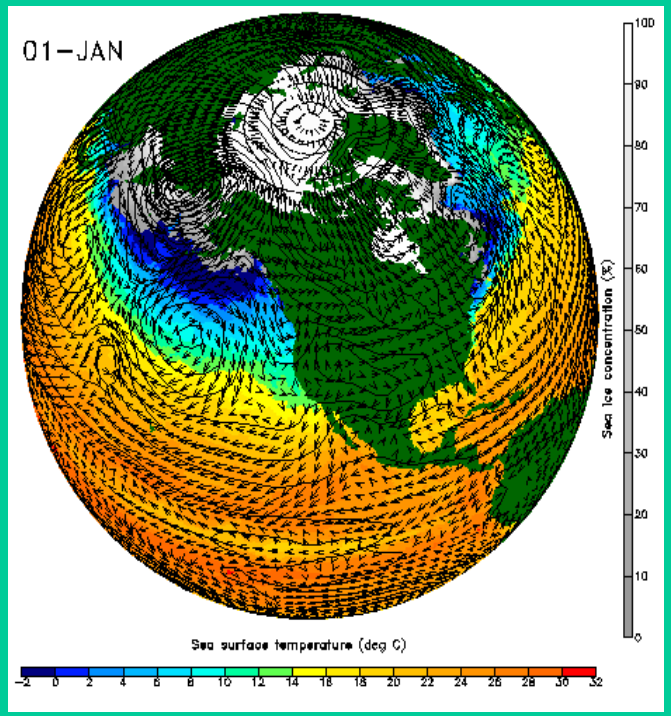
Short Range – · – · – · – · – · – · – · – · – Long Range

hours ----------> **days** ----------> **weeks** ----------> **months** ---------> **year**

- Flash Flood Warning
- Flash Flood Guidance
- Headwater Guidance
- Flood Forecast Guidance
- Reservoir Inflow Forecasts
- Spring Snow Melt Forecasts
- Water Supply Volume

Some Recent results Of Precipitation estimates from NWP Models:

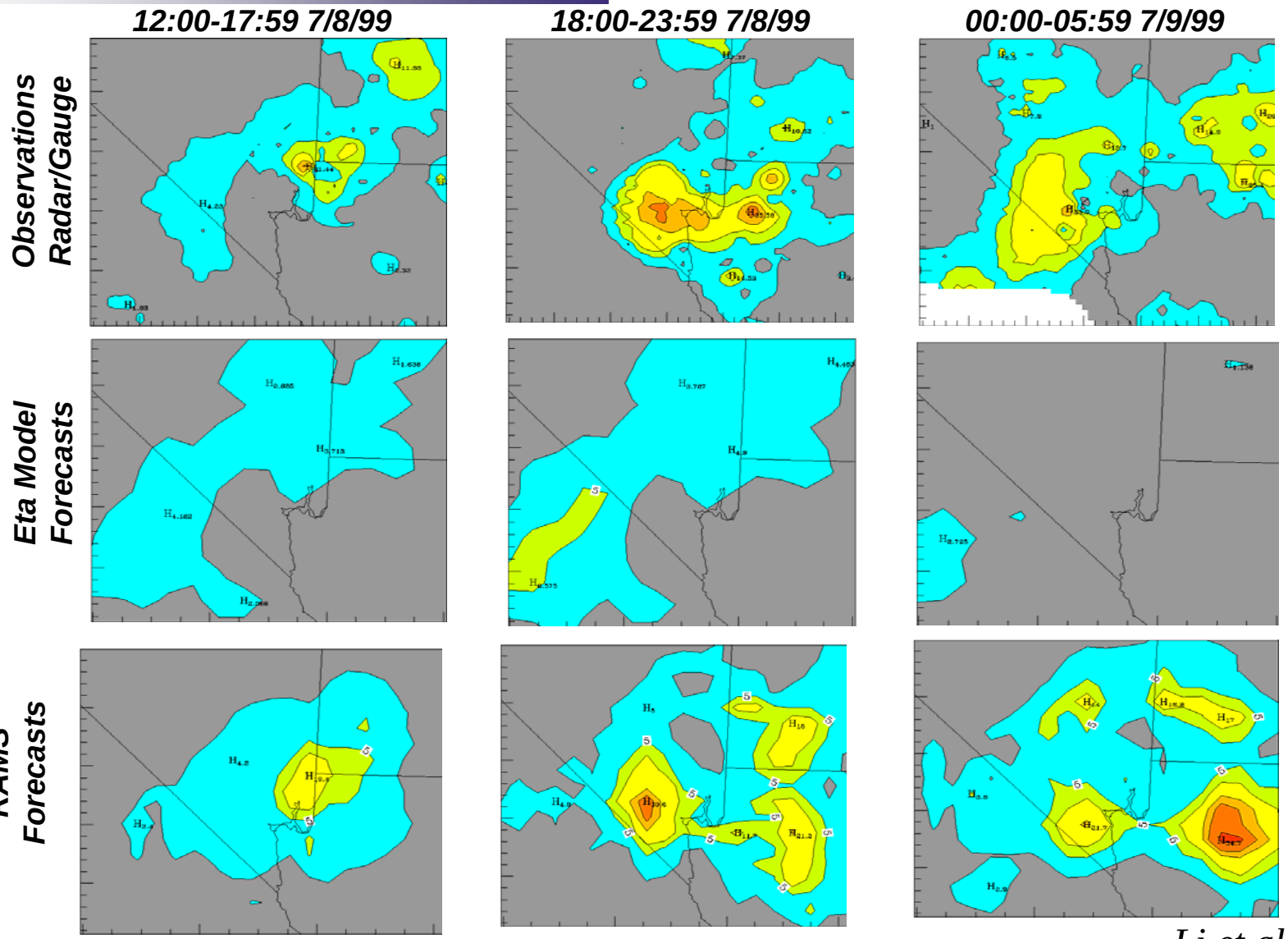
NWP



How Accurate Are QPF Estimates for Hydrologic Applications?

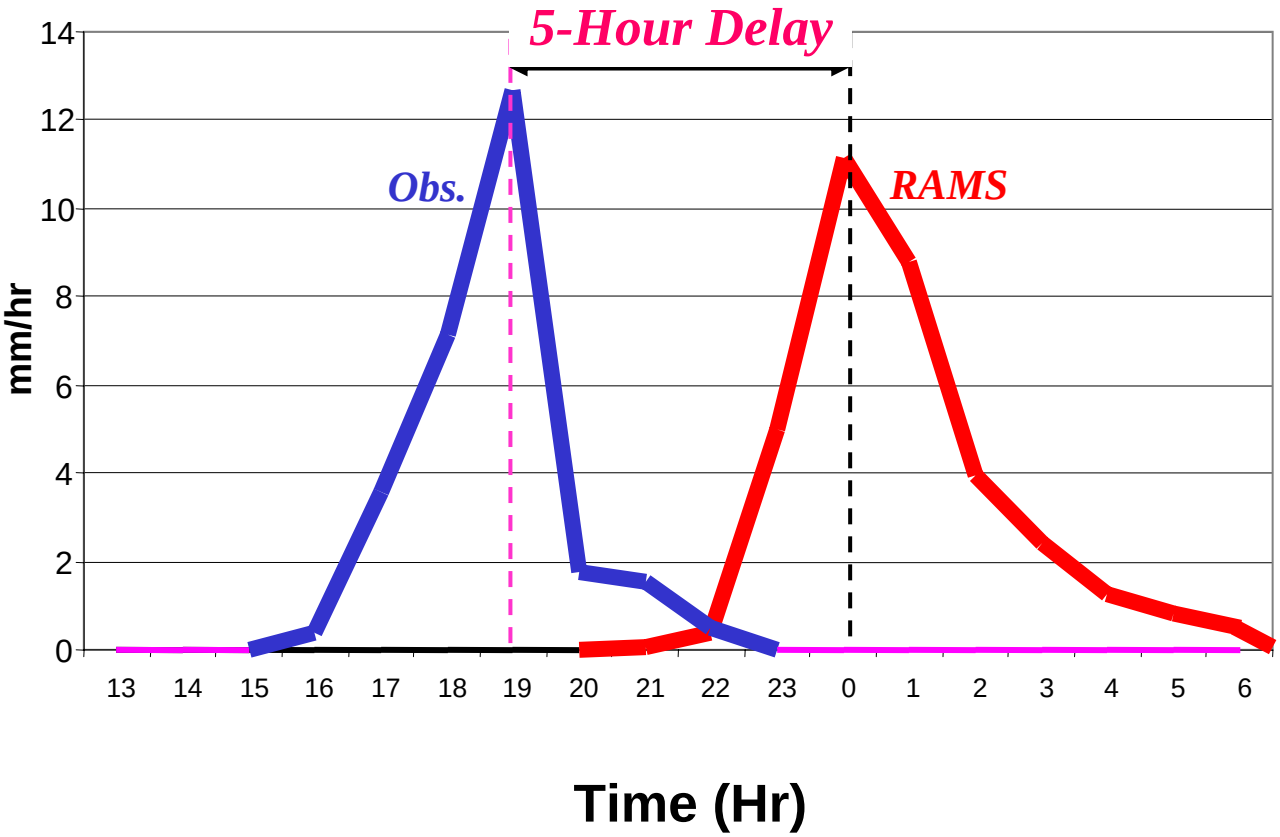
Flash Flood Scale: QPF Estimates for Las Vegas July 8, 1999

The Storm's Rainfall Measurements and Forecasts



Li et al 2004

Accurate Timing is Critical



Li et al 2004

Stakeholder Acceptability of QPF in Practice

A limited Survey

QPF use in the Southwest US

- **Quantitative Use:**

  NWS Colorado River Basin Forecast Center

  Direct input of HPC/QPF into river forecast models

  Critical for short-term forecasting

- **Most users "Minimal Qualitative Guidance"**

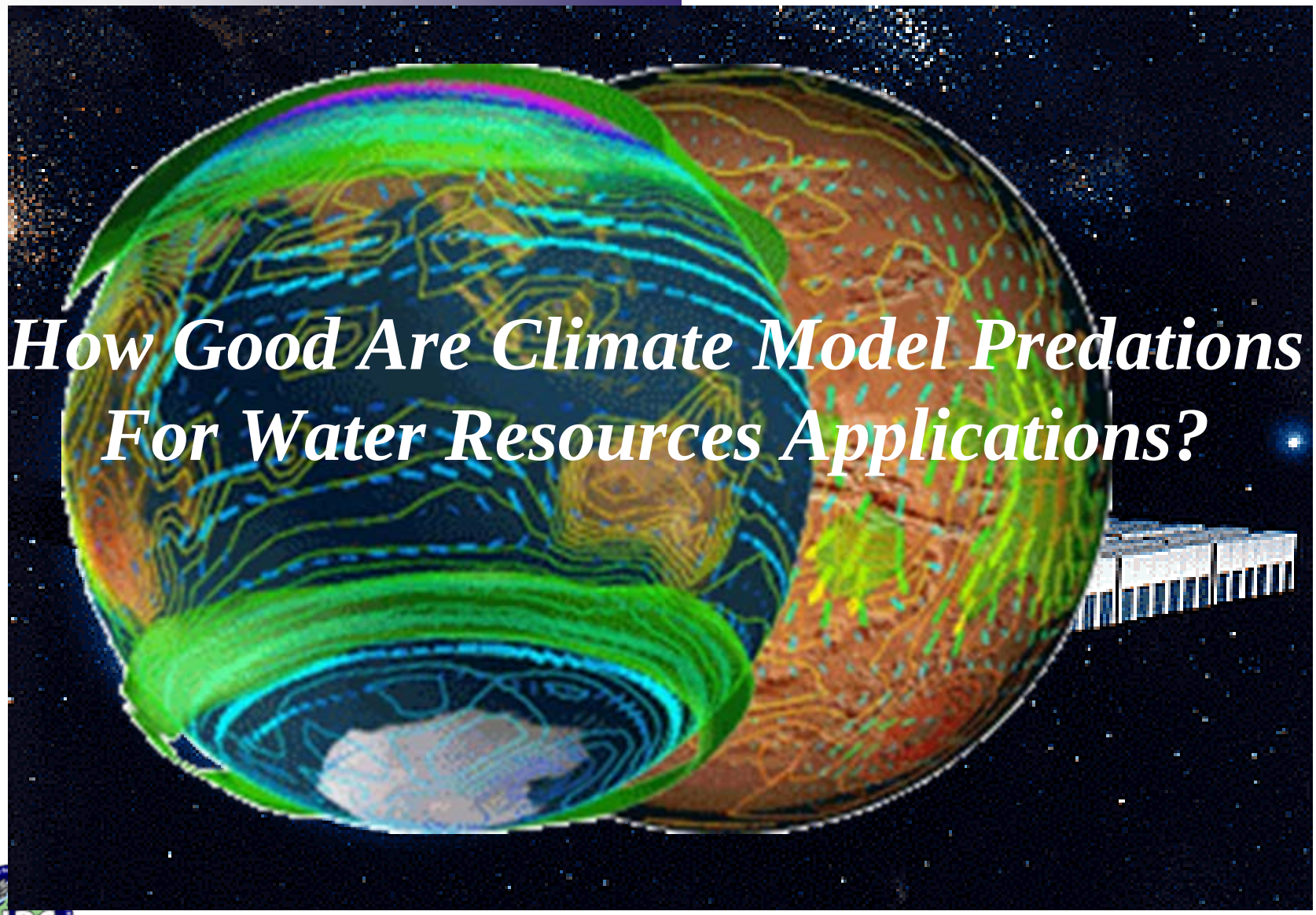
  Maricopa County Flood District (Phoenix)

  Salt River Project (Phoenix)

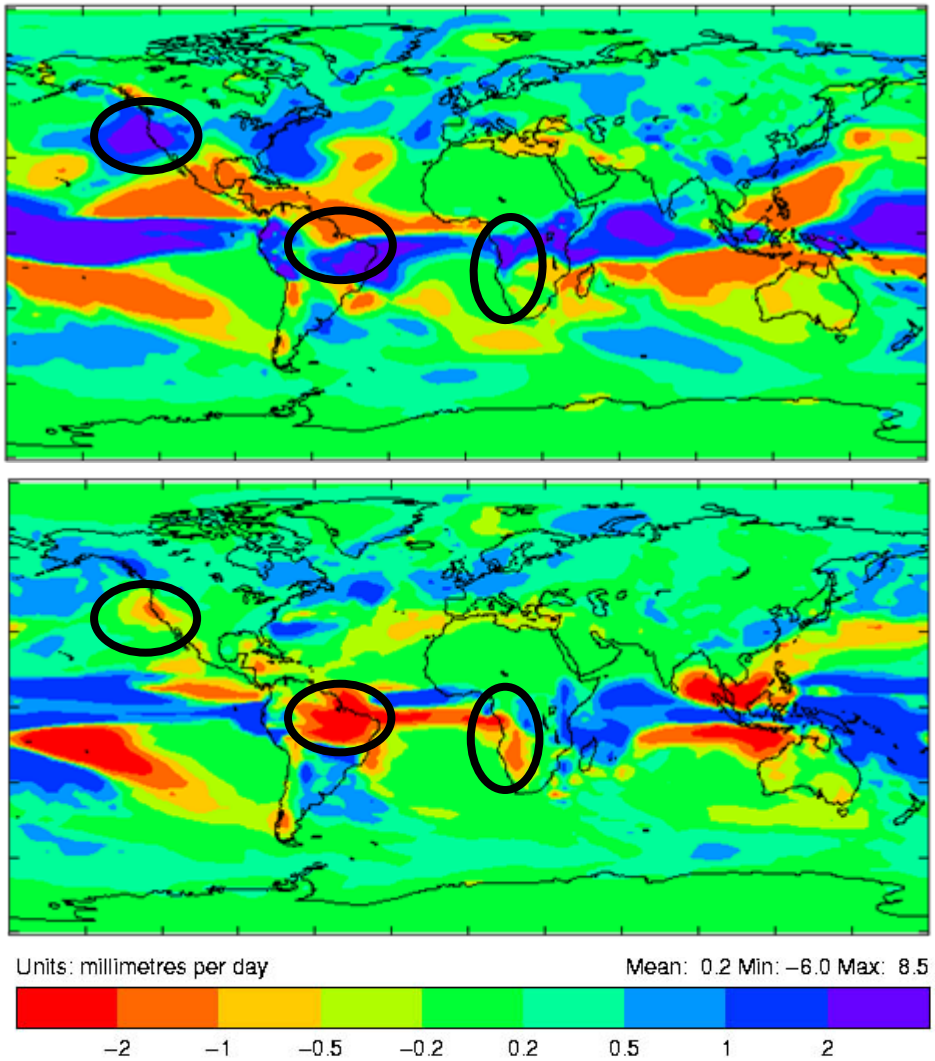
  Clark County Flood District (Las Vegas)

  Pima County Flood District (Tucson)

From Climate → to Hydrology



Climate model Predictions about the future? →globally



DJF Precipitation Changes
CM2 - Old model

CM3 - Updated model

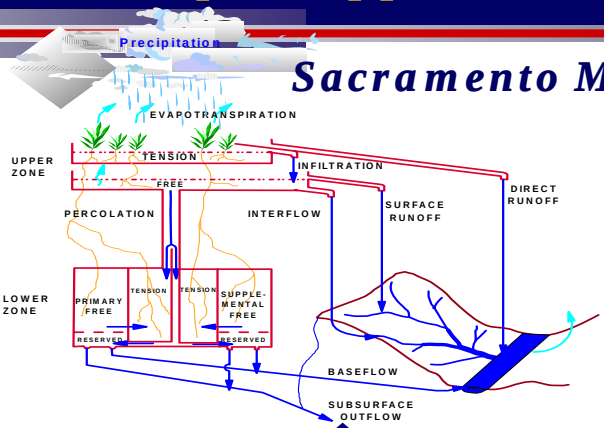
Significant differences in regional outcomes!

Source: Hadley Center (Climate Change Projections)

How about Hydrologic Predictions?

Hydrologic Models of Different Complexity

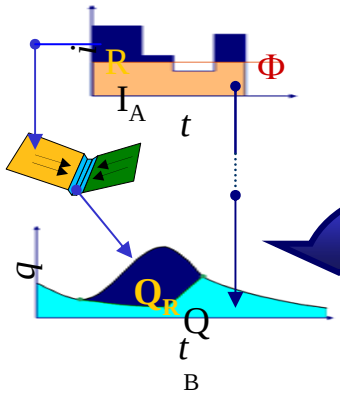
Sacramento Model



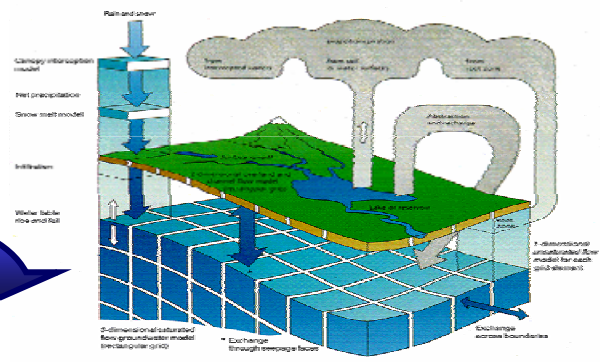
API

Φ Index partitioning
Overland routing

Sum up flow components

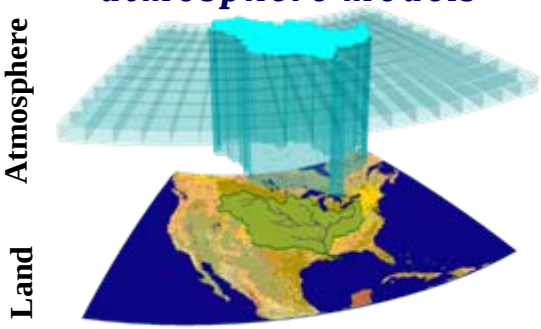


Mike SHE Model

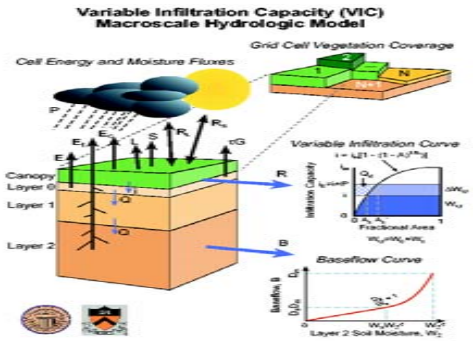


Hydrologic Models

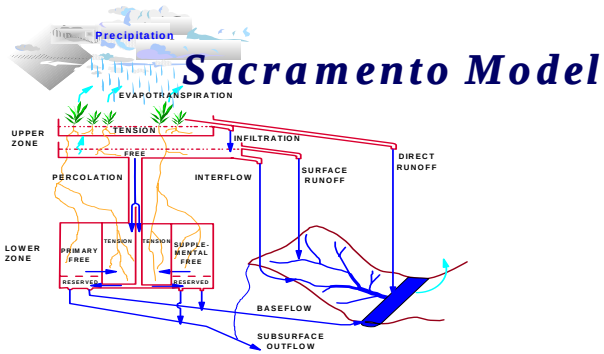
Mesoscale coupled land-atmosphere models

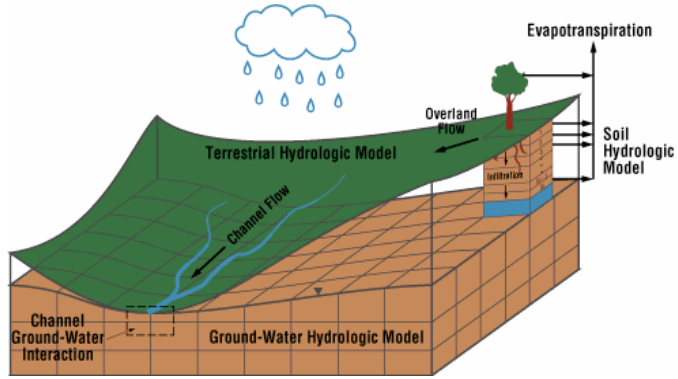


VIC Model



DMIP Findings: In a Nutshell

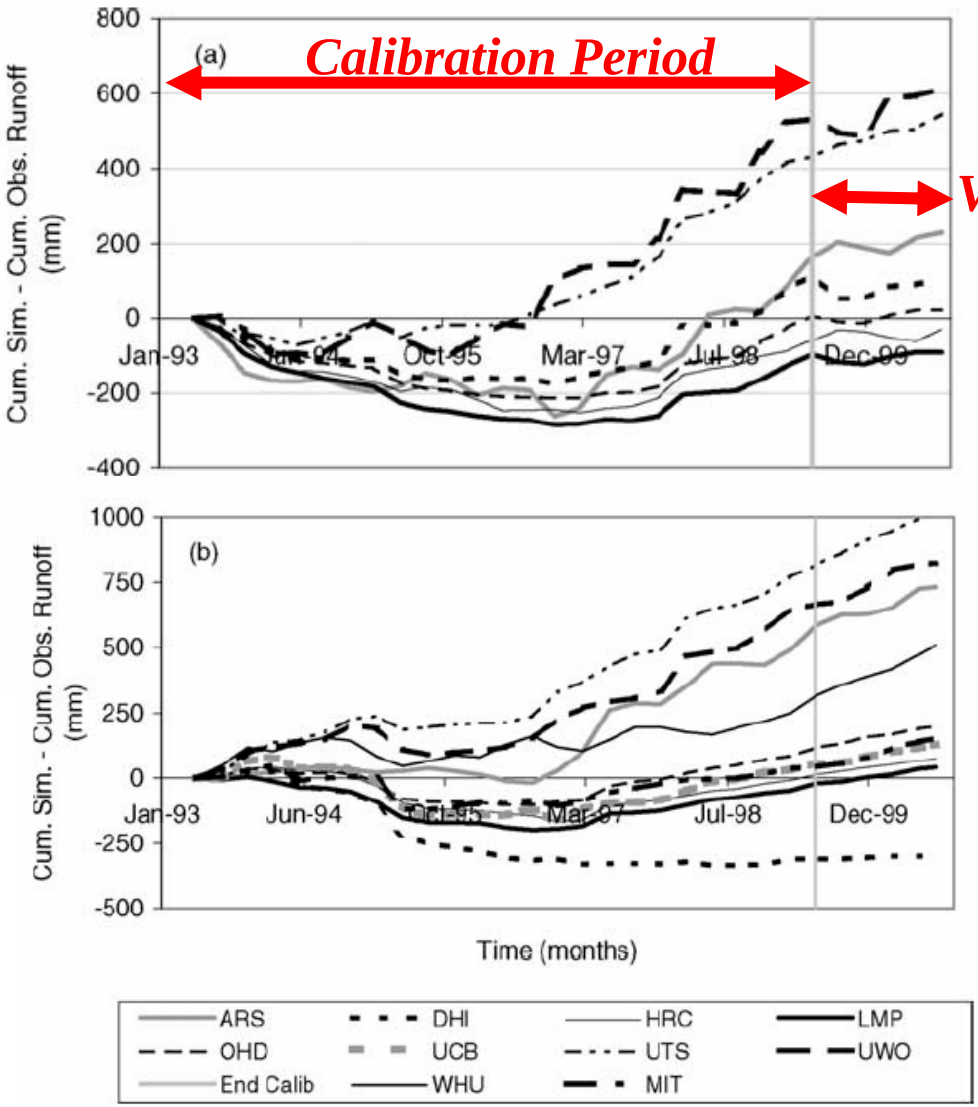




No Major Difference between the performance of Lumped and distributed models

Reed et al., J. of Hydrology, October 2004

Distributed Model Intercomparison Project (DMIP)



Performance of different distributed models

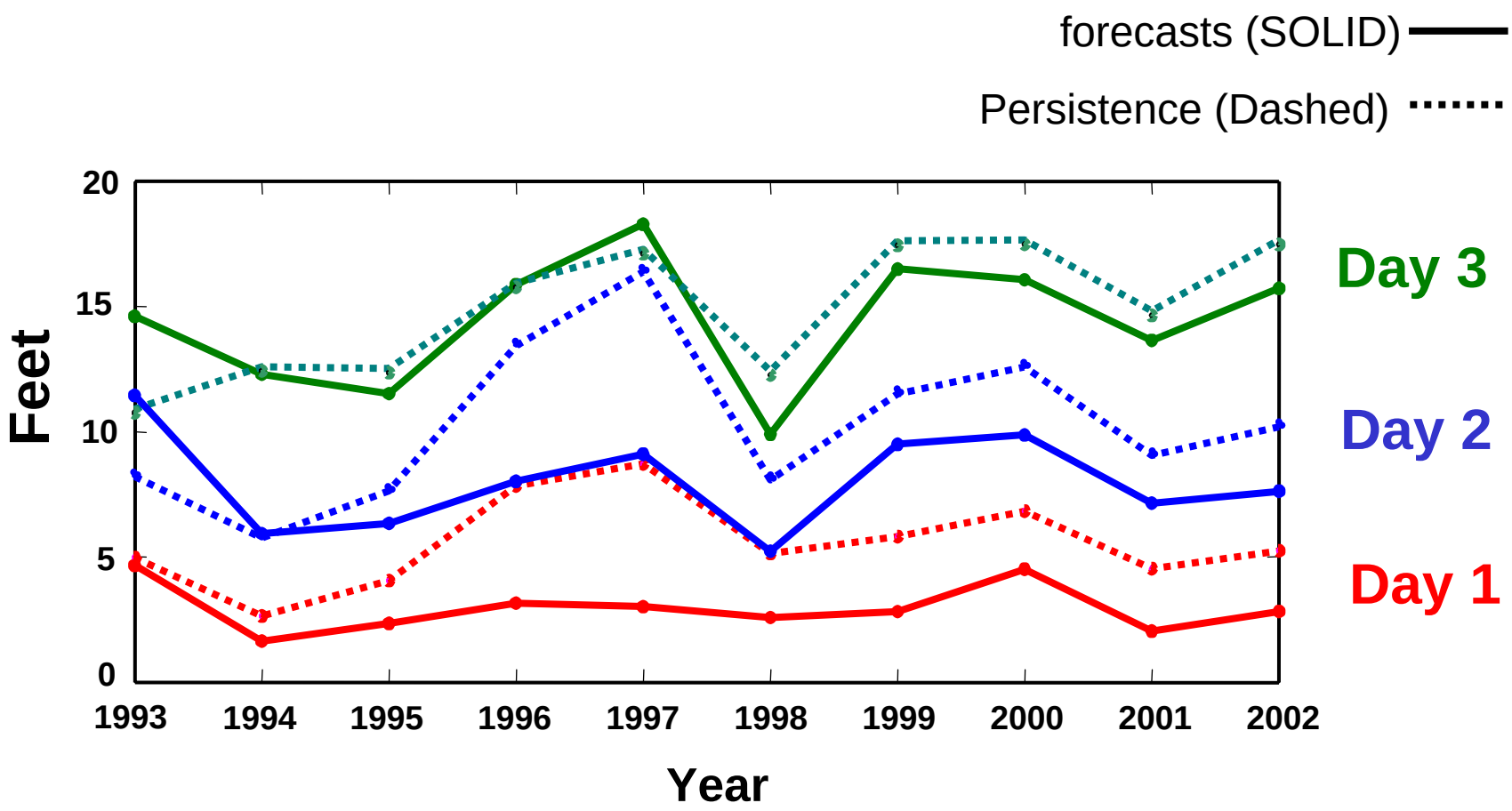
Cumulative simulation errors for:

(a) Watts Basin
(b) Blue Basin

DMIP Results (From Reed et al., 2004)

Some Verification Results: NWS-SMA Model

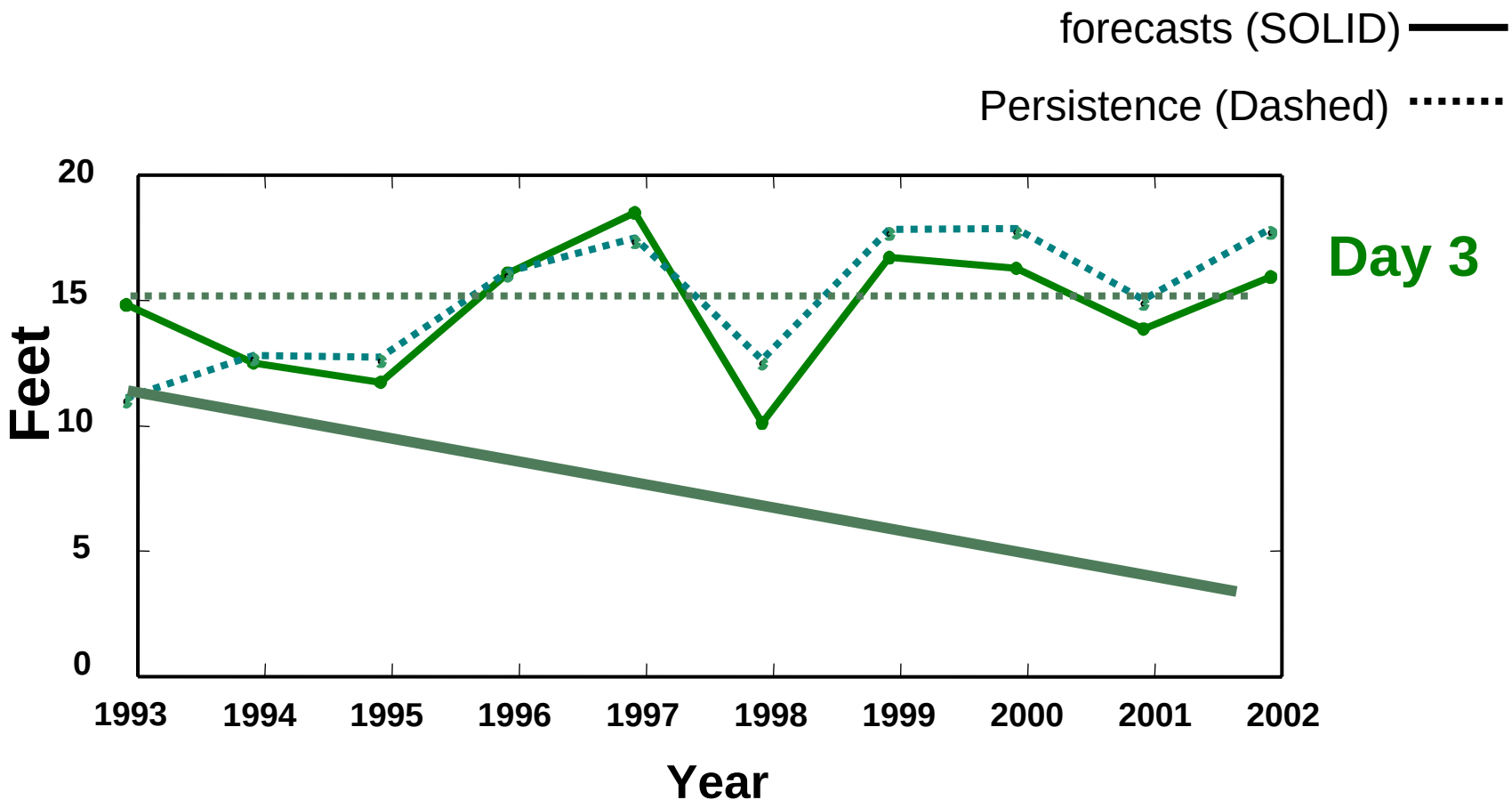
RMSE above flood stage: 5 Arkansas/Oklahoma locations



Edwin Welles: Dissertation 2005

Not much improvement In forecast Skill beyond day 2 !

Increase Forecast Lead time, Improve Accuracy Over Time….

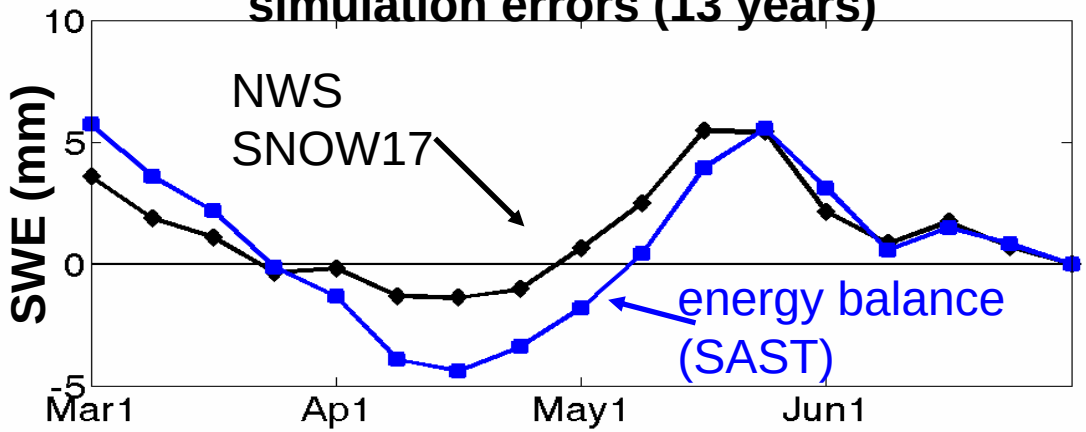


Edwin Welles: 2005

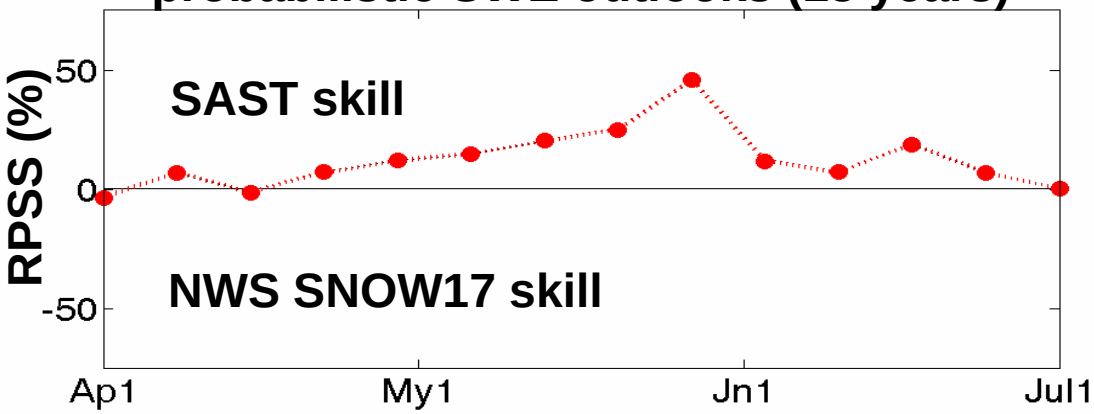
Comparison of Snowmelt Models

Temperature Index (TI) vs. Energy Balance (EB) Method

snow water equivalent (SWE) model simulation errors (13 years)



ranked probability skill scores for probabilistic SWE outlooks (13 years)

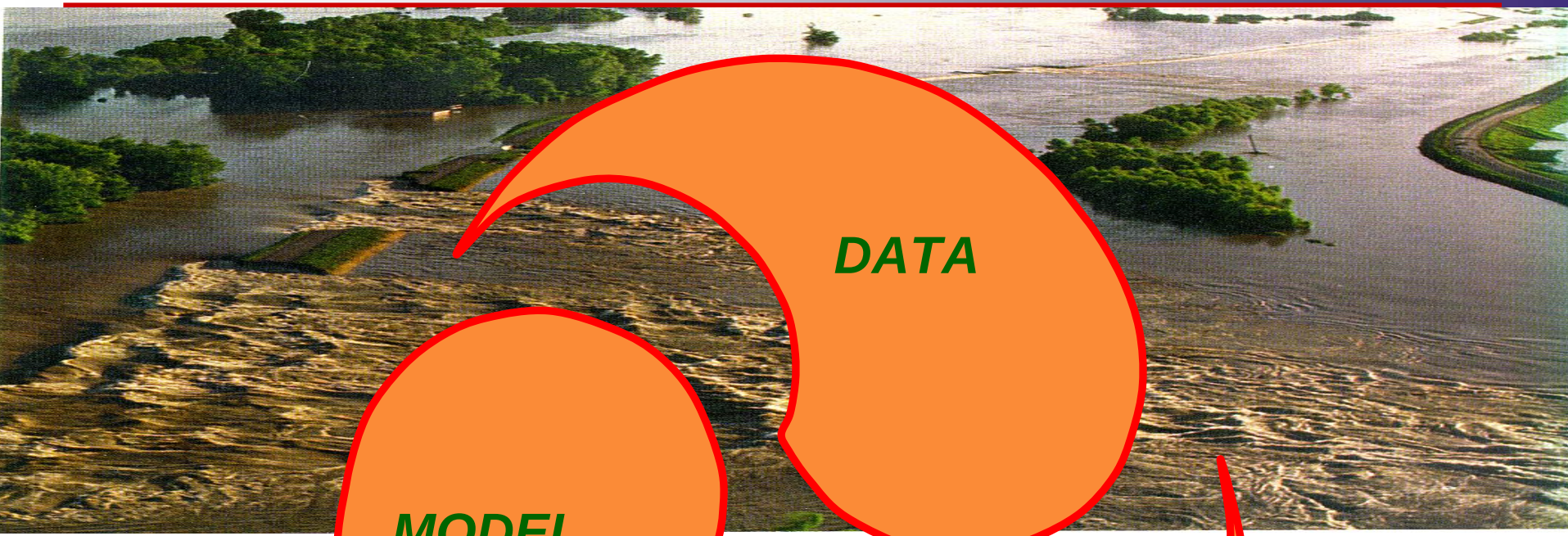


Main finding of her work:

- **No major difference between the performance of TI and EB methods based on the limited data she was able to find for a fair comparison.**
- **Data Limitation a big factor for EB methods**

Kristie Franz: 2006

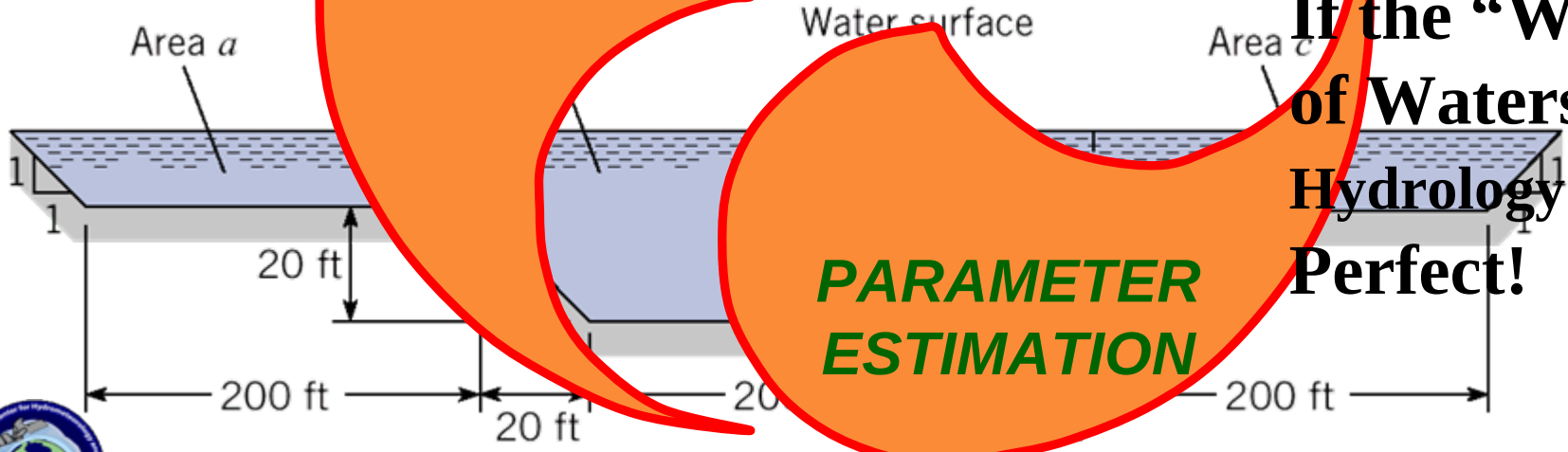
Requirements and State of Hydrologic Forecasting



DATA

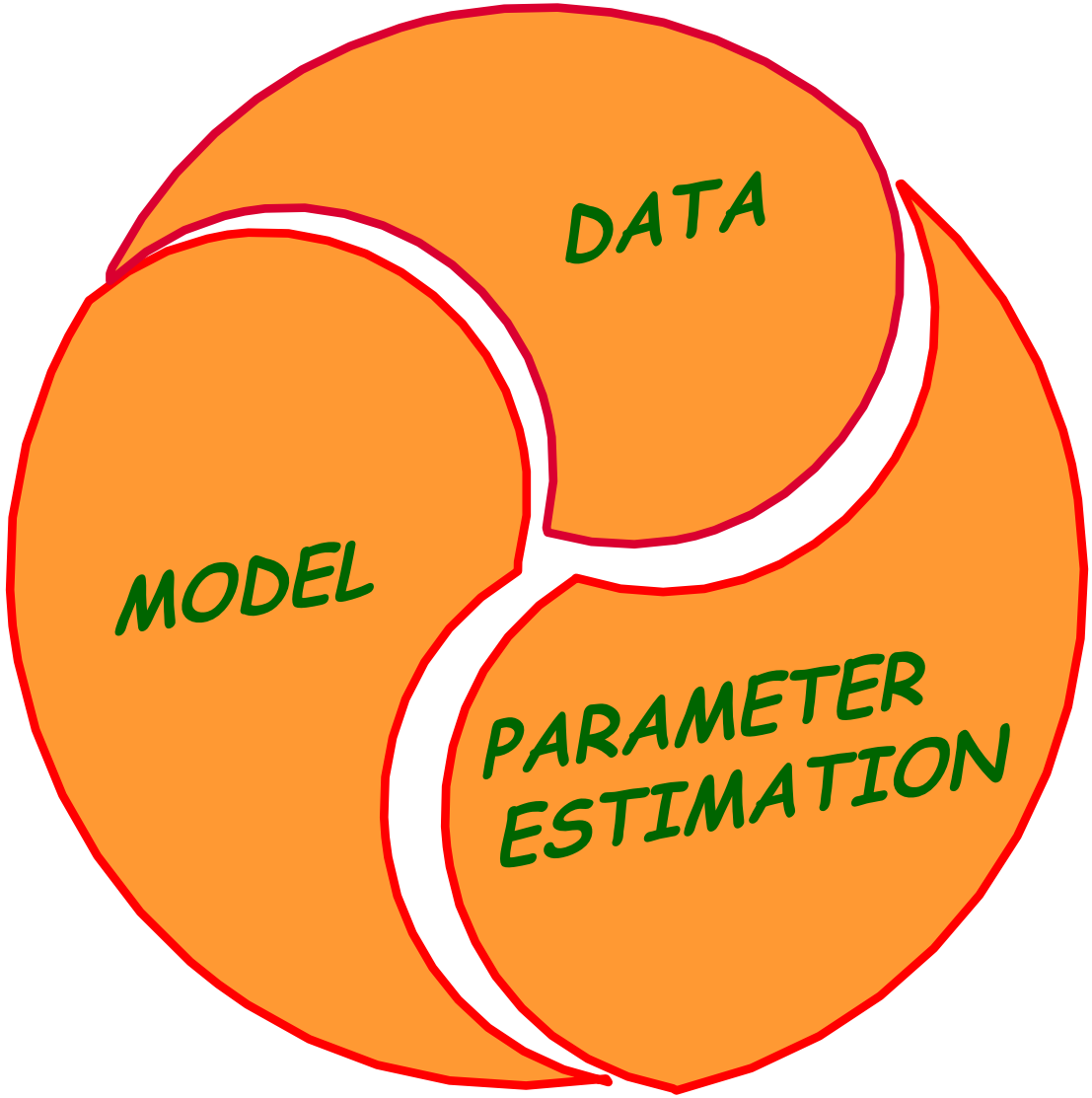
MODEL

PARAMETER ESTIMATION

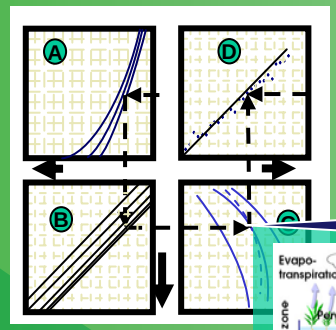


If the "World" of Watershed Hydrology Was Perfect!

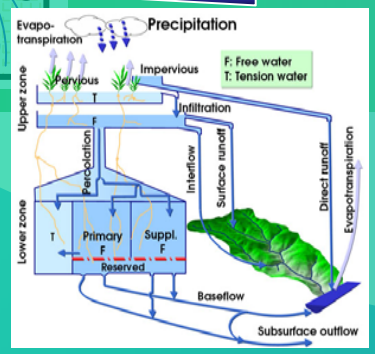
Hydrologic Modeling



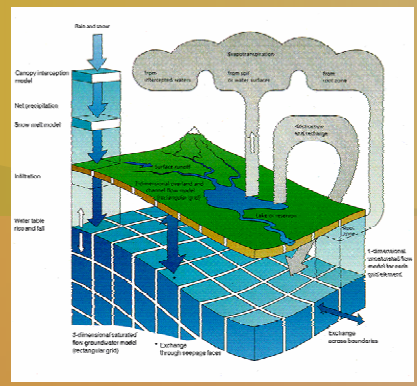
Evolution of Hydrologic R-R Models



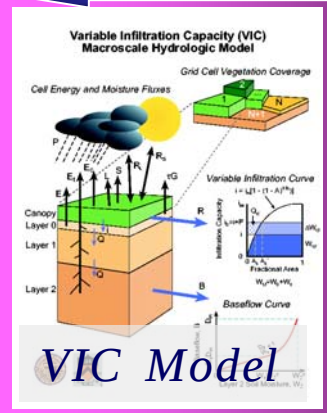
API Model



Sacramento Model



Mike SHE Model, DHI



VIC Model

Lumped

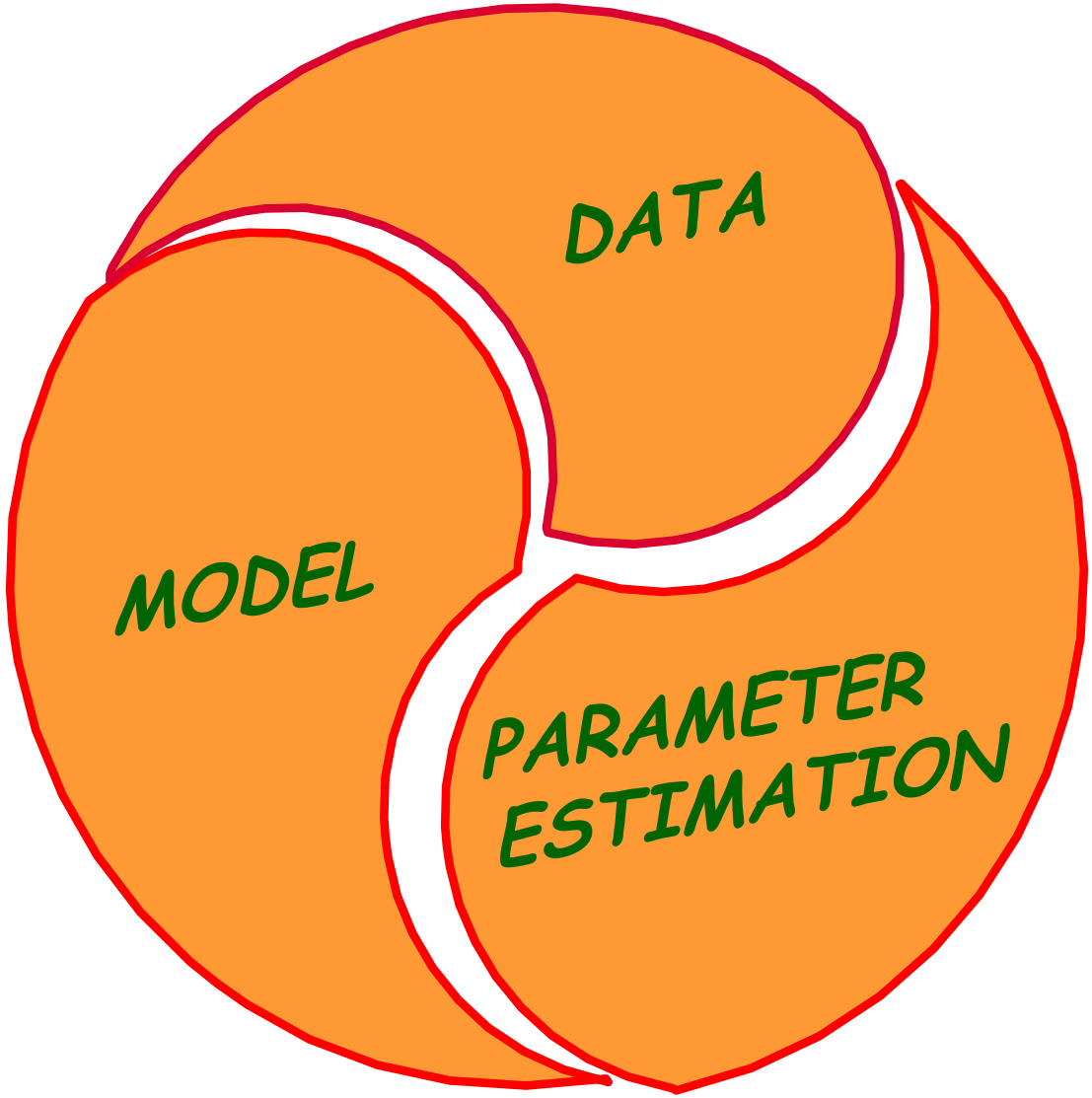
"Simple"

Time

Distributed

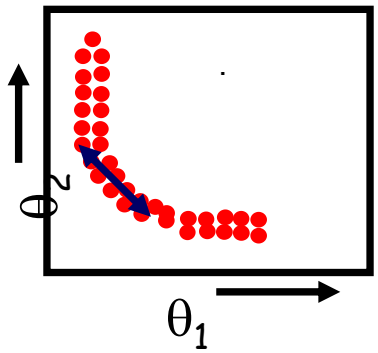
Physically-based

Model Calibration



Parameter Uncertainty Methods

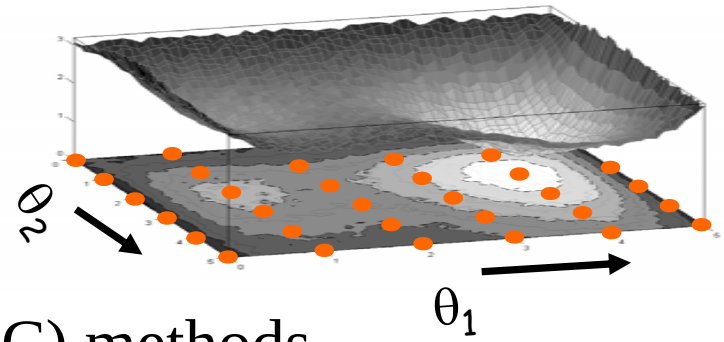
(1) First-order approximations near global optimum (UA Group, Kuczera etal)



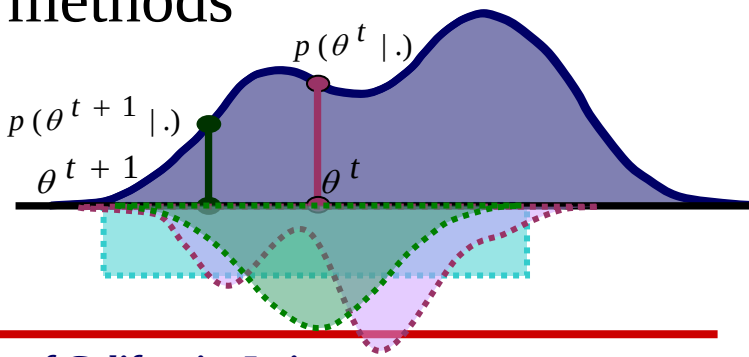
Limitations

- **Assumes Model is Linear**
- **Assumes Posterior Dist. Guassian**

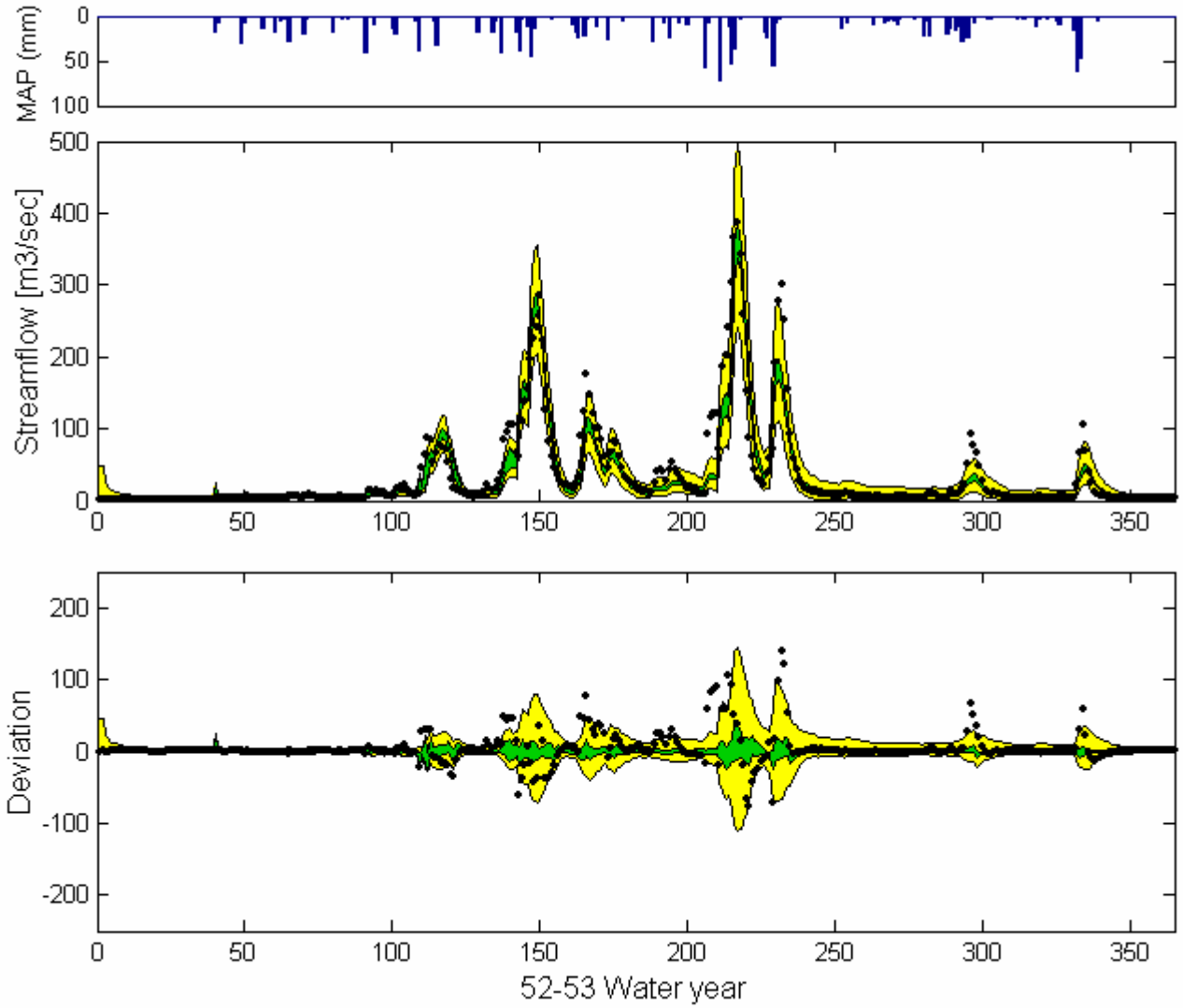
(2) Generalized Likelihood Uncertaintv Estimation (GLUE) method (Beven and co-workers)



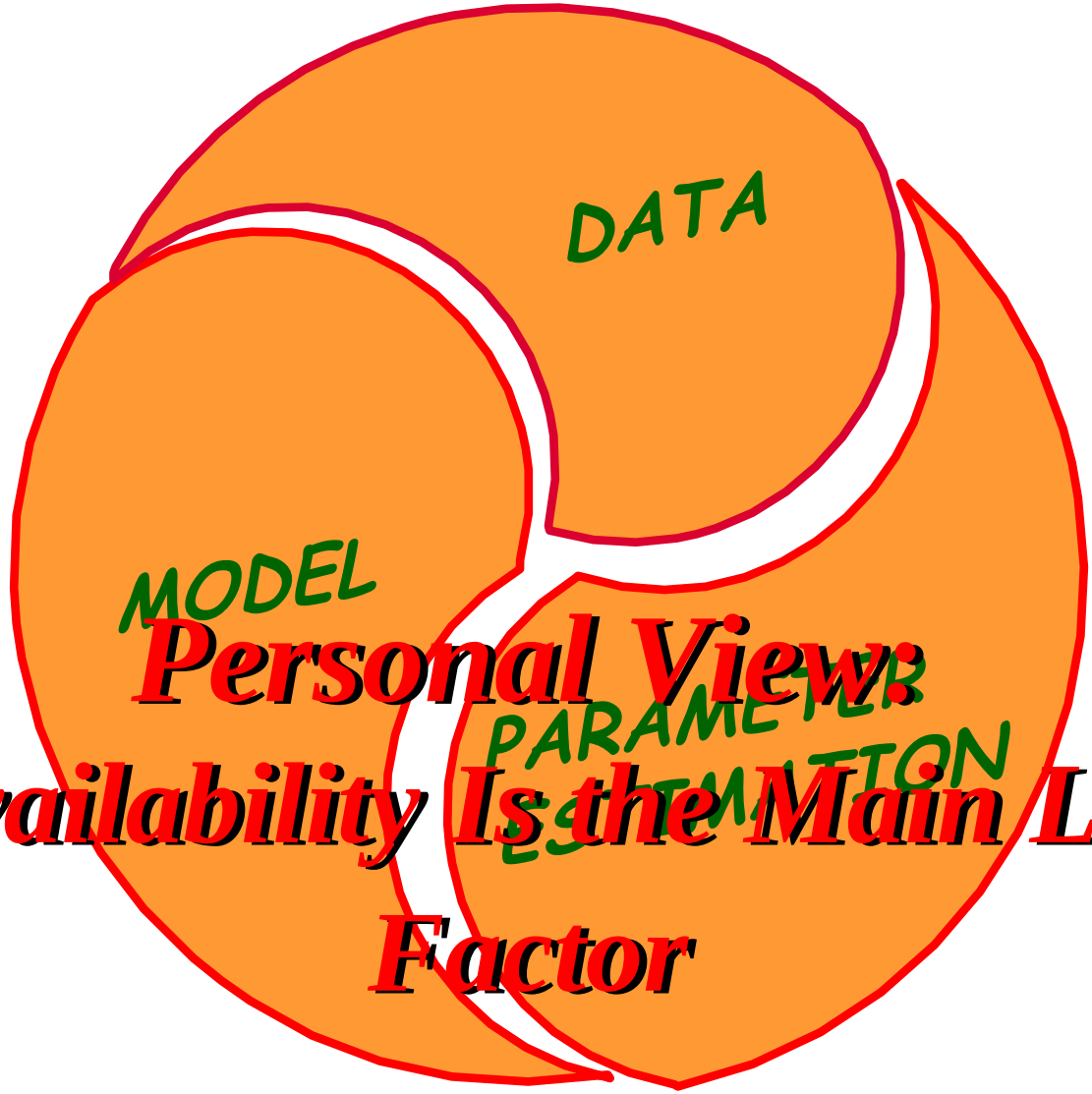
(3) Markov Chain Monte Carlo (MCMC) methods (UA Group, Vrugt and others)



Flow Ranges instead of point estimates



Data Requirements

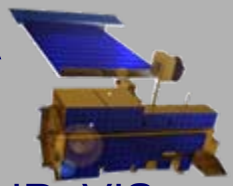


Personal View:

Data Availability Is the Main Limiting Factor

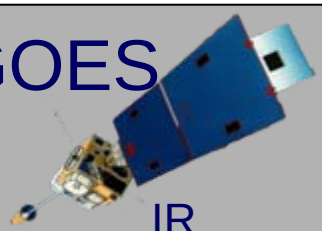
Satellite-based Observations will be critical

NASA
EOS



MODIS IR+VIS
ASTER
CERES

GOES



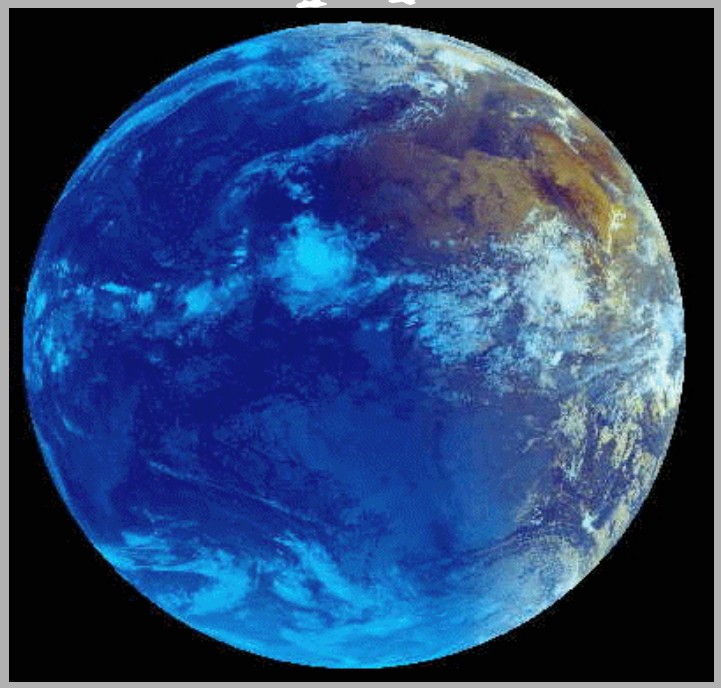
IR
VIS
SOUNDING

NOAA

DMSP

NASA
TRMM

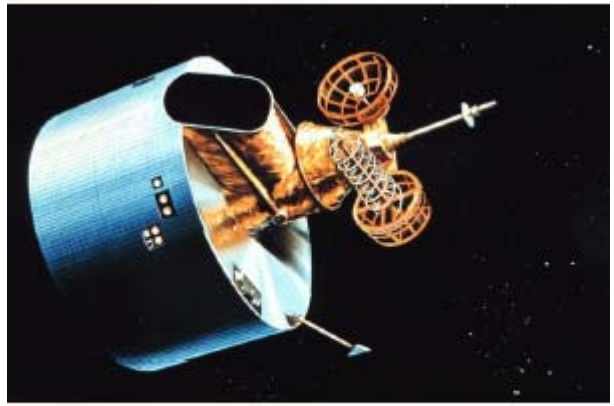
TMI
PR
VIRS



Precipitation Observations: Which to trust??

Rain Gauges

WSR-88D Radar



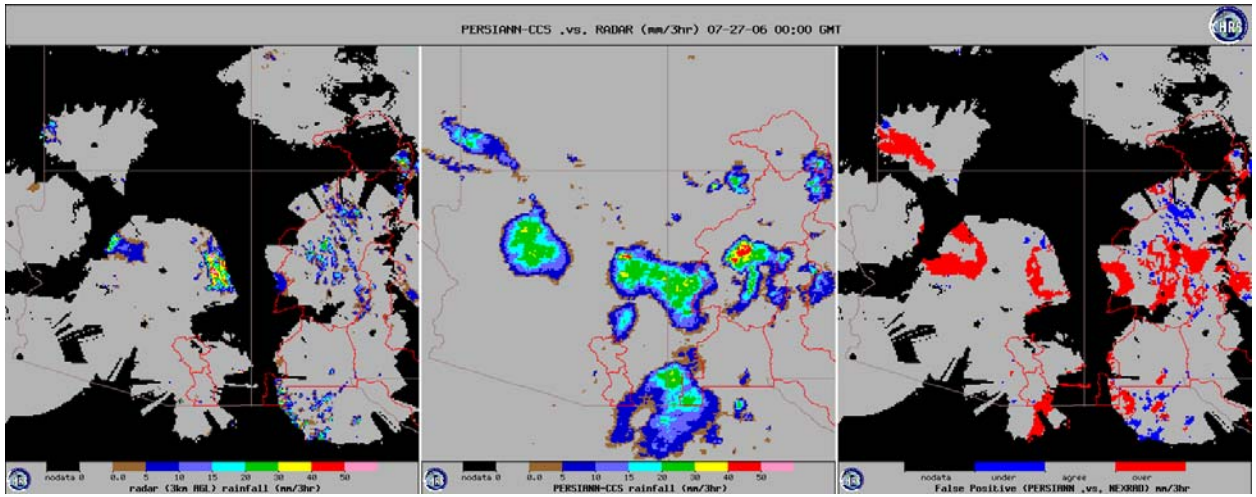
Satellite

Sources: R. Fulton, D.-J. Seo. and J. Breidenbach, AMS Short-Course on QPE/QPF, 2002

Verification: A Painful but Critical Requirement

In summer of 2006, Southwestern U.S. experienced a series of record flash floods due to a "strong" North American Monsoon.

This demo shows the potential of using satellite rainfall estimates to improve flood warning.



Radar beams (3-km above ground level) are blocked by mountains in SW.

Strong convection starts over mountains where radar coverage is poor. PERSIANN's continuous monitoring of storm systems, provides useful information for early warning.

Differences between PERSIANN and radar images exist.

Red: PERSIANN showed Rain but Radar showed No Rain

Blue: PERSIANN No Rain vs. Radar Rain

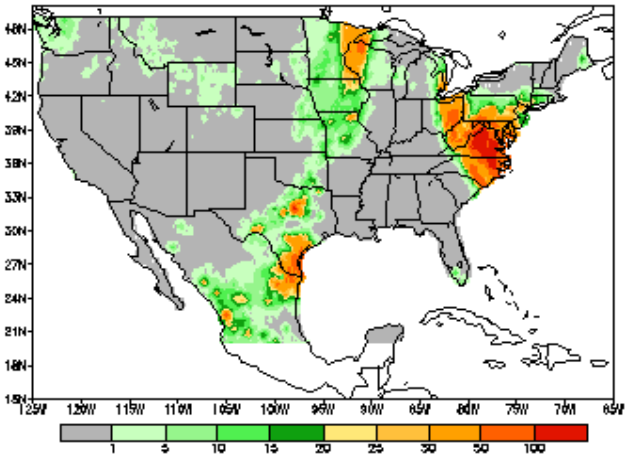
X. Gao, K. Hsu, B. Imam, et al., 2005

Positive Steps: Daily Precipitation Validation (US)

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



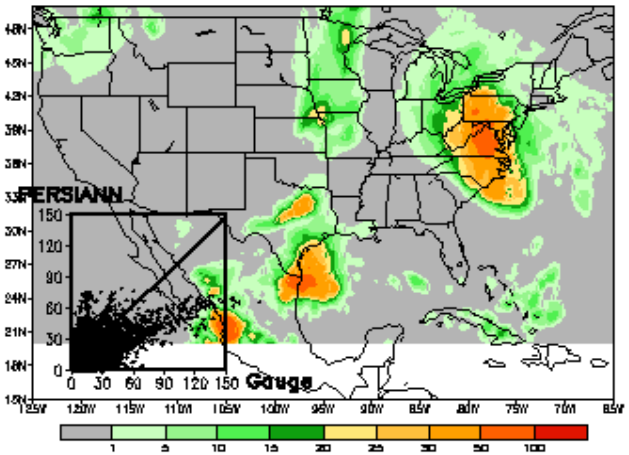
	(G) gauge	(S) PERSIANN	(R) radar
Number of points:	13828.	13828.	13828.
# points w/rain:	4249.	4665.	2971.
Mean rain rate:	5.55	4.25	3.13
Cond. rain rate:	17.82	12.47	14.46
Max. rain rate:	181.99	79.07	131.45

	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

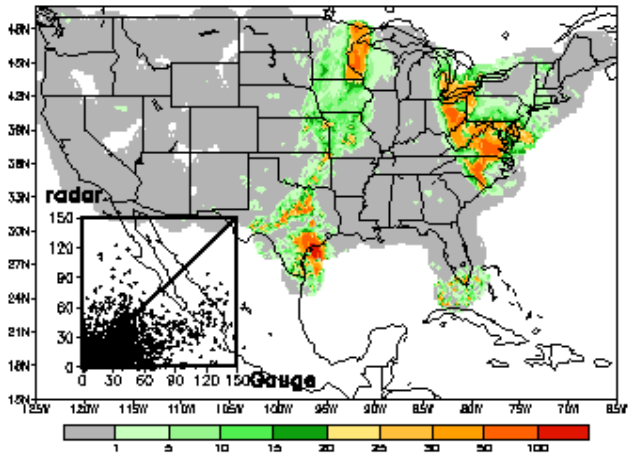
gauge \ PERSIANN	< 1	≥ 1
< 1	8082.	1497.
≥ 1	1081.	3168.

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

PERSIANN



Radar



Some On-Going Activities:

International

- PUBS
- GEWEX Initiatives (HAP, HEPEX)
- UNESCO Programs and OTHERS…..

USA

- AHPS
- CUAHSI AND some others

It requires International cooperation to make progress

Let me Stop and have my Colleagues add their thoughts

Especially, their " Messages to the Next Generation"

Because Kuni did a lot of Thinking this Morning!

So, I invite him to speak next!

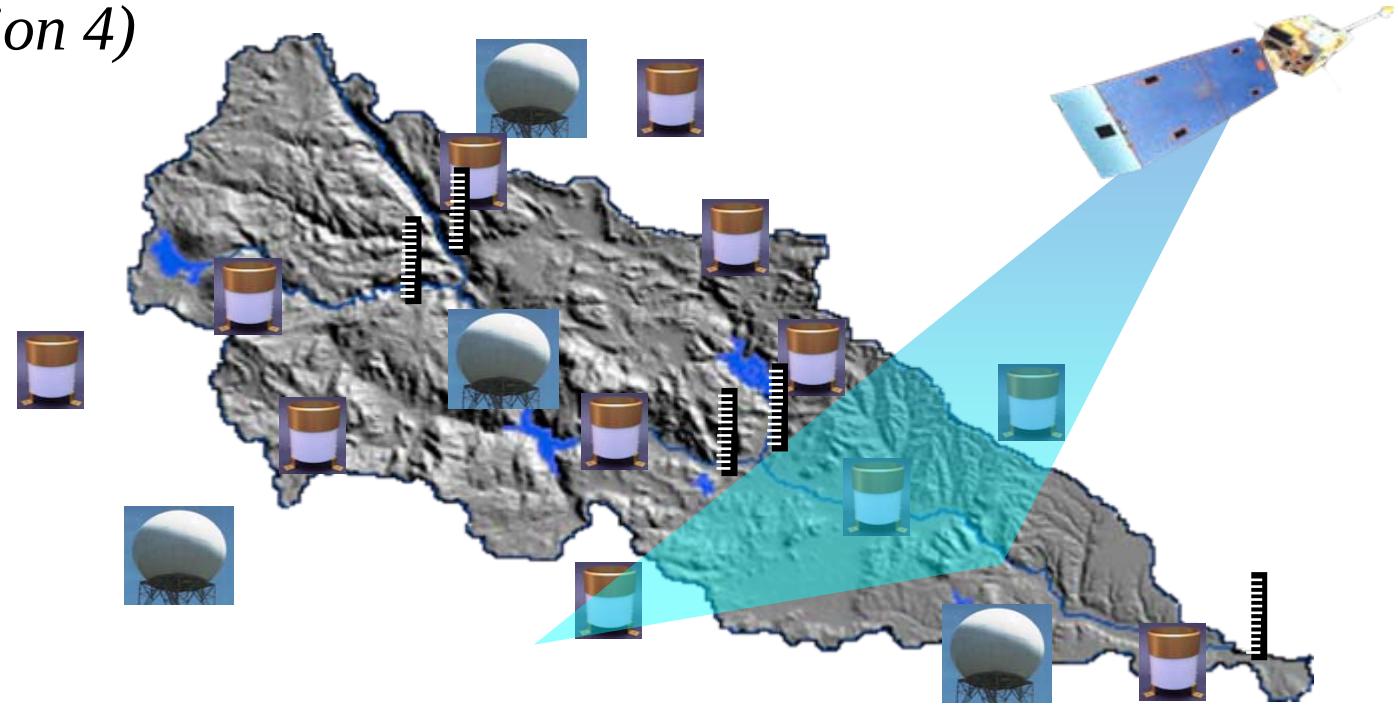
Thanks For the Invitation
and Listening
Mt. Fuji Sept. 2006

PUBS: Prediction of Ungauged Basins

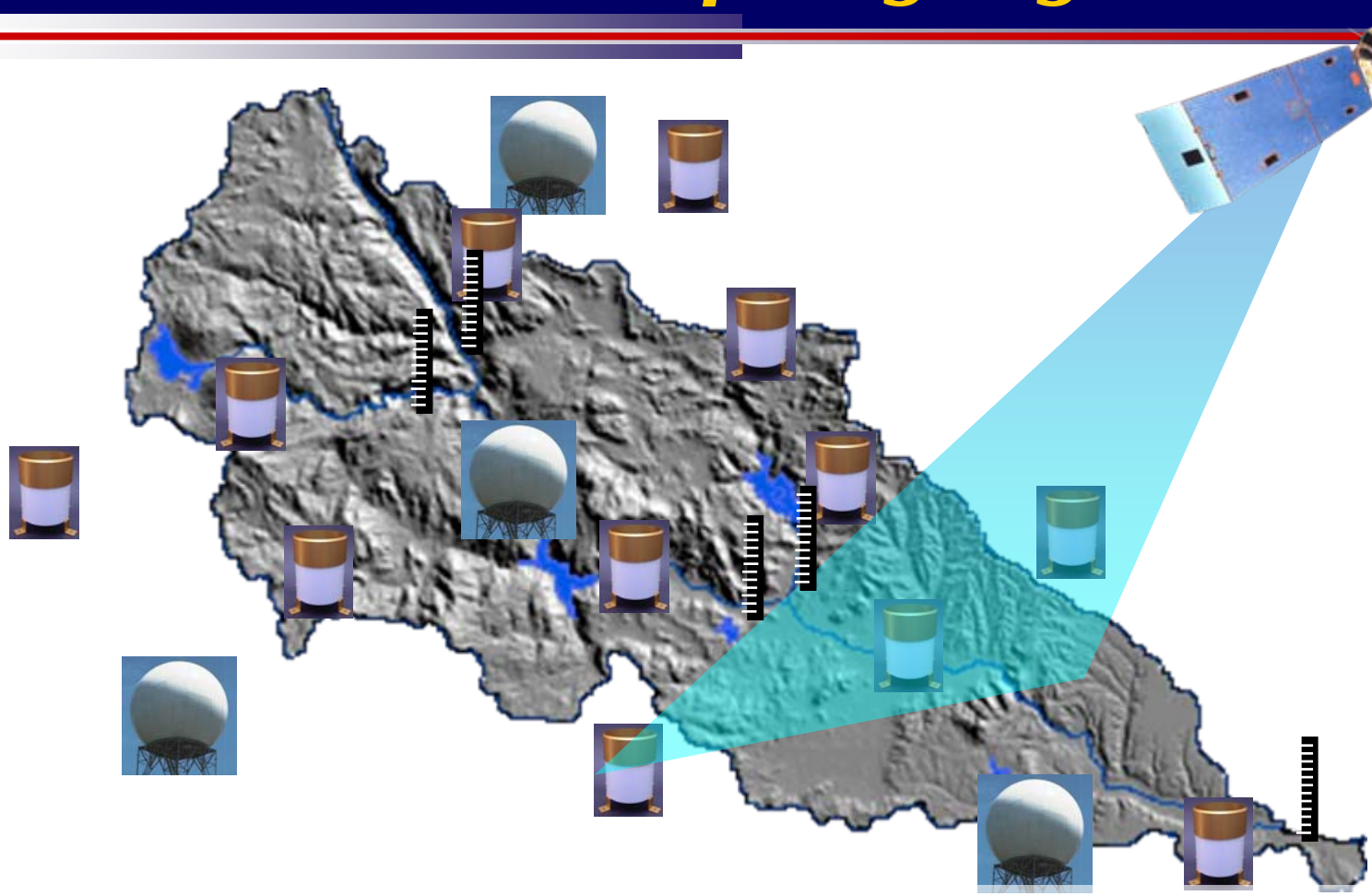
Definition

prediction or forecasting of the hydrological responses … **of ungauged or poorly gauged basins**, and **its uncertainty**, … with no possibility or allowance for direct calibration

"Every Basin is "Ungauged" in some respect. *(PUB Science Plan Version 4)*



PUBS: Prediction of Ungauged Basins



What Distinguishes PUBS uniqueness?

"**all thing to all people**", or "**business as usual**".

Dreaming a Future Scenario for Hydrometeorology

Irvine Weather

MY Y! RSS

Currently:		High: 86°
79°	Thunder in the Vicinity	Low: 68°

0 10 20 30 40 50 60 70 80 90 100 110

- Text Forecast
- Records & Averages
- Get this forecast by email
- Get Yahoo! Weather on your desktop

5 Day Forecast

Today	Tomorrow	Thu	Fri	Sat	6-10 Day
Sunny	Partly Cloudy	Sunny	Partly Cloudy	Mostly Sunny	Extended Forecast
High: 80° Low: 58°	High: 82° Low: 60°	High: 80° Low: 62°	High: 81° Low: 64°	High: 79° Low: 63°	

Dreaming a Future Scenario for Hydrometeorology

Irvine Weather

MY Y! RSS

Currently:		High: 86°
79°	Thunder in the Vicinity	Low: 68°

0 10 20 30 40 50 60 70 80 90 100 110

- Text Forecast
- Records & Averages
- Get this forecast by email
- Get Yahoo! Weather on your desktop

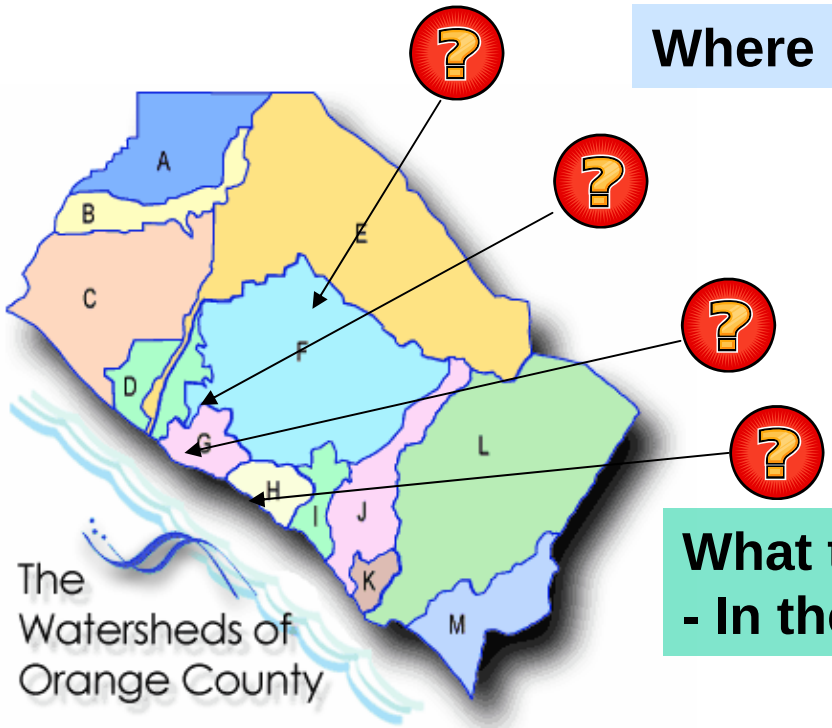
5 Day Forecast

Today	Tomorrow	Thu	Fri	Sat	6-10 Day
Sunny	Partly Cloudy	Sunny	Partly Cloudy	Mostly Sunny	Extended Forecast
High: 80° Low: 58°	High: 82° Low: 60°	High: 80° Low: 62°	High: 81° Low: 64°	High: 79° Low: 63°	

5 Day Hydrologic Forecast (Streamflow)

Today	Tomorrow	Thu	Fri	Sat	6-10 Day
Low Risk	Med Risk	Low Risk	High Risk	Flooding	Extended Forecast
High: 20ft Low: 18ft	High: 28ft Low: 25ft	High: 18ft Low: 14ft	High: 34ft Low: 32ft	High: 34ft Low: 34ft	

Might as Well: Go a Step Further Dreaming!



Where in the watershed?

What time on Saturday?
- In the morning, afternoon, or at night?

5 Day Hydrologic Forecast (Streamflow)

Today	Tomorrow	Thu	Fri	Sat	6-10 Day
Low Risk	Med Risk	Low Risk	High Risk	Flooding	Extended Forecast
High: 20ft Low: 18ft	High: 28ft Low: 25ft	High: 18ft Low: 14ft	High: 34ft Low: 32ft	High: 34ft Low: 34ft	