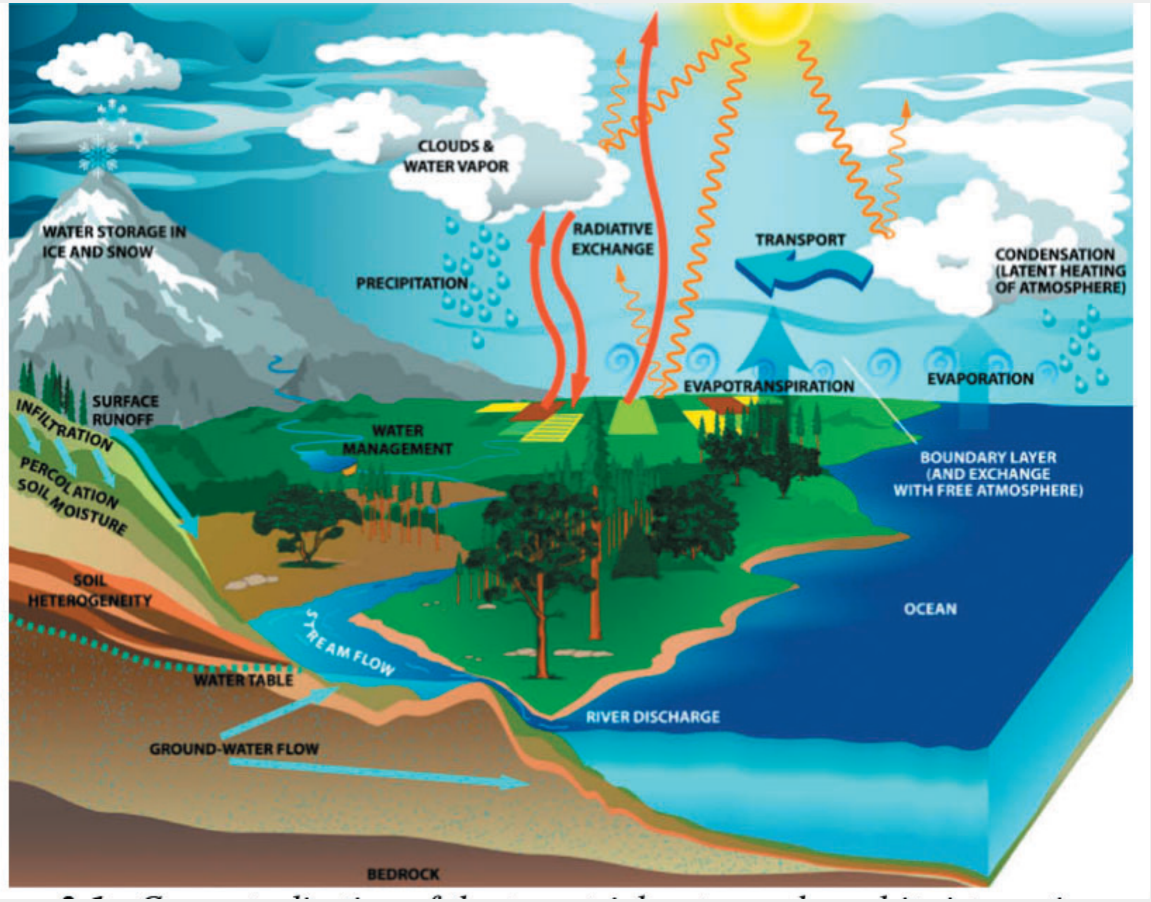
What does modeling mean to the hydrologic (water science) community



Larry Band - University of North Carolina

EarthCube Modeling for the Geosciences Workshop

April 22-23, 2013, Boulder

Community Hydrologic Modeling Project CHyMP

- **Objective**: Advance hydrologic sciences by enabling community modeling.
- **3 workshops**
  - **Scoping**. 20+ participants; Academics, Fed. Agency, Private Sector March 2008 [*Famiglietti et al*., 2008].
  - **Blueprint**. 50+ participants, March 2009 [*Famiglietti et al*., 2010].
  - **Community Model Platform**. 30+ participants, March 2011. [*Famiglietti et al*., 2011].
- **Outcomes**
  - Planning with National Agencies on National Water Model
  - Current Strategic Plan

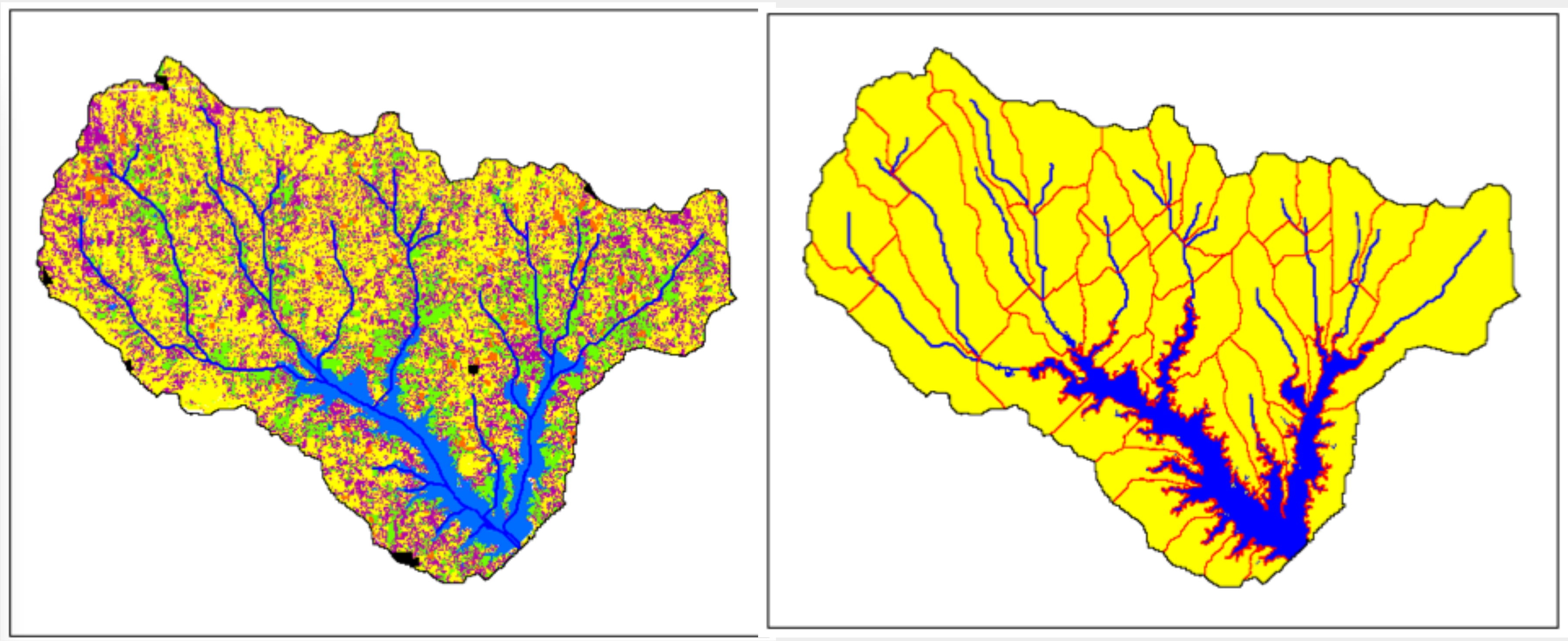
  Implementation to concentrate on CUAHSI-CLM

Differentiating hydrologic models

- What is the control volume?
  - Water and what constituents?
  - Methods for estimating flux, storage and transformations?
  - Coupling of components?
- What are the boundary and initial conditions and how are they represented?
- Time/space steps and domains
- Parameterization and calibration methods
- Data assimilation
- Land surface/subsurface heterogeneity

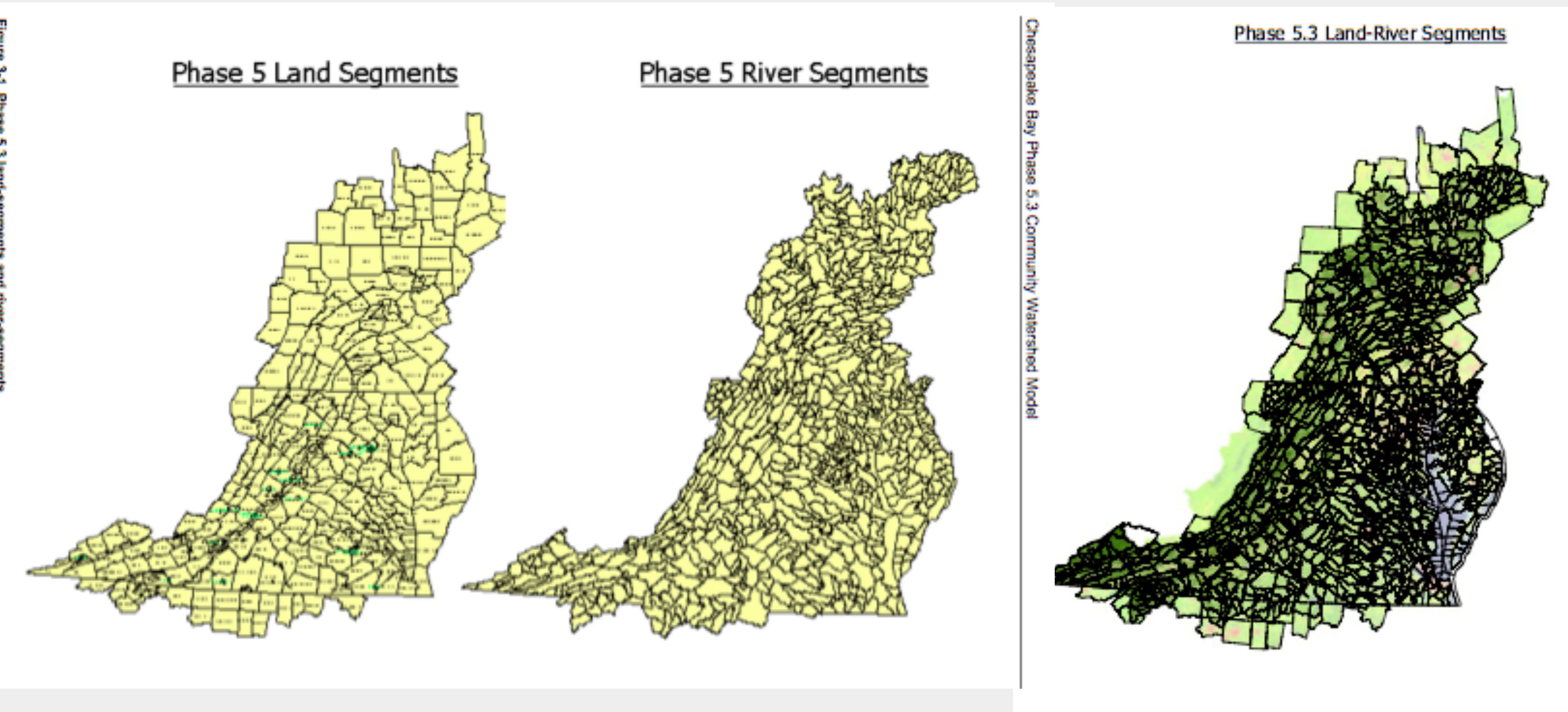
- Purpose

SWAT Hydrologic Response Units (HRU) and sub-basin delineation



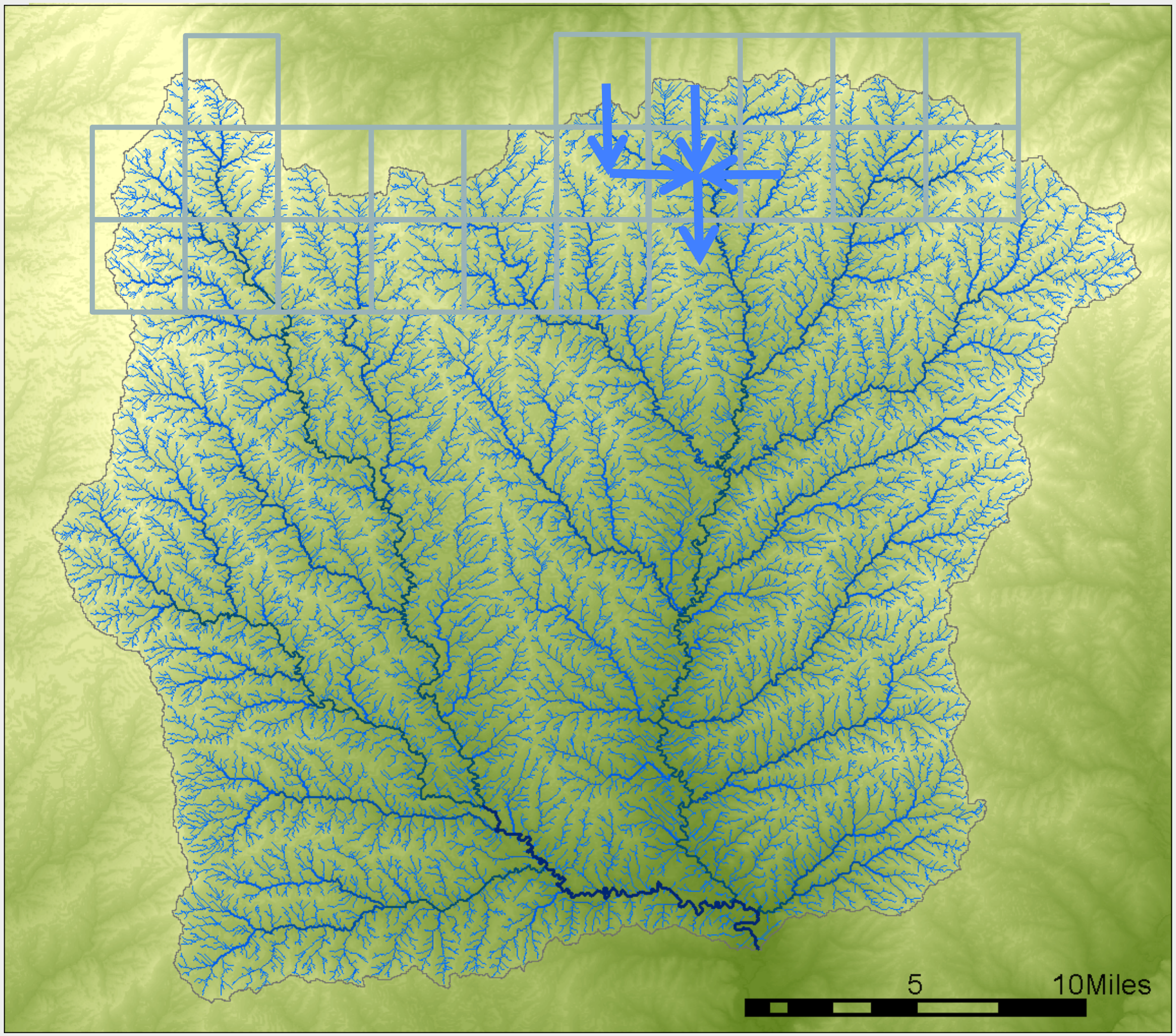
One river reach per sub-basin, 1-d flux, transformation, storage equation sets solved at HRU level, water, solute and sediment routed to sub-basin outlet

Chesapeake Bay Watershed Model: Intersection of Land and River Segments



Flux, storage, transformation equation sets solved at land segment and drainage reach level. Within land segment, equations solved over HRUs which are aspatial – no lateral routing.

Distributed Parameter Models: Hillslopes as Control Volumes

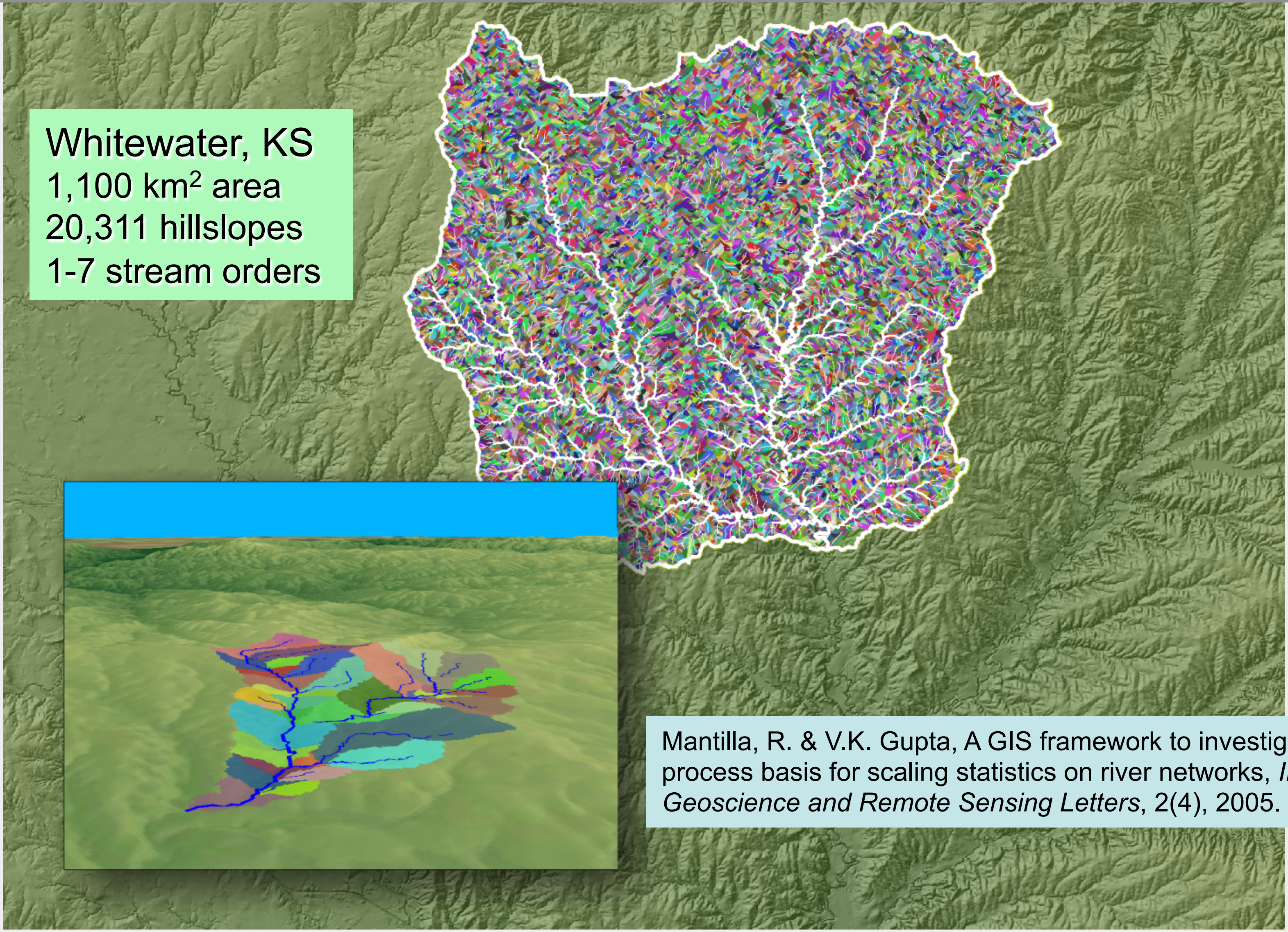


W. Krajewski, University Iowa, Iowa Flood Center

Landscape Decomposition

Preserving the full extent of the river network structure

Whitewater, KS
1,100 km^2 area
20,311 hillslopes
1-7 stream orders

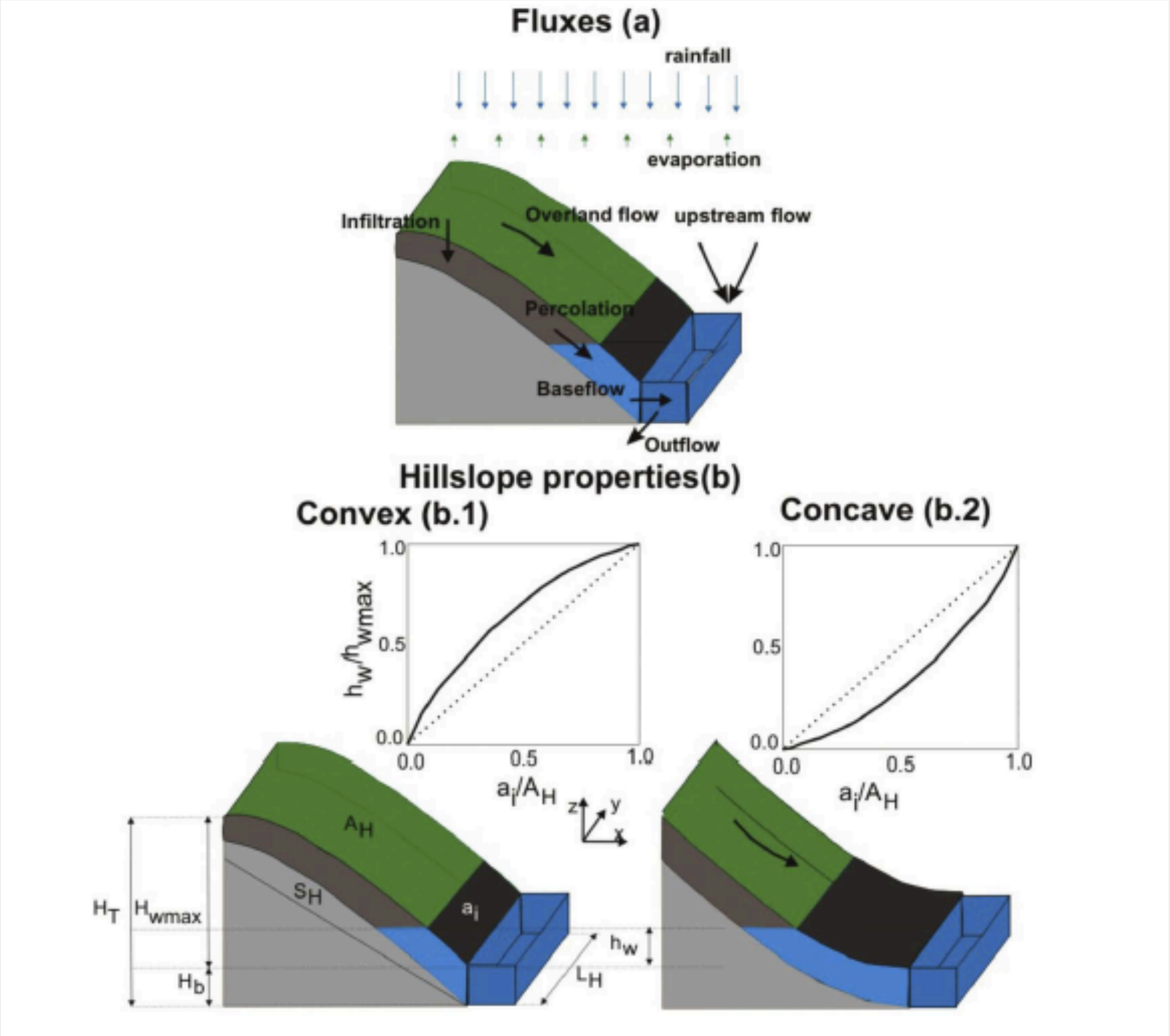


Mantilla, R. & V.K. Gupta, A GIS framework to investigate the process basis for scaling statistics on river networks, *IEEE - Geoscience and Remote Sensing Letters*, 2(4), 2005.

W. Krajewski, University Iowa, Iowa Flood Center

Hydrologic Models: Landscape Decomposition

Hillslope as control volume: Storage/flux based on hillslope shape and soil properties

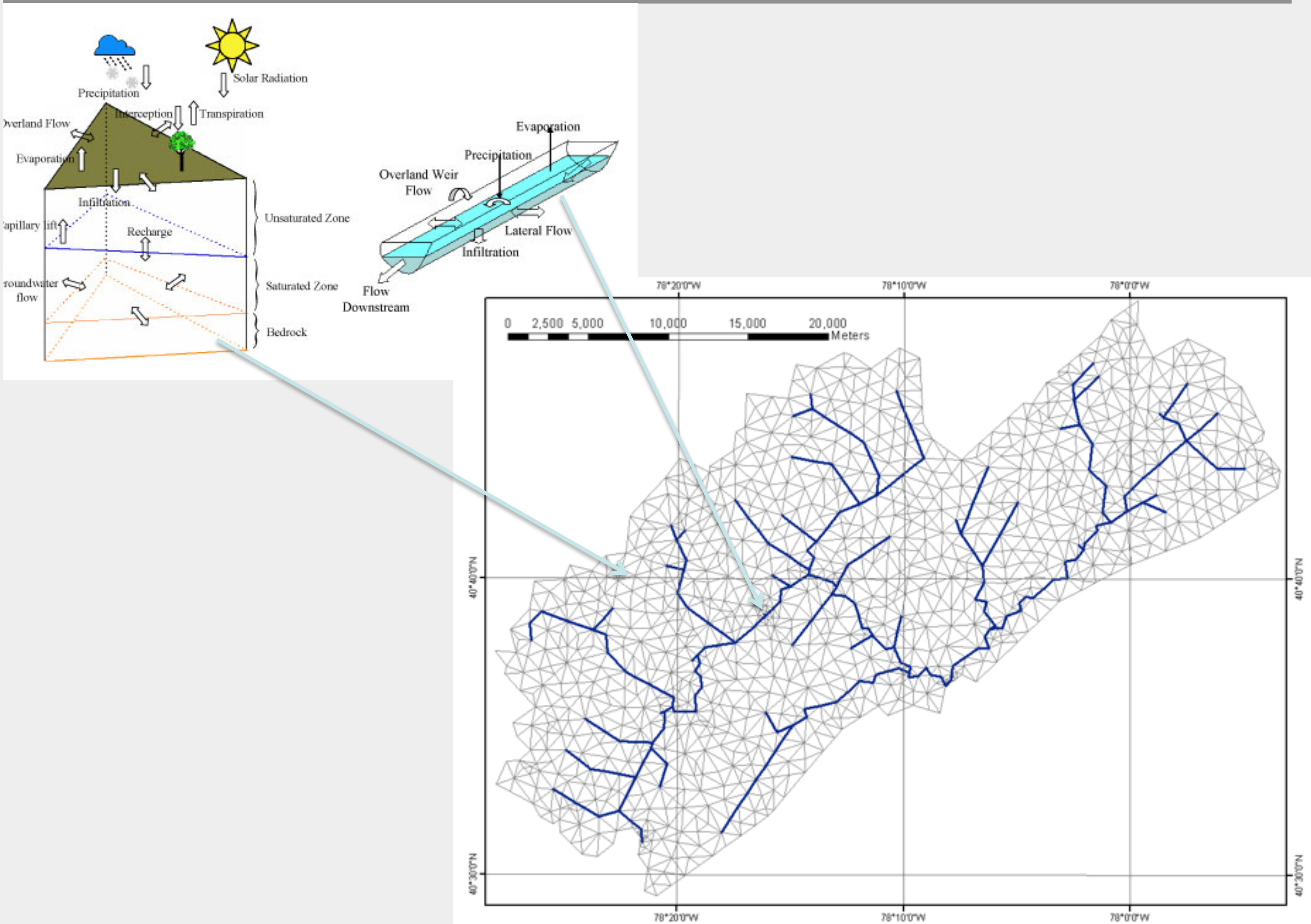


Cunha et al 2012, Adv Wat Res

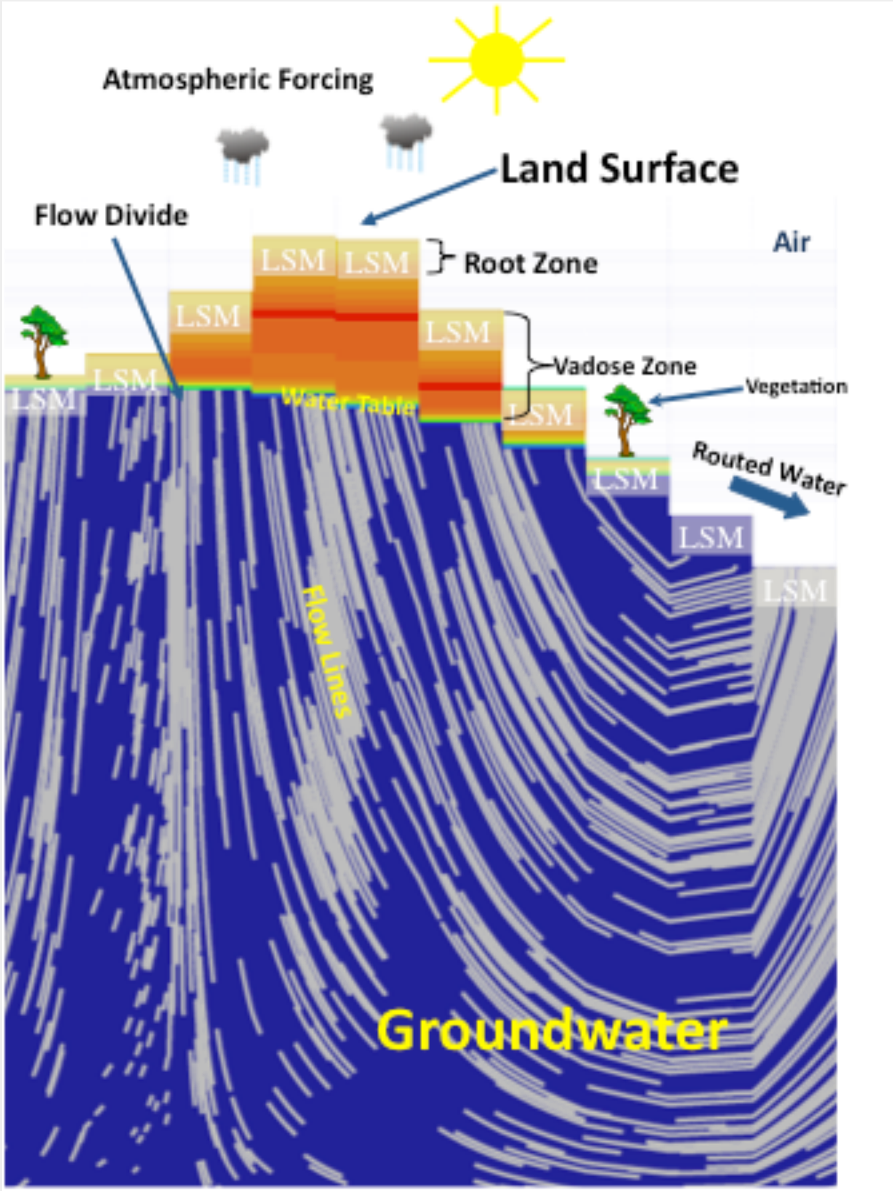
Multi-physics based models

- Development of tightly coupled surface-subsurface flow equation sets, simultaneously solved with efficient solvers using finite grid, finite volume, regular or irregular mesh strategies
  - PiHM – Chris Duffy, Penn State
  - Parflow - Reed Maxwell, Colorado School of Mines
  - HydroGeoSphere - Ed Sudicky, University Waterloo
  - ……
- Coupled with land surface, ecosystem, atmospheric models (e.g. CLM, Biome-BGC, WRF) to provide dynamics and feedbacks with linked systems

PiHM control volumes and mesh



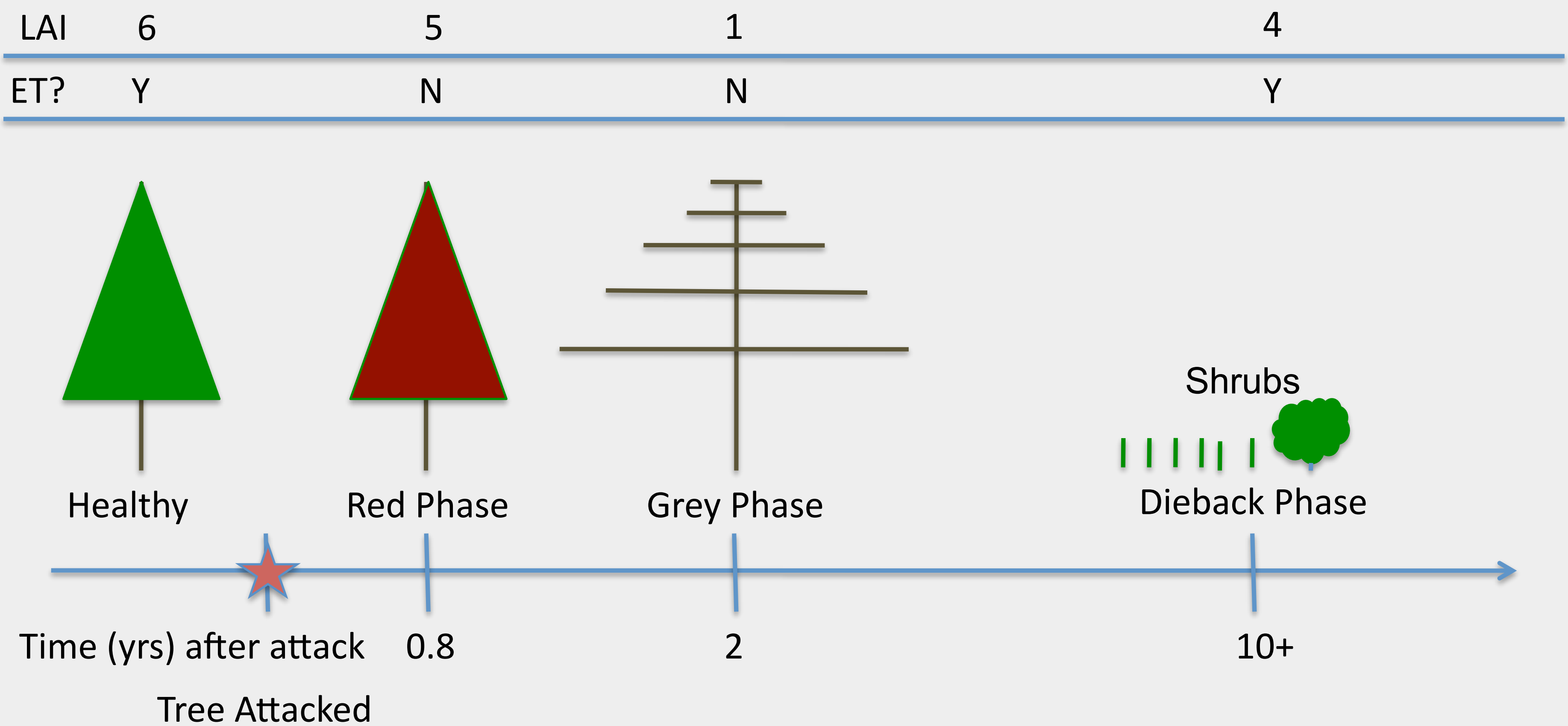
ParFlow: an integrated hydrologic model



- Growing number of *integrated* SW-GW models: HGS, CATHY, PIHM, InHM, we use/develop ParFlow
- Groundwater flow: variably-saturated three-dimensional Richards equation
- Overland flow/surface runoff: free-surface overland flow boundary condition (Mannings + kinematic wave)
- Land surface water and energy fluxes: Common Land Model (CLM), includes infiltration, canopy and vegetation processes, and coupled water-energy balance
- Fully-coupled, mass conservative, parallel implementation

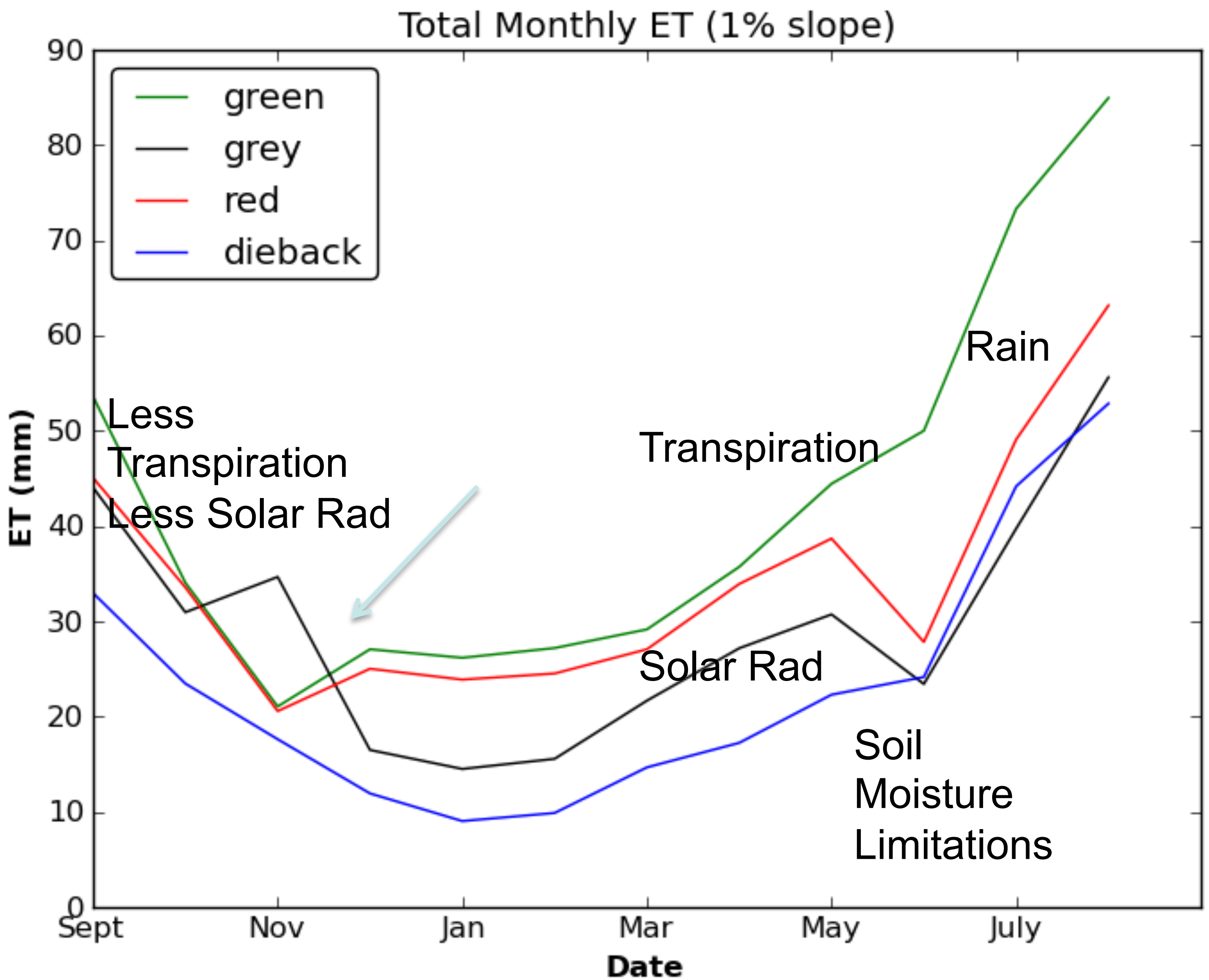
Kollet and Maxwell (2008), Kollet and Maxwell (2006), Maxwell and Miller (2005), Dai et al. (2003), Jones and Woodward (2001); Ashby and Falgout (1996)

Four Stages of MPB infestation



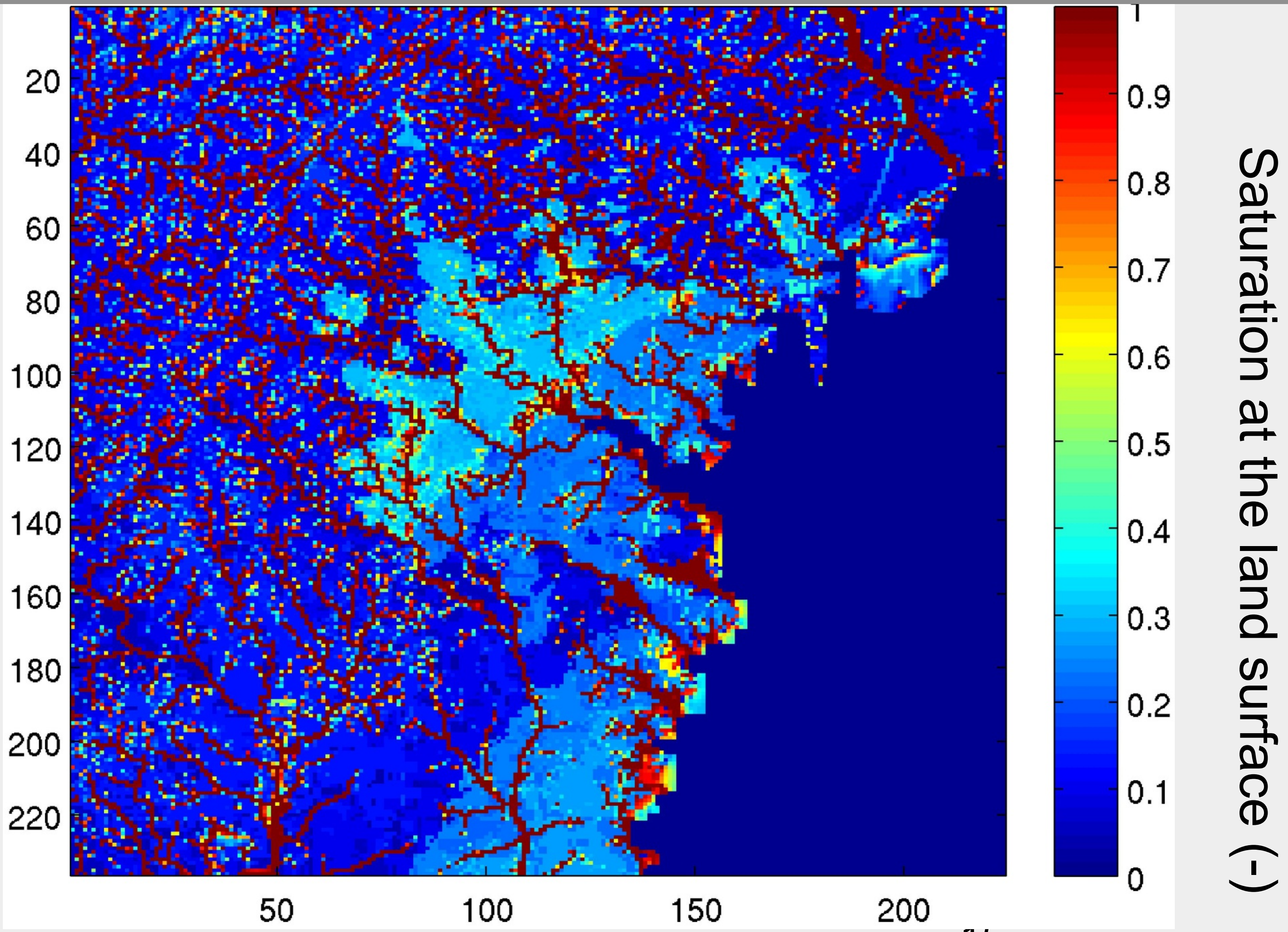
Reed Maxwell, Colorado School Mines

Results: ET (Soil Evap + Transpiration)



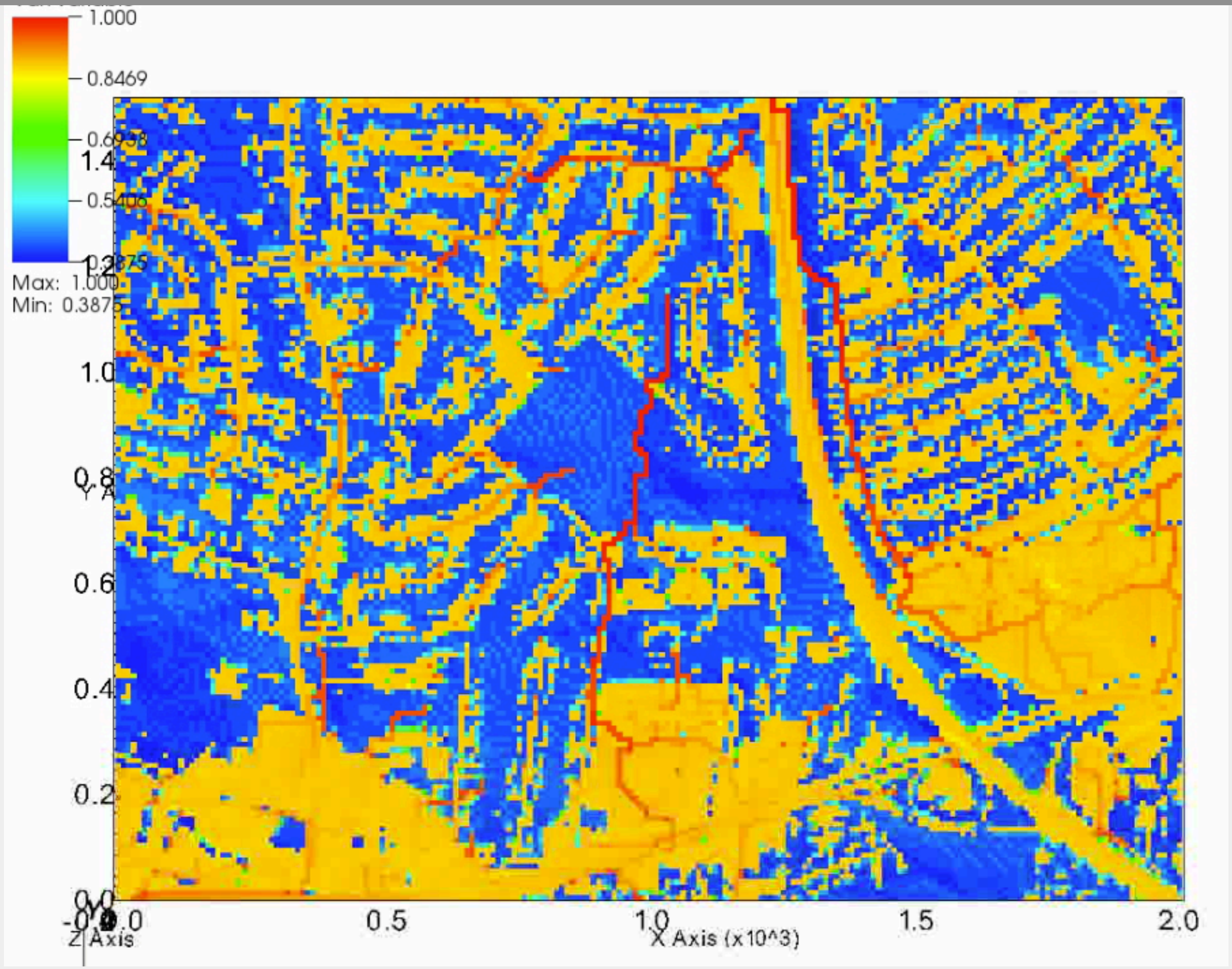
Reed Maxwell, Colorado School Mines

Regional-scale implementation



Claire Welty, UMBC

Subwatershed-scale implementation



Claire Welty, UMBC

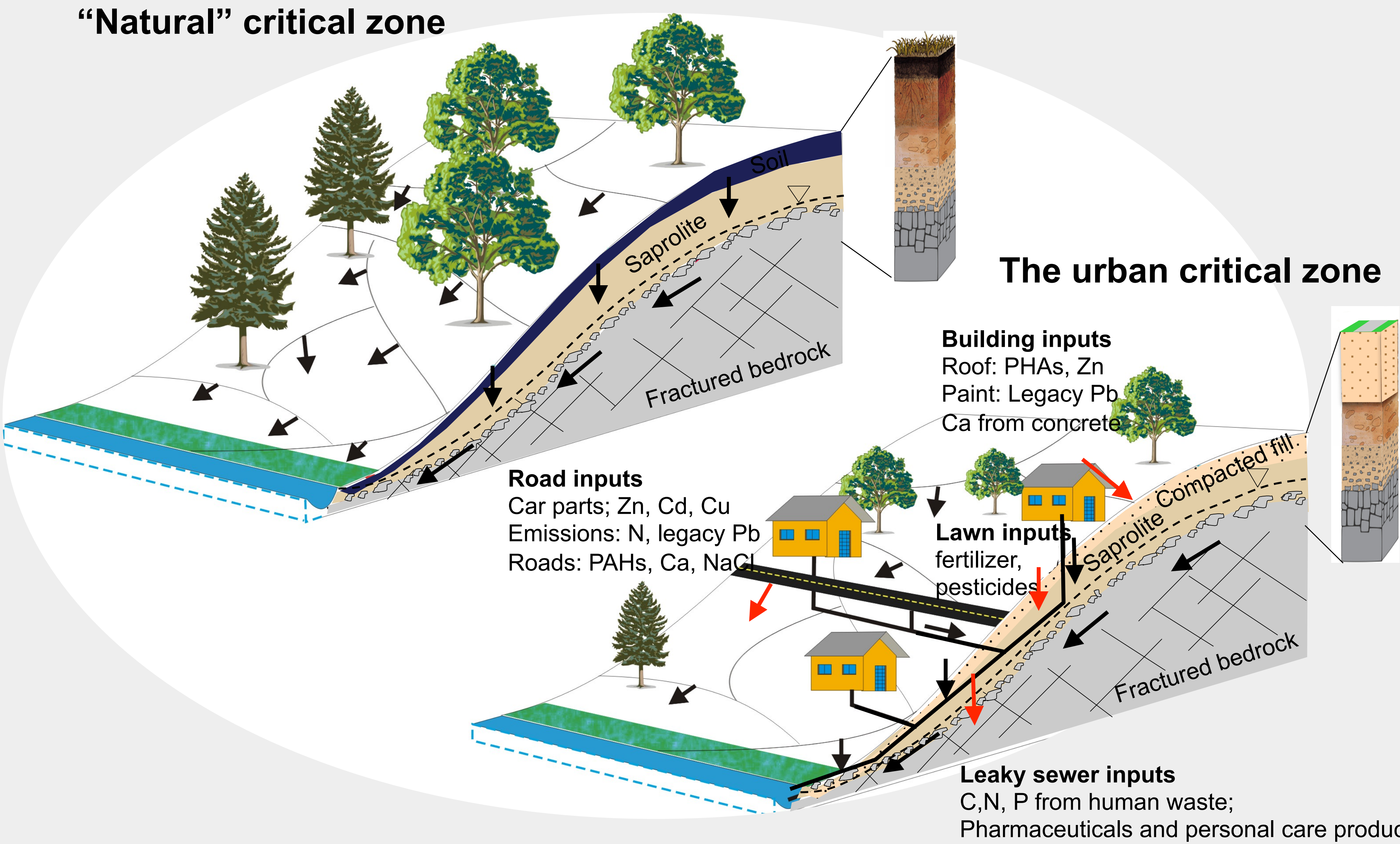
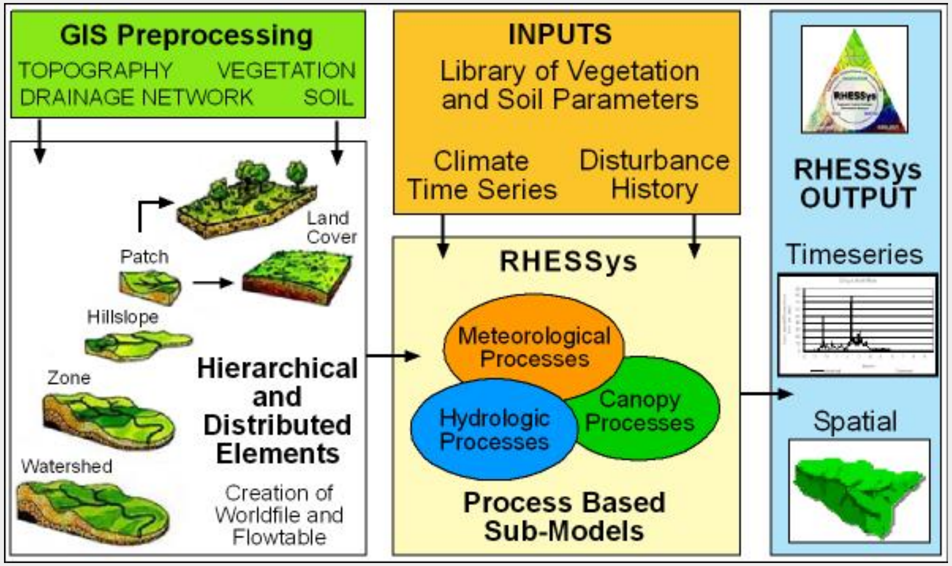
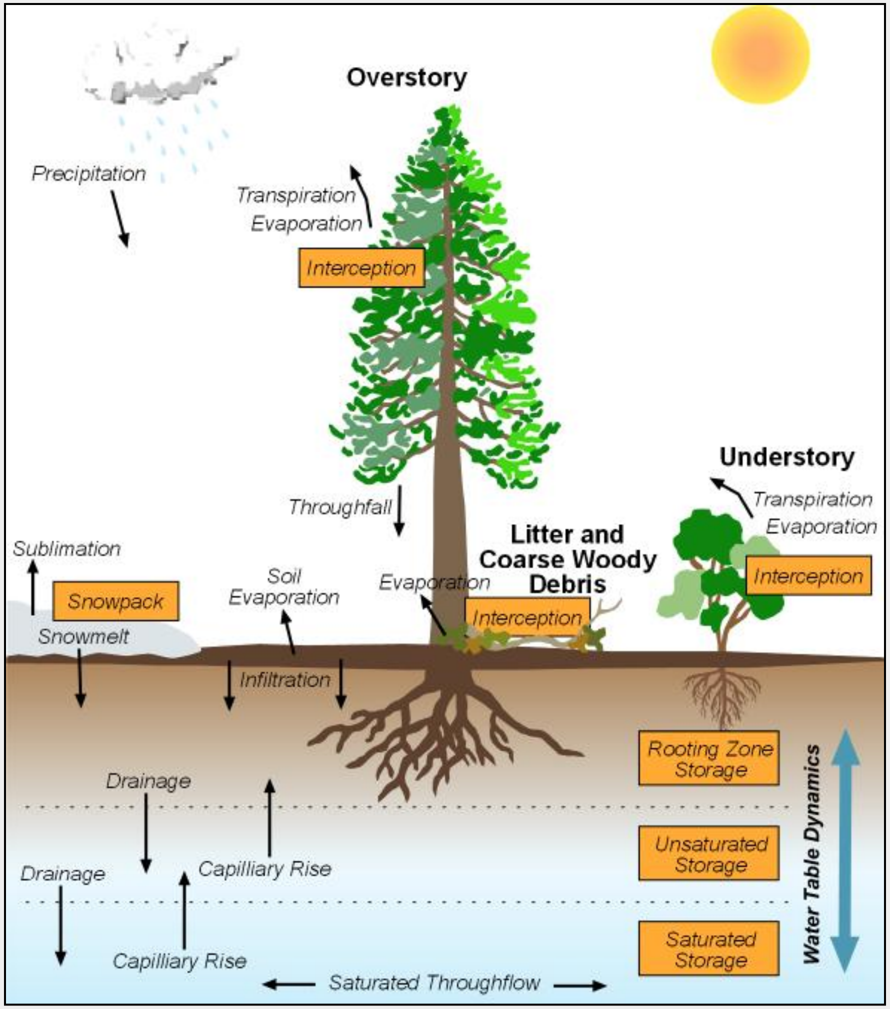
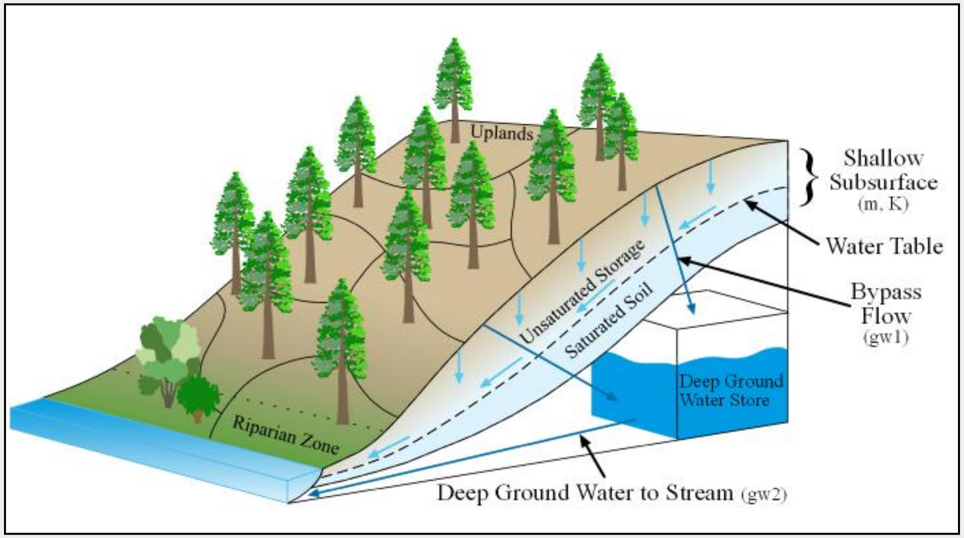


Figure 1. The natural and urban critical zones. In the urban critical zone, topsoil is replaced by compacted fill, sewers and other utilities pierce the subsurface creating preferential flow paths, and there are additional chemical inputs from the built environment.

RHESSys:
Regional Hydro-Ecological Simulation System



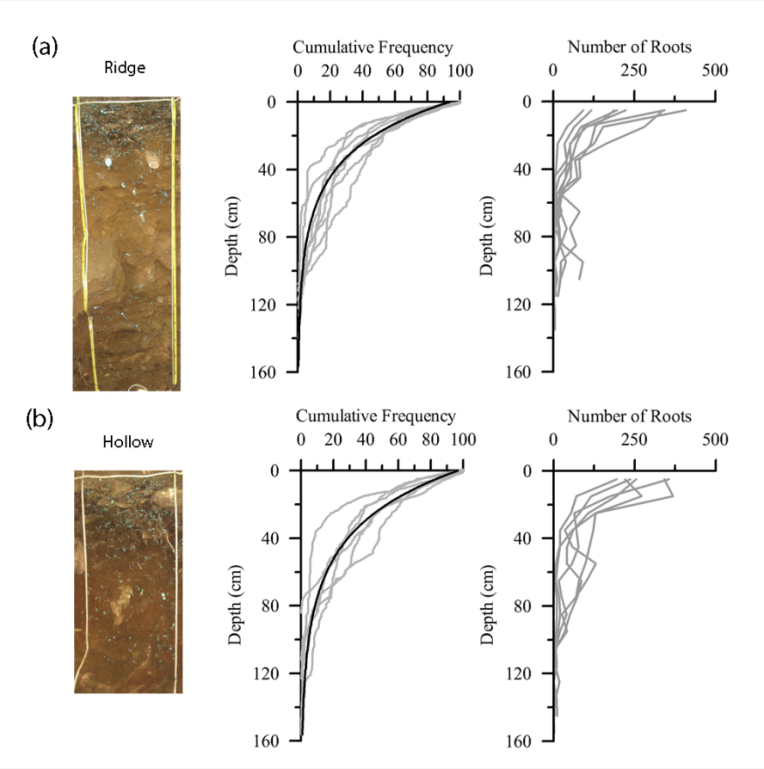




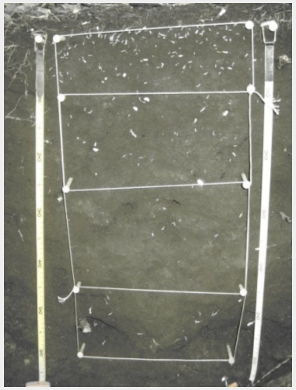
(Courtesy of Janet Choate)

Rooting depth along hydrologic flowpath

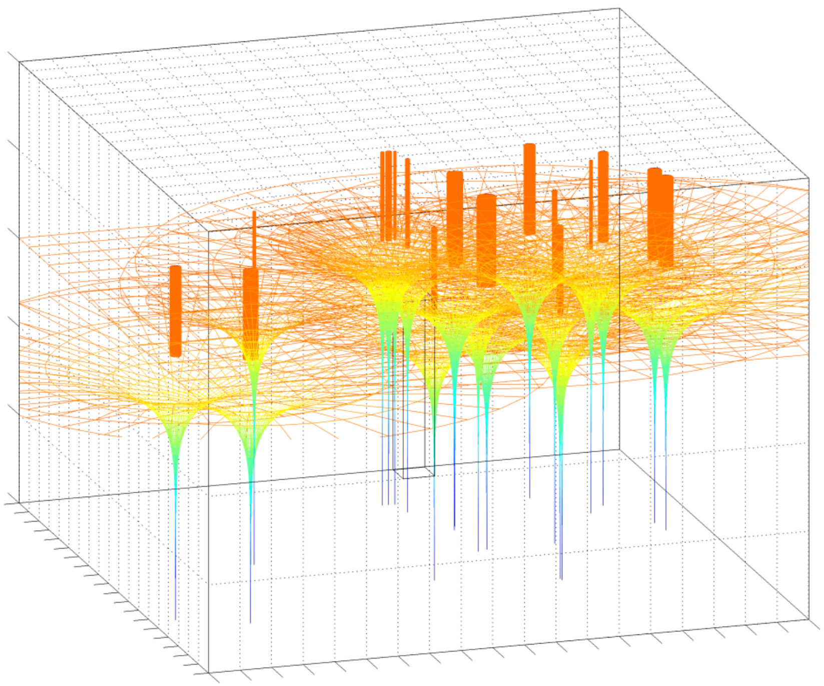
- Excavation of root profiles (there must be an easier way…) covariance with topographic position, canopy properties

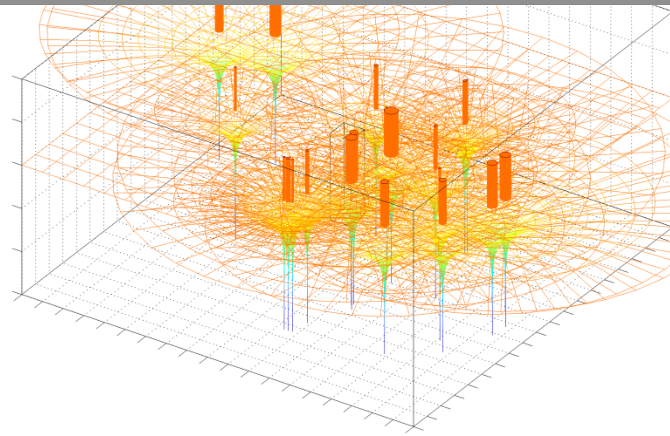


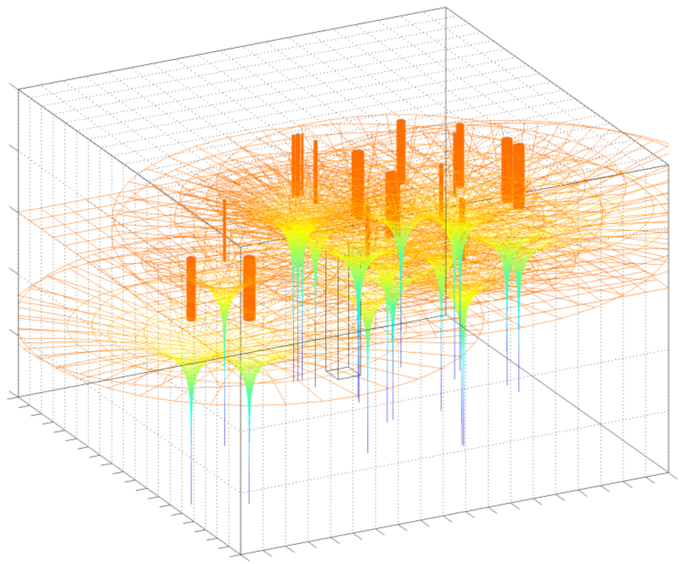
(Hales *et al.* 2009; *Journal of Geophysical Research*)




The 3-D root architecture model

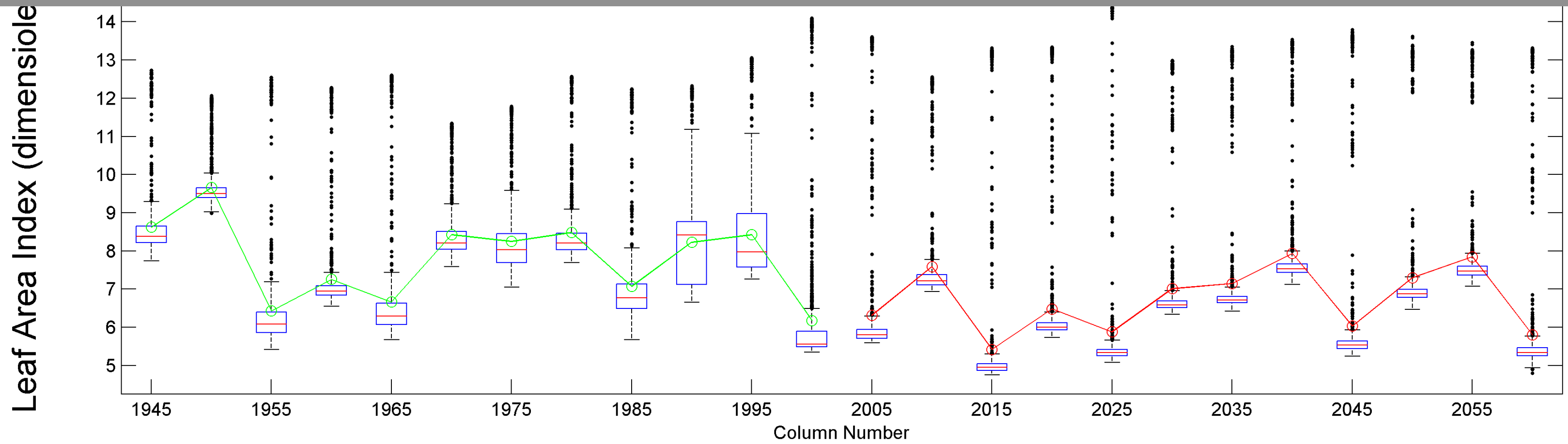


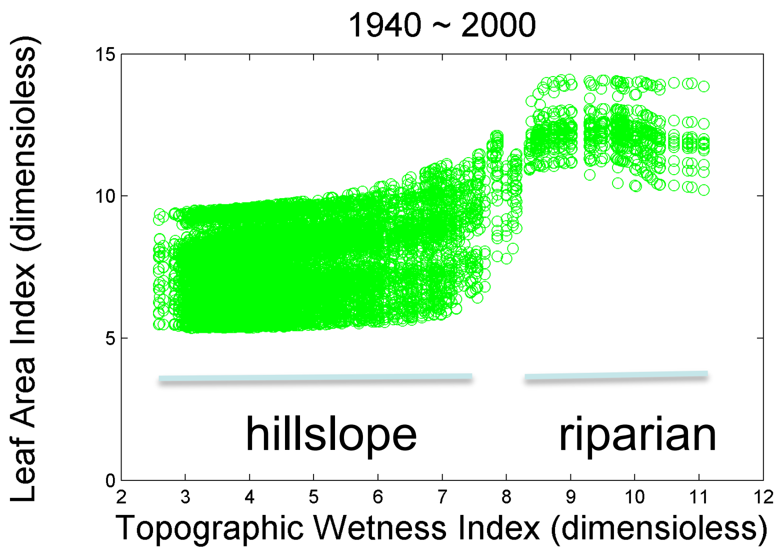


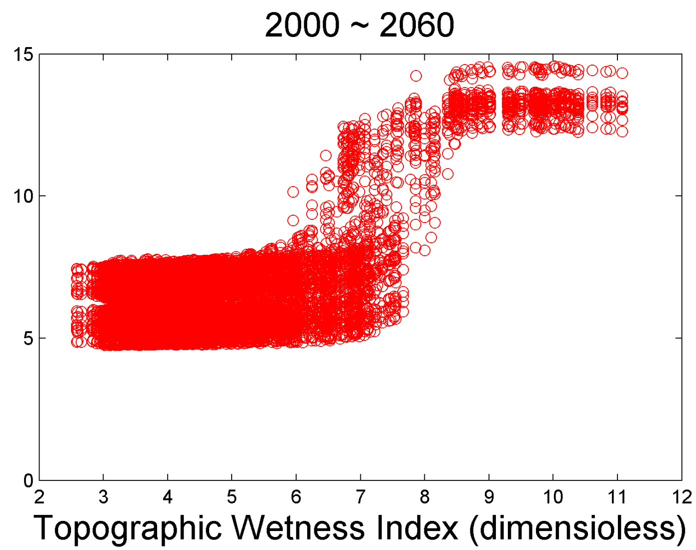


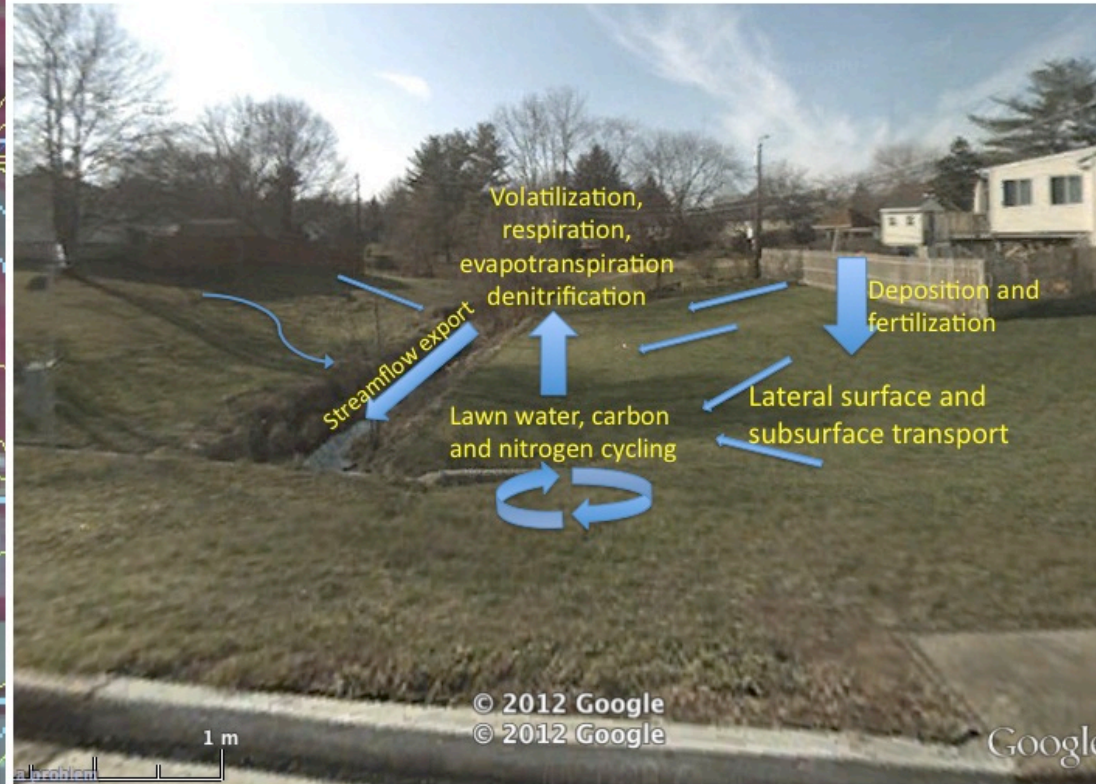
- Dendritic root model
- Allocation dynamics and allometry from canopy model and lidar canopy properties

Transient simulations:
Measured –> hypothesized climate

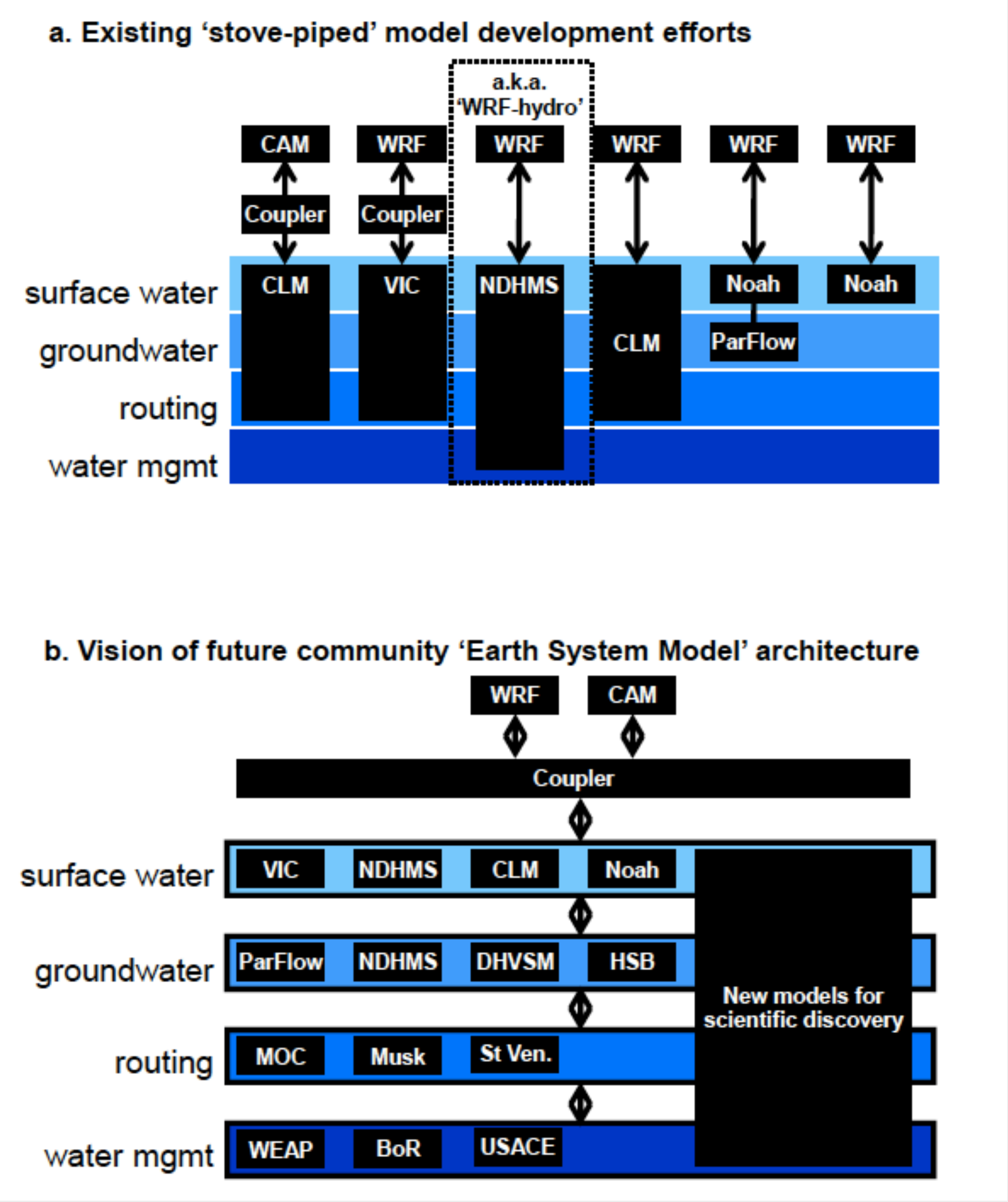








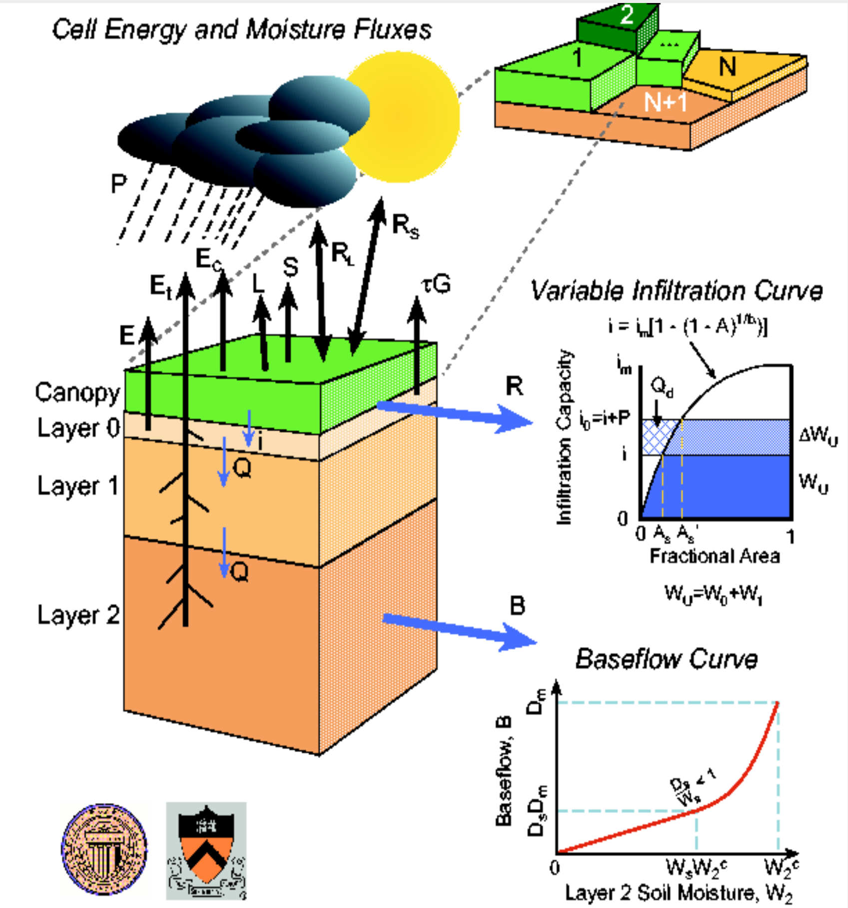
Roof drainage to swale between houses



http://climatemodeling.science.energy.gov/f//Water_Cycle_Workshop/Day1_Topic3_Gochis.pdf

VIC Hydrologic Model

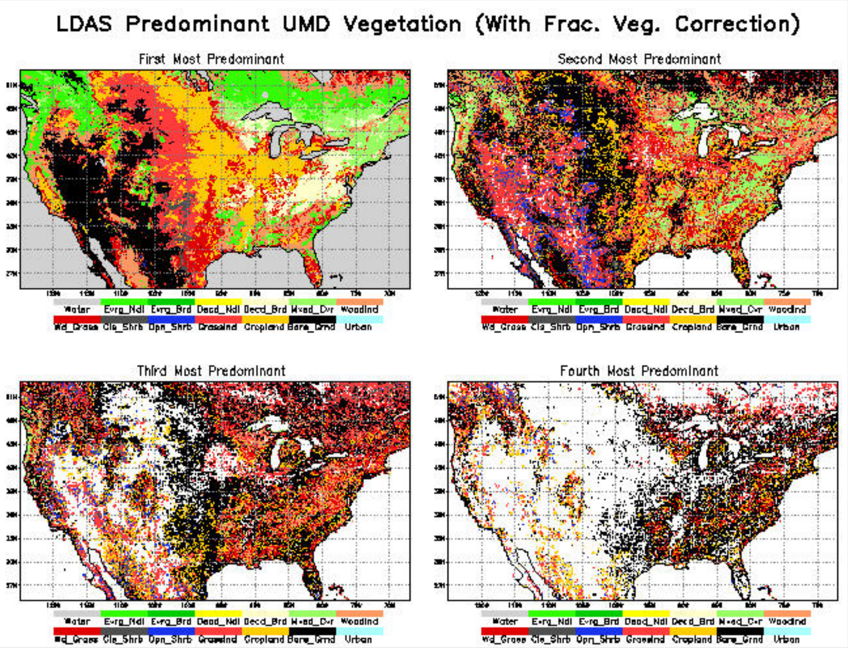
- Variable Infiltration Capacity (VIC) Model
- Developed at University of Washington/ Princeton University
- Widely used for macro-scale hydrologic modeling



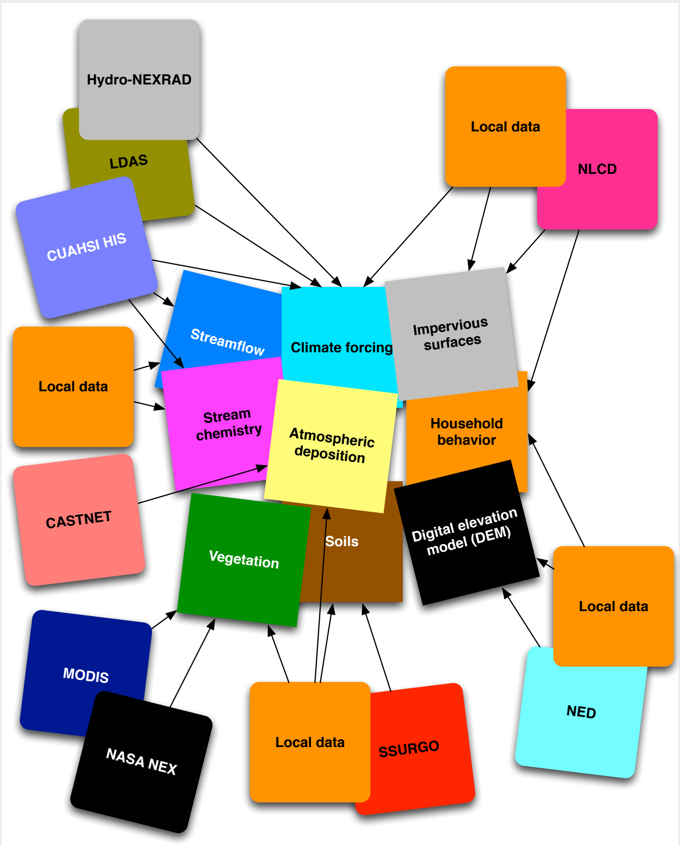
Source : Gao et al. (2009)

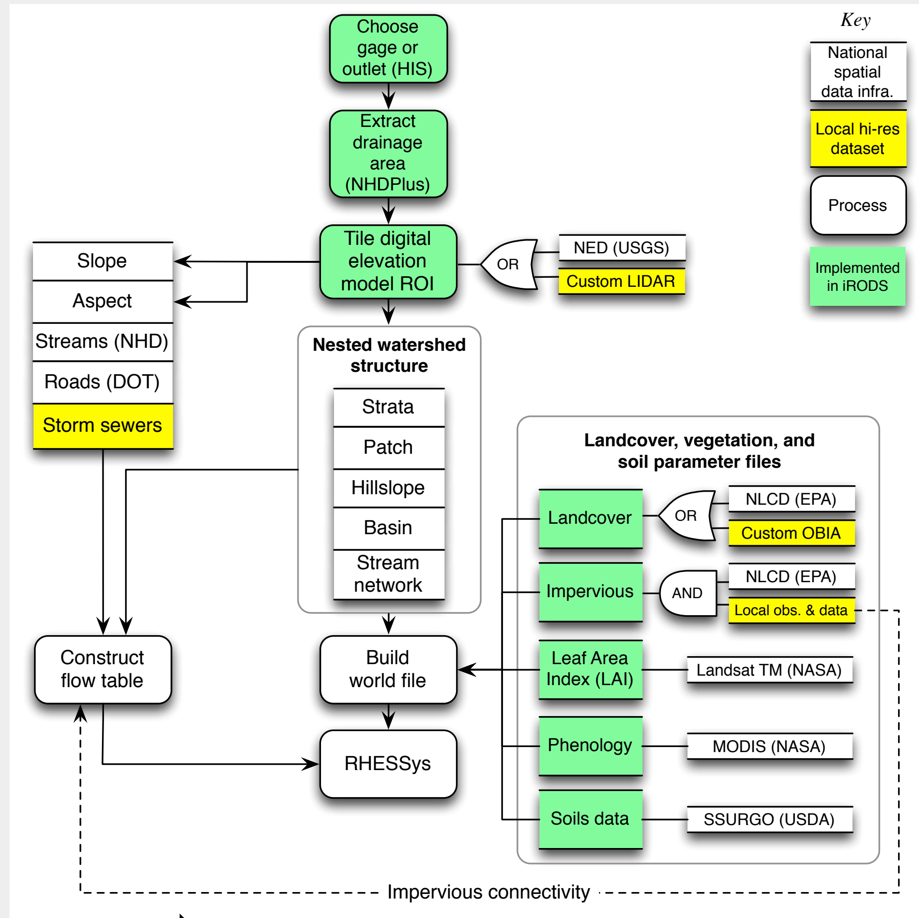
VIC Data Needs

- **Meteorological Forcing data**
  - Precipitation from National Climatic Data Center (NCDC)
  - Maximum and minimum temperature from NCDC
  - Wind Speed from National Centers for Environmental Prediction / National Center for Atmospheric Research (NCAR/NCEP)
- **Topography data**
  - HYDRO1K datasets /GTOPO30 DEM
- **Soil and vegetation data**
  - Soil parameter from Land Data Assimilation Systems (LDAS)
  - Vegetation parameter from LDAS
  - Vegetation library from LDAS



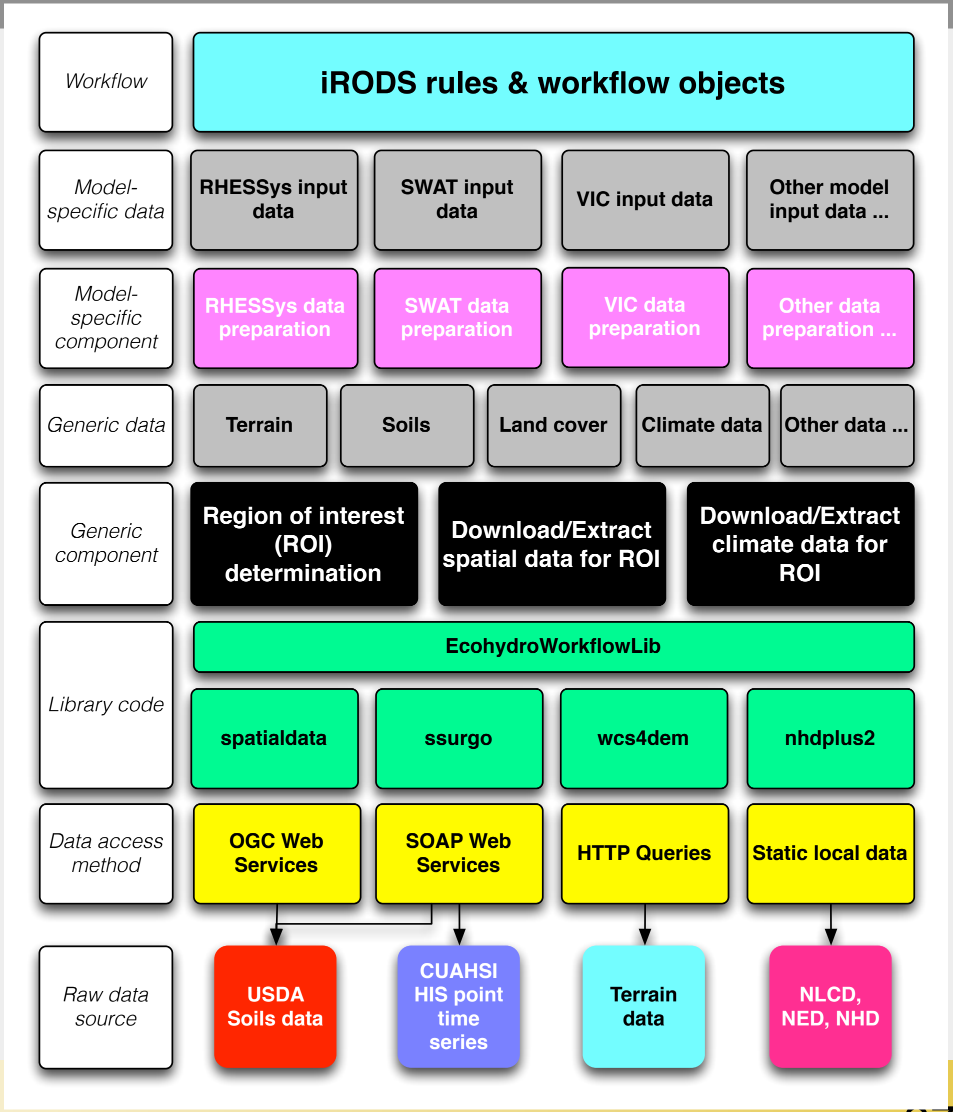
RHESSys data preparation: workflow development





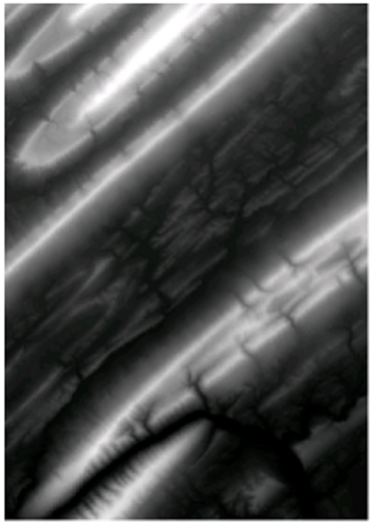
Manual workflows → Workflow framework

Ecohydrology data preparation software architecture

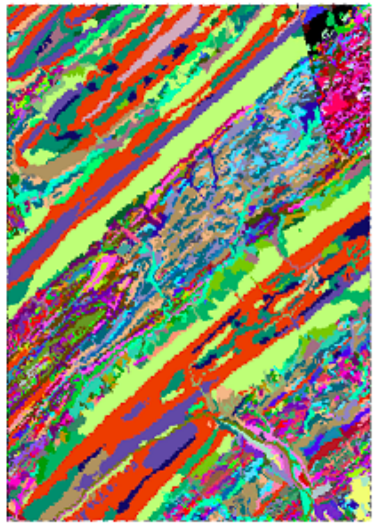


Essential Terrestrial Variables (ETV)

Elevation from USGS NED

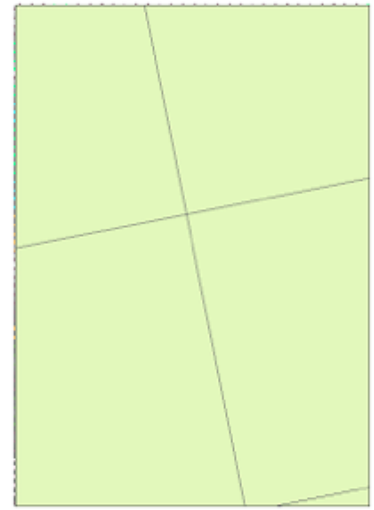


Soils from SSURGO

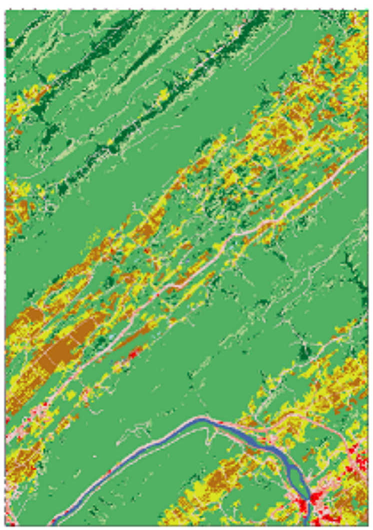


Soils from Statsgo

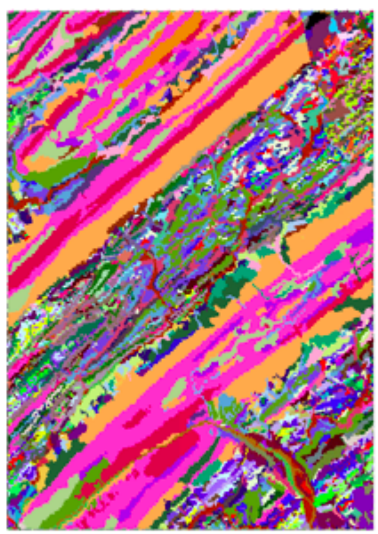
NLDAS Forcing Variables



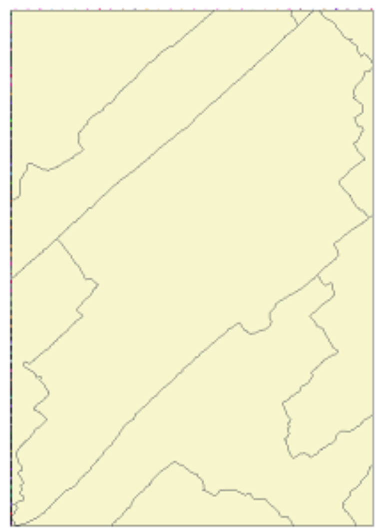
National Land Cover Database



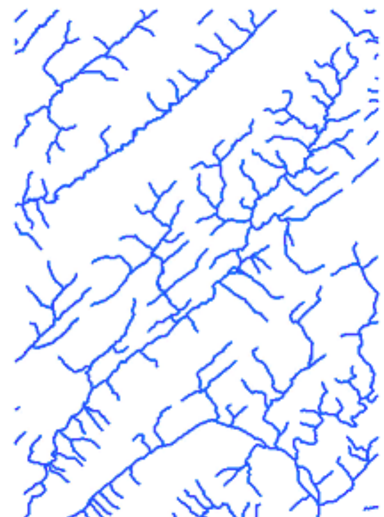
Geology based on Soils



NHD HUC12



NHD Streams



HydroTerre Data System

http://www.hydroterre.psu.edu/

Towards a National Water Modeling System

Don Cline
Chief, Hydrology Laboratory
National Weather Service

Jerad Bales
Chief Scientist for Water
U.S. Geological Survey

Bill Scharffenberg
HEC-HMS Lead Developer
Hydrologic Engineering Center
Institute for Water Resources
U.S. Army Corps of Engineers

Witek Krajewski
Chair, CUAHSI Board of Directors
Director, Iowa Flood Center
Chair, Water Resources Engineering,
University of Iowa

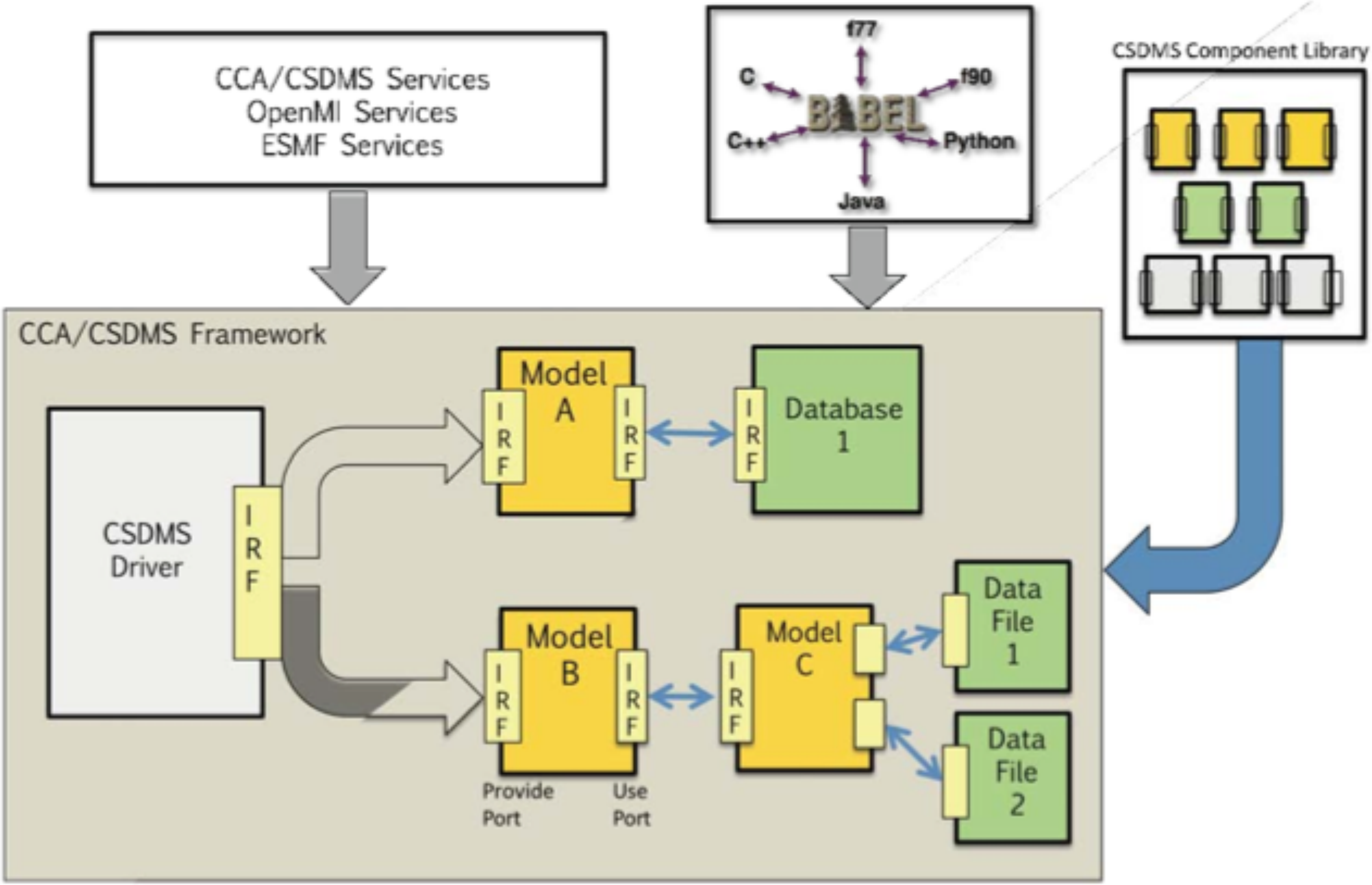


Figure 2. The CSDMS model coupling domain.

Other national efforts: Australian Water Resources Assessment

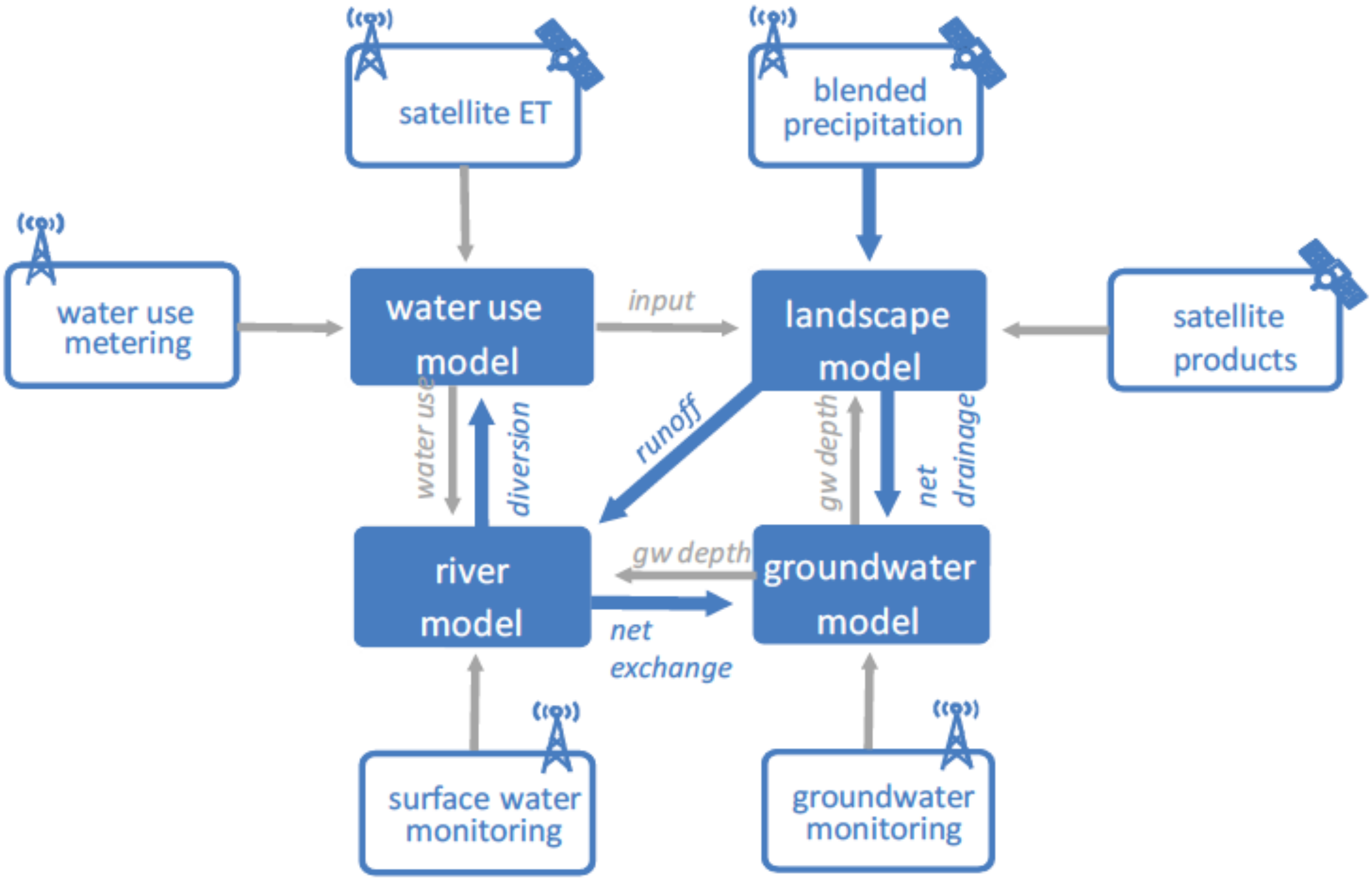


Figure 3: Conceptual diagram showing the modular structure of the AWRA system. Each blue box represents one or more component model containers(s); open boxes represent input data streams

Albert van Dijk, CSIRO, WIRADA Conference,

Hydrologic models evolving towards more coupled earth systems design

- Coupling methods
- Scaling methods to incorporate small scale heterogeneity
- Methods for generation of well documented and repeatable model set up and results as part of an integrated cyberinformatics environment