Lecture I
Hydrological modeling requirements for Water Resources Applications - Model 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

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

CHRS & Affiliates: A truly International Team

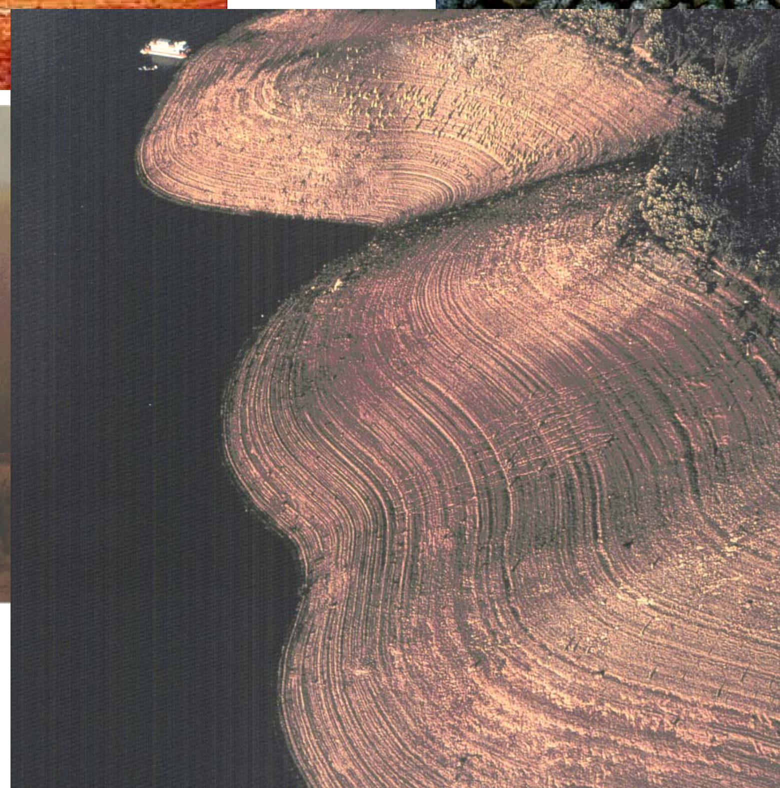
Two Primary Water Resources/Hydrology Challenges:

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

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

Hydrologic Forecasting Needs: Flash Floods

Droughts: The Other hydrologic Extreme

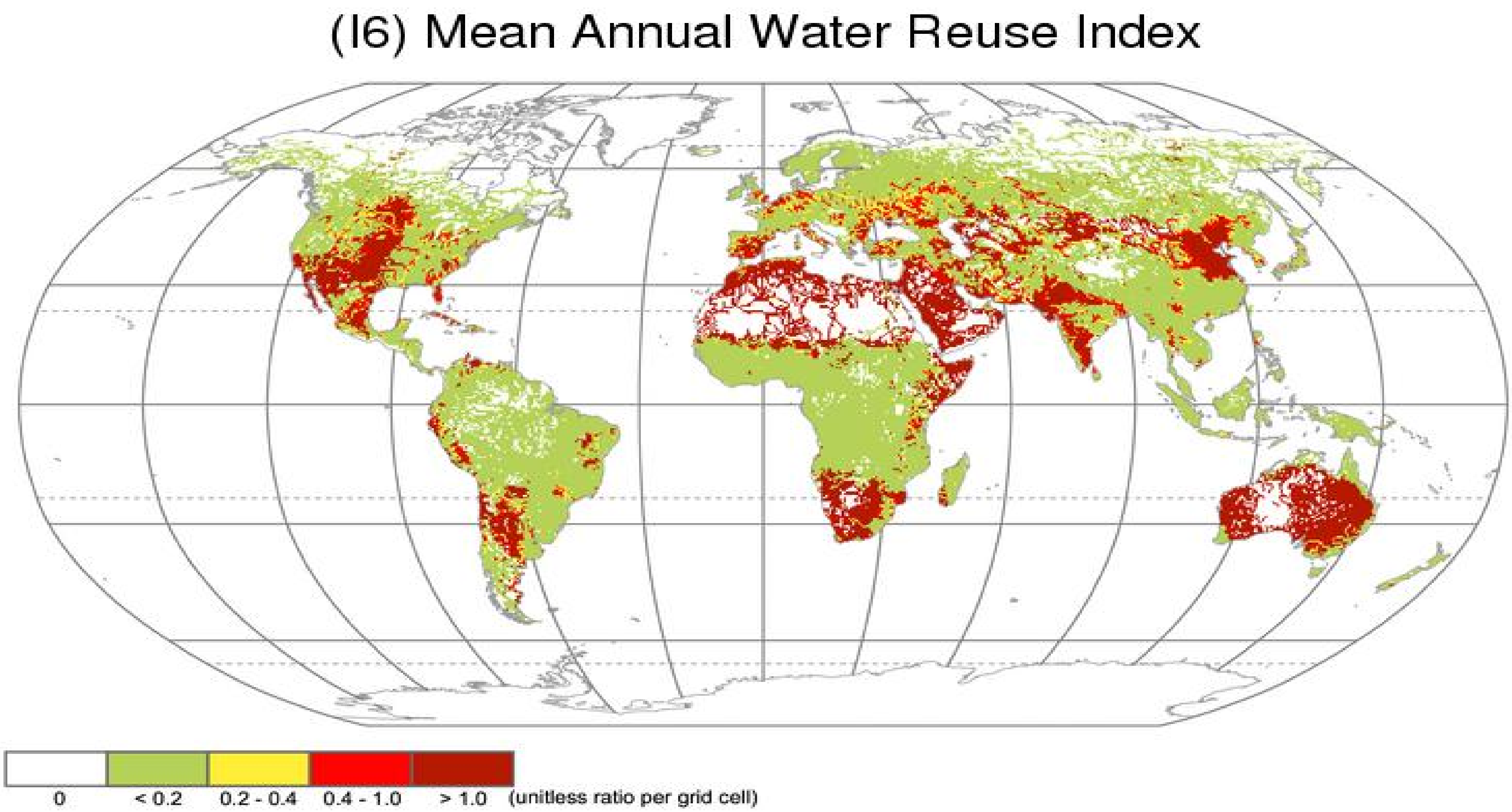


Two Primary Water Resources/Hydrology Challenges:

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

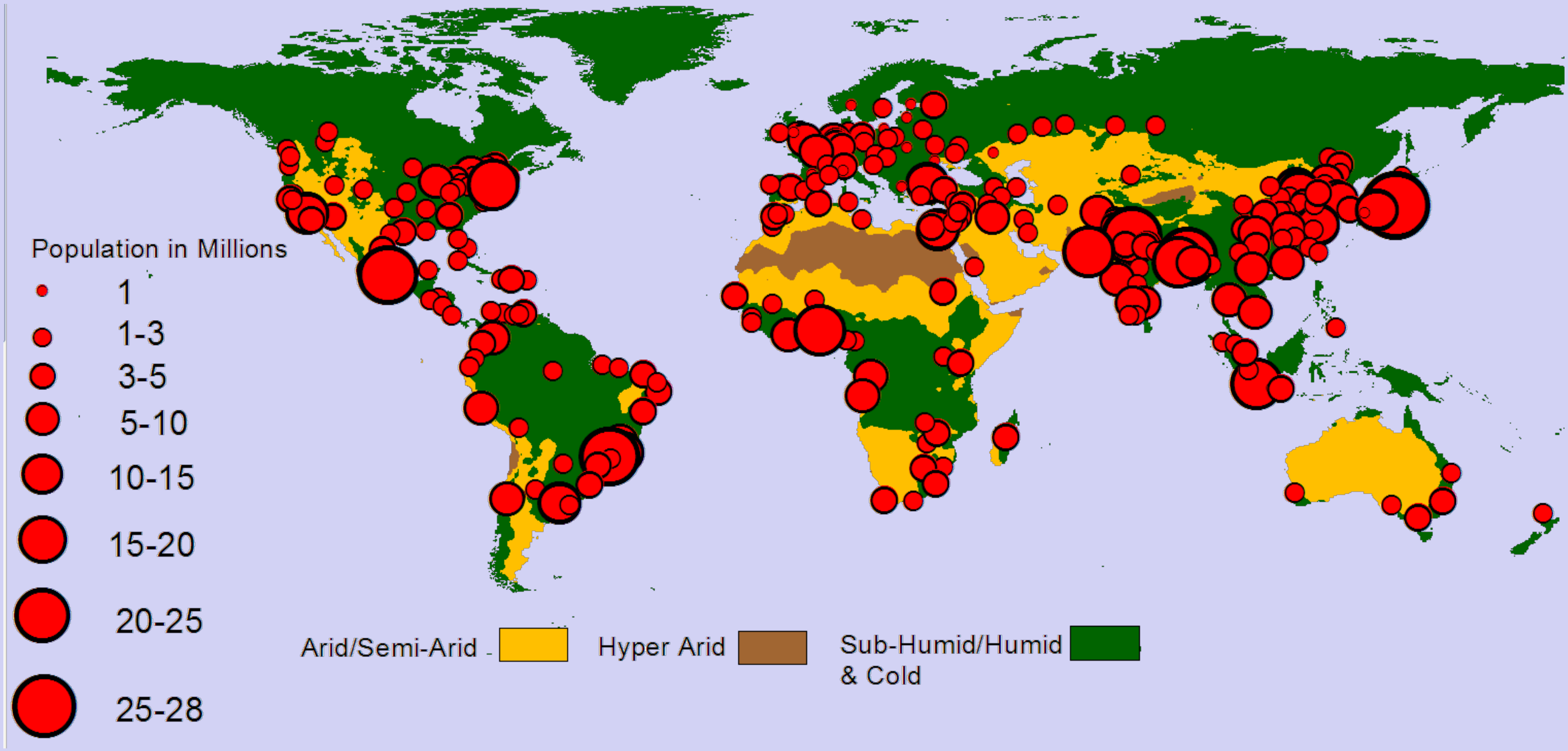
- ***Water Supply Requirements (Quantity and Quality)***

Projected Regions of Water Stress



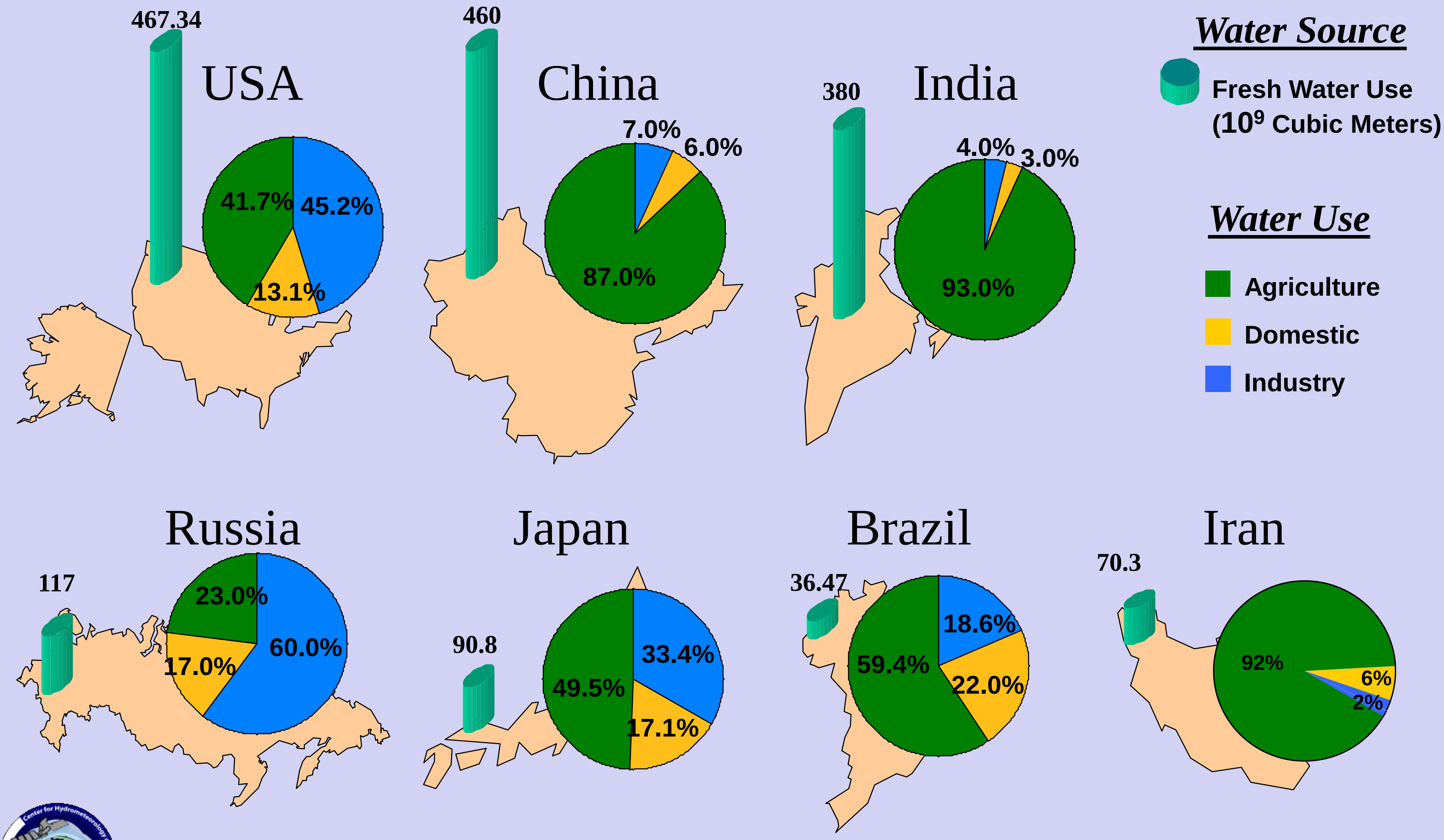
Increasing Population: Number of Mega Cities

Projected Global Population: 8.3 Billion by 2025



Global Urban population 1970: ~37%
2010: ~53%

Distribution of Fresh Water Use



Primary Solution To Meet Hydrologic Extremes and Water Resources Needs

Engineering Approach:

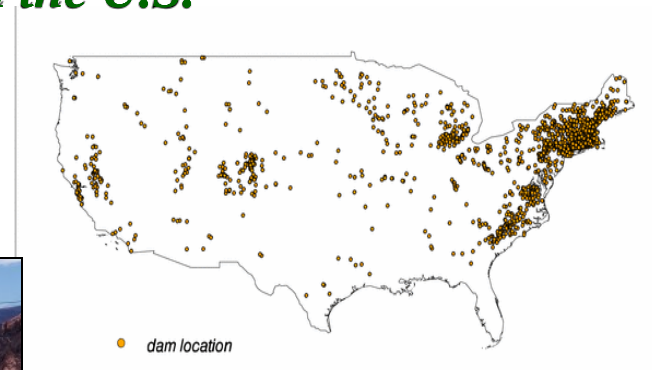
Control, Store, Pump and Transfer

A Century of Water Resources Development: *Engineering success*

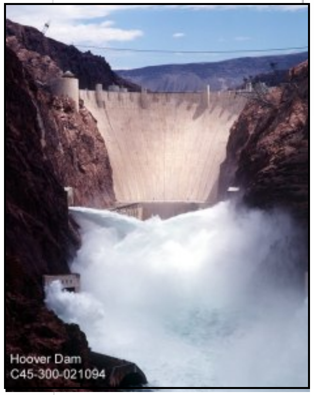
Impact on Design and Operation of Global Infrastructure

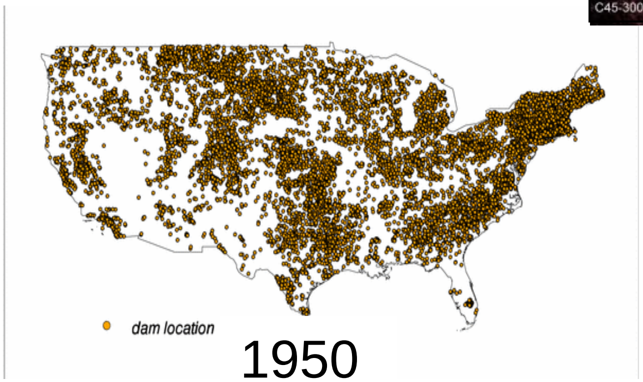
More than 70,000 Dams in the U.S.

1800

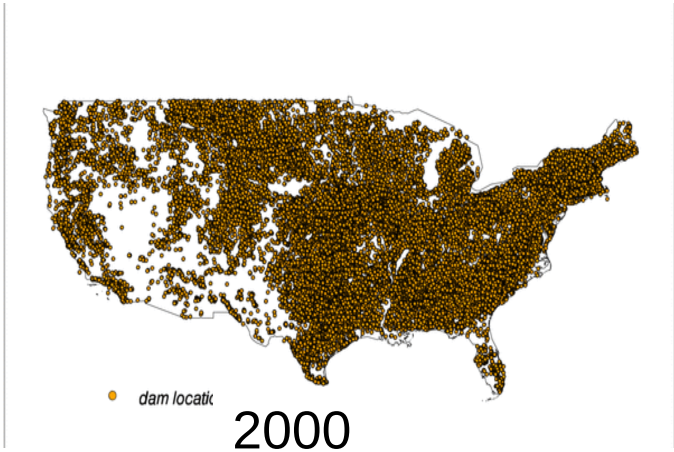


1900





1950



2000

Provided by: C. J. Vörösmarty

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

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

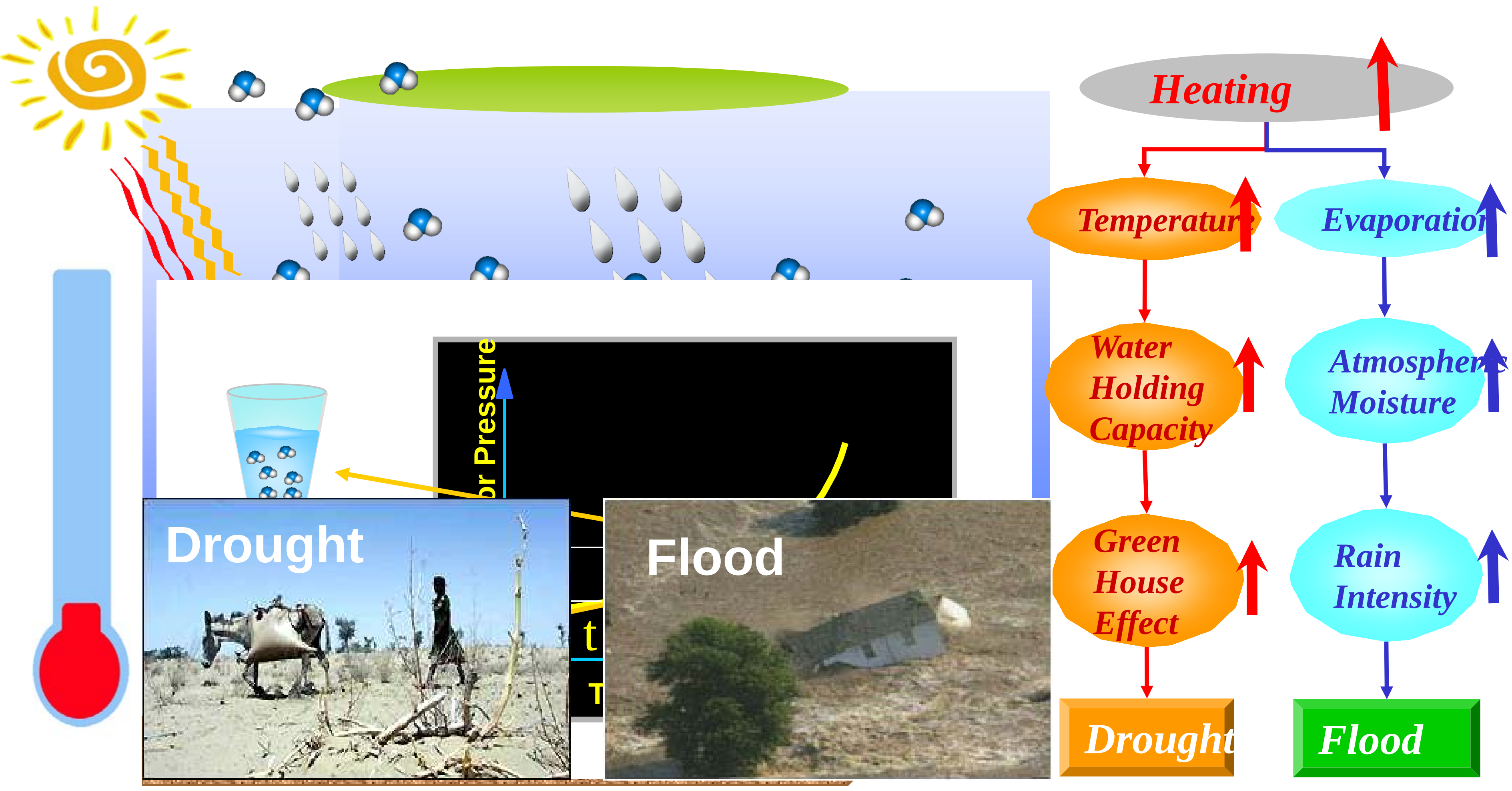
Mid-range ***Long-range***

Forecast Requirements

A Key Consideration:

The Link Between Climate and Hydrology

Global Warming And Hydrologic Cycle Connection



Created by: Gi-Hyeon Park

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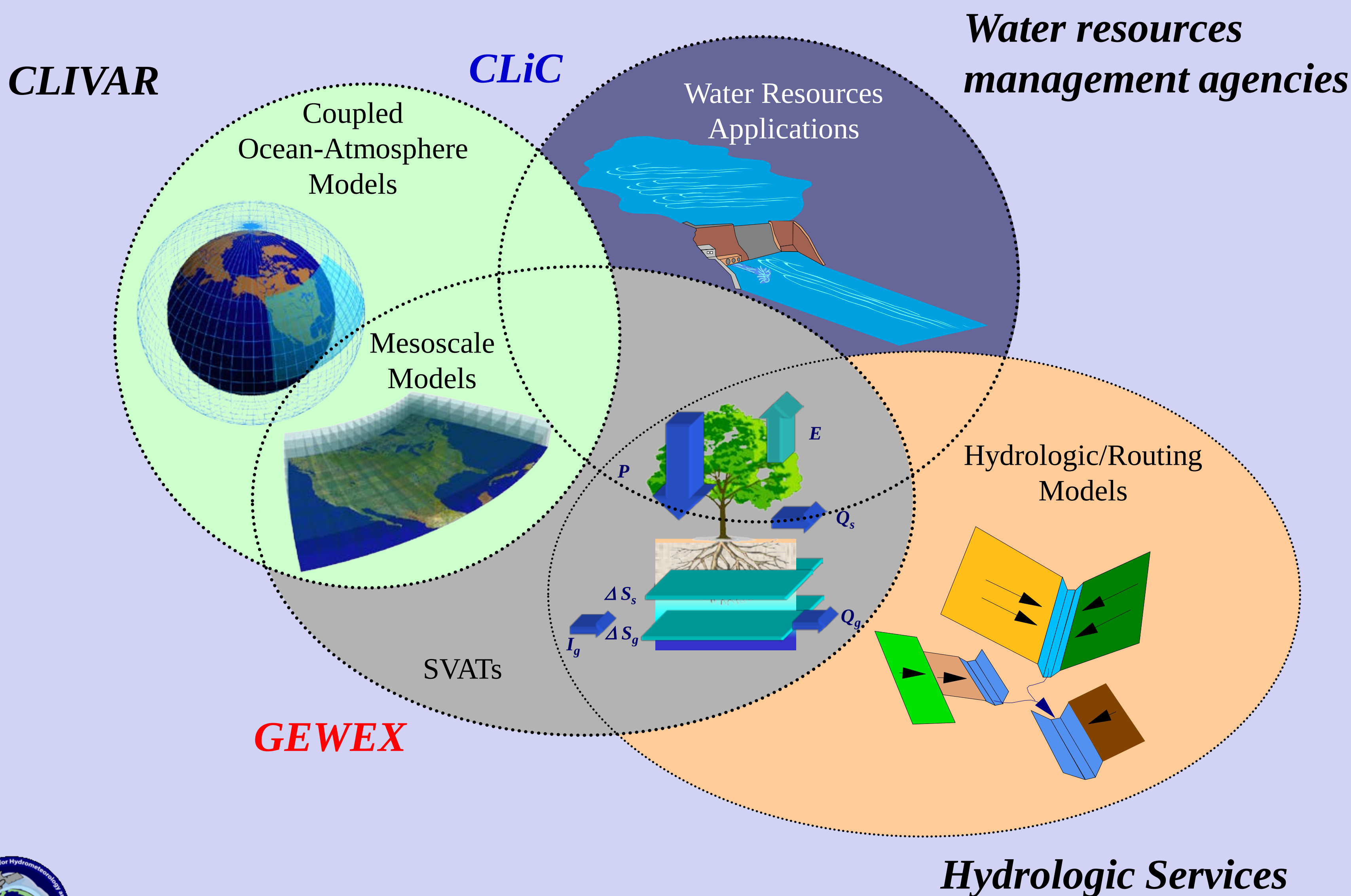
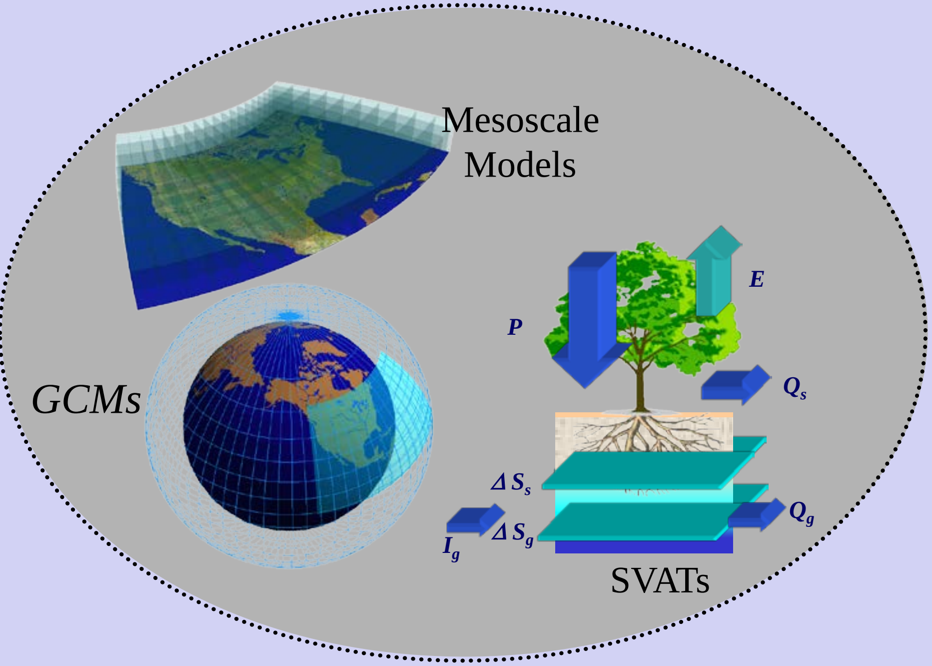
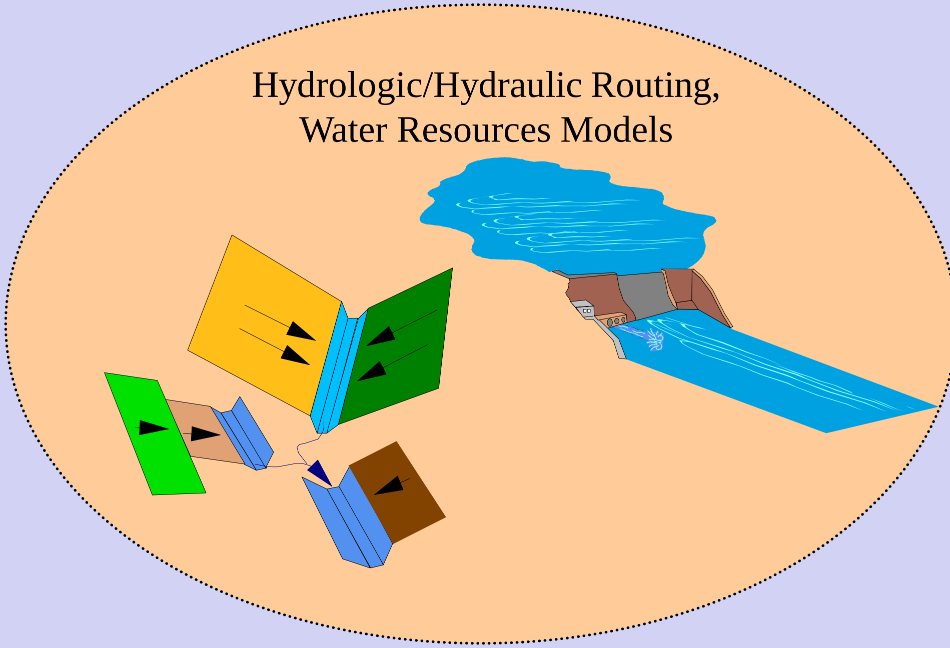
From the Global- to Watershed-Scale



SCIENCE / *ENGINEERING*





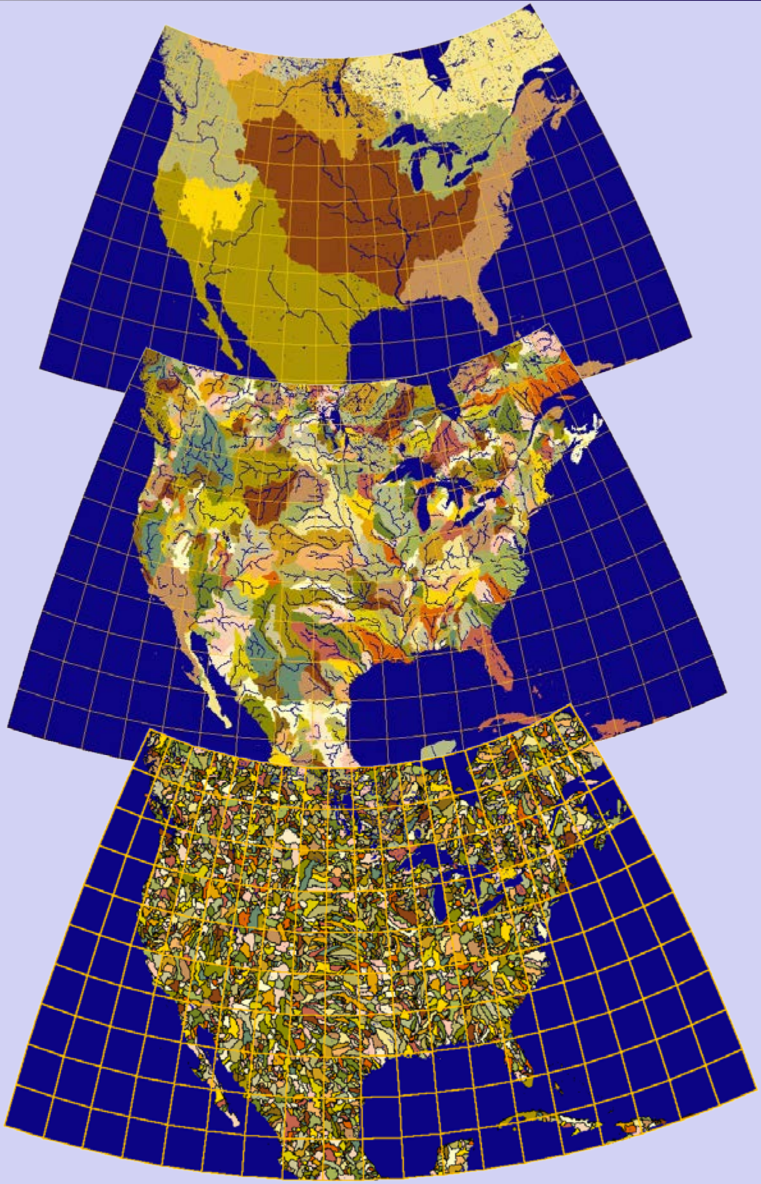
Hydroclimate Science

Hydrologic/Hydraulic and Water Resources Engineering

River Basins and Watersheds

Continental Scale:

Different Scales
Different Issues



Watershed Scale:

Where hydrology happens
Where stakeholders exist

Climate-Scale approaches to addressing hydrologic extremes

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

hours - - - - -> days - - - - -> weeks - - - -> months - - -> seasons - - -> years - - - - - - -> decades

Flash Flood Warning

Flash Flood Guidance

Flood Forecast Guidance

Reservoir Inflow Forecasts

Spring Snow Melt Forecasts

•Use of climate models: down-scaling and ensemble schemes

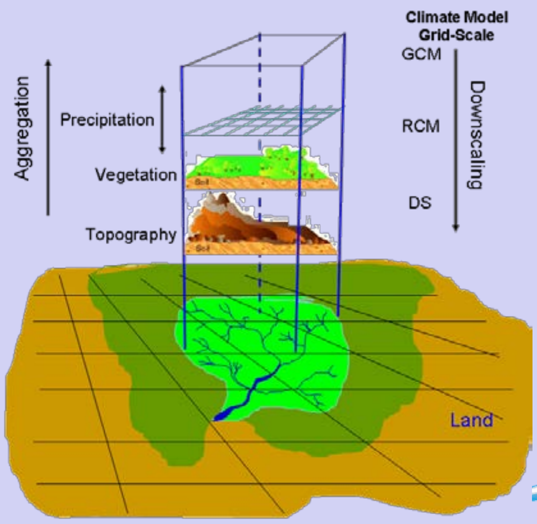
•Traditional statistical hydrology methods:

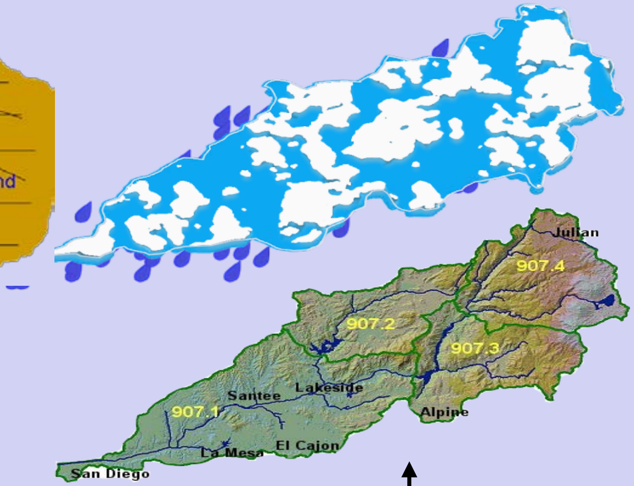
Long-range

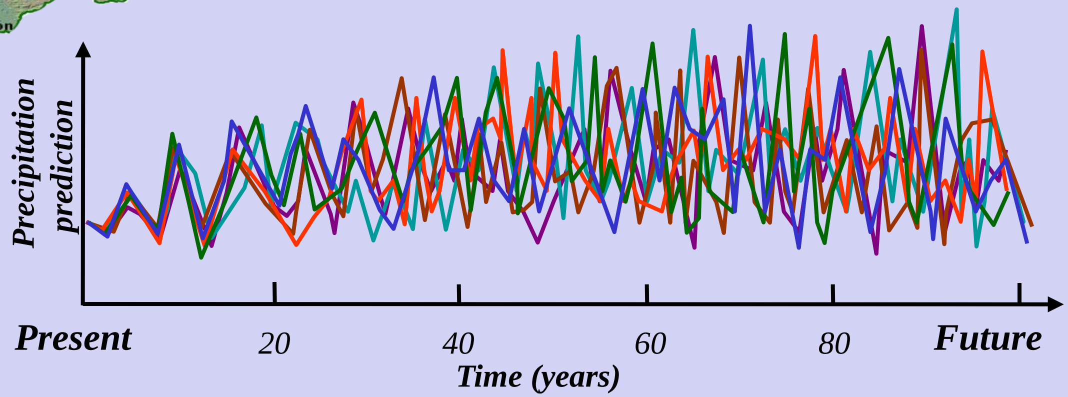
Forecast Requirements

Climate Model Downscaling to Regional/Watershed Scales

Generation of Future Precipitation Scenarios

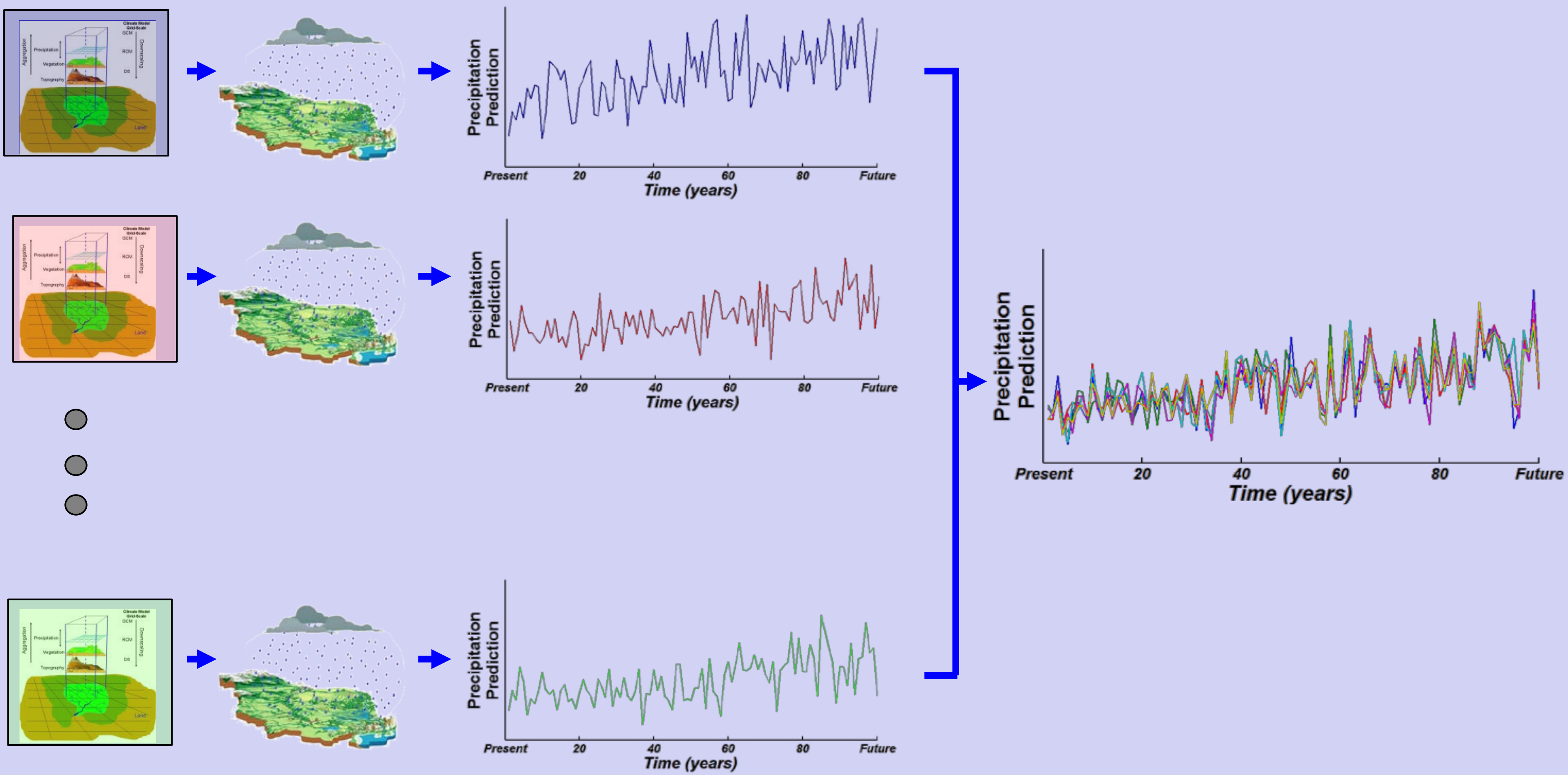






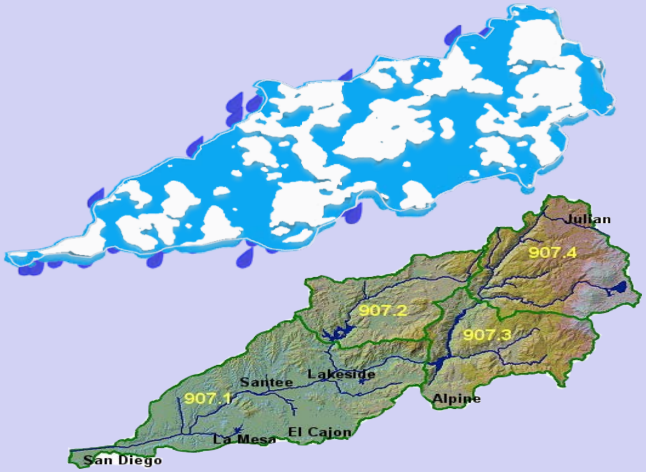
Ensemble Approach

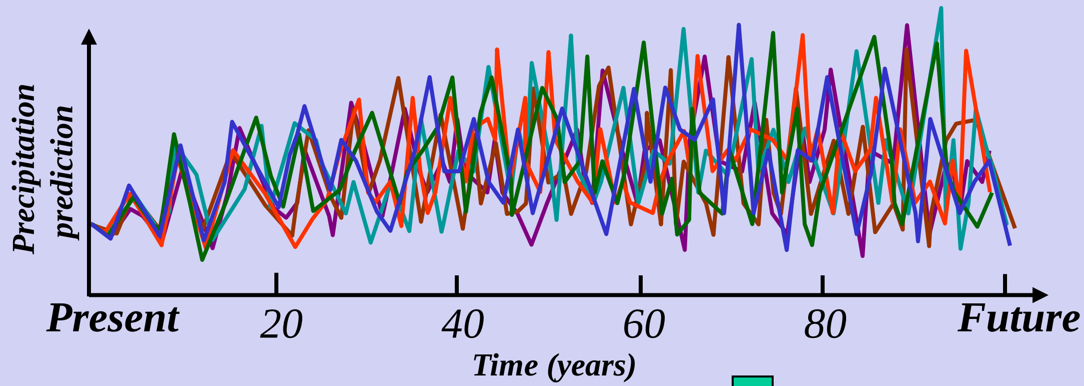
Generation of Future Precipitation Scenarios

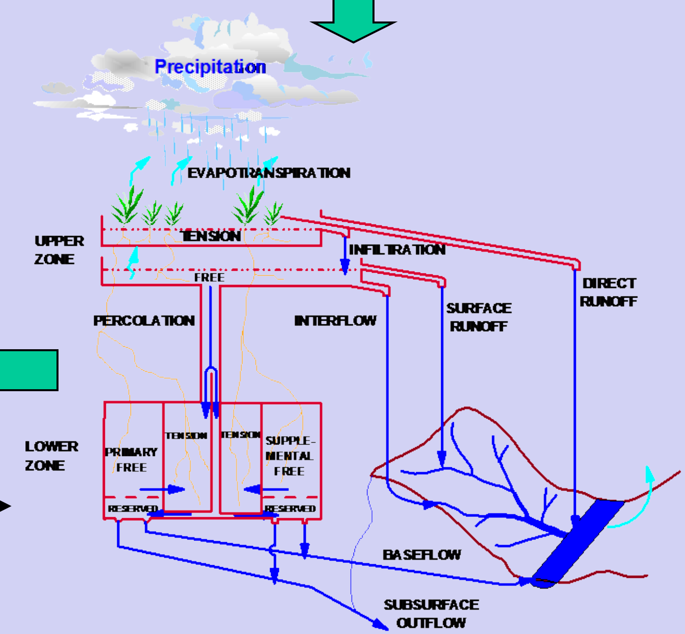


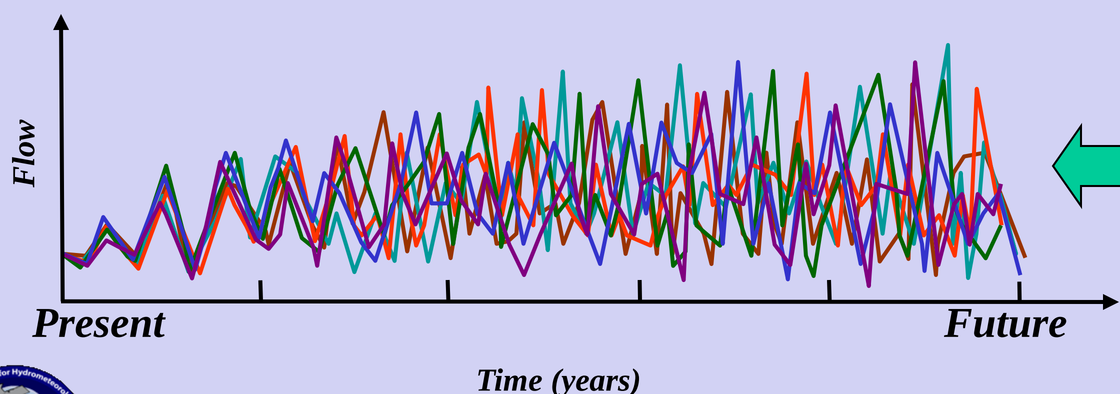
Downscaled Precipitation to Runoff Generation

Generation of Future Runoff Scenarios

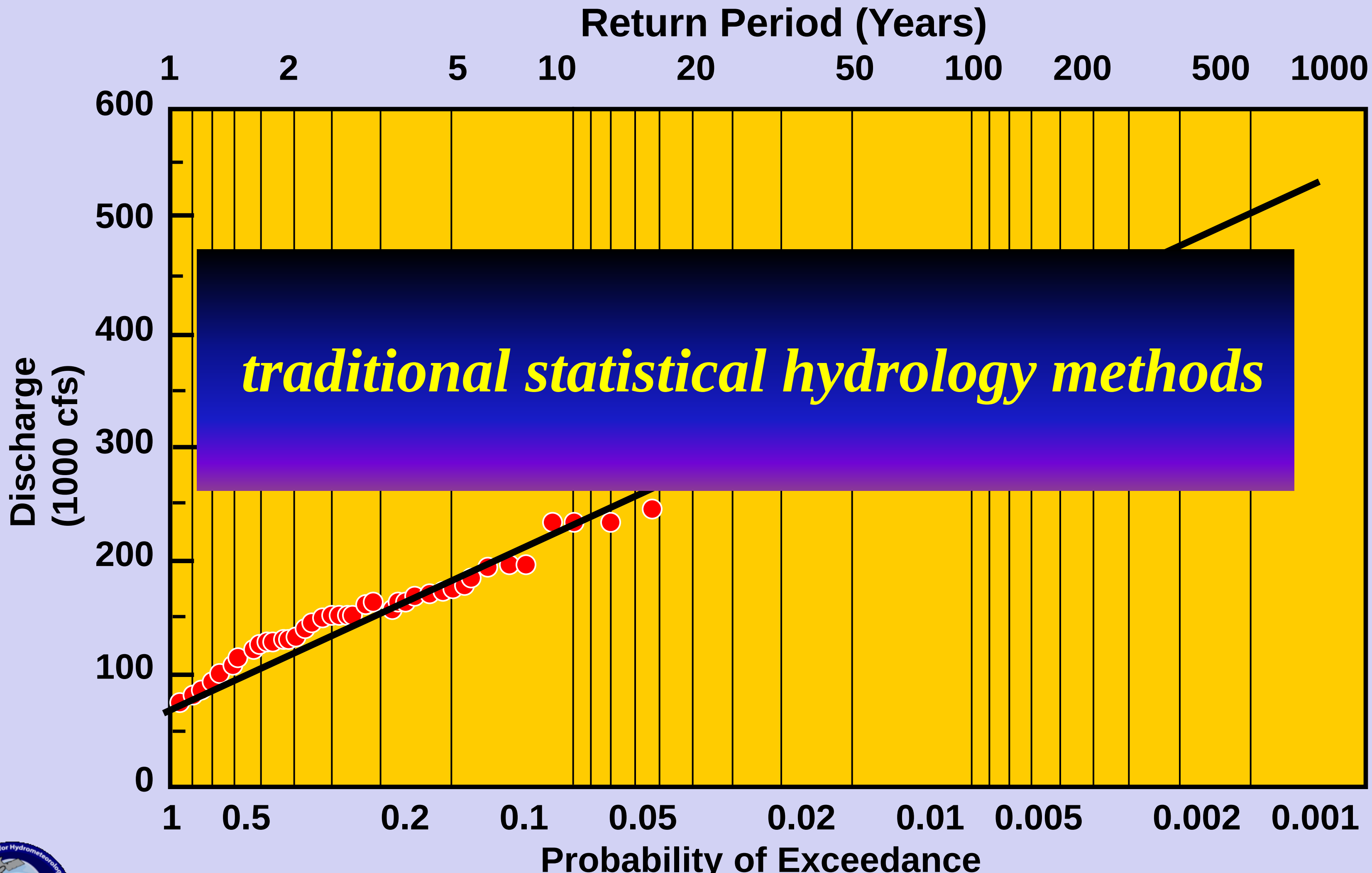




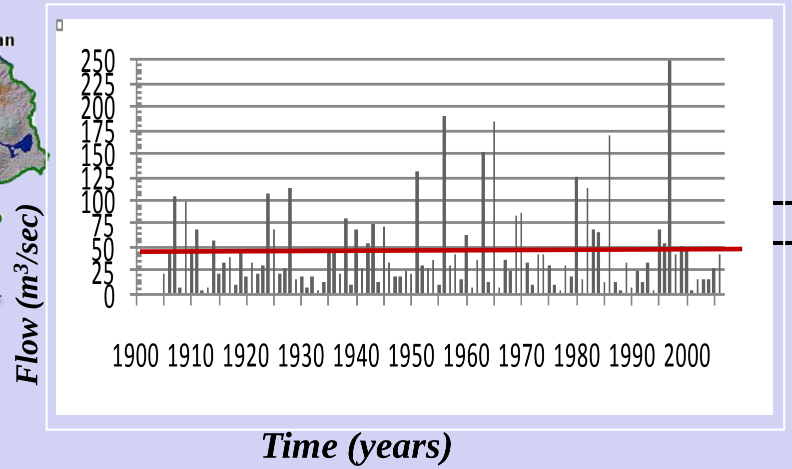


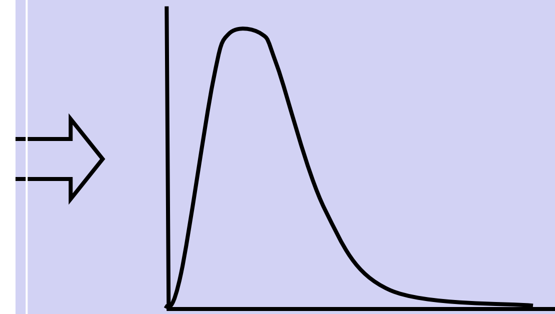


Alternative Approach to Climate Model Downscaling

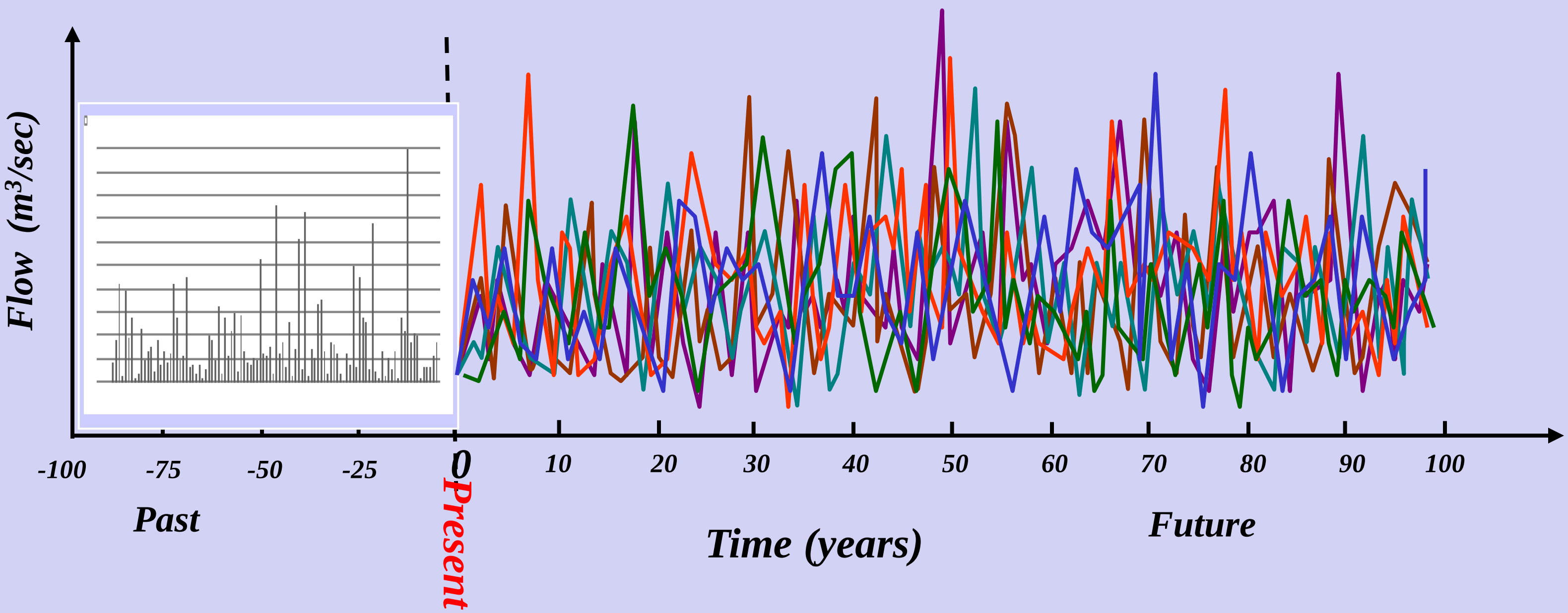


Statistical Hydrology: “synthetic” stream flow Generation





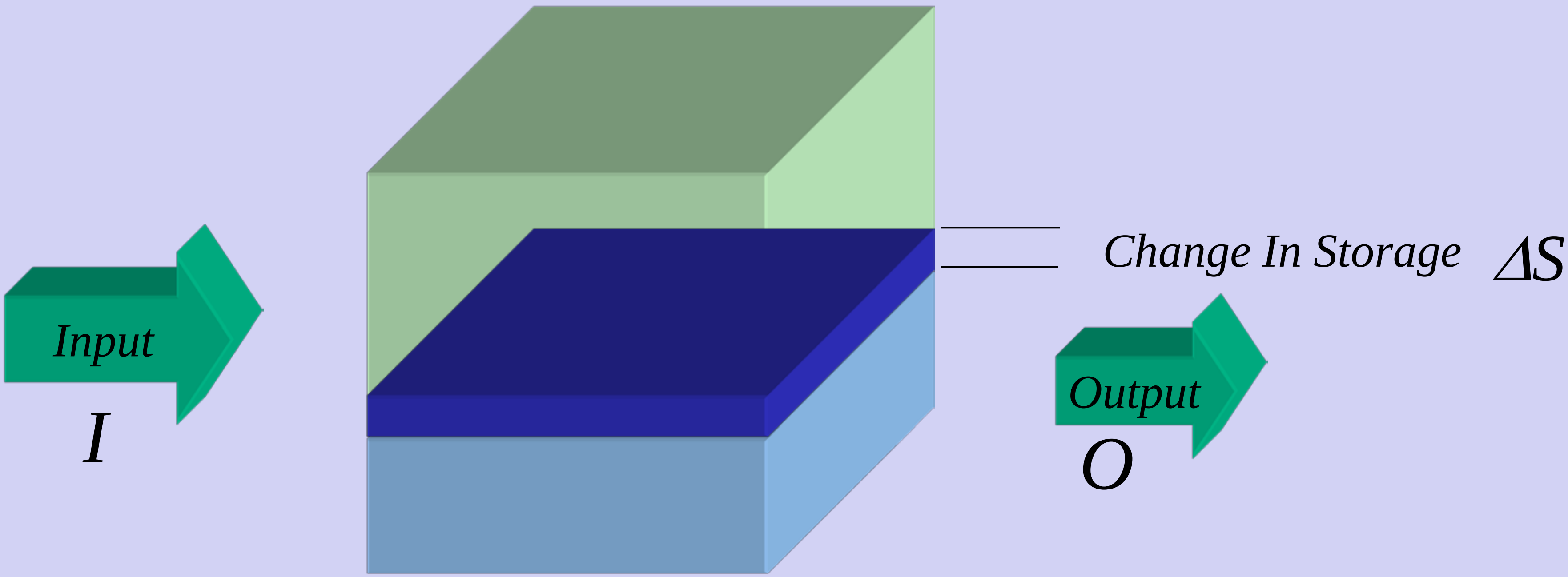
Probability density function



Brief Review of Rainfall Runoff modeling:

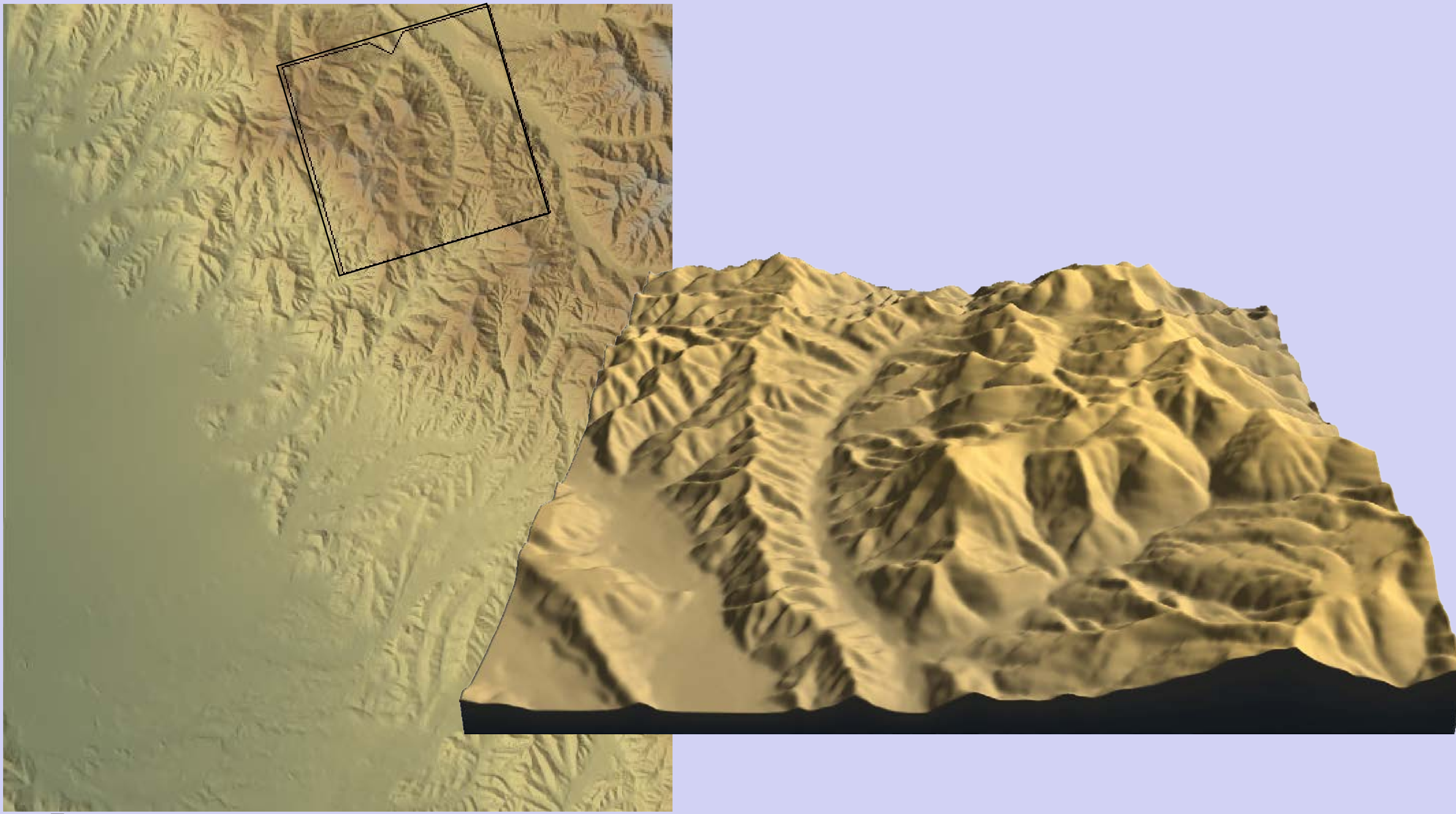
Progress in Hydrologic Modeling

Fundamental Law



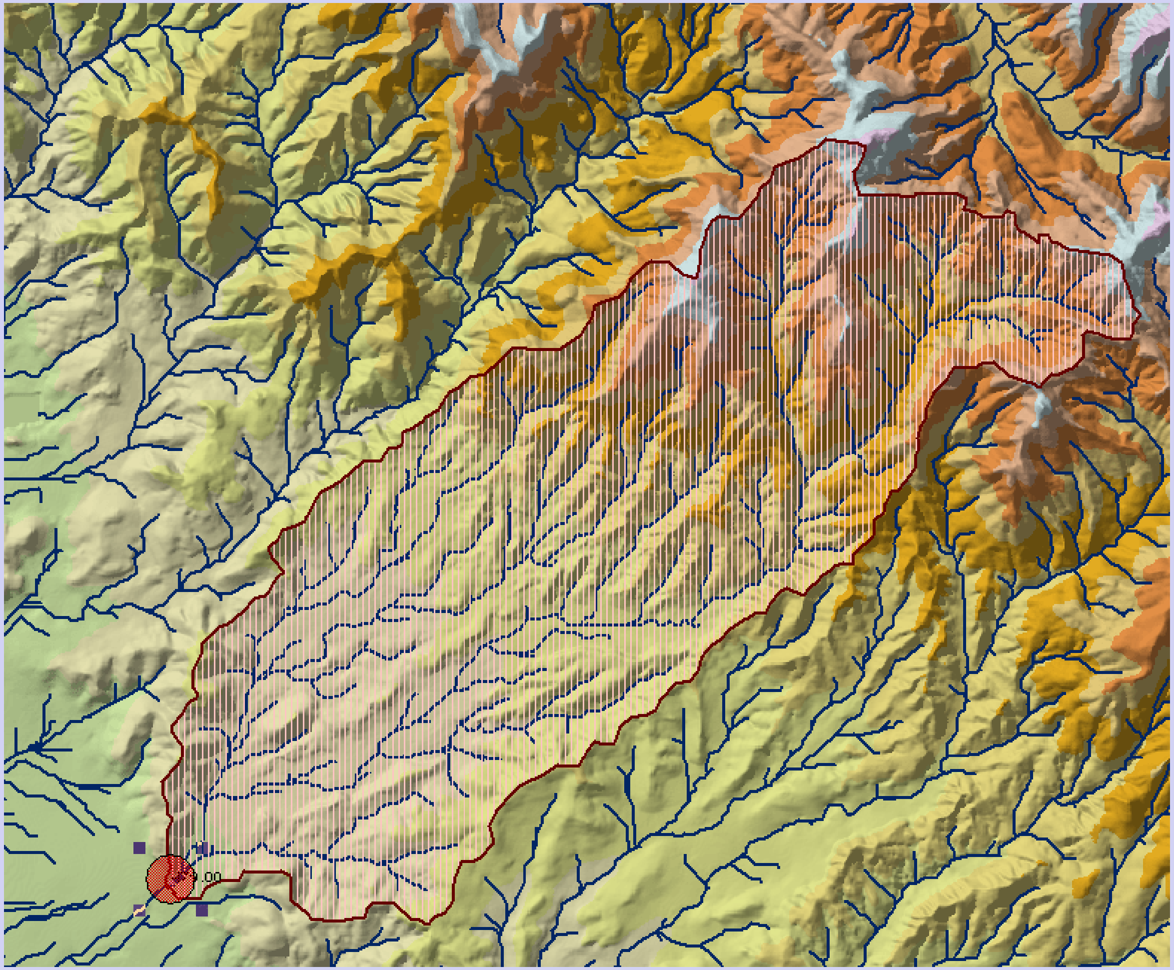
$$\boxed{I - O = \Delta S}$$

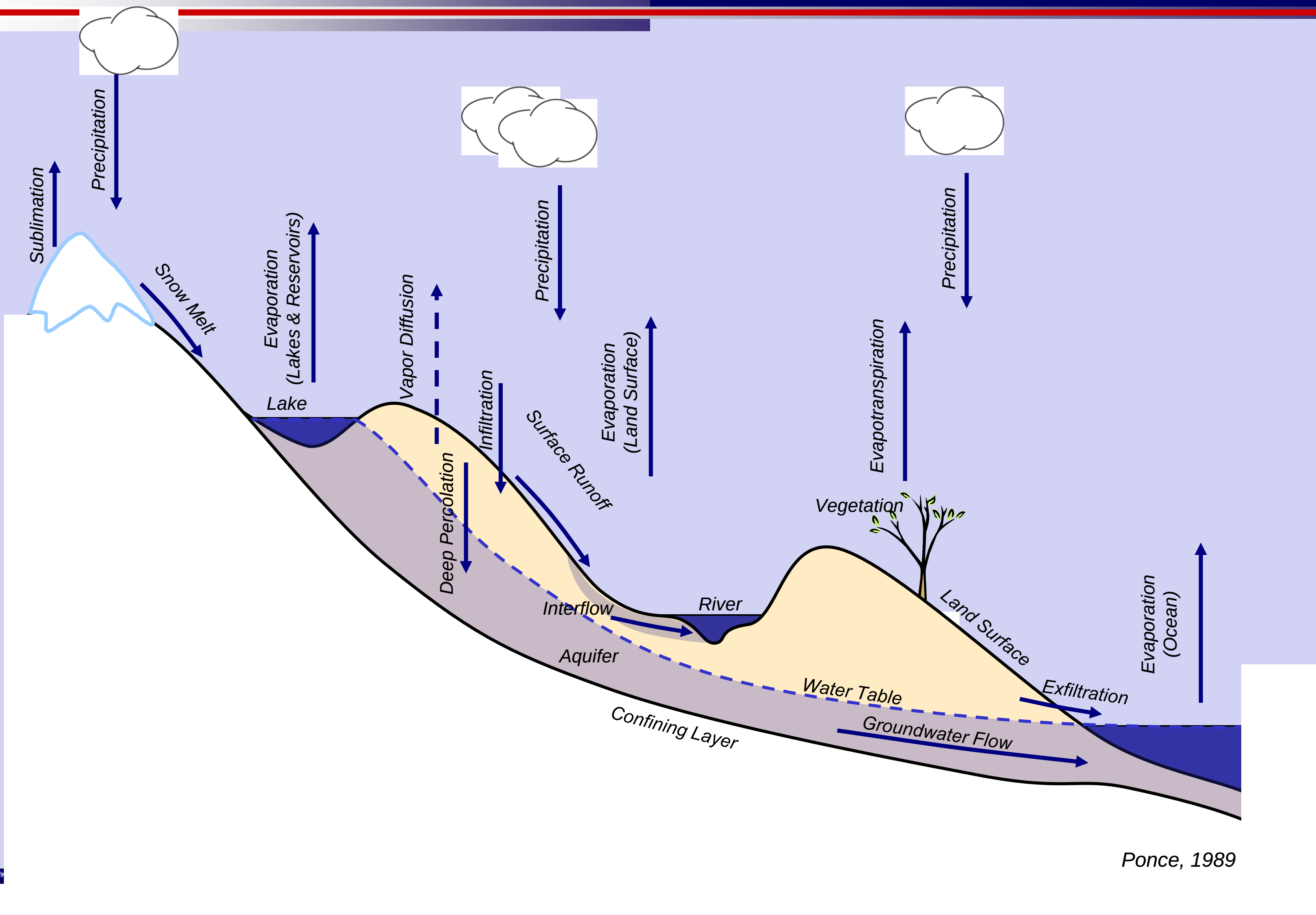
Nature's Way → Terrain



The Watershed

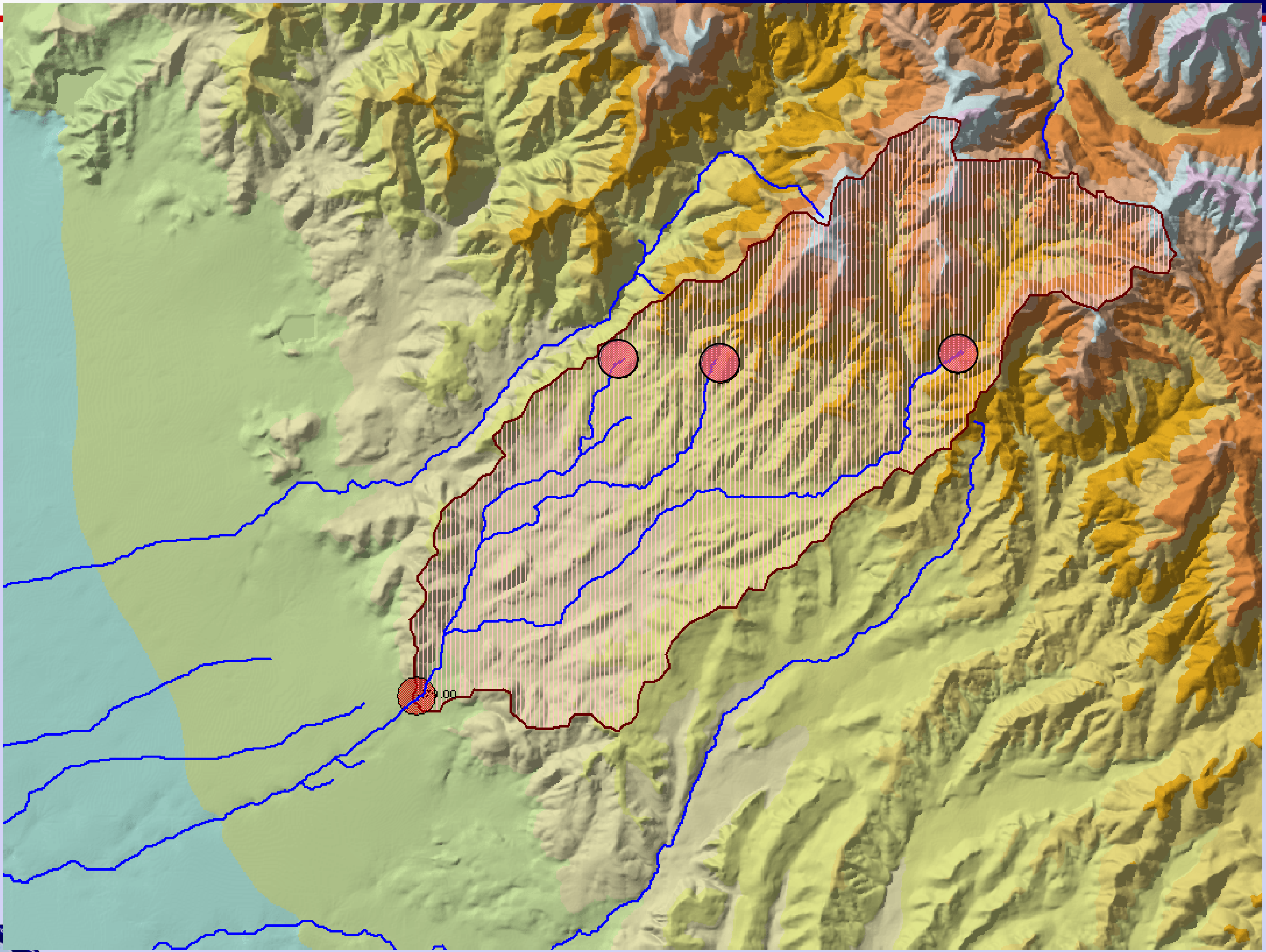
Area km2	12.78
Perimeter km	19.344
Min Elevation m	478.00
Max Elevation m	1756.00
Mean Elevation	930.34
Max Flow Length	8.878



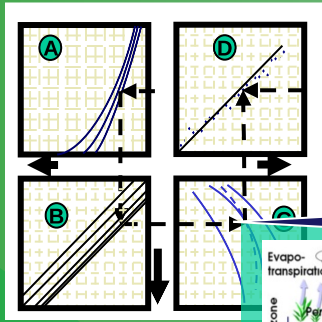


Sublimation
Precipitation
Snow Melt
Evaporation
(Lakes & Reservoirs)
Lake
Vapor Diffusion
Precipitation
Infiltration
Surface Runoff
Evaporation
(Land Surface)
Deep Percolation
Interflow
River
Aquifer
Confining Layer
Evapotranspiration
Precipitation
Vegetation
Land Surface
Water Table
Groundwater Flow
Exfiltration
Evaporation
(Ocean)
Ponce, 1989

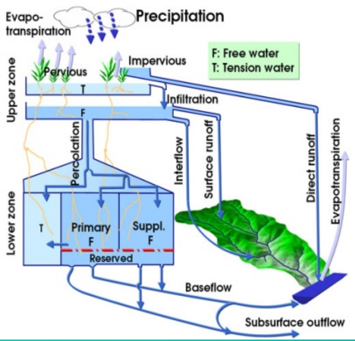
Trace The Water Drop



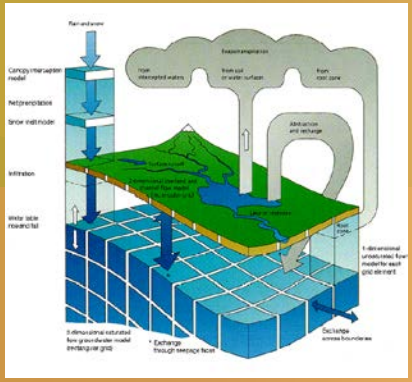
Evolution of Hydrologic R-R Models



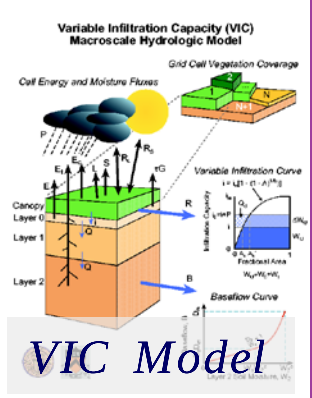
API Model



Lumped Conceptual



Distributed (Mike SHE)



VIC Model

Lumped

"Simple"

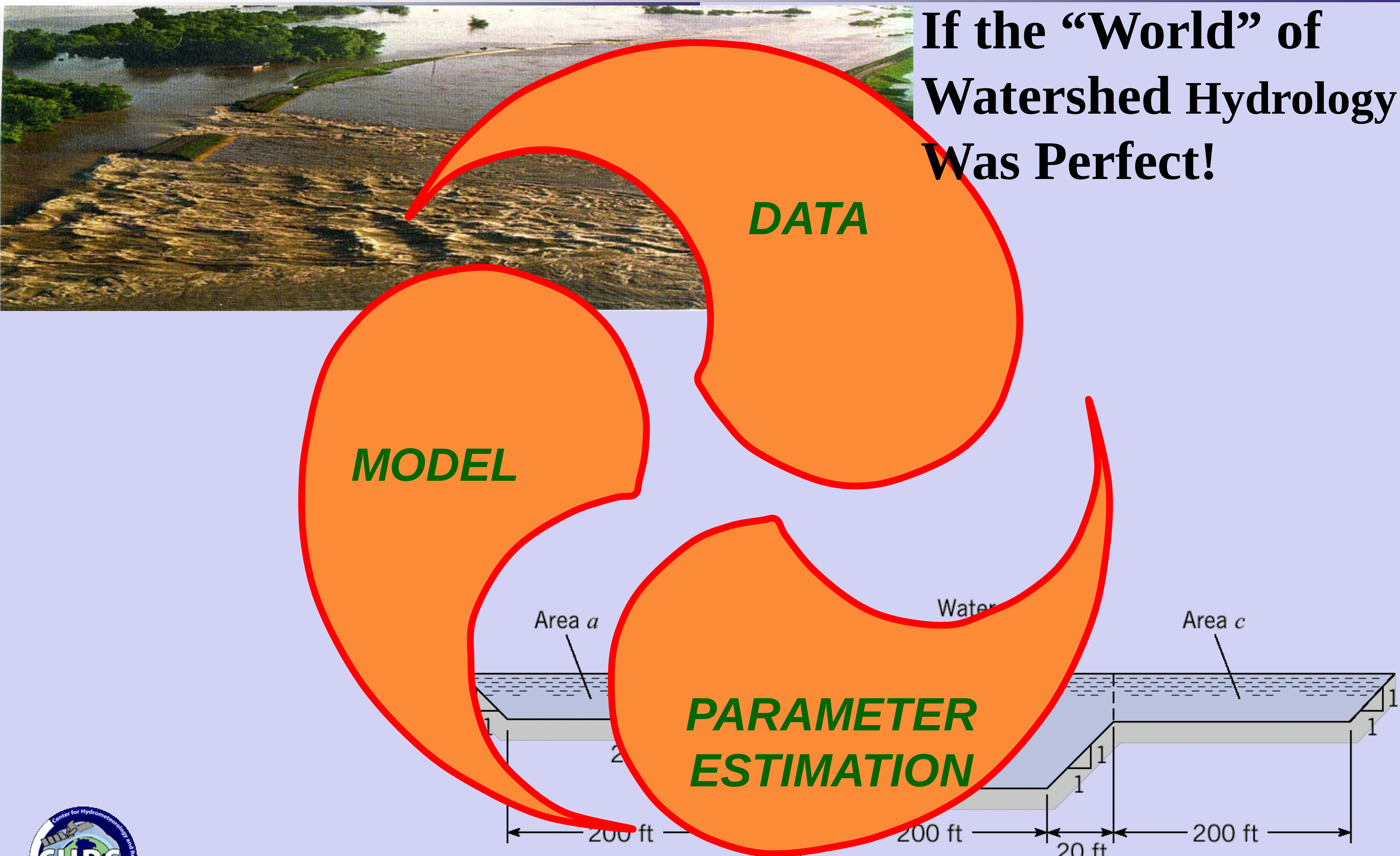
Time

Distributed

Physically-based

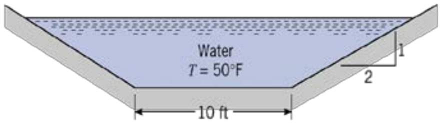
Hydrologic Modeling: 3 Elements!

If the "World" of Watershed Hydrology Was Perfect!

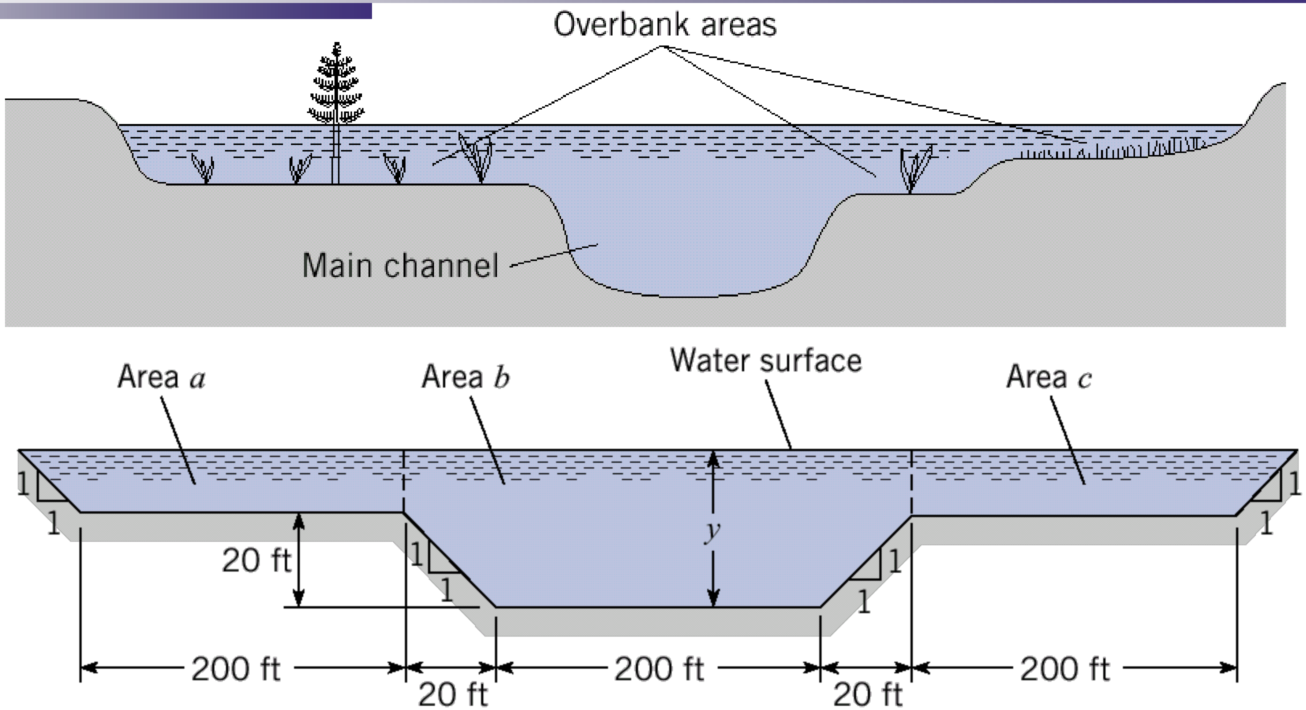


Flow in Channels: How far can we go simplifying?

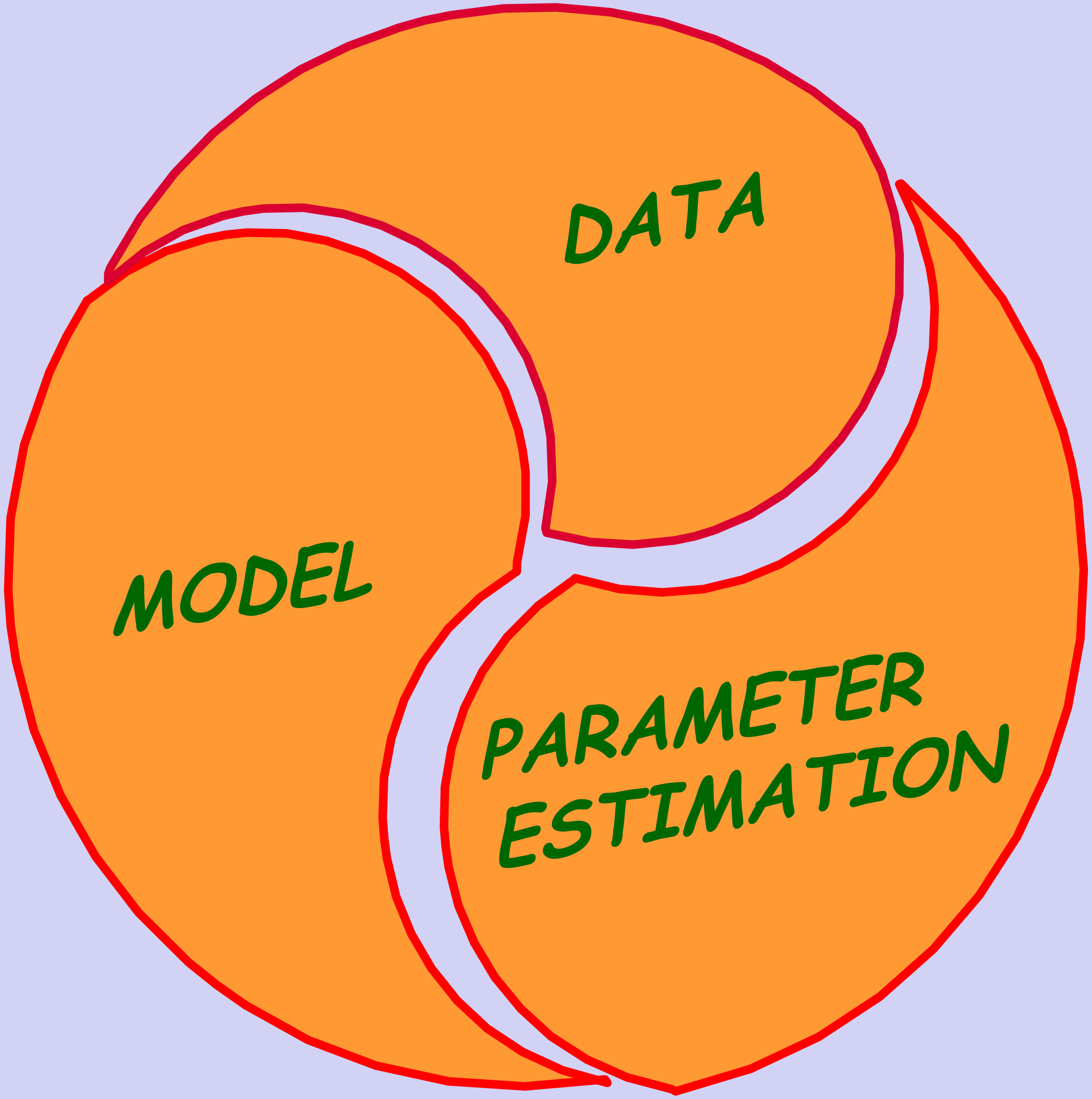
$V = n^{-1} R^{2/3} S^{1/2}$



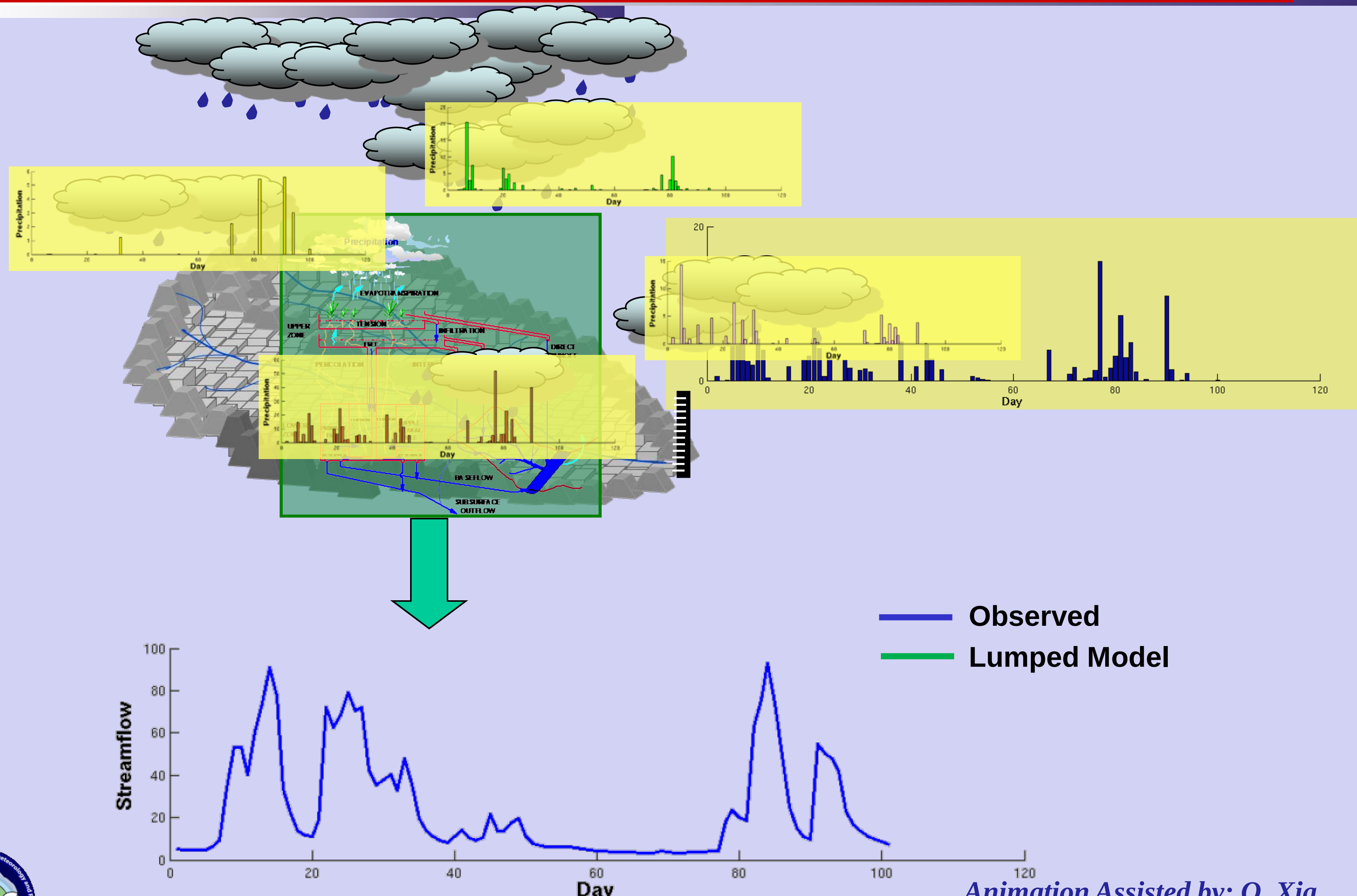
n – Manning Coefficient
R – Hydraulic Radius
S – Energy Slope



Hydrologic Modeling



Hydrologic Modeling: “Lumped”



Animation Assisted by: Q. Xia

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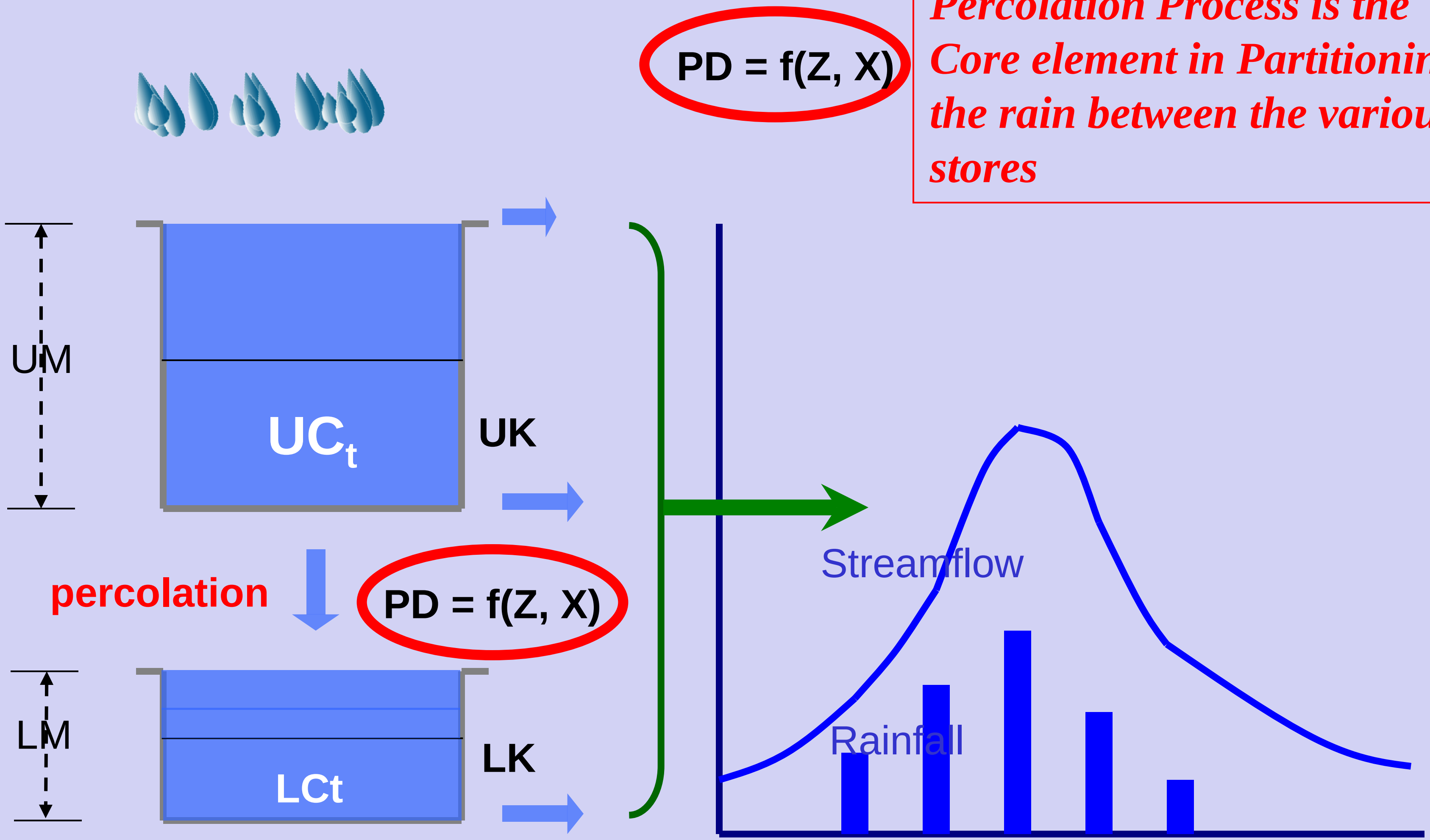
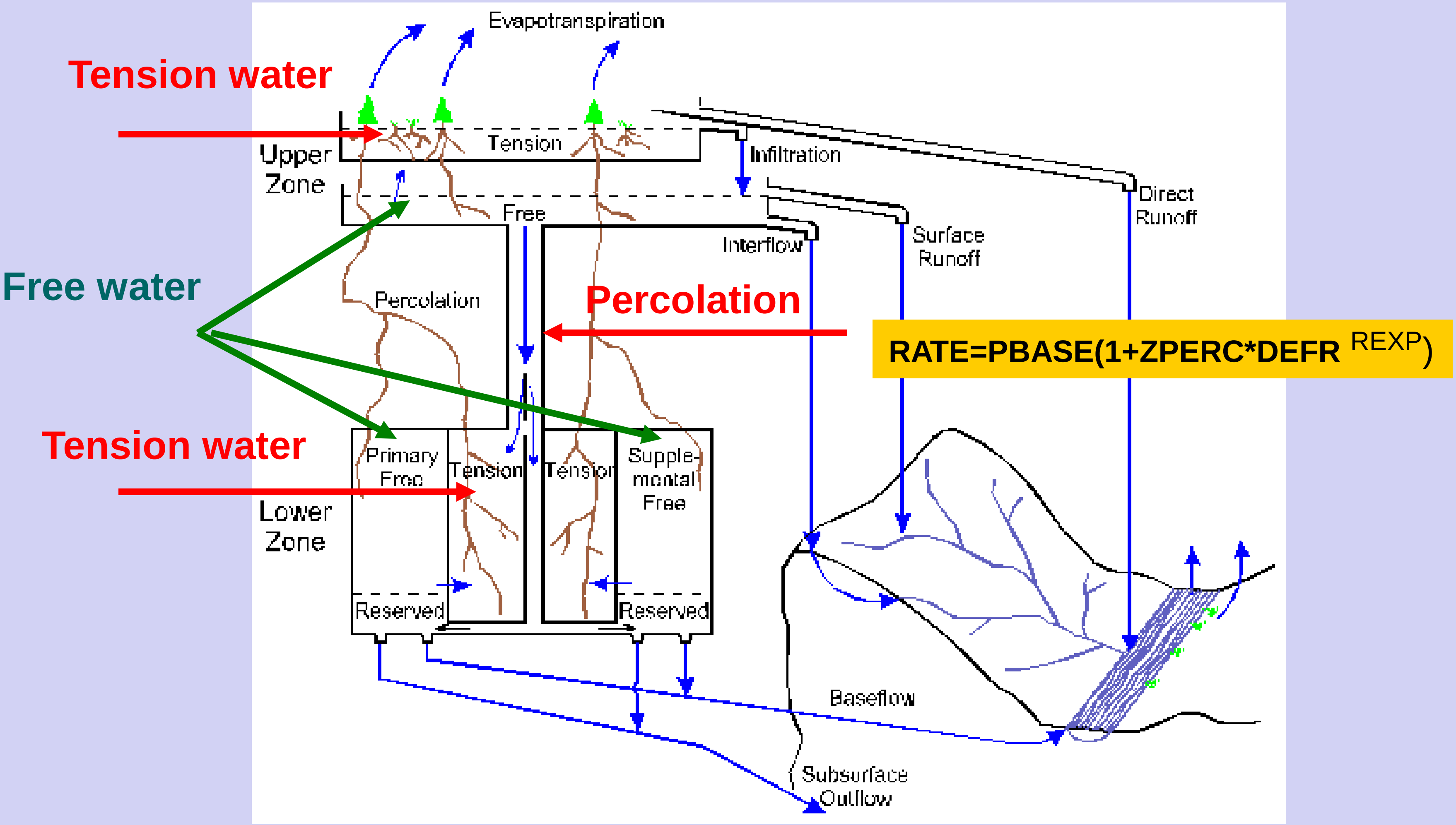
A look into the "heart" of R-R Models



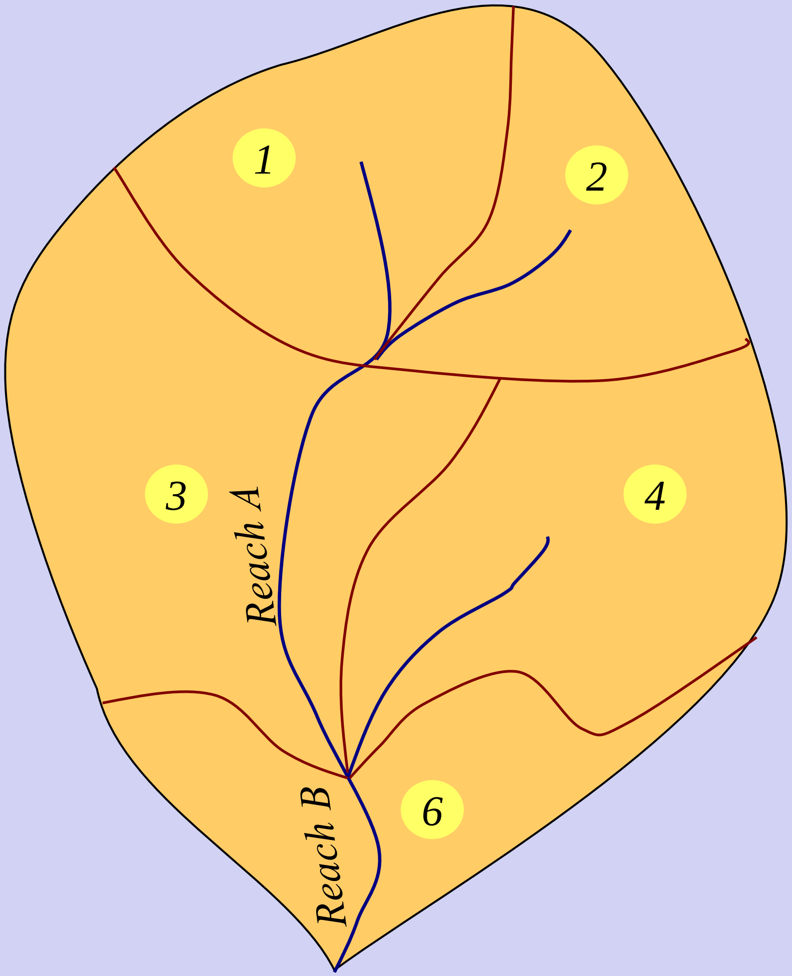
Percolation Process is the Core element in Partitioning the rain between the various stores

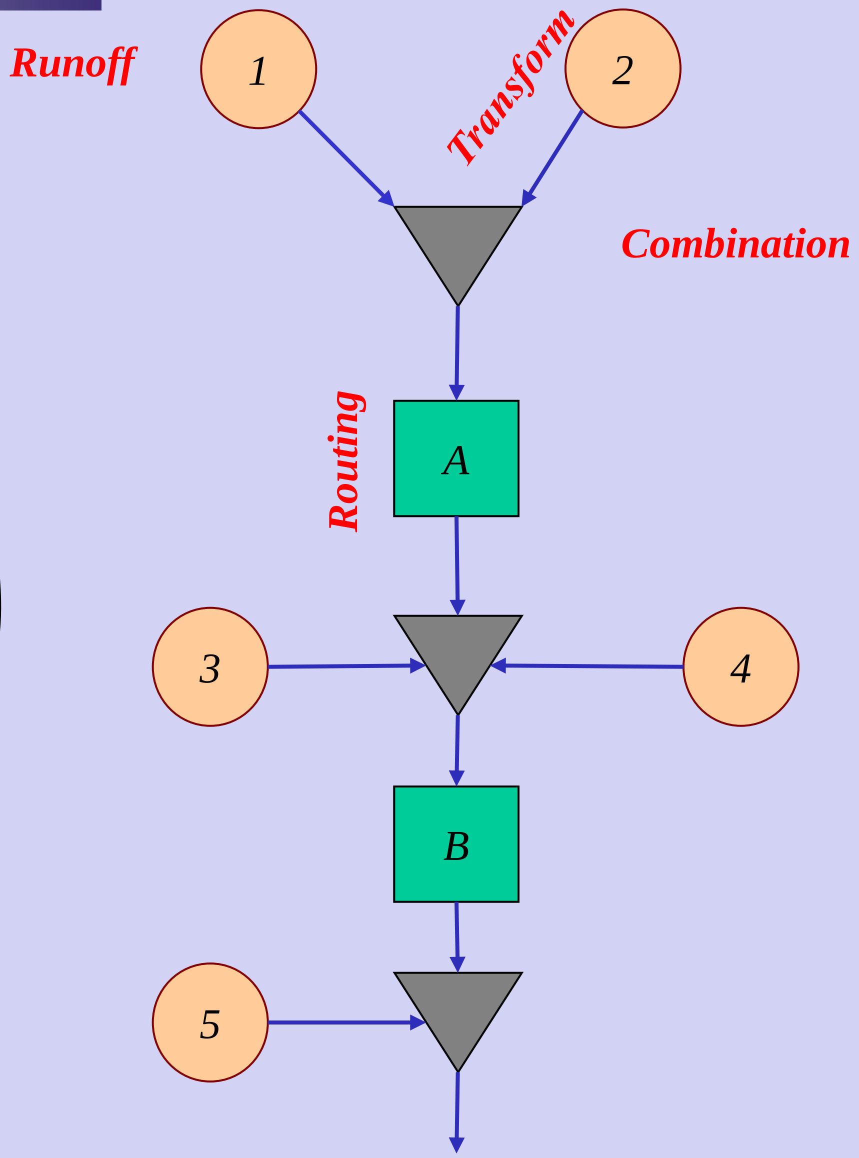
NWS Soil Moisture Accounting Model: SMA-NWSRFS



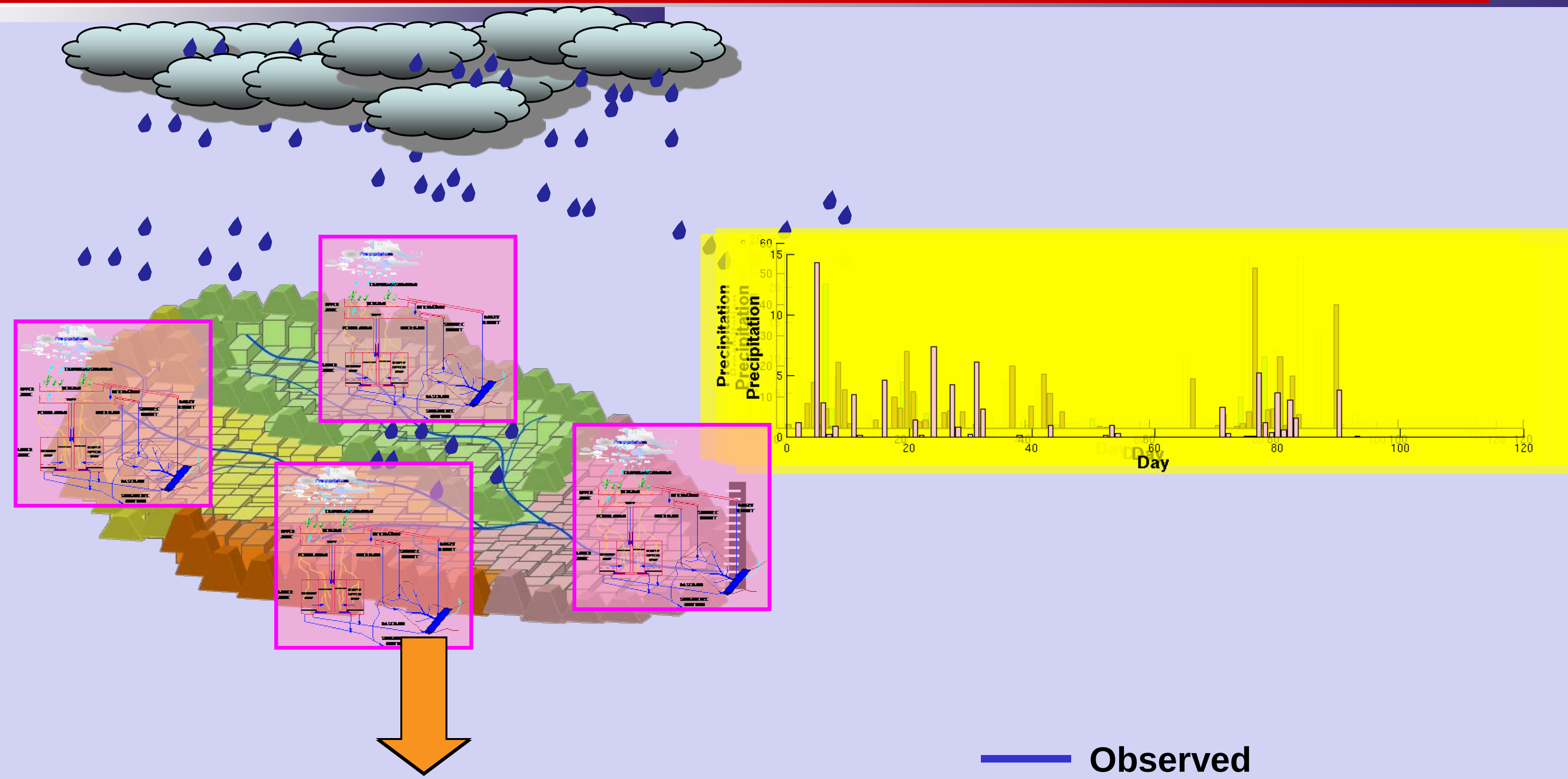
Nonlinear structure with large number of parameters

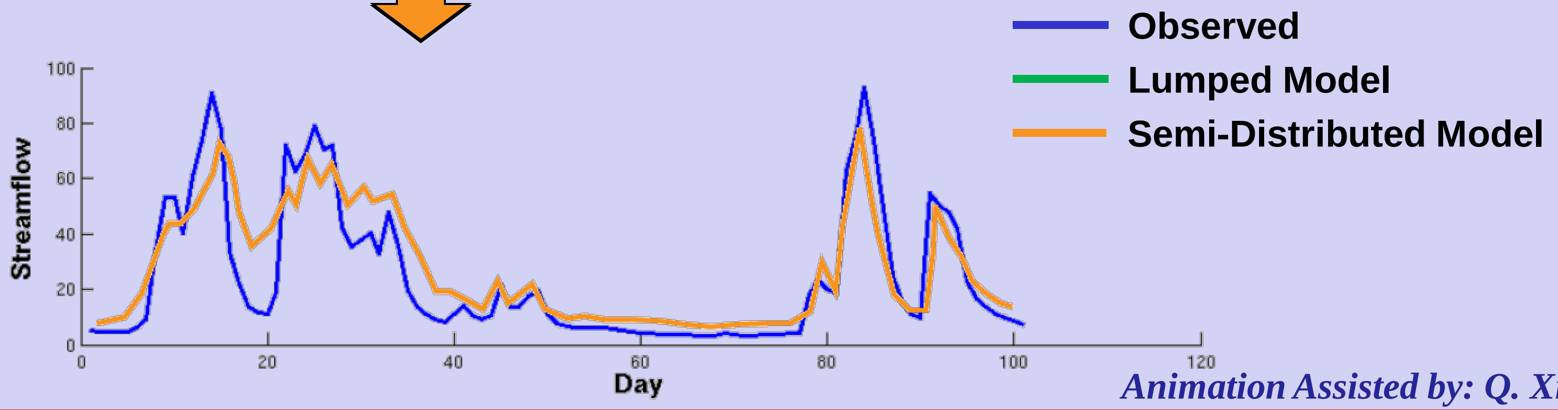
"Semi-distributed" Hydrologic Models





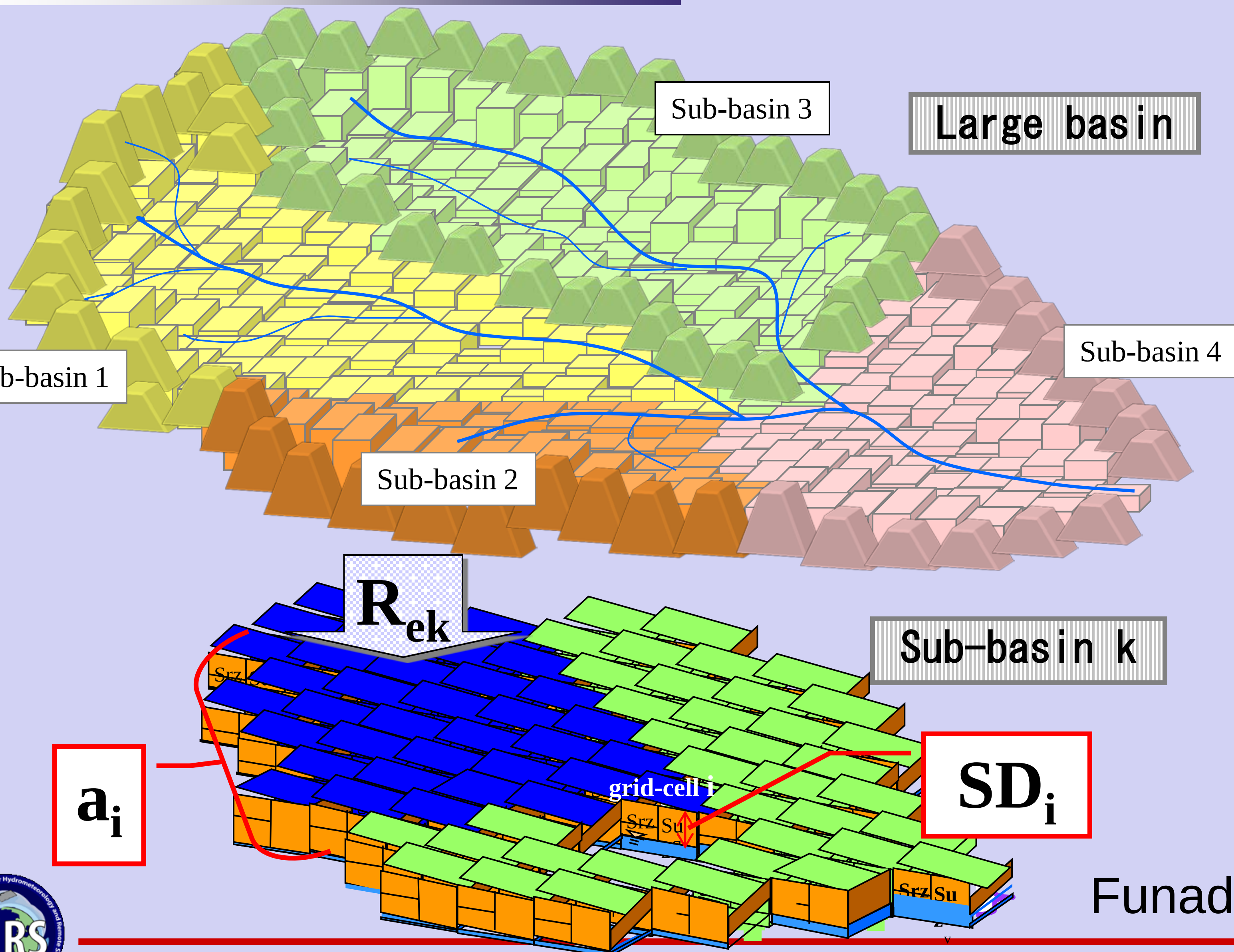
“Semi-distributed” Hydrologic Models





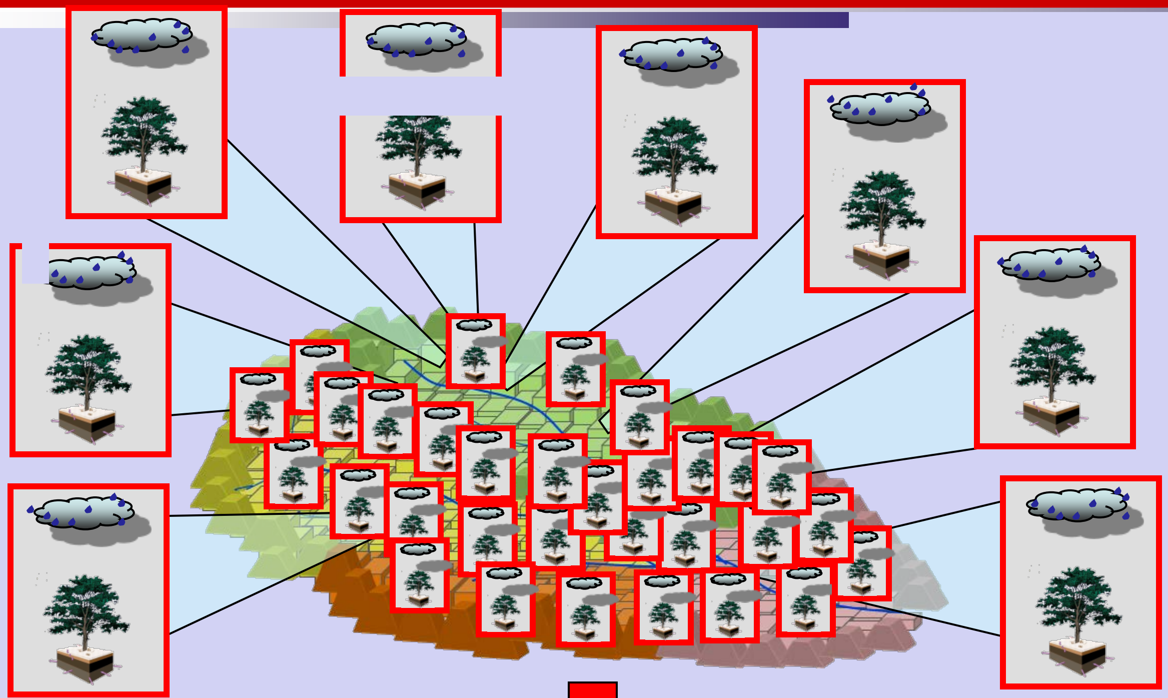
Animation Assisted by: Q. Xia

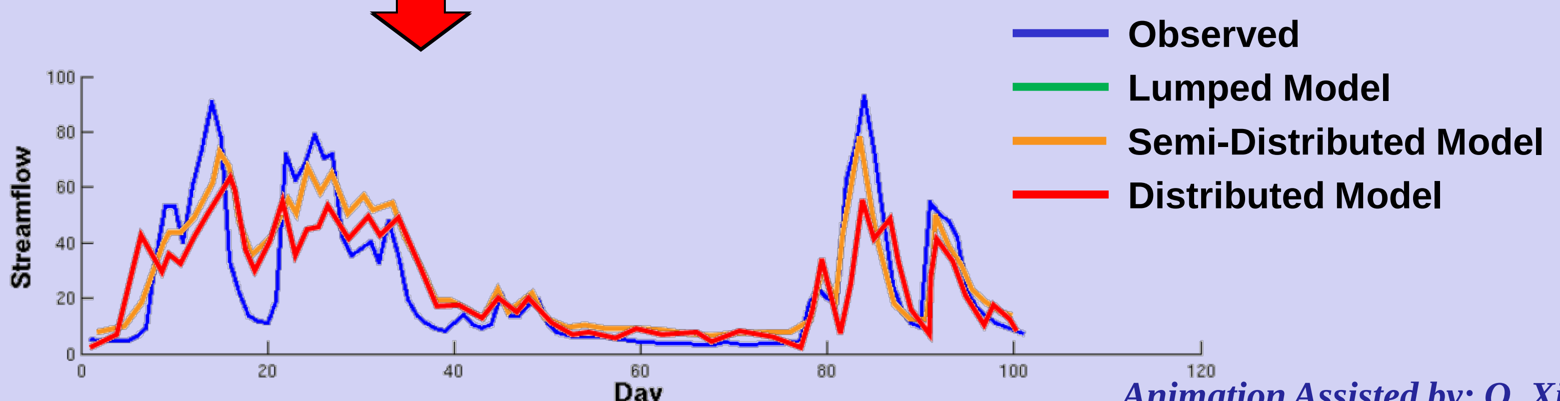
Example of Distributed Model Appl. in large Basins



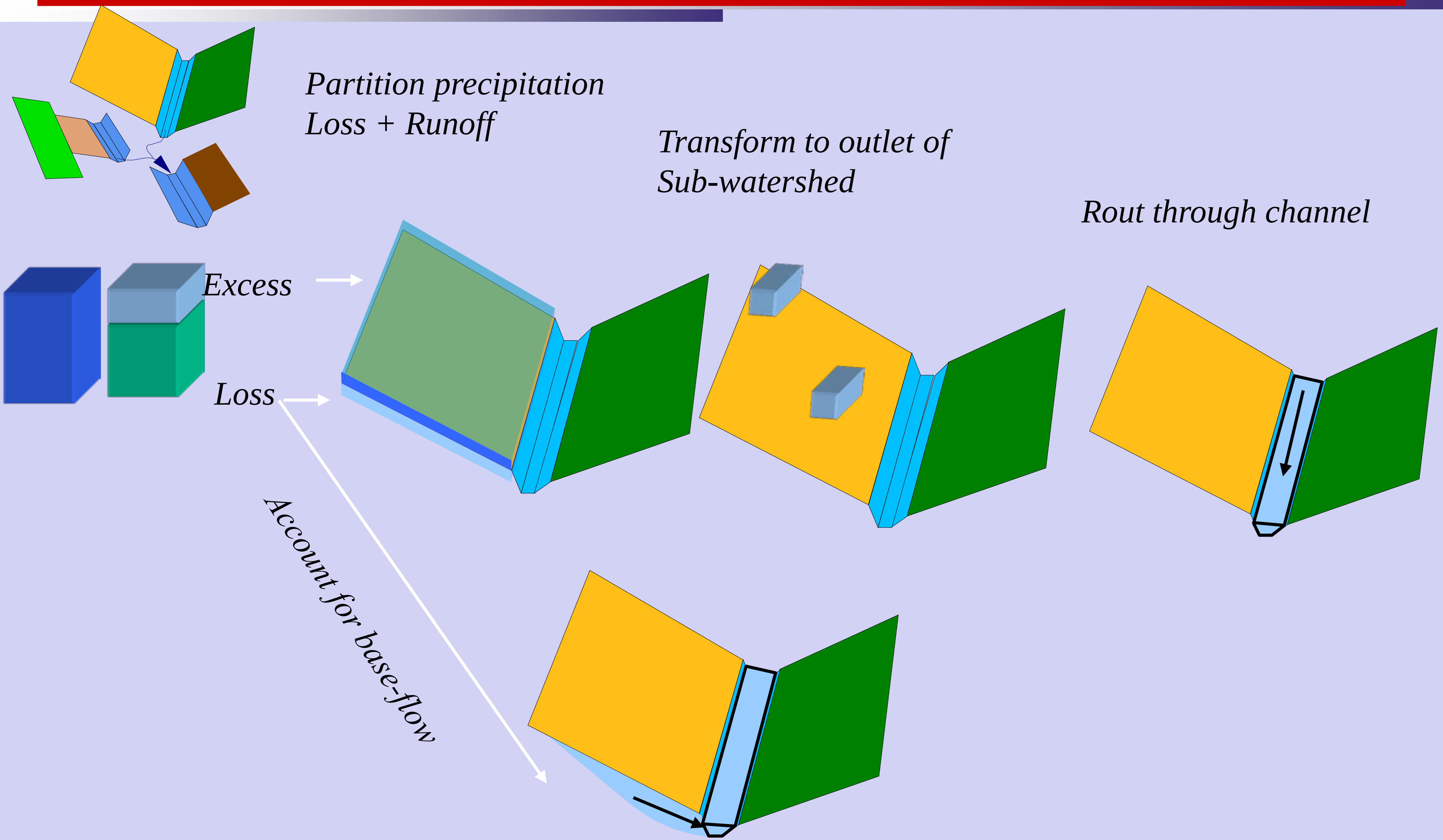
Funada, 2004

Example of Distributed Model



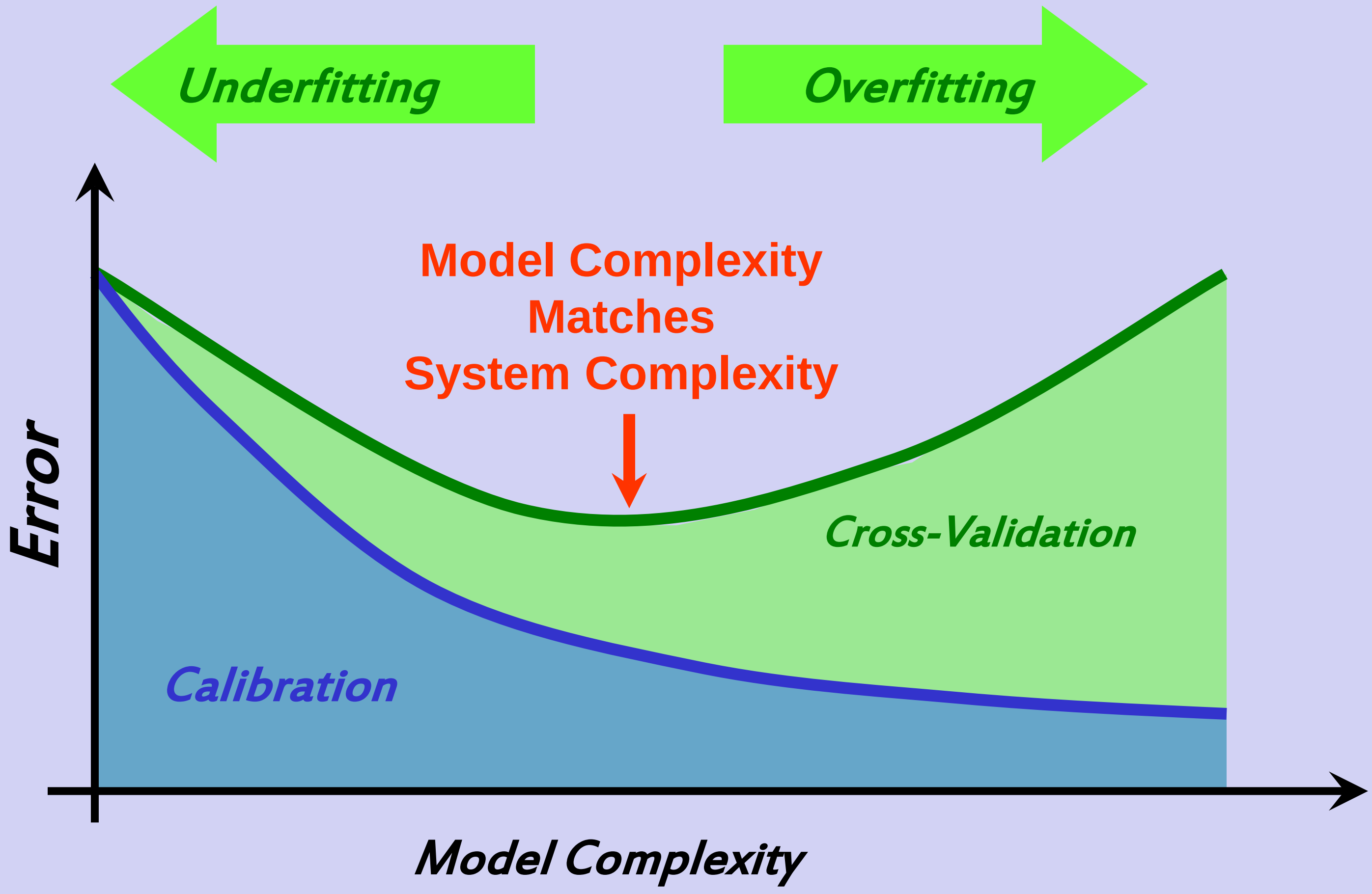


Animation Assisted by: Q. Xia



Partition precipitation
Loss + Runoff
Transform to outlet of
Sub-watershed
Rout through channel
Excess
Loss
Account for base-flow

Continued need for Some Form of Calibration

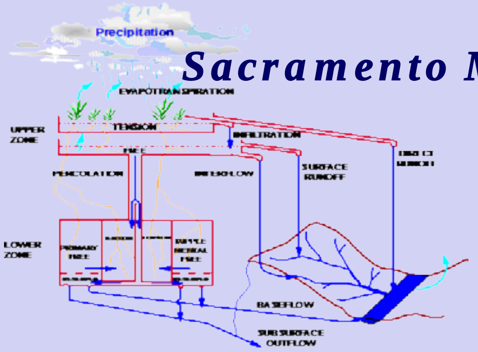


Source: Gershenfeld, 1999

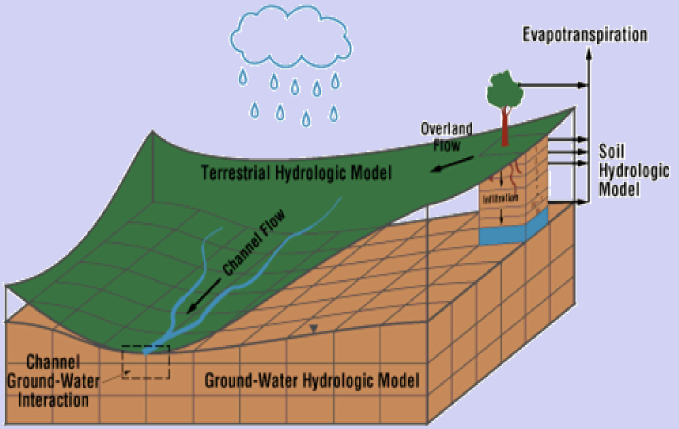
Reviewing some recent model evaluation studies

DMIP-1 Findings: In a Nutshell

Sacramento Model



No Major Difference between the performance of Lumped and distributed models

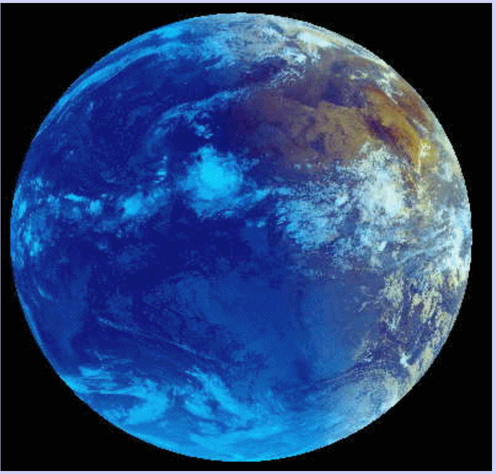


DMIP 1 Results (From Reed et al., 2004)

Recent Assessment of Seasonal Climate Forecasts

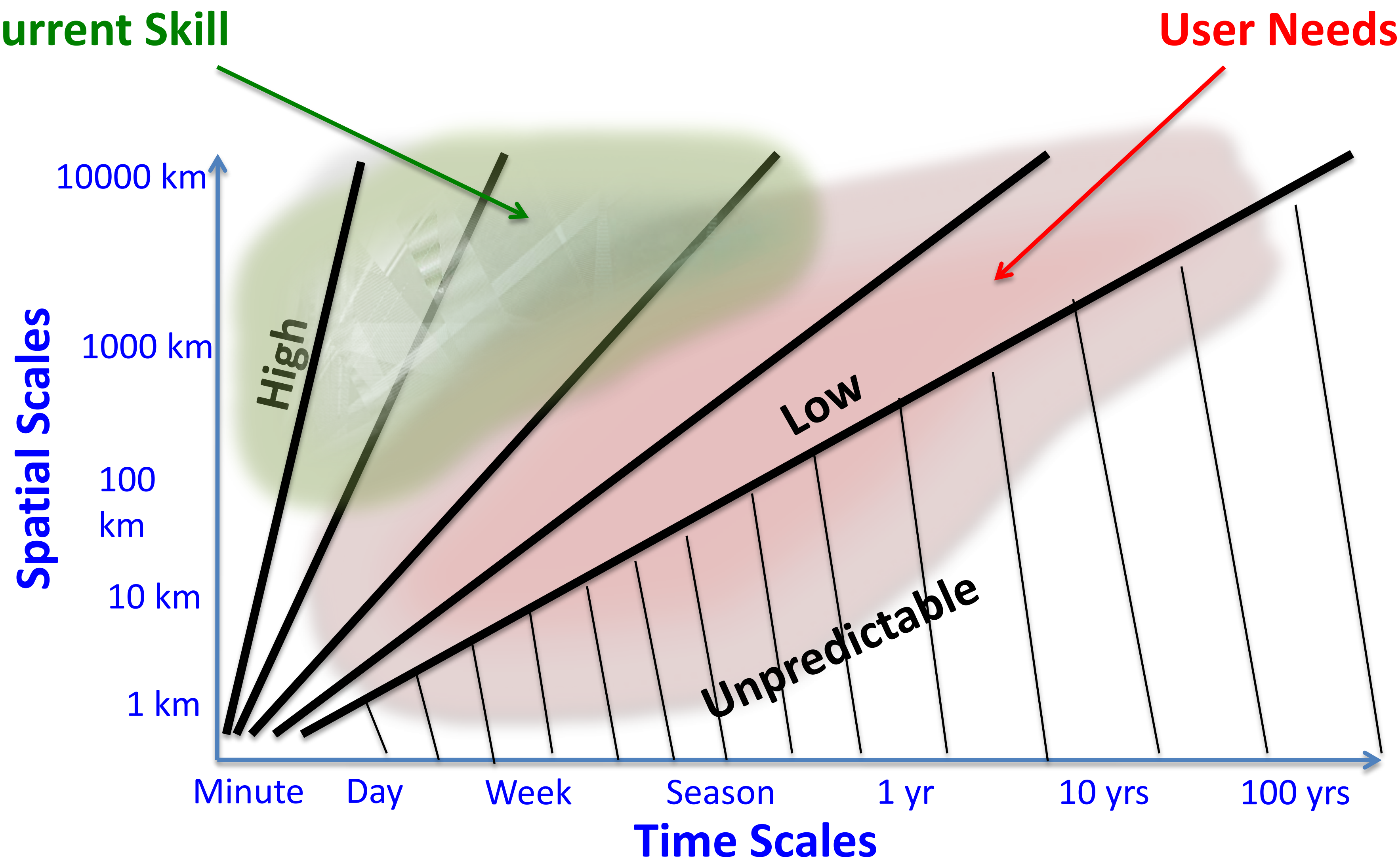
Quoting from Science, Vol. 321, 15th August 2008

Livezey &Timofeyeva - BAMS, June 2008.



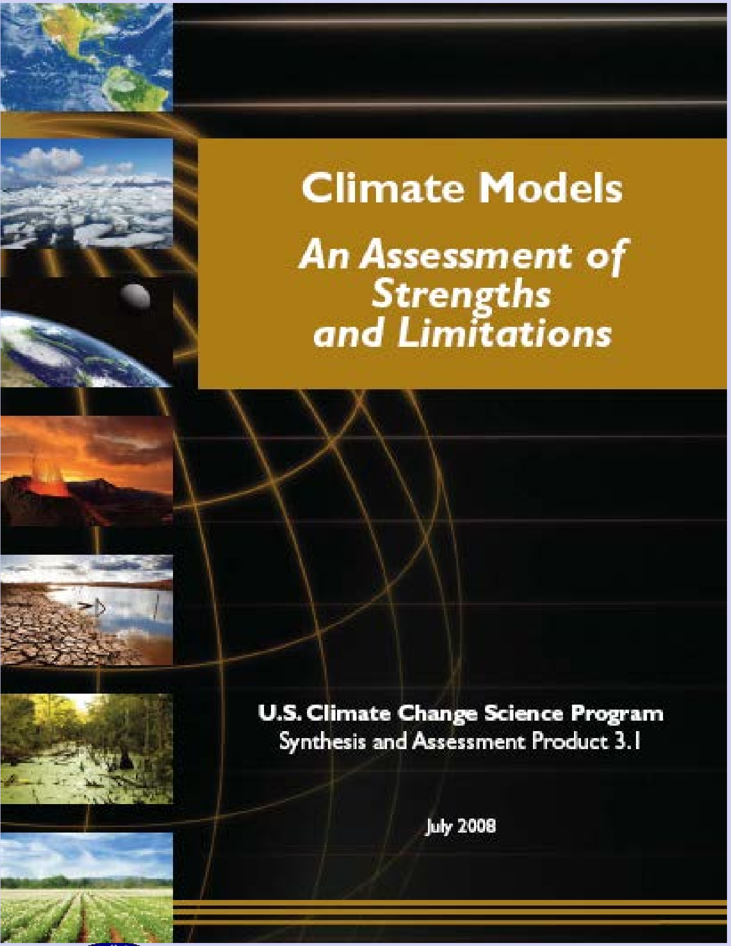
- ***"About the only time forecasts had any success predicting precipitation was for winters with an El Nino or a La Nina"***

Drought Predictability



Provided by Siegfried Schubert 2011

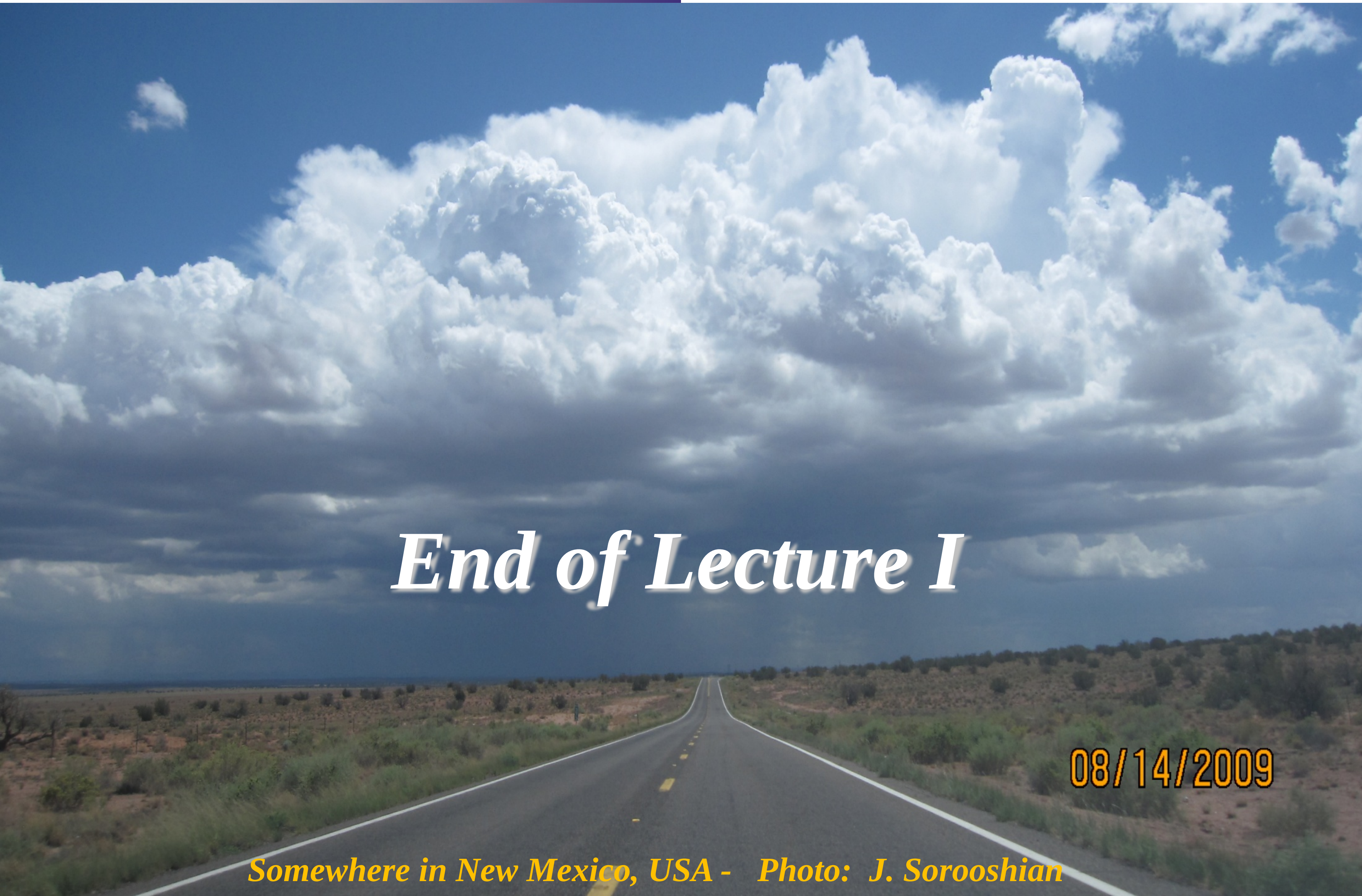
Recent Assessment of Climate Models



- 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

End of Lecture I



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