Structure, Function and Dynamics of Watersheds:

Emerging Science and Management Issues

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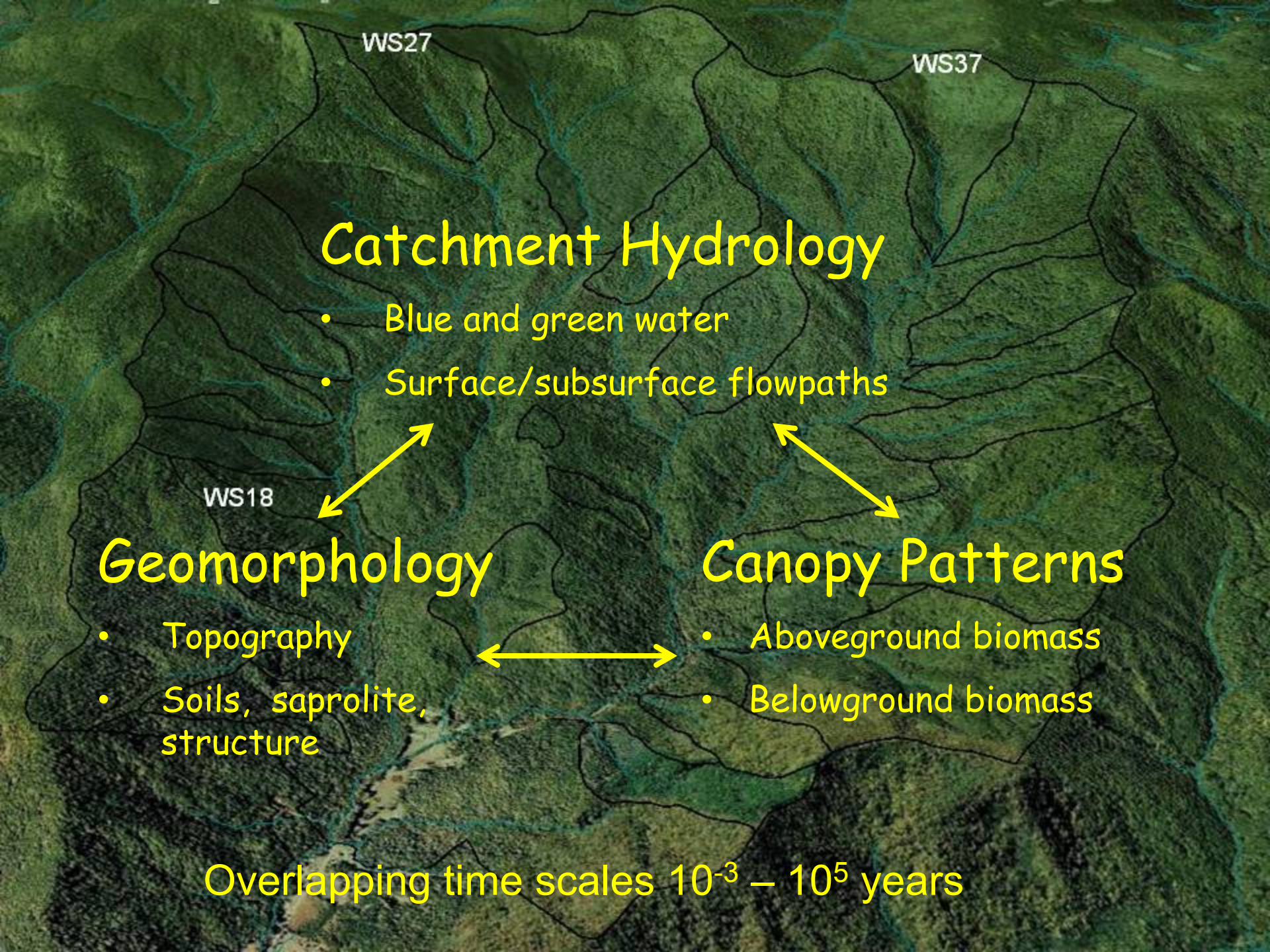
Roots of watershed hydrology paradigms

- Engineering hydrology (watershed based):
  - –Flood, drought, water supply
- Agricultural hydrology (field based):
  - – irrigation, drainage, erosion, fertilization
- Acid rain era:
  - – coupling of field/hillslope based hydrologic/ biogeochemistry to catchment scales
- Stormwater permitting:
  - – link/mitigate distributed sources of runoff/pollutants to receiving water impact
- – Earth Systems Science:
  - – coupled water, carbon, nutrient, energy cycling
  - – land-atmosphere interactions/geomorphic development



Catchment Hydrology

- Blue and green water
- Surface/subsurface flowpaths

Geomorphology

- Topography
- Soils, saprolite, structure

Canopy Patterns

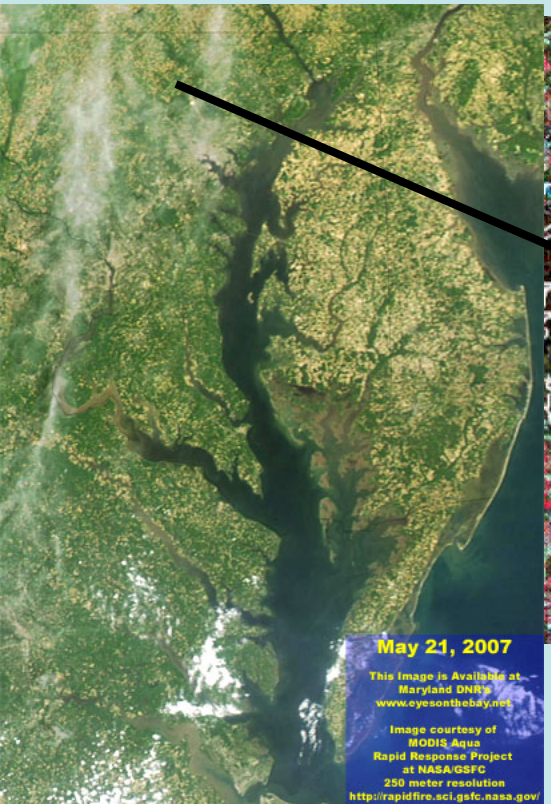
- Aboveground biomass
- Belowground biomass

Overlapping time scales 10^{-3} – 10^{5} years

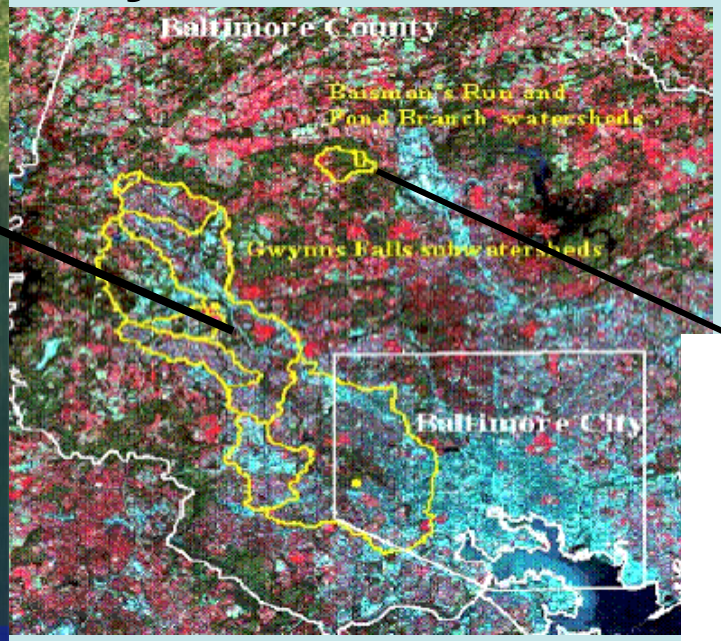
Challenge: Develop predictive understanding of nested river basins:

1. distributed water stores, fluxes and residence times,
2. NPS pollutant sources, transport and transformation,
3. response of sources/receiving water bodies to restoration and inadvertent change

CBW $10^5 km^2$

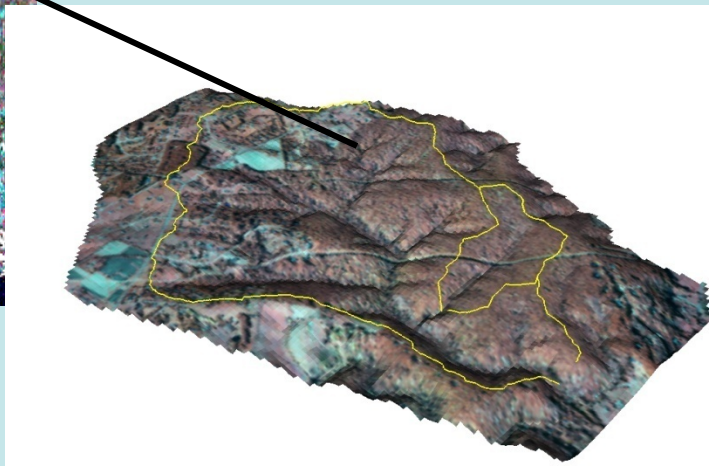


Gwynns Falls $10^2 km^2$



Baltimore LTER

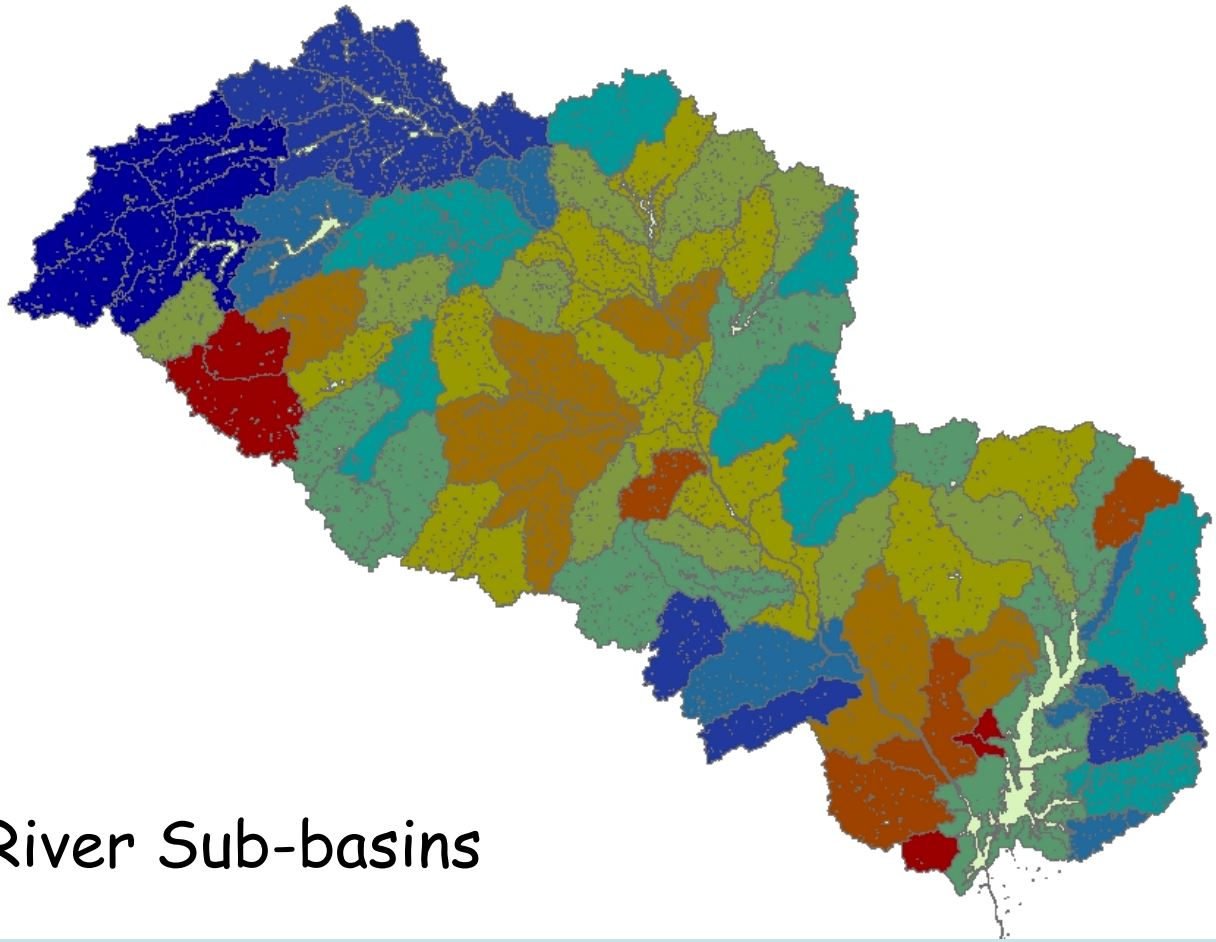
Baisman Run $10^0 km^2$



Current Water Quantity/Quality operational modeling based on conceptual balances lumped at watershed or subwatershed

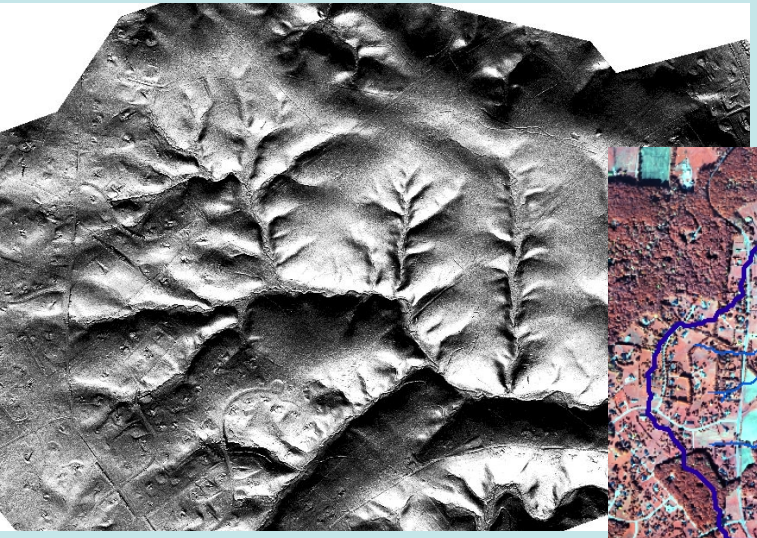
- HSPF, SWAT, … aspatial distribution of HRU within subwatershed
- Conceptual water storage and flux calibrated to historical rainfall/runoff information
- Chemical loads typically modeled by EMC set from land use (HRU), sediment with soil loss eq with delivery coefficients
- Specific intervention (e.g. BMP) may change HRU or treated as constant efficiency applied edge-of-field
  - e.g. Chesapeake Bay Watershed Model

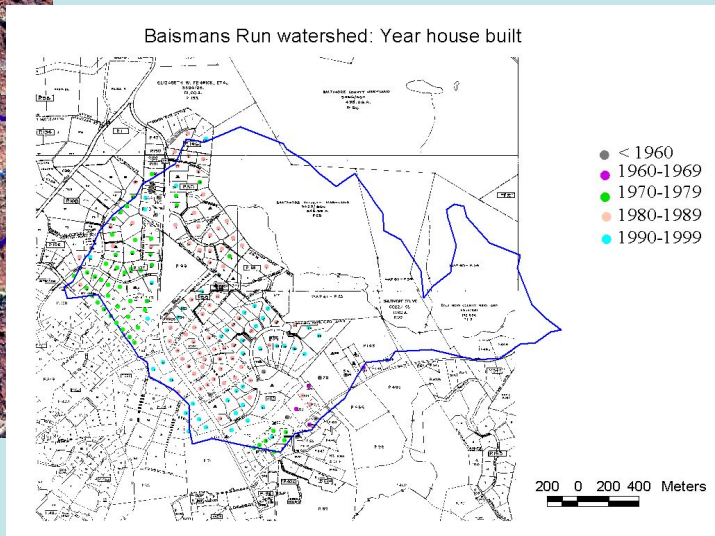
Models based on paradigms developed prior to availability of spatial data infrastructure: dependent on large number of unobservable, calibrated parameters



Haw River Sub-basins

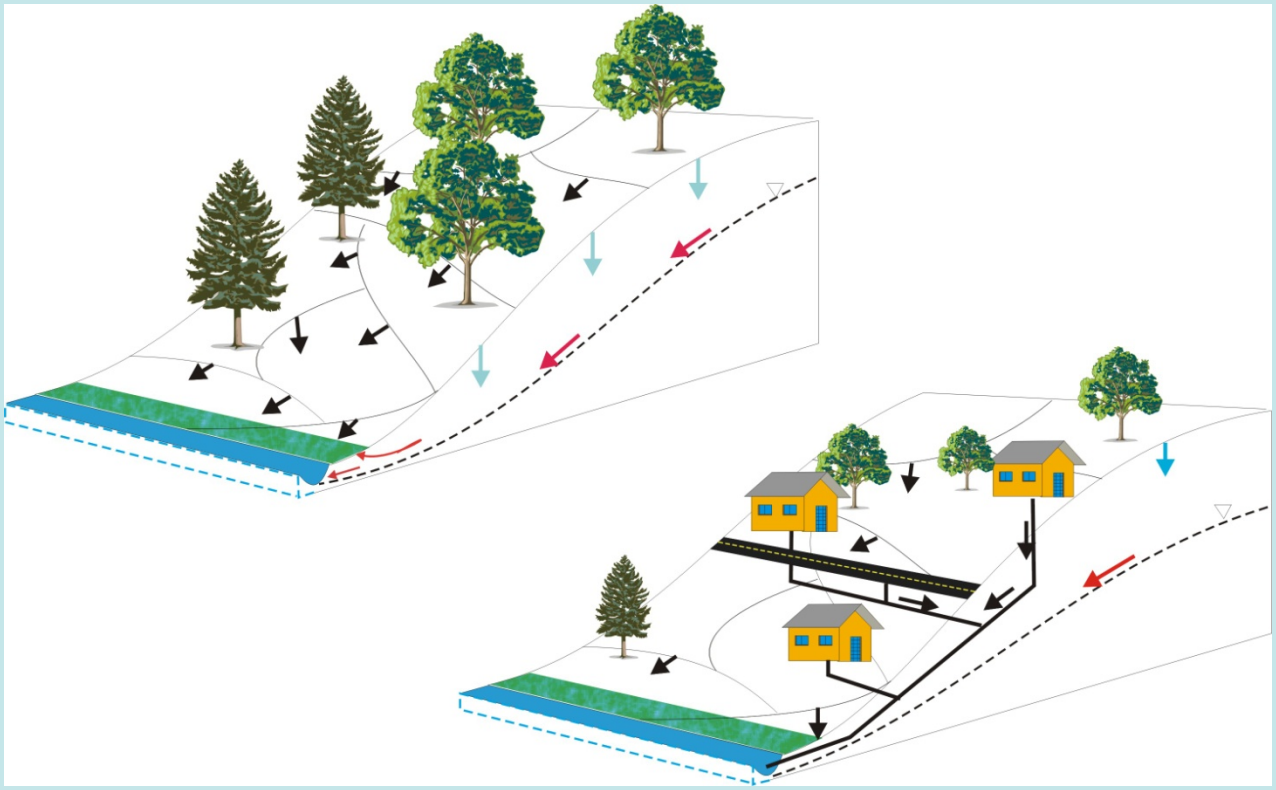
New spatial data infrastructure facilitates high resolution distributed models - more commensurate to observations, ability to resolve flowpath structure





- Incorporate more process based feedbacks between hydrology, land cover, ecosystem, biogeochemical and human components
- Need for **synthetic** approach including **monitoring, modeling, informatics** across interdisciplinary boundaries

Hierarchical framework to connect sources to receiving waters: Connectivity of ecosystems patch->hillslope->catchment scale



- patch scale water, carbon, nutrient budgets
- hillslope flowpath transport/transformations
- in-stream transport/transformations
    - feedback to management of stormwater & soil water

Value and evolution of Federal, State, Local Agency Spatial Data Infrastructure

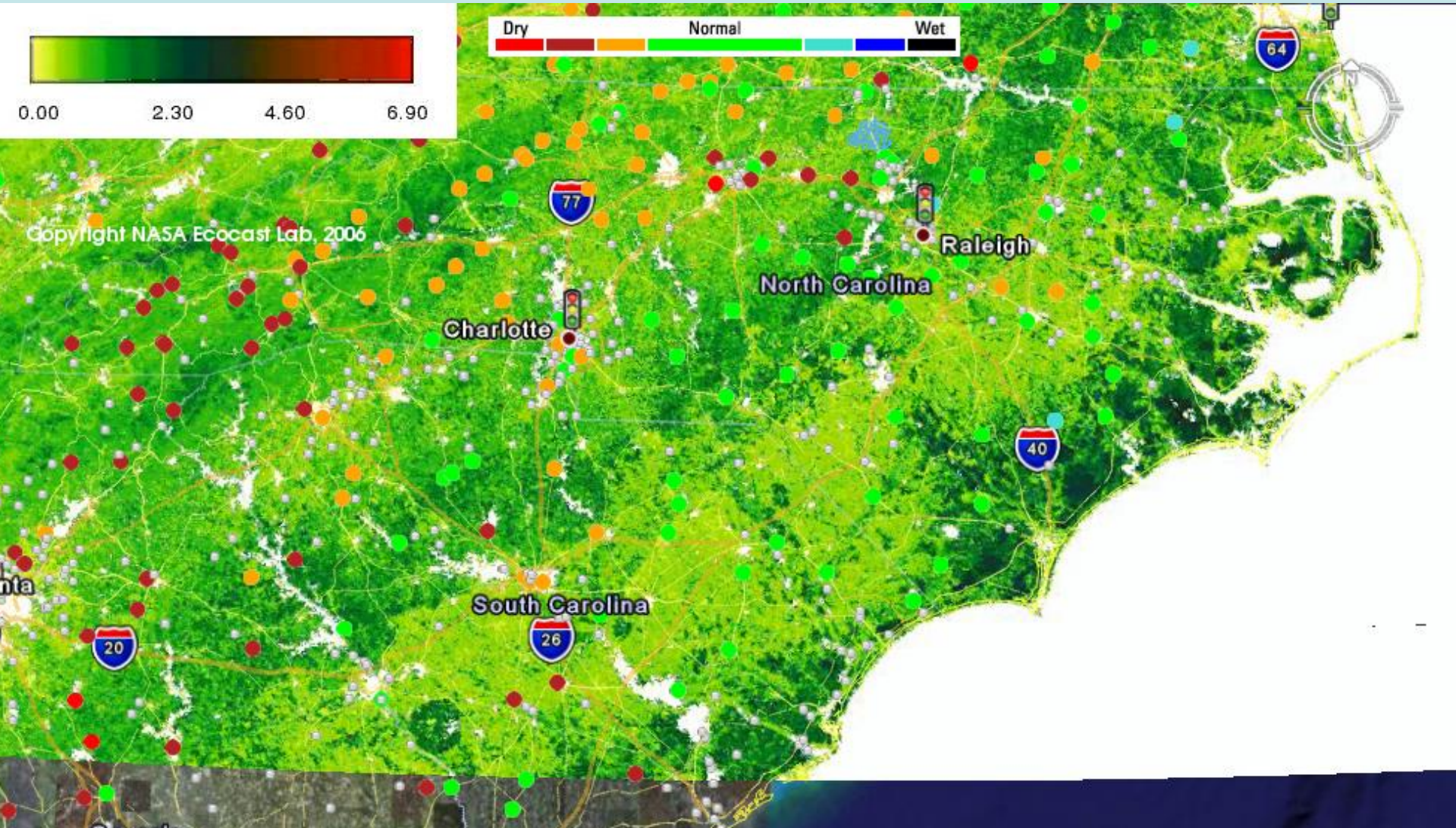
Modeling paradigms leveraging rich spatial information provided by multiple sources:

- Federal NED, State (e.g. NC) lidar elevation data
- EPA NLCD, local detailed land cover/infrastructure GIS
- USDA STATSGO/SSURGO Soils, local?

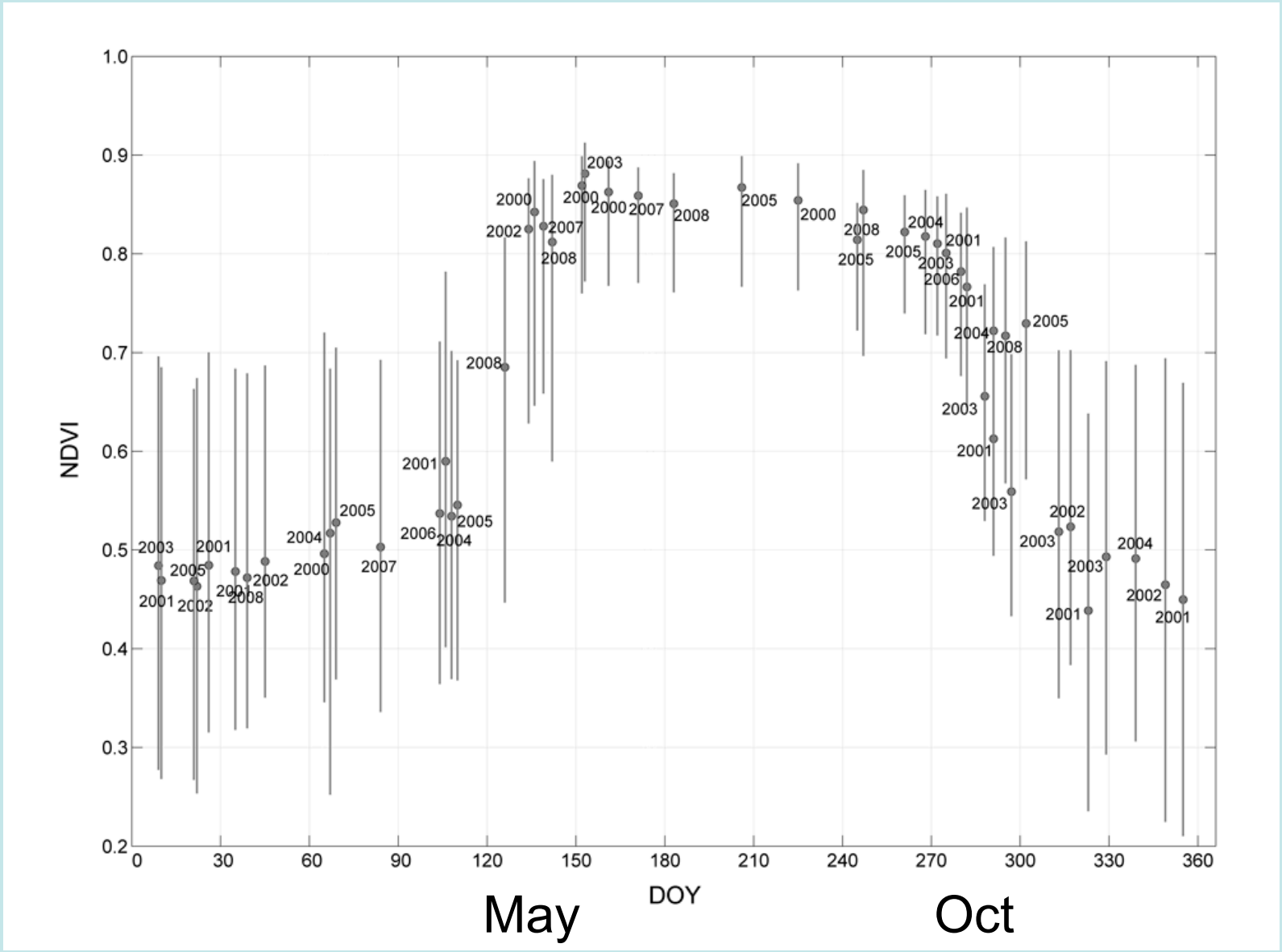
- Data assimilation (observations -> model):
  - Advanced weather monitoring and modeling
  - Satellite near real-time vegetation cover, soil moisture
  - Real time streamflow (need commensurate groundwater)
  - Soil moisture network?

Previous spatial data on topography, land cover and vegetation were not sufficient for this approach

Near real-time MODIS LAI with real time USGS gauge data from NASA Earth Exchange (NEX)



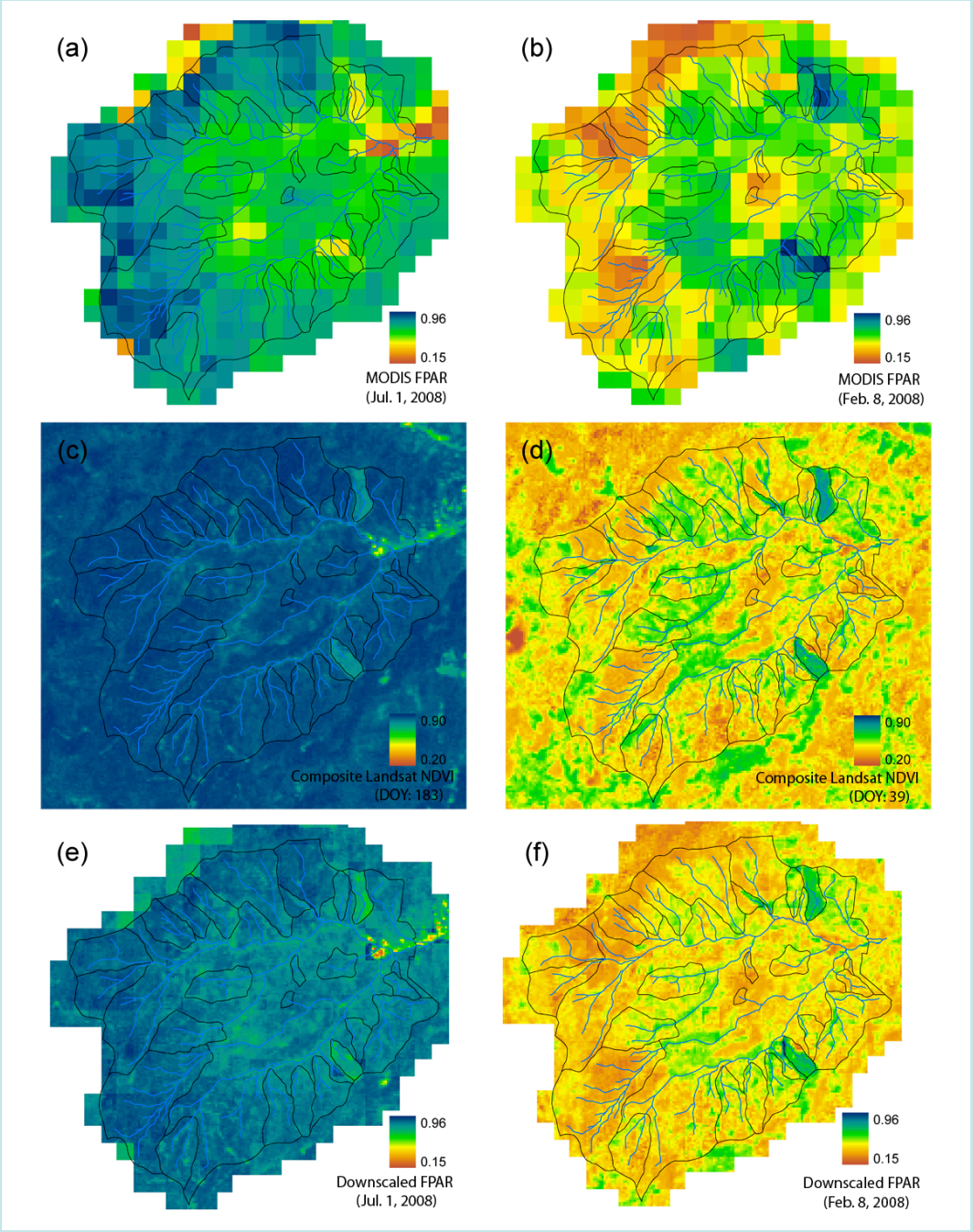
Composite DOY phenology from ~50 ETM scenes



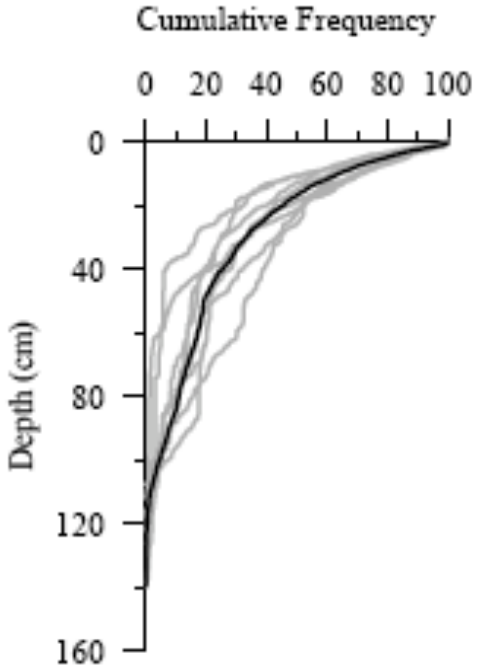
Integrating composite period MODIS FPAR with 30m TM canopy information provides high spatial and temporal resolution phenology

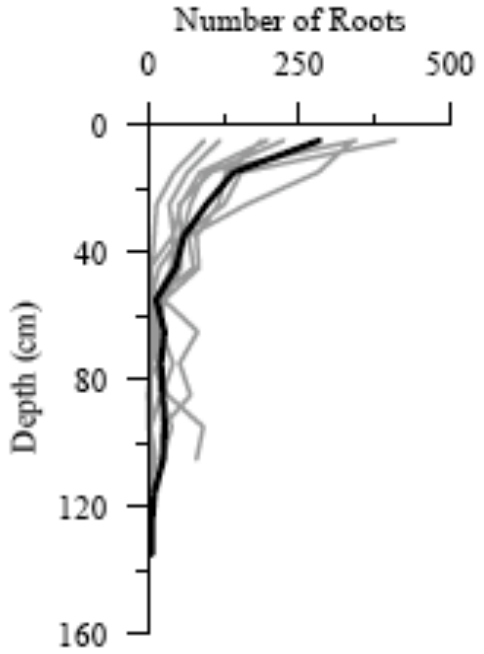
Important for subtropical storm generated flood and landslide prediction during fall transitional season

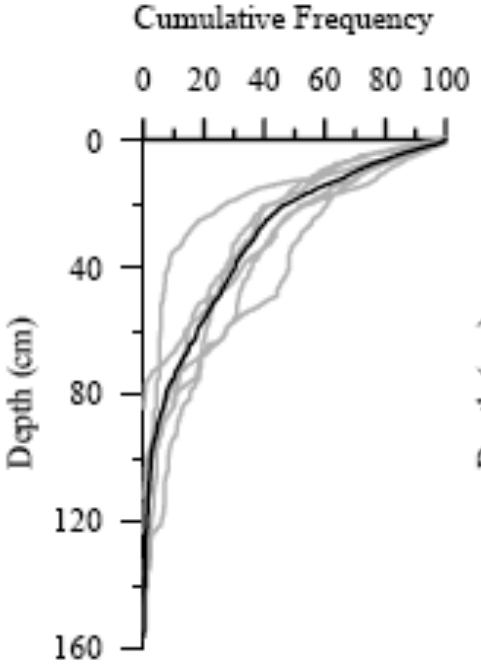
Hwang et al, RSE, 2011

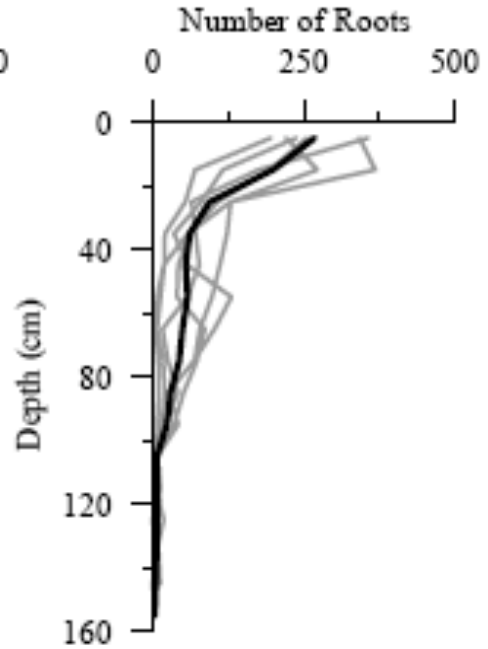


Root depth, density, diameter, strength by species and topographic position









Hales et al 2009 JGR

Hydromet Nowcasting/Forecasting Structure

NC LIDAR

Econet

National Hydrography Dataset

Meteorological data and forecasts (NOMADS/WRF)

Regional HydroEcological Simulation System

Stream Flow

Low flow - Drought

Flood hazard

Soil Moisture, saturation

Landslide hazard

Land Data Assimilation System (NASA GSFC)

Fire fuel load and moisture

Wildfire hazard

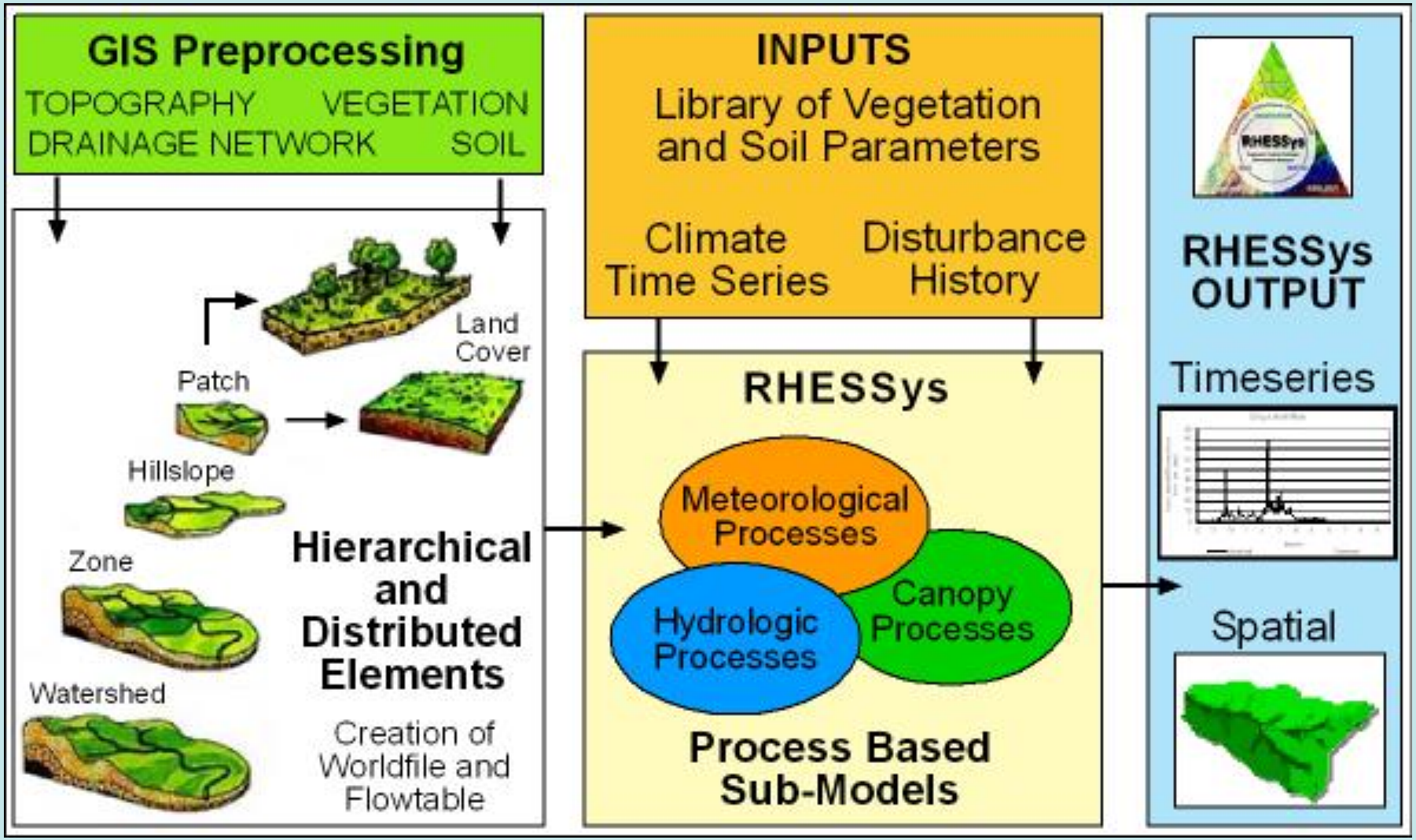
Ecocasting: MODIS Leaf area index phenology (NASA ARC)

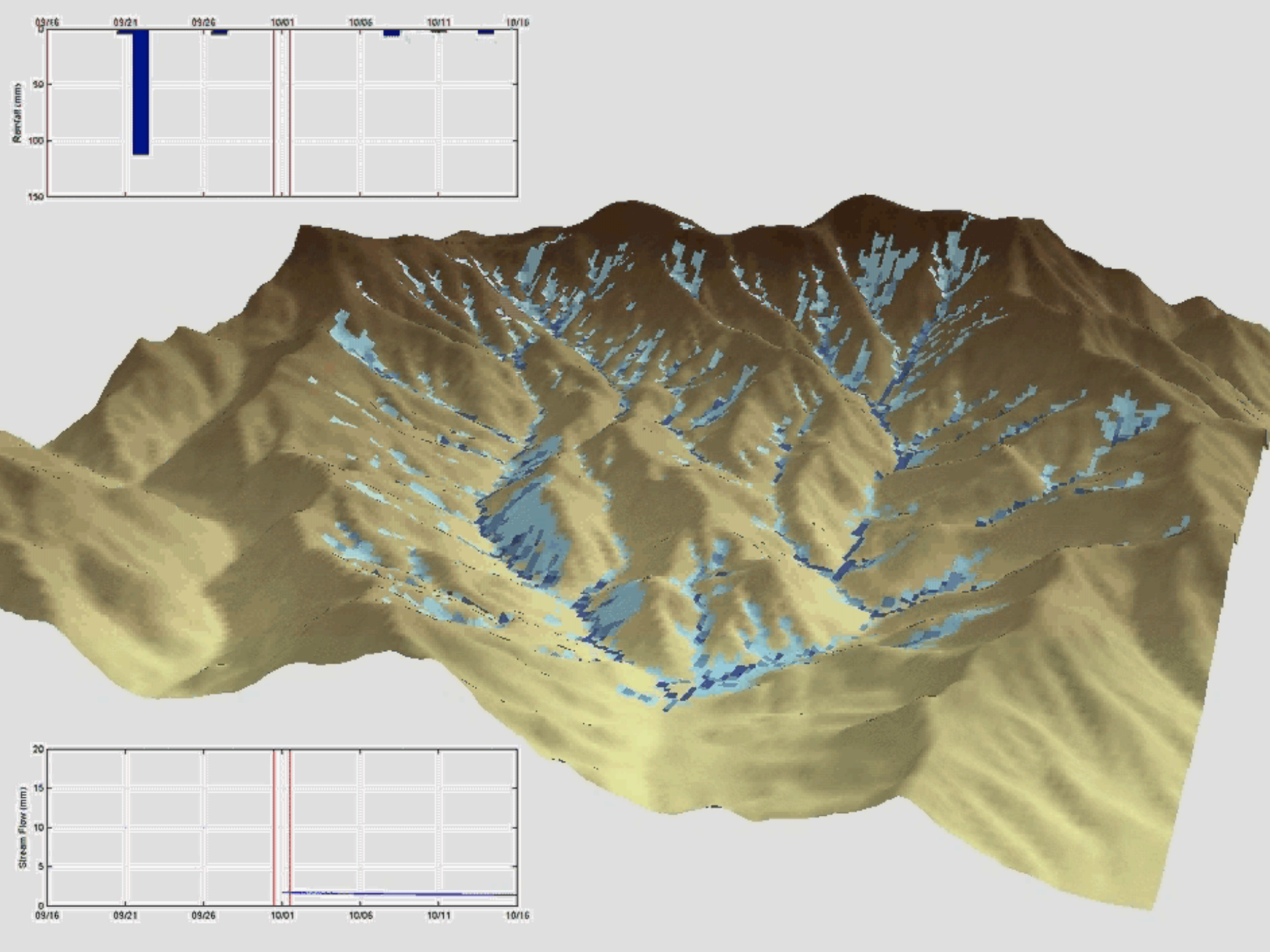
Land cover and land use

Digital Soils

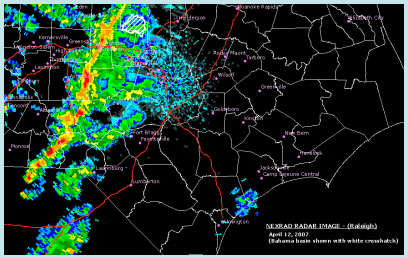
Regional HydroEcological Simulation System: RHESSys

hierarchical watershed model for water, carbon and nutrients

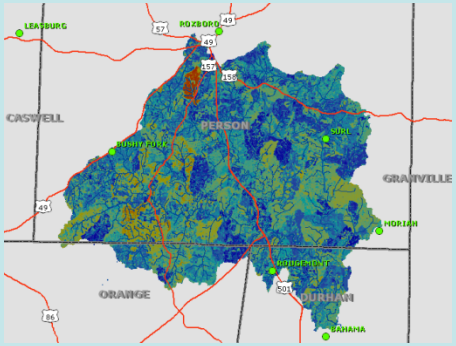



09/16
09/21
09/26
10/01
10/06
10/11
10/16
Rainfall (mm)
0
50
100
150
Stream Flow (mm)
20
15
10
5
0

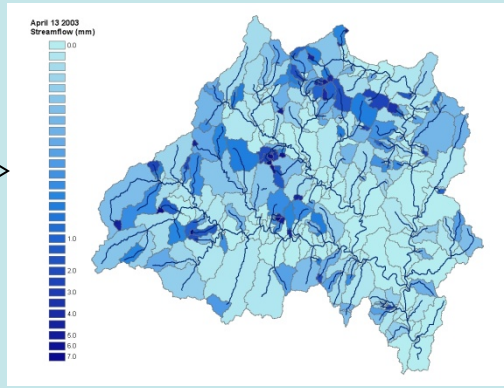
Hydromet now/forecasting



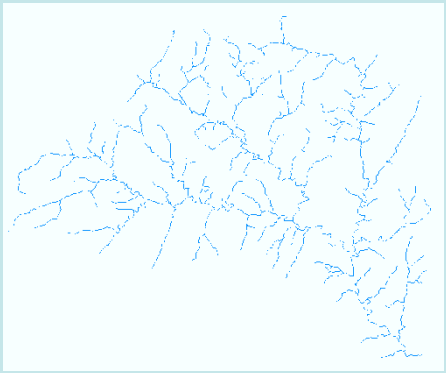
QPE



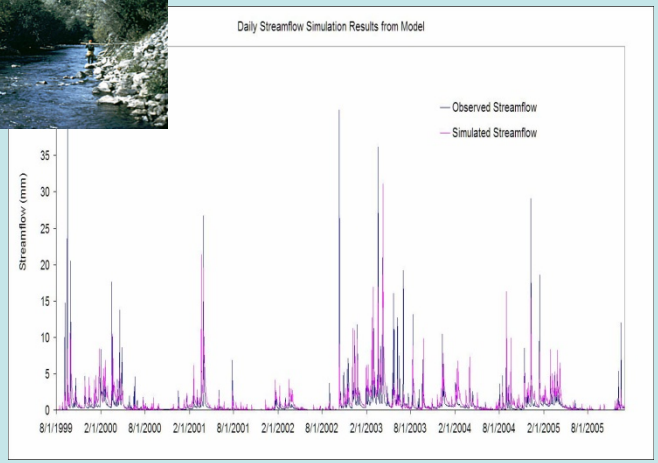
Soil Moisture



Hillslope Runoff

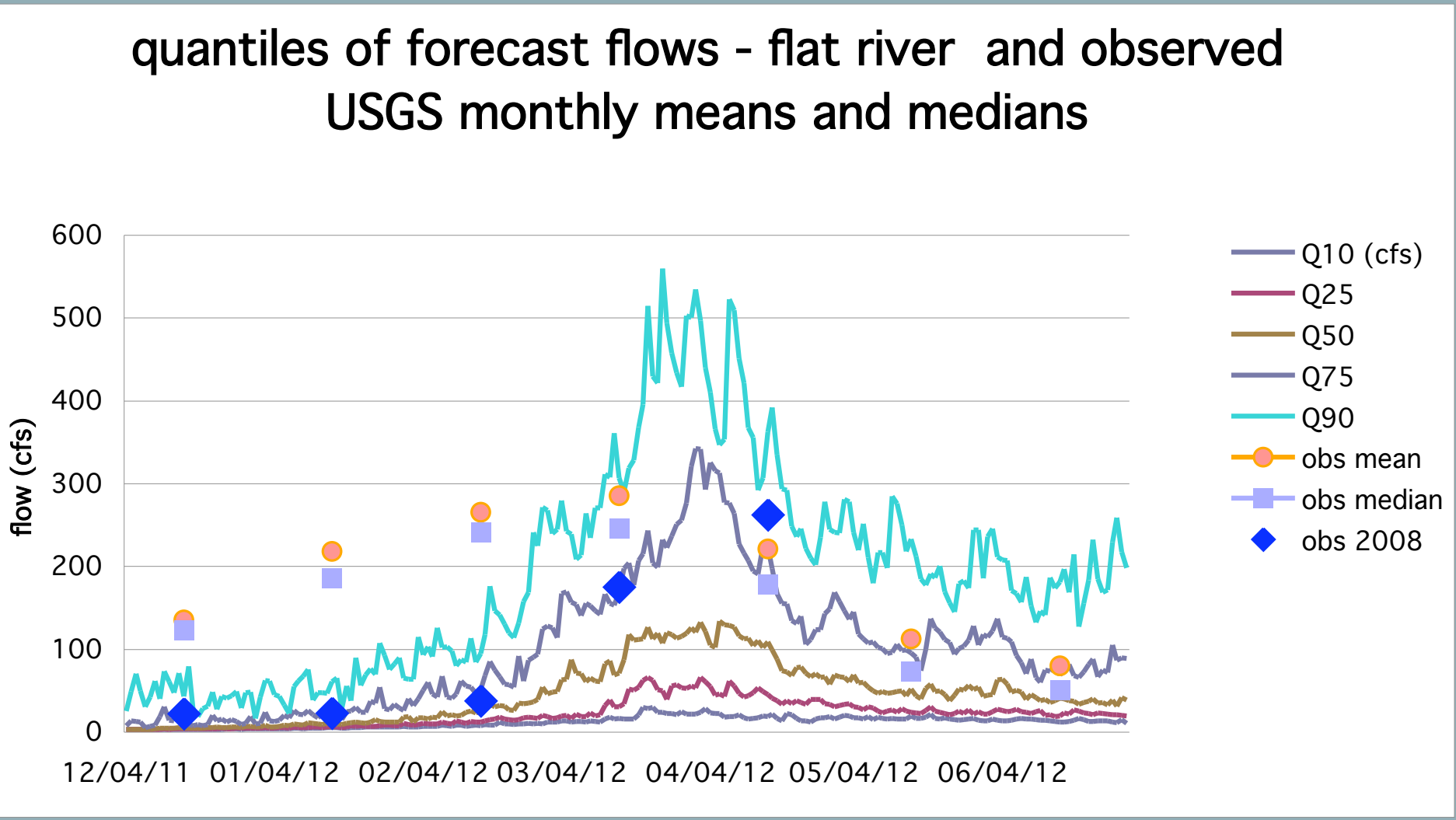


Stream Network



Streamflow

Flow forecast probabilities: Model runs December 3rd with 50 years of meteorologic data for the Flat River

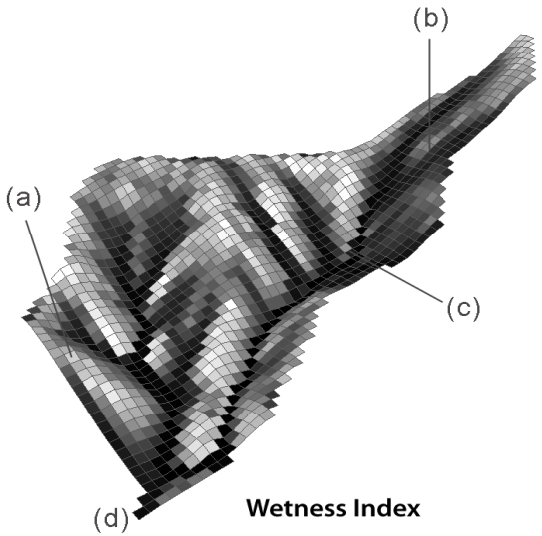


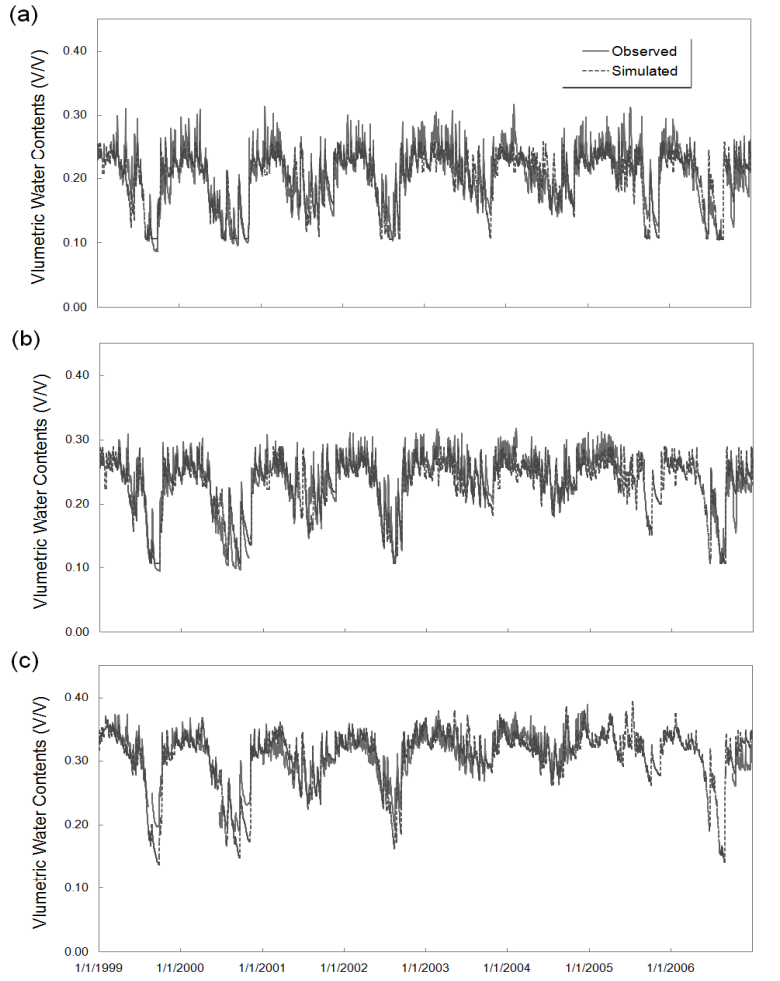
Summary

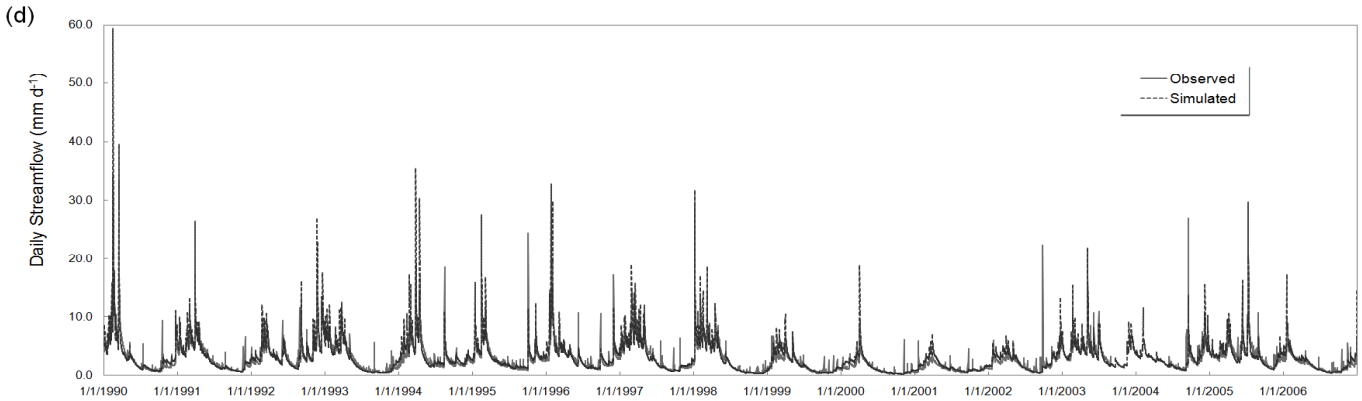
- River Basin Science focuses on nested watershed scales, integrating monitoring, modeling and informatics to support cross-disciplinary and multiple science and management objectives

  - Require advanced informatics to integrate and federate disparate information sources (sensors, models, …)
    - Unique opportunity given current level of investment

  - Build WQ^2 capability at major watershed level, scaling to local catchments, leverage emerging multi-scale spatial data infrastructure
    - Demonstration projects in HMT, other observatory, campaign opportunities
    - Demonstrate for multiple use: water supply & flood forecasting, drought management, fire hazard, nutrient management, watershed level permitting, stormwater







W18: Simulated and observed runoff and gradient soil moisture plots (average 0-60 cm)