

# *Ensuring Water in a Changing World*

## *State of Hydrologic Prediction: What have we learned up to recent time?*



*NOAA Water Science Challenge Workshop*  
*30 Aug. – 1 Sept. 2011, Boulder CO*  
Center for Hydrometeorology and Remote Sensing, University of California,  
Irvine

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# *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*

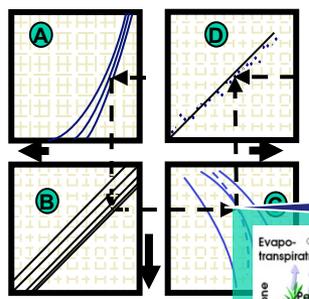
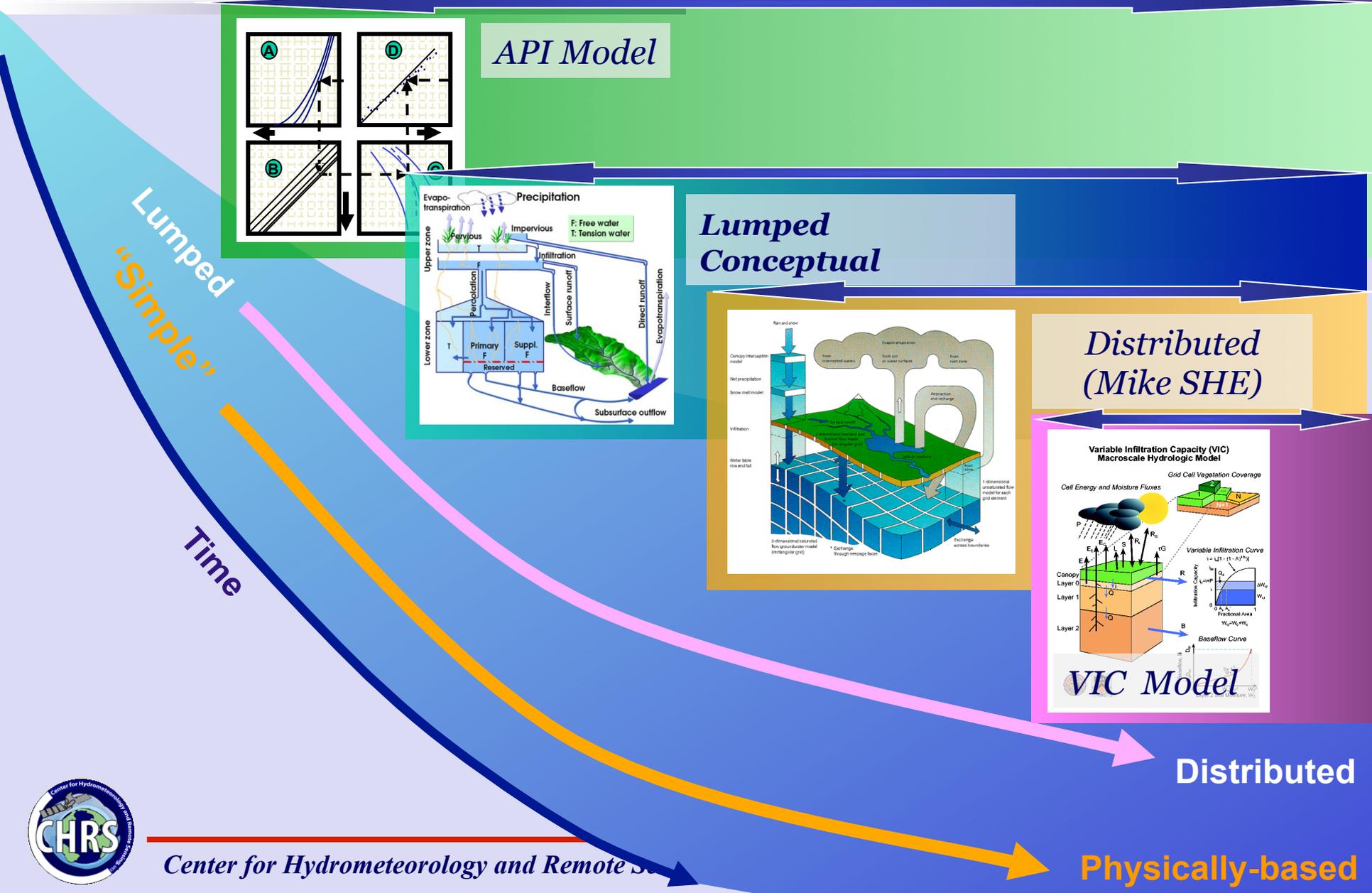
*Mid-range*

*Long-range*

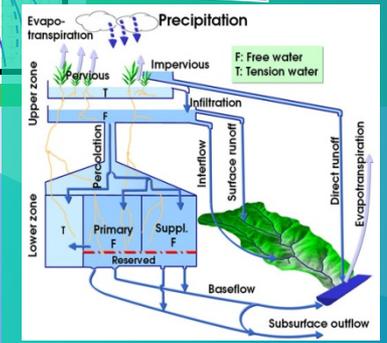
*Forecast Requirements*



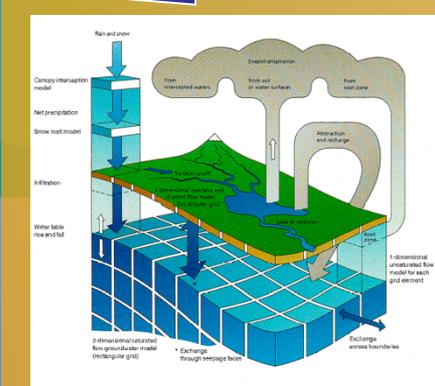
# Evolution of Hydrologic R-R Models



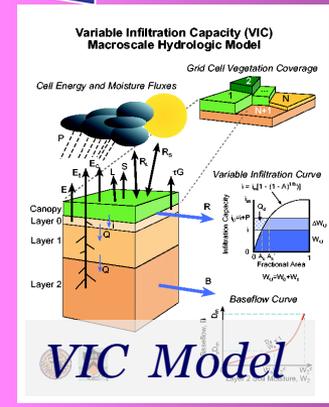
API Model



Lumped Conceptual



Distributed (Mike SHE)



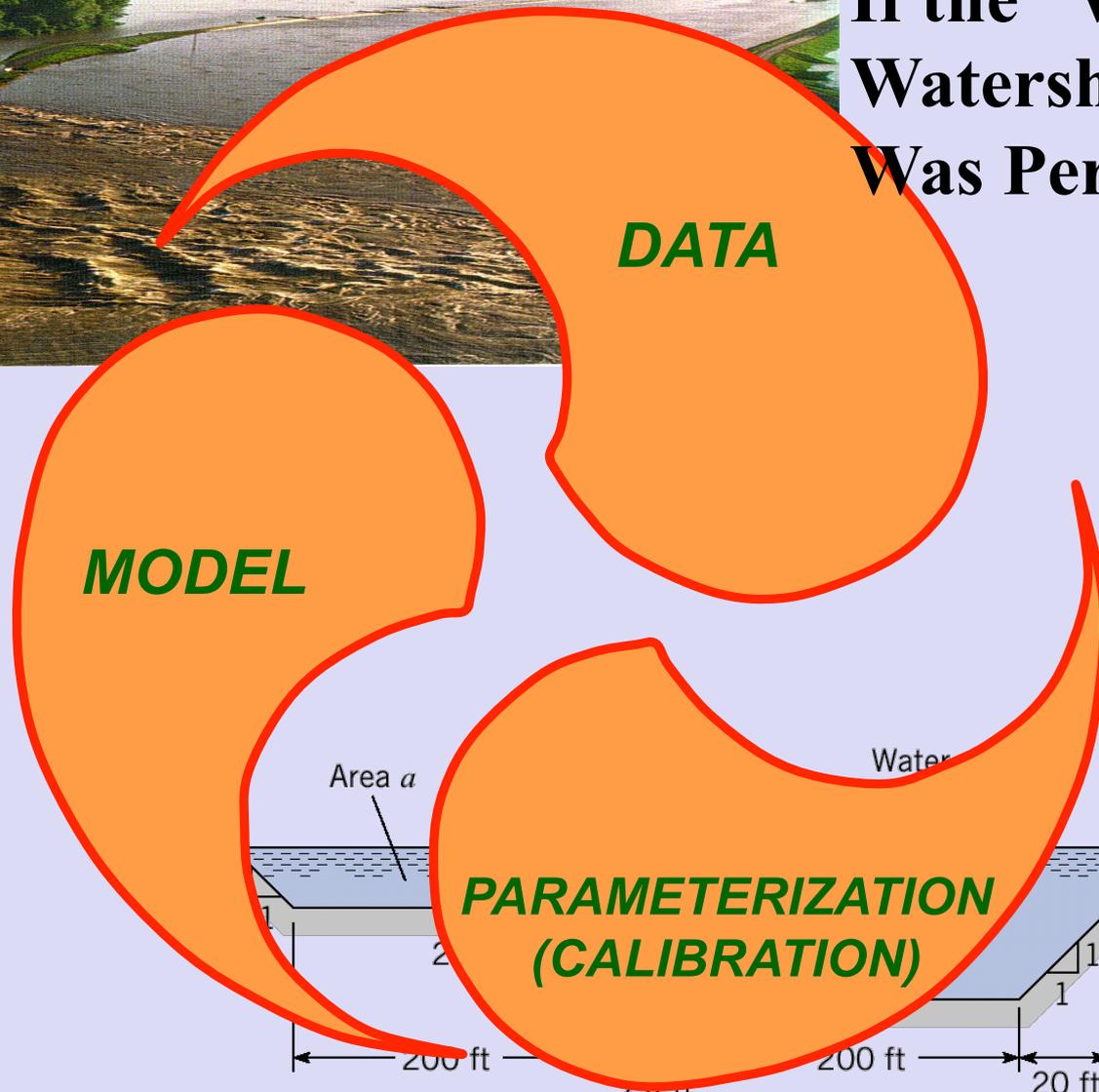
Distributed Physically-based



# Hydrologic Modeling: 3 Elements!



If the “World” of Watershed Hydrology Was Perfect!





*Reviewing some recent model  
evaluation studies*

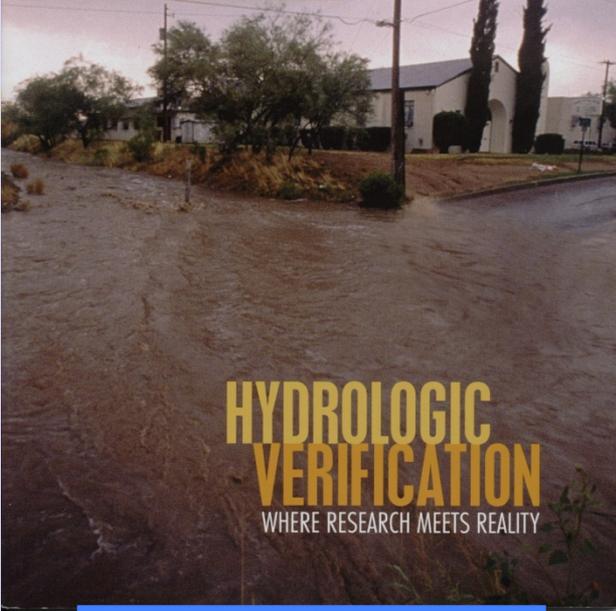
# Status of Forecast Skill in Hydrologic Models

Volume 88 Number 4 April 2007

# BAMS

Bulletin of the American Meteorological Society

DYNAMICAL CLIMATE REANALYSIS  
HURRICANE DESTRUCTIVE POTENTIAL  
AEROSOLS IN ARCTIC CLIMATE



## HYDROLOGIC VERIFICATION

WHERE RESEARCH MEETS REALITY

### HYDROLOGIC VERIFICATION

A Call for Action and Collaboration

BY EDWIN WELLES, SOROOSH SOROOSHIAN, GARY CARTER, AND BILLY OLSEN

## River-Level Forecasting Shows No Detectable Progress in 2 Decades

And you thought weather forecasters had it tough. Hydrologists looking to forecast the next flood or dangerously low river flow must start with what weather forecasters give them—predictions of rain and snow, heat and cold—and fold that into myriad predictive models. Then those models must in turn forecast how rain and any melted snow will flow from rivulet to river while liable to loss to evaporation, groundwater, reservoirs, and farmers' fields. During their century in the forecasting business, hydrologists have developed a modicum of skill, but a newly published study fails to find any improvement during the past 20 years in forecasting river levels out to 3 days.

"It's a pretty shocking result," says hydrologist Thomas Pagano of the U.S. Department of Agriculture's Natural Resources Conservation Service in Portland, Oregon, who was not involved in the study. If the new results are widely applicable, "we're treating water in terms of skill." The answer, Pagano and others say, is for hydrologic forecasters to evaluate their past performance much more rigorously.

Grading past forecasts has long been standard practice in weather forecasting. Such forecast verification has shown that in the early to mid-1990s really did lengthen warning times of tornadoes. Weather forecasters also compare proposed improvements in forecasting procedures against past performance before adopting them. Yet "little verification of hydrologic forecasts has been conducted to date," says hydrologist Edwin Welles of the National Weather Service (NWS) in Silver Spring, Maryland.

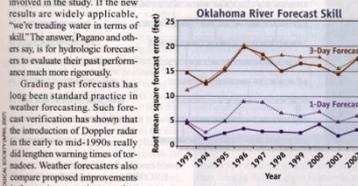
So Welles—who has worked at NWS since 1994—tackled hydrologic verification in his 2005 dissertation for the University of Arizona. He considered NWS forecasts and observations of river levels during 10 years at four locations in Oklahoma, and during 20 years at 11 locations along the mainstem of the Missouri River. On the Missouri, a forecast location had 500 to 1000 upstream basins feeding water to it. Each basin required its own set of calibrated predictive models, each predicting a different step in water flow, such as

how much water was added by melting snow versus how much soaked into the ground.

In the April *Bulletin of the American Meteorological Society* (BAMS), Welles and colleagues report mixed results. Forecasters showed real skill in predicting river levels 1 and 2 days in advance compared with assuming that river levels would not change. But despite new models, more-powerful computers, better ways of displaying data and results, and even improved precipitation forecasts from NWS, the 1- and 2-day predictions didn't become more accurate over the 1 or 2 decades of the verification study, at least in the two areas studied.

Troubleshooting hydrologic forecasting to understand why it's been resisting improvement will take "objective study and well-structured verification," says Welles. "not expert opinion or ad hoc experience." BAMS

### Oklahoma River Forecast Skill



Flat-lining. Although errors in river-level forecasts (solid lines) can be smaller than a simple assumption of no change (dotted lines), errors have not declined with changes in forecasting procedures.

Editor-in-Chief Jeff Rosenfeld agrees. Writing in an accompanying editorial, he finds that "forecasting must include verification if it is to be scientific. Every forecast is like a hypothesis, and in science every hypothesis must ultimately be tested."

NWS is taking Welles's research seriously. It began verifying river forecasts at all 4600 of its locations last year. And last fall, an NWS team produced a plan based on Welles's research that should lead to a single hydrologic verification system by 2011. By then, forecasters should be stroking against the current toward better forecasts.

—RICHARD A. KERR

## SCIENCE SCOPE

### War on TB

The World Health Organization (WHO) has jumped on the news wave following the Atlanta lawyer who flew commercially to several countries with a dangerous form of tuberculosis. WHO's Stop TB Partnership will issue new guidance this month for countries battling drug-resistant forms of the disease. Although TB is curable, drugs fail in one-third of people with multidrug-resistant strains and in more than two-thirds of those with extensively drug-resistant forms.

WHO's Paul Nunn says strengthening labs in the developing world is key. "South Africa has more laboratories capable of doing culture and drug-susceptibility testing than the rest of the continent put together," he says. The plan also calls for expanding surveillance and implementing infection-control measures in hospitals. The plan's estimated yearly cost is \$1 billion, but Nunn predicts it would save 1.2 million lives by 2015.

—JOHN COHEN

### Trial for Vaccines

Parents who blame vaccines for their children's autism finally have their day in court. Congress shielded vaccine manufacturers from liability in 1986, requiring that claims be filed with the U.S. Court of Federal Claims in Washington, D.C., before a federal compensation fund pay damages. More than 4800 parents have filed claims since 1999, and the court began hearing evidence this week in a representative test case.

The main focus is on a mercury-based preservative called thimerosal. Epidemiologists have found no link between autism and this ingredient, which has been phased out of almost all childhood vaccines (Science, 12 September 2003, p. 1454). "This sort of palaver has the potential to inhibit vaccination," rues William Schaffner of Vanderbilt University in Nashville, Tennessee. A ruling could take as long as a year.

—ERIC STOKSTAD

### Get Back to the Lab

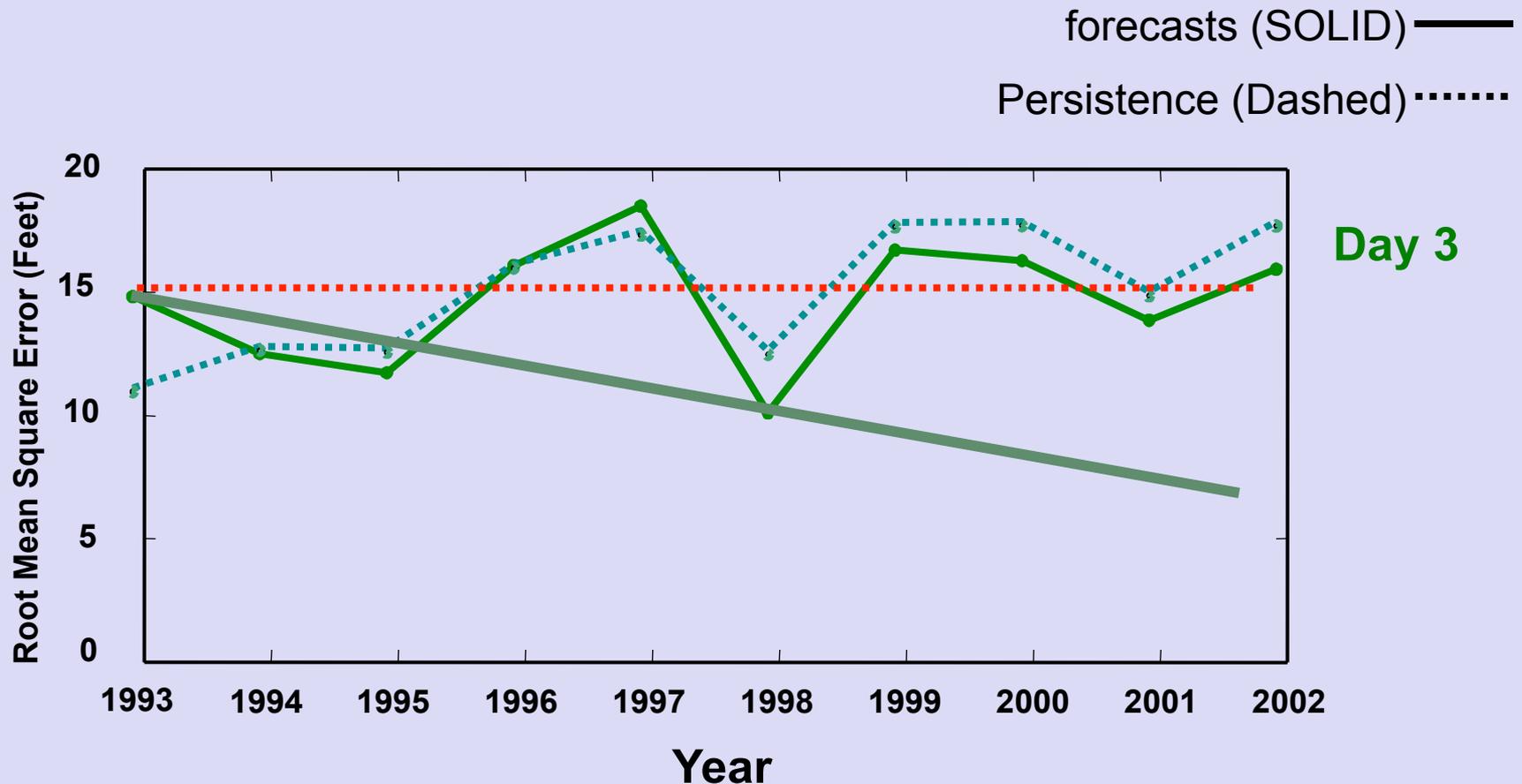
Asian research funding could soon eclipse European public and private spending on research and development (R&D), says a new report released by the European Union (E.U.). China could overtake the E.U. by 2009 in terms of R&D spending as a percentage of gross domestic product, the report says. It notes that European industry contributes less to research: only 55% of total R&D spending, compared to 66% (U.S.), 67% (China), and 75% (both Japan and South Korea).

—DANIEL CLERY



# Some Verification Results: *NWS-SMA Model*

**RMSE above flood stage: 5 Arkansas/Oklahoma locations**

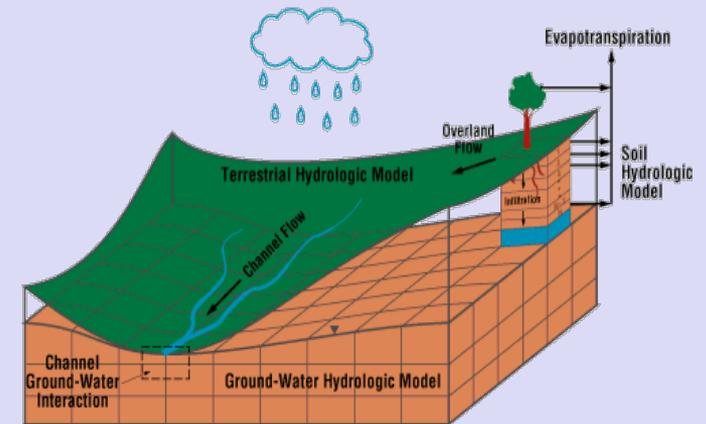


Edwin Welles: 2005

# DMIP-1 Findings: In a Nutshell



No Major Difference between the performance of **Lumped** and **distributed** models



DMIP 1 Results (From Reed et al., 2004)

# *Some General conclusion from DMIP 2*

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- 1. “Distributed models of the type used for hydrologic modeling &/or forecasting can produce very reasonable estimates of soil moisture over diverse climatic regimes. More confident that we are getting the 'right answer for the right reason'.”*
- 2. “Distributed models that performed well for basin outlet simulations were generally able to perform well at interior simulation points.”*
- 3. “Distributed models require **high-quality data** for optimal use. More studies are needed into forcing data error propagation through distributed models.”*
- 4. “DMIP 1 and now DMIP 2 consistently show that the **best overall performing models combine the strengths of the so-called 'conceptual models' with the so-called 'physics based models'.**”*



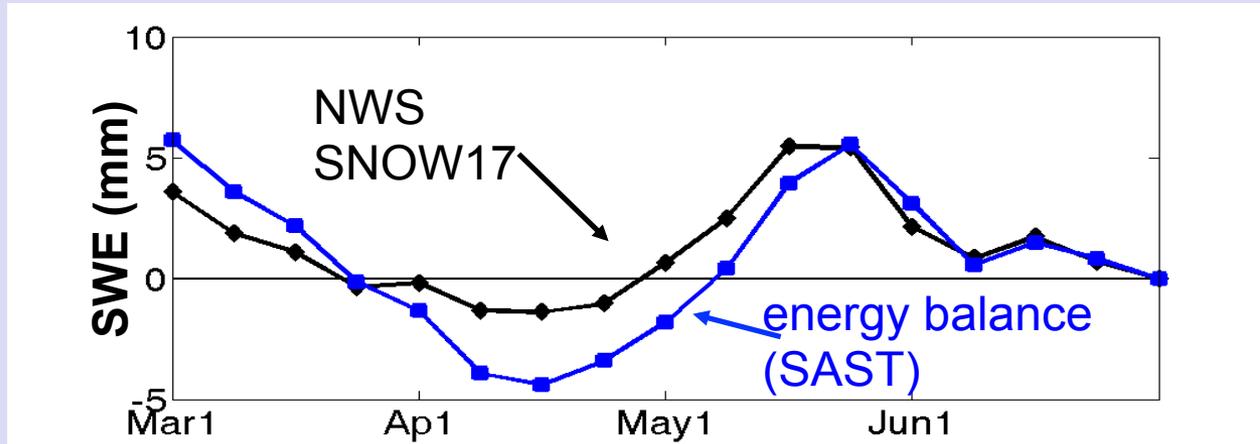
*Provided by: Michael Smith - OHD*

# Comparison of Snowmelt Models



## Temperature Index vs. Energy Balance Method

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



- Energy balance model had greater simulation errors
- But more skill in probabilistic predictions of SWE, if initialized with observed SWE
- data availability and quality issues still hinder the implementation of more advanced energy balance snowmelt models

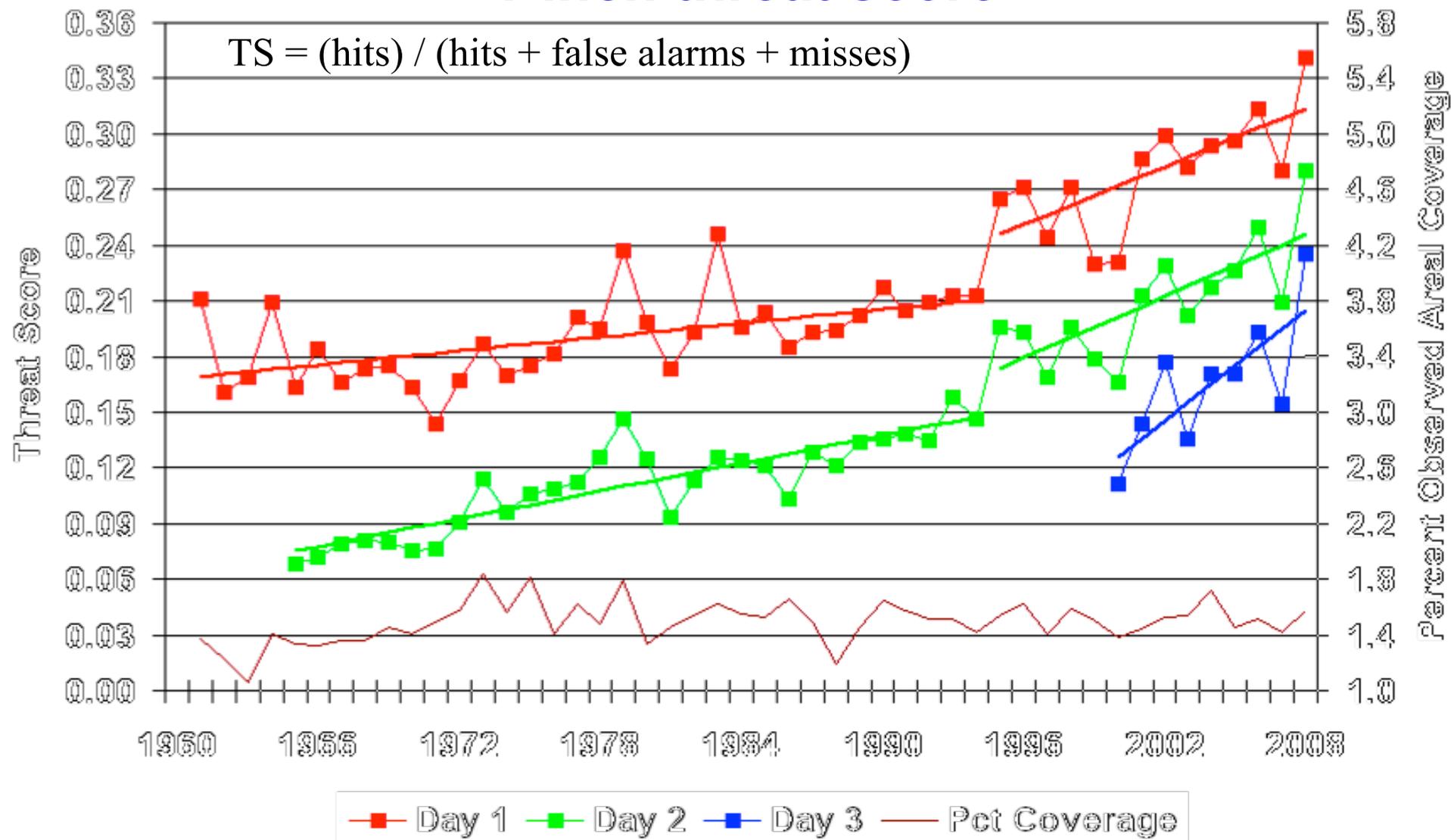


K. Franz et al, 2008 a&b



# HPC QPF verification 1-inch threat score

$$TS = (\text{hits}) / (\text{hits} + \text{false alarms} + \text{misses})$$

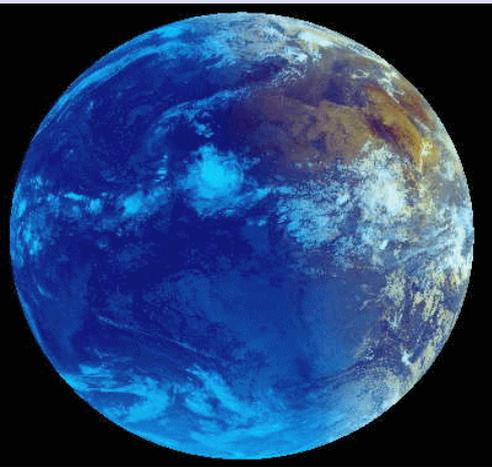


# *Recent Assessment of Seasonal Climate Forecasts*

*Quoting from  
Science, Vol. 321,  
15<sup>th</sup> August 2008*

*Livezey & Timofeyeva - BAMS, June 2008.*

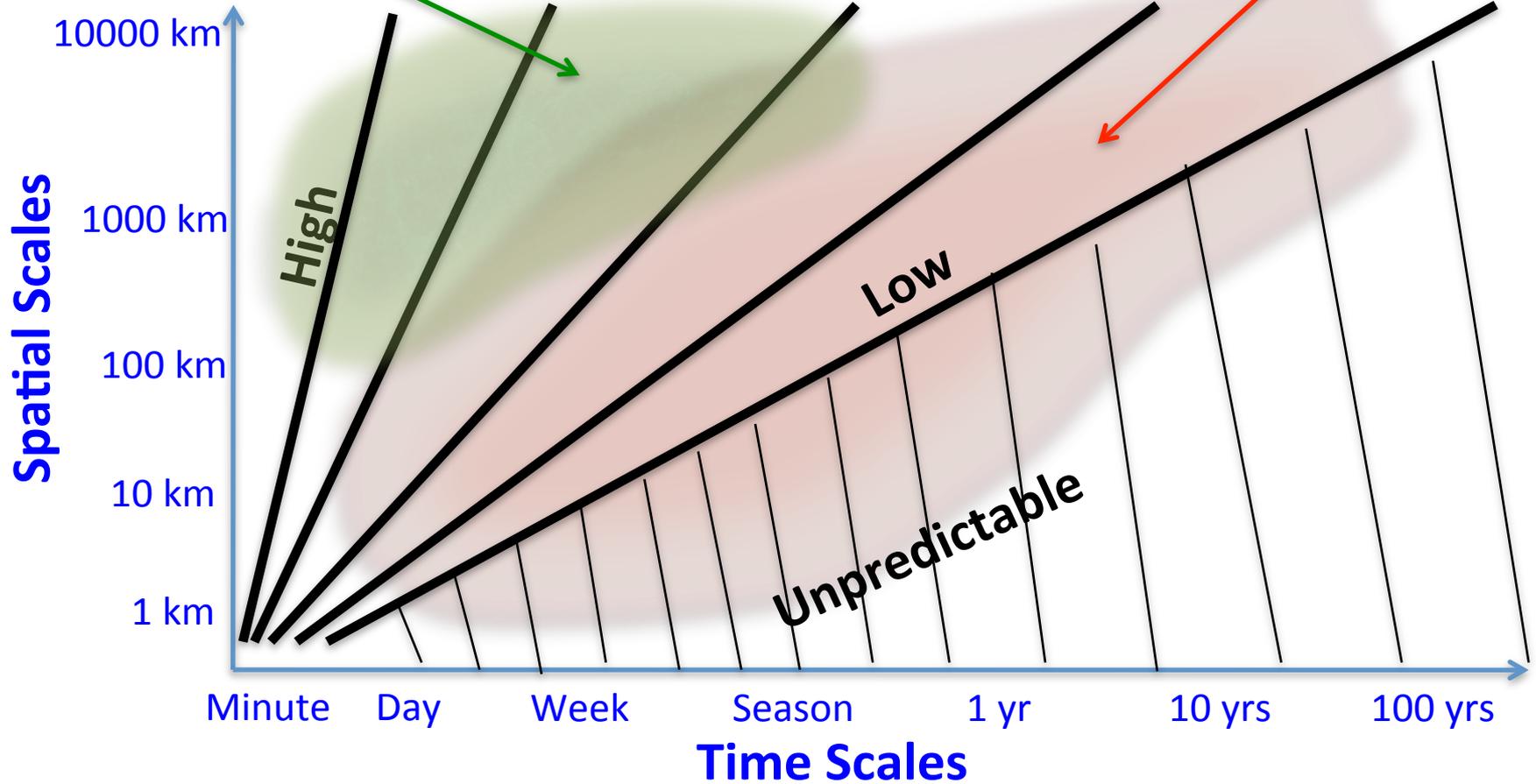
- *“About the only time forecasts had any success predicting precipitation was for winters with an El Nino or a La Nina”*



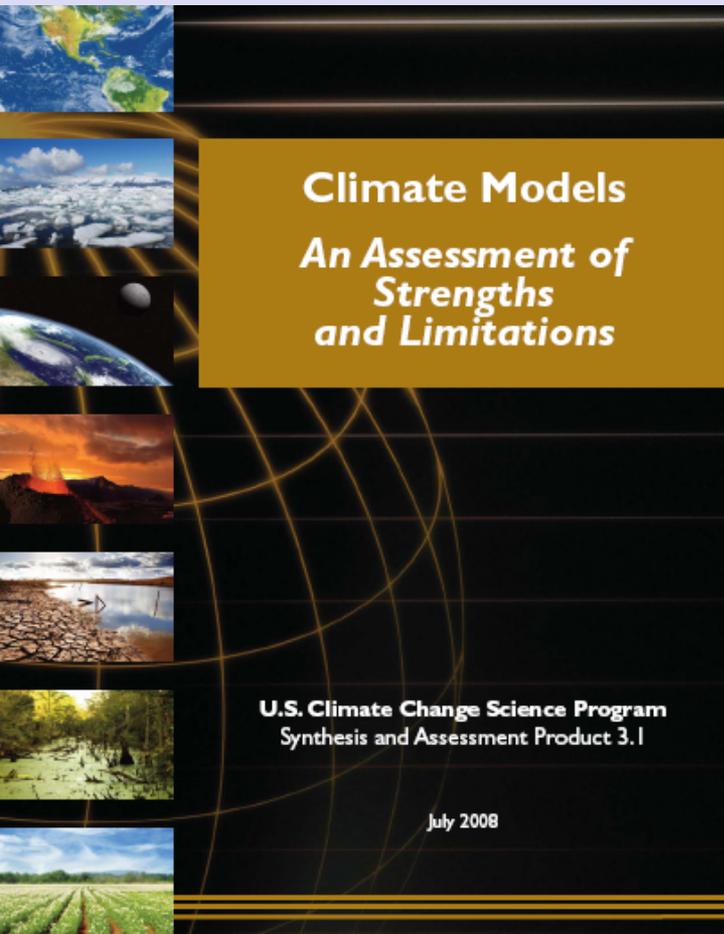
# Drought Predictability

Current Skill

User Needs



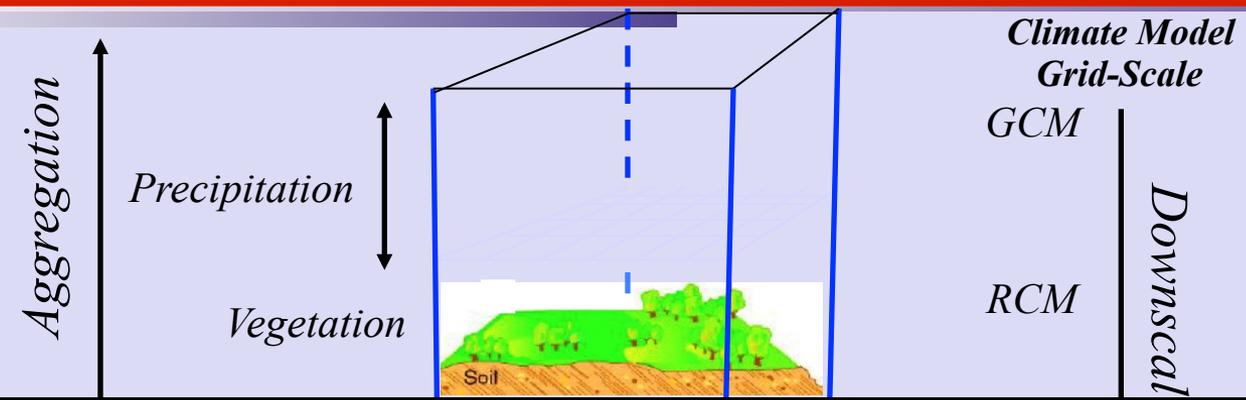
# Recent Assessment of Climate Models



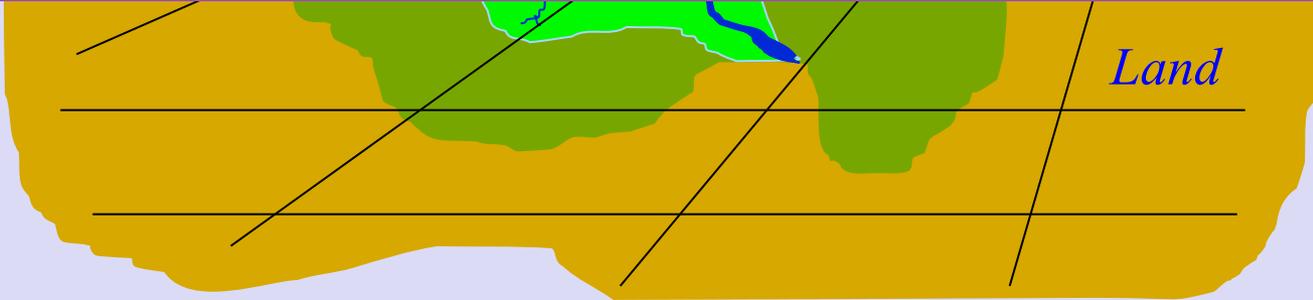
- Regional trends in extreme events are not always captured by current models
- It is difficult to assess the significance of these discrepancies and to distinguish between model deficiencies and natural variability



# Climate Model Downscaling to regional/watershed Scale



***A Valid Question to Ask:***  
***Given the Current State of Climate Models (especially at regional scales), What is the added-value of all the Downscaling Studies over traditional statistical hydrology methods in water resources studies?***



# *Interpretation of Information: El Nino Event of 1997*

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## What Forecasts Said:

“Approximately a 50% Probability of Seasonal Rainfall totals being in the wettest 33% of 1961-90”

## What Agencies Prepared for:

**Business as Usual (nothing)**

**5-10% Above Normal Rainfall**

**50% Above Normal Rainfall**

**100% Above Normal Rainfall**

**Floods equivalent to 1992-93**

**Floods worse than 1992-93 (total Armageddon)**

*Work of Hartman, Pagano, et al 2000*

