Towards a National CyberInfrastructure For Multi-Scale Data-Model Harmonization

from
Shared Discovery
to
Shared Decision Making

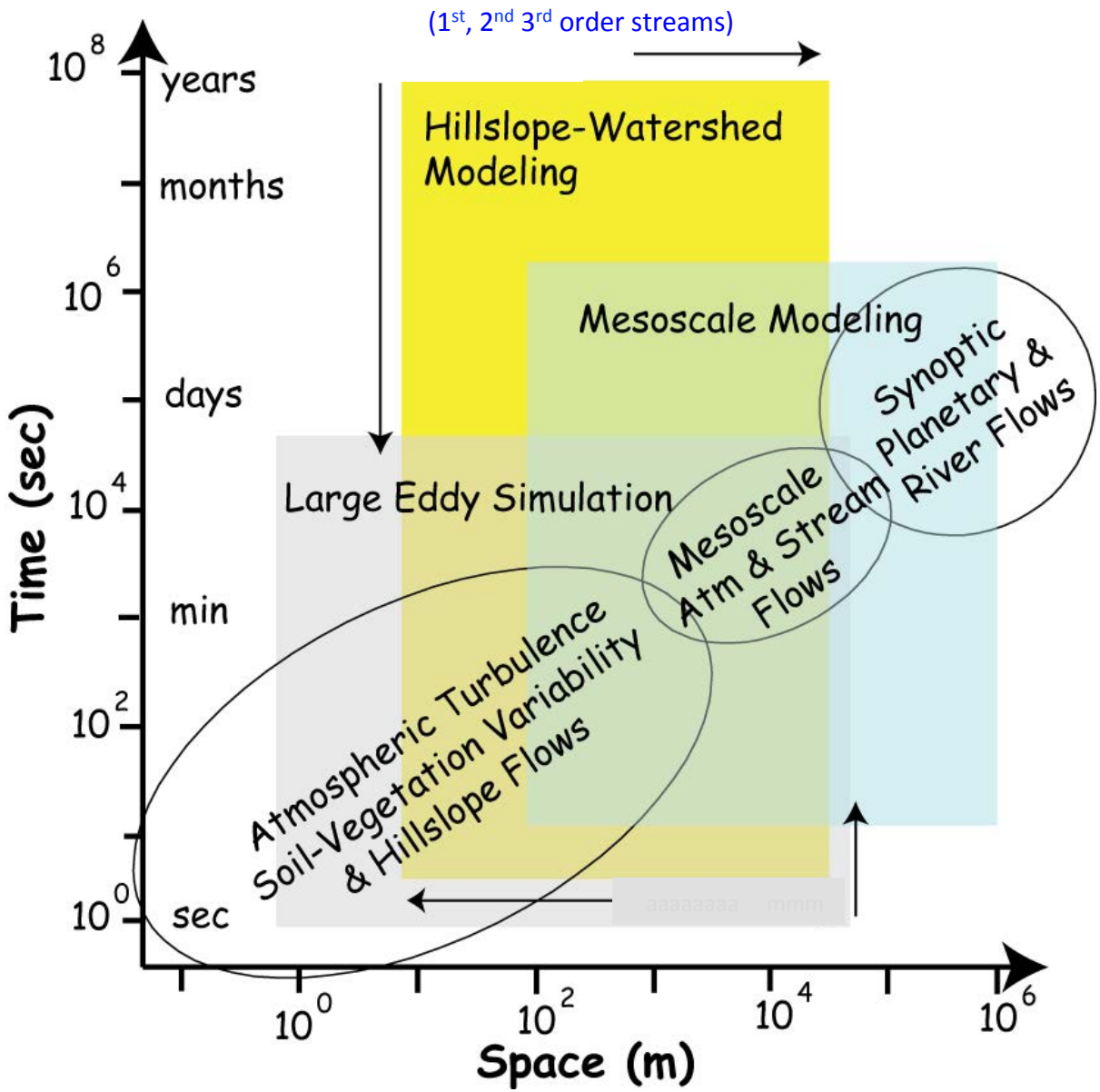
2,268 USGS
HUC 8
watersheds

The Watershed as Basis

For Modeling at Ecological & Human Scales

103,444 USGS
HUC 12
watersheds

Importance of Upland Regions in Multi-Scale Modeling



Numerical Watershed Prediction: A National Strategy for Data

Issues & Questions

Upland Watersheds represent 40-70% of catchment area->ungauged

The Essential Terrestrial Variables - National Products?

Integrated Cyberinfrastructure for Data and Models

Downscaling Climate Reanalysis and Environmental Observatories

Platform for interagency collaboration & research support?

What are the Essential Terrestrial Variables?

Water-Energy-Biogeochemistry

- Atmospheric Forcing (precipitation, snow cover, wind, relative humidity, temperature, net radiation, albedo, photosynthestic atmospheric radiation)
- Digital elevation models (30, 10, 3, 1m resolution)
- River/Stream discharge, stage, cross-section
- Soil (texture, C/N, organic, hydrologic & thermal properties)
- Groundwater (levels, extent, hydrogeologic properties)
- Land Cover (biomass/leaf area index, phenology,…….)
- Land Use (human infrastructure, demography, ecosystem disturbance, property & political boundaries)
- Environmental Tracers- stable isotopes
- Water Use and Water Transfers
- Lake/Reservoir/Diversion (levels, extent, discharge, operating rules)

Most data reside on federal servers ….many petabytes

A-Priori Data Sources…

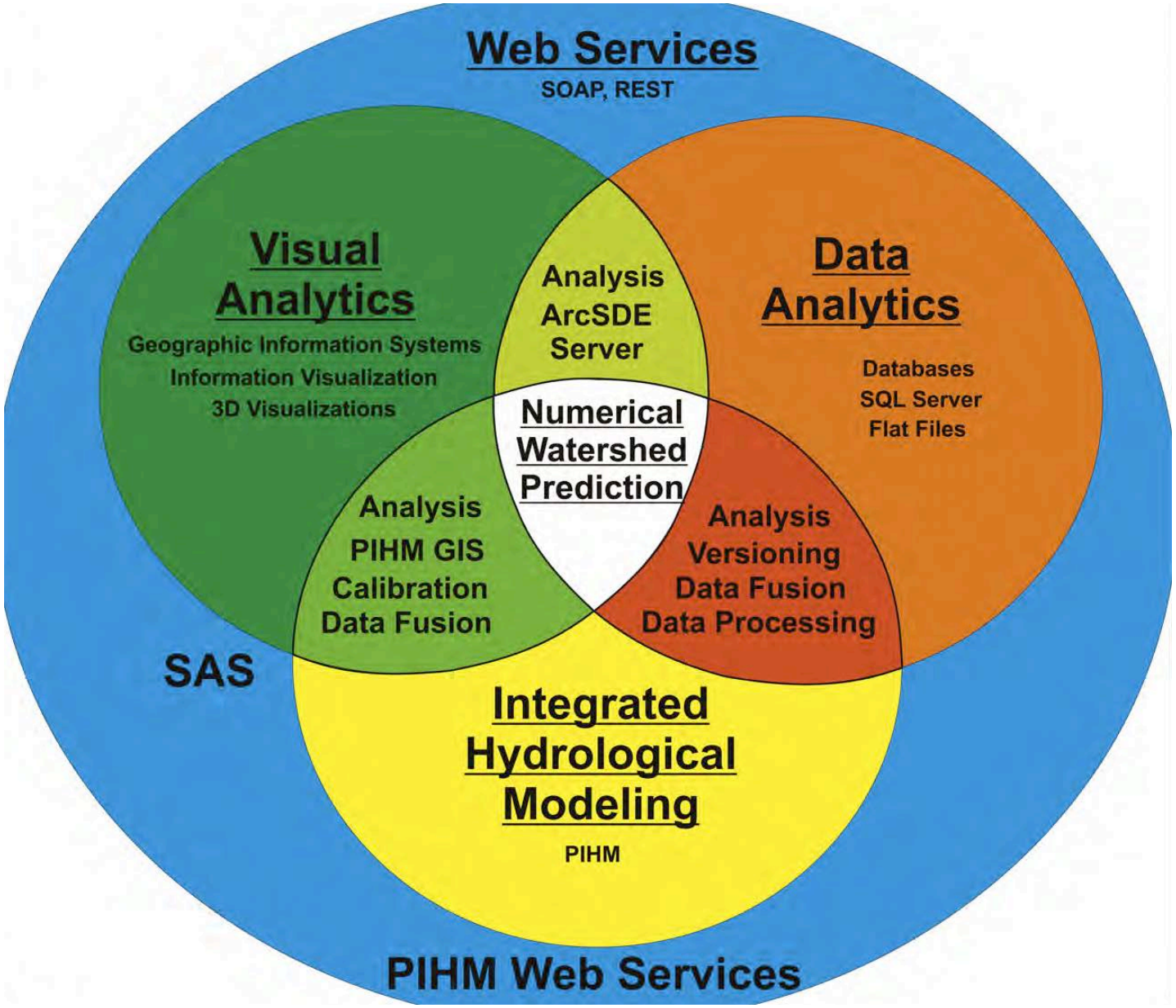
Feature/ Time Series	Property	Source
Soil	Porosity; Sand, Silt, Clay Fractions; Bulk Density	CONUS, SSURGO and STATSGO http://www.soilinfo.psu.edu/index.cgi?soil_data&conus http://datagateway.nrcs.usda.gov/NextPage.asp http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/
Geology	Bed Rock Depth; Horizontal and Vertical Hydraulic Conductivity	http://www.dcnr.state.pa.us/topogeo/, http://www.lias.psu.edu/emsl/guides/X.html
Land Cover	LAI	http://glcf.umiacs.umd.edu/data/landcover/data.shtml, http://ldas.gsfc.nasa.gov/LDAS8th/MAPPED.VEG/LDASmapveg.shtml;
	Manning's Roughtness	Hernandez et. al., 2000
River	Topology: From Node – To Node, Neighboring Elements;	Derived using PIHMgis (Bhatt et. al., 2008)
	Manning's Roughness;	Dingman (2002)
	Coefficient of Discharge	ModHms Manual (Panday and Huyakorn, 2004)
	Shape and Dimensions;	Derived from regression using depth, width and discharge data from http://nwis.waterdata.usgs.gov/usa/nwis/measurements
Forcing	Prec, Temp. RH, Wind, Rad.	National Land Data Assimilation System : NLDAS-2
DEM		http://seamless.usgs.gov/
Streamflow		http://nwis.waterdata.usgs.gov/nwis/sw
Groundwater		http://nwis.waterdata.usgs.gov/nwis/gw

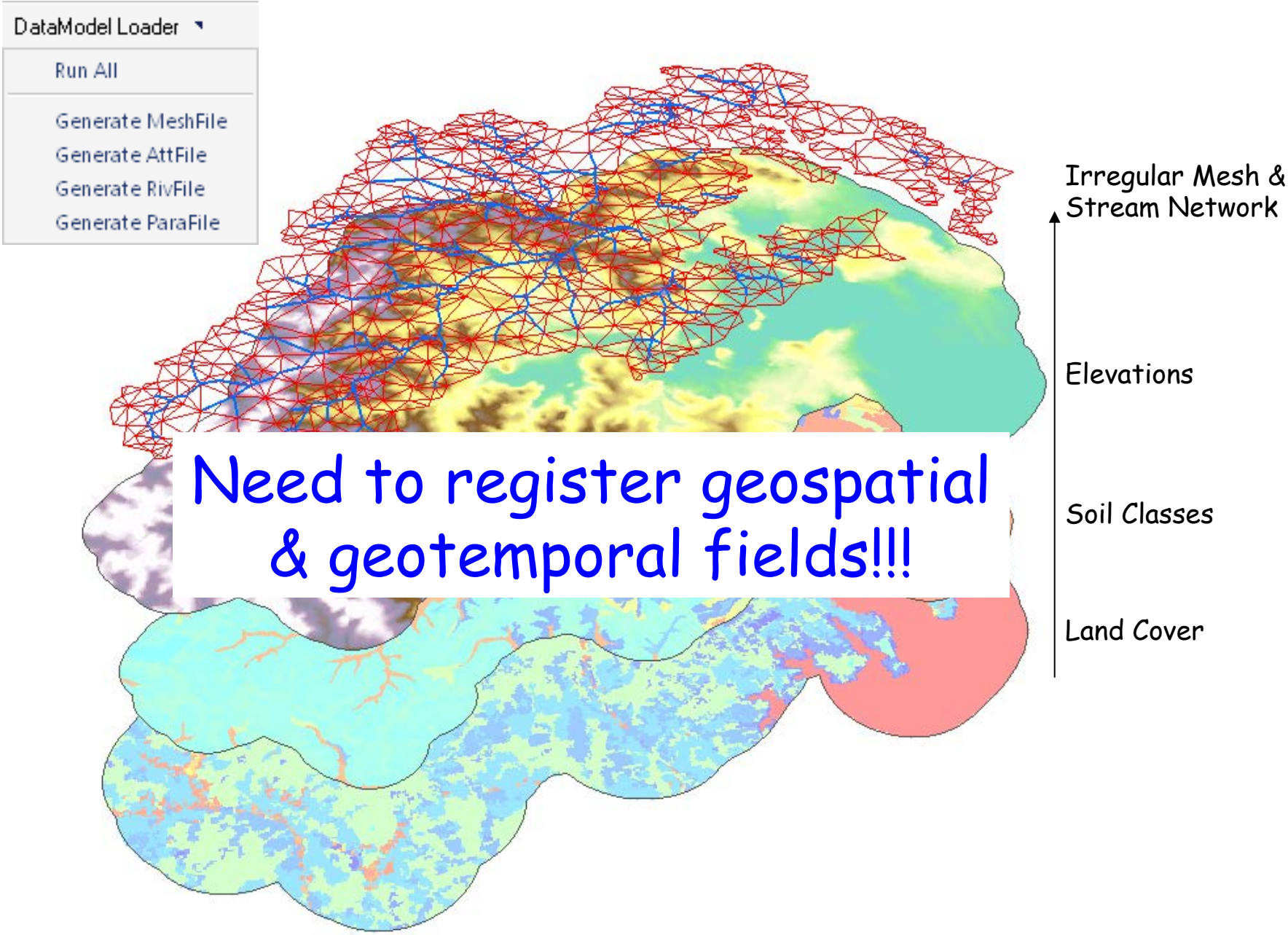
Models Formulated at Process Scales!!

Process	Governing equation/model	Original governing equations	Semi-discrete form
Channel Flow	St. Venant Equation	$\frac{\partial h}{\partial t}+\frac{\partial(uh)}{\partial x}=q$	$\left(\frac{d\zeta}{dt}=P_c-\sum Q_{gc}+\sum Q_{oc}+Q_{in}-Q_{out}-E_c\right)_i$ [1]
Overland Flow		$\frac{\partial h}{\partial t}+\frac{\partial(uh)}{\partial x}+\frac{\partial(vh)}{\partial y}=q$	$\left(\frac{\partial h}{\partial t}=P_o-I-E_o-Q_{oc}+\sum_{j=1}^{3}Q_s^{ij}\right)_i$ [1]
Unsaturated Flow	Richard Equation	$C(\psi)\frac{\partial\psi}{\partial t}=\nabla\cdot(K(\psi)\nabla(\psi+Z)$	$\left(\frac{d\zeta}{dt}=I-q^0-ET_s\right)_i$ [2]
Groundwater Flow		$C(\psi)\frac{\partial\psi}{\partial t}=\nabla\cdot(K(\psi)\nabla(\psi+Z)$	$\left(\frac{d\zeta}{dt}=q^0+\sum_{j=1}^{3}Q_g^{ij}-Q_l+Q_{gc}\right)_i$ [3]
Interception	Bucket Model	$\frac{dS_I}{dt}=P-E_I-P_o$	$\left(\frac{dS_I}{dt}=P-E_I-P_o\right)_i$
Snowmelt	Temperature Index Model	$\frac{dS_{snow}}{dt}=P-E_{snow}-\Delta w$	$\left(\frac{dS_{snow}}{dt}=P-E_{snow}-\Delta w\right)_i$
Evapotranspiration	Pennman-Monteith Method	$ET_0=\frac{\Delta(R_n-G)+\rho_a C_p\frac{(e_s-e_a)}{r_a}}{\Delta+\gamma(1+\frac{r_s}{r_a})}$	$\left(ET_0=\frac{\Delta(R_n-G)+\rho_a C_p\frac{(e_s-e_a)}{r_a}}{\Delta+\gamma(1+\frac{r_s}{r_a})}\right)_i$

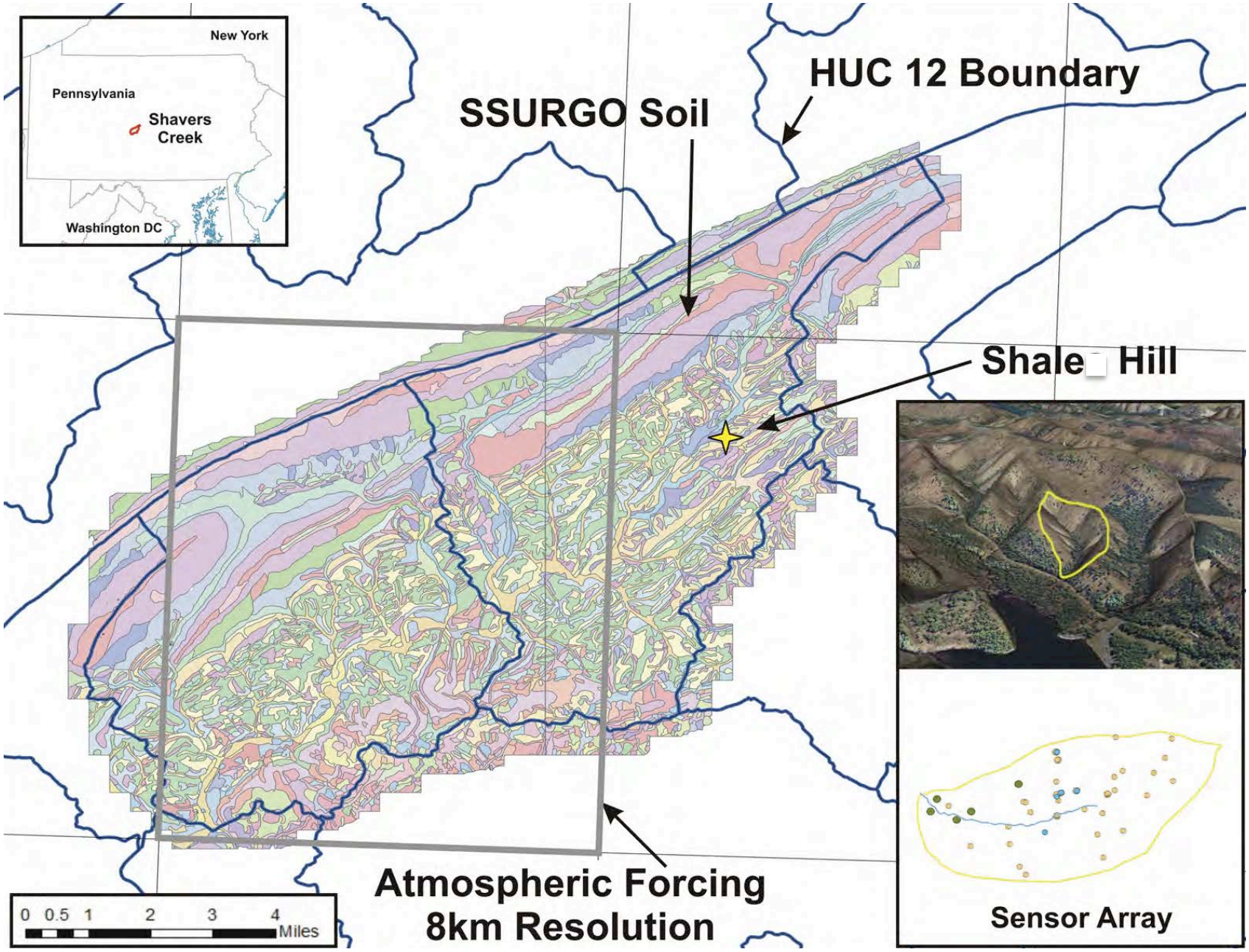
Towards a New Cyberinfrastructure For Harmonizing Models and Data

Shared Discovery
&
Shared Decision Making


Web Services
SOAP, REST
Visual Analytics
Geographic Information Systems
Information Visualization
3D Visualizations
Analysis
ArcSDE
Server
Data Analytics
Databases
SQL Server
Flat Files
Numerical Watershed Prediction
Analysis
PIHM GIS
Calibration
Data Fusion
Analysis
Versioning
Data Fusion
Data Processing
SAS
Integrated Hydrological Modeling
PIHM
PIHM Web Services



Need to register geospatial & geotemporal fields!!!


New York
Pennsylvania
Shavers Creek
Washington DC
SSURGO Soil
HUC 12 Boundary
Shale Hill
Atmospheric Forcing
8km Resolution
0 0.5 1 2 3 4
Miles
Sensor Array

HydroTerr: A Prototype for Model-Data Harmonization

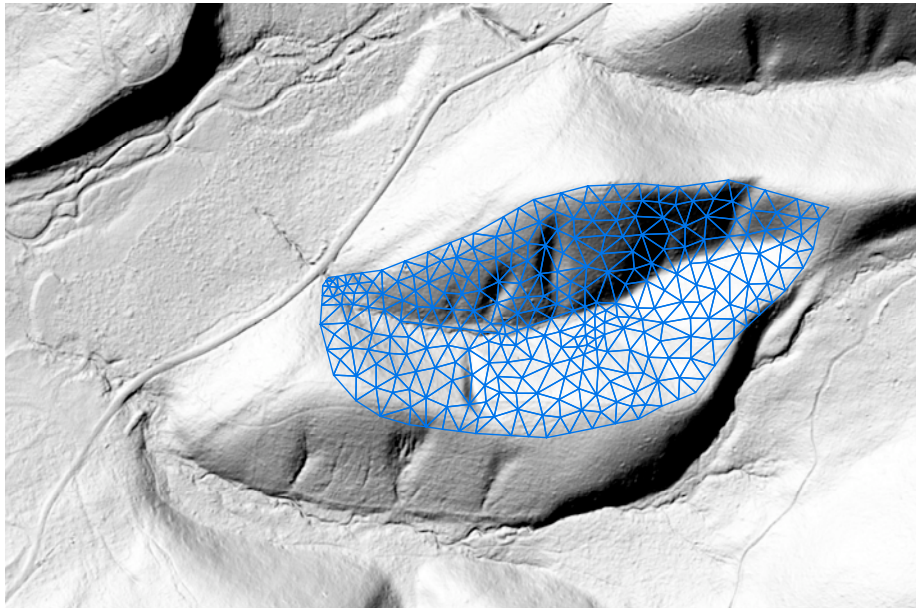
Land Parcel Data; NHD: Stream, Lake, HUC'; USDA: Soils/Crops; NLCD: LU_LC;

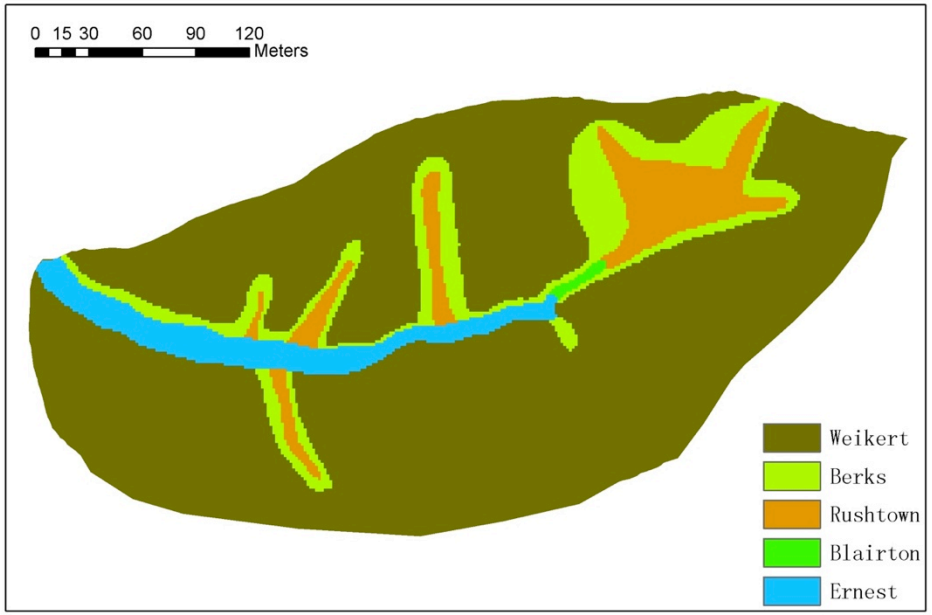
Dynamic Down-Scaling of Reanalysis for Assessing the Impact of Climate and Landuse Change at Human Scales

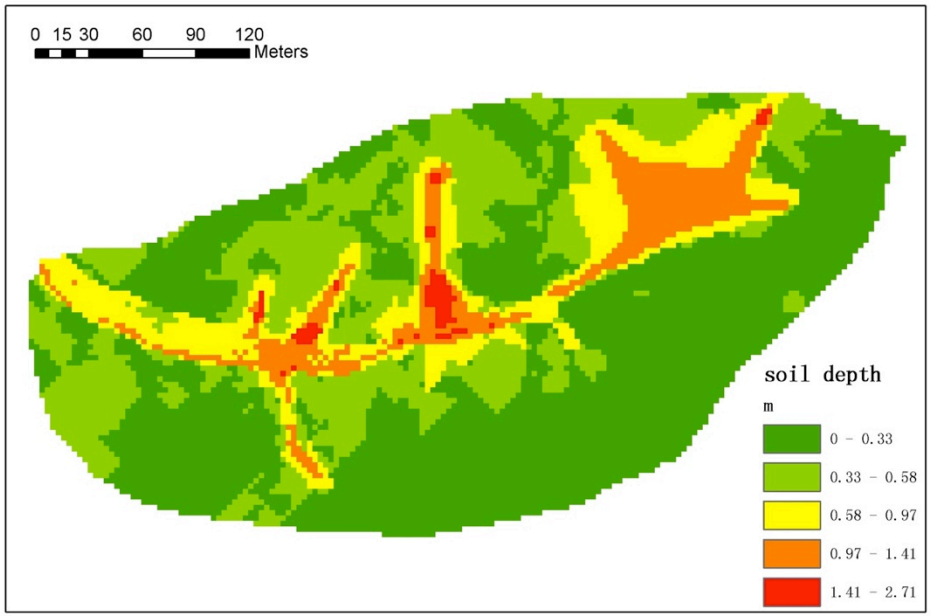
Re-analyze and assimilate past observations with current modeling context

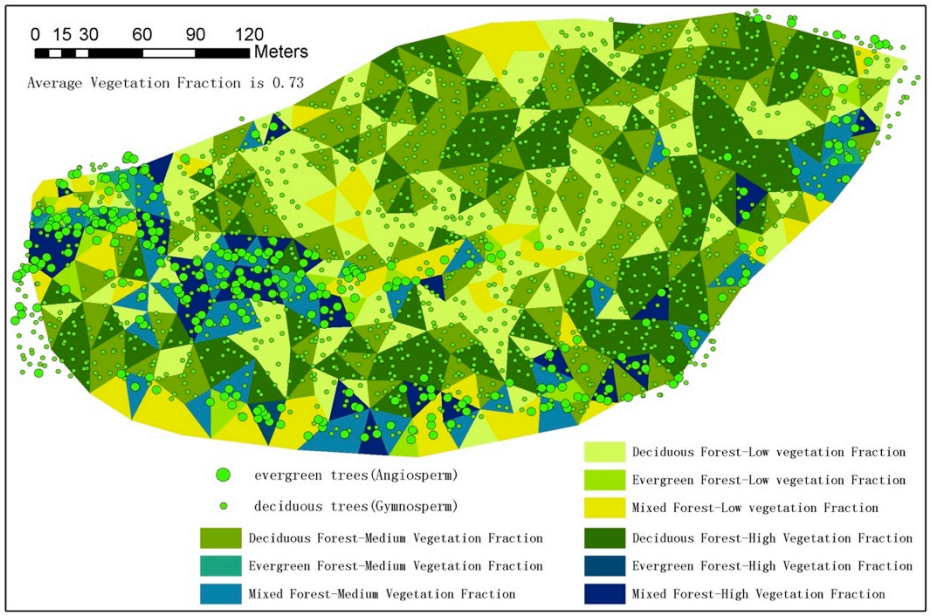
Reanalysis products produce space-time fields valuable to scientists, stakeholders and resource managers

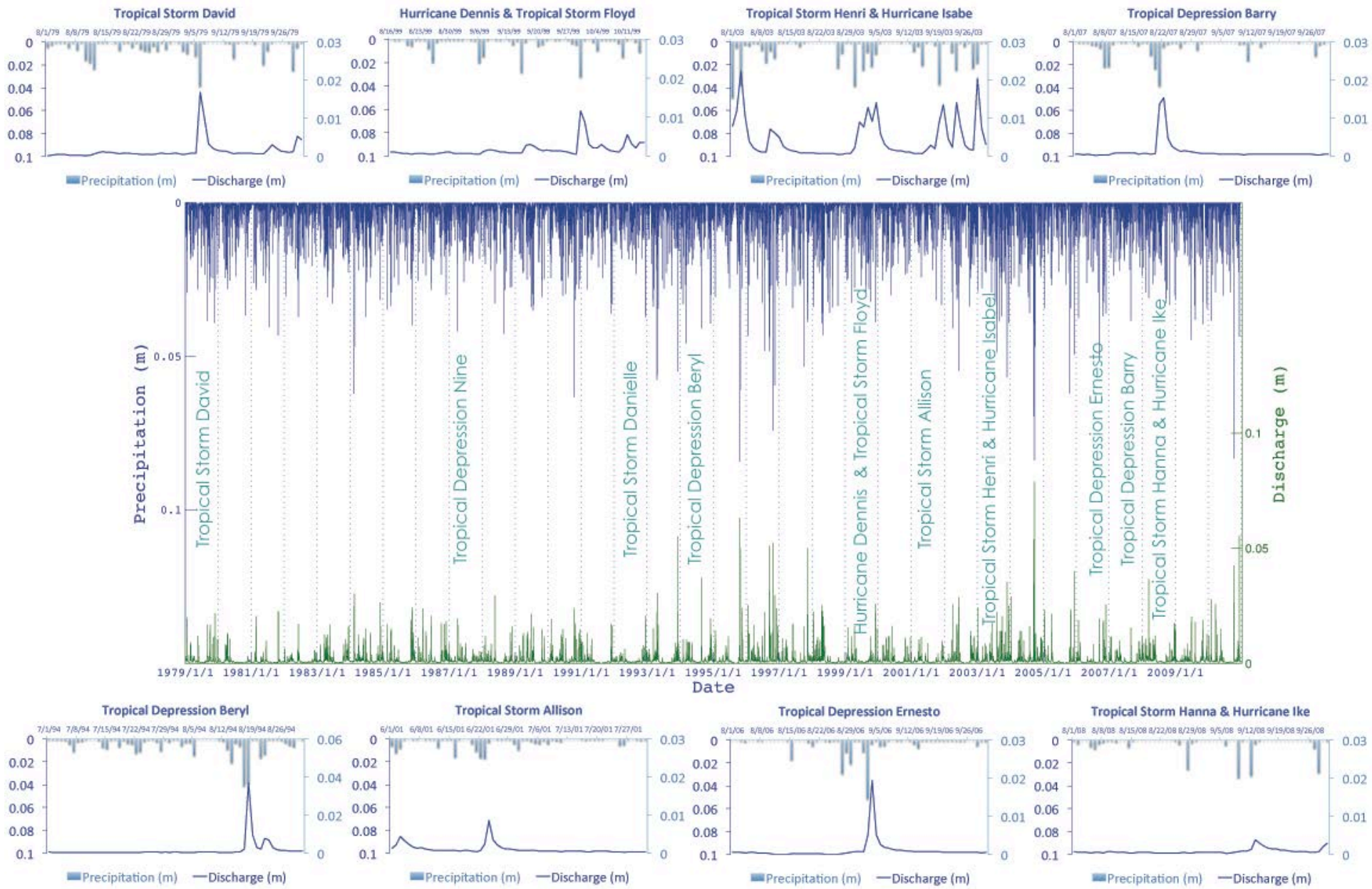
CZO Data ->lidar, Soil, Regolith,Veg





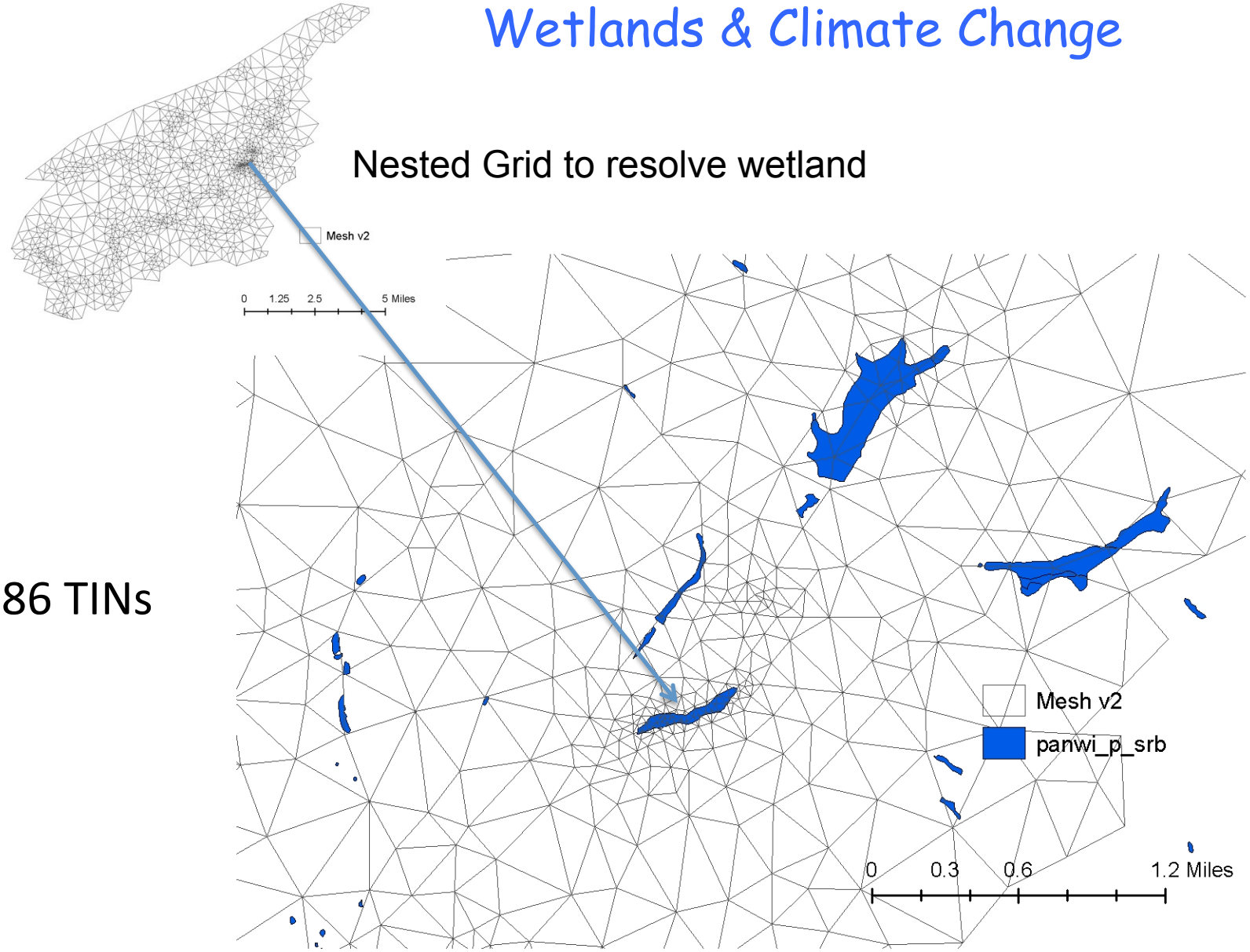





Tropical Storm David
Hurricane Dennis & Tropical Storm Floyd
Tropical Storm Henri & Hurricane Isabe
Tropical Depression Barry
Precipitation (m)
Discharge (m)
Tropical Storm David
Tropical Depression Nine
Tropical Storm Danielle
Tropical Depression Beryl
Hurricane Dennis & Tropical Storm Floyd
Tropical Storm Allison
Tropical Storm Henri & Hurricane Isabel
Tropical Depression Ernesto
Tropical Depression Barry
Tropical Storm Hanna & Hurricane Ike
Date
Tropical Depression Beryl
Tropical Storm Allison
Tropical Depression Ernesto
Tropical Storm Hanna & Hurricane Ike

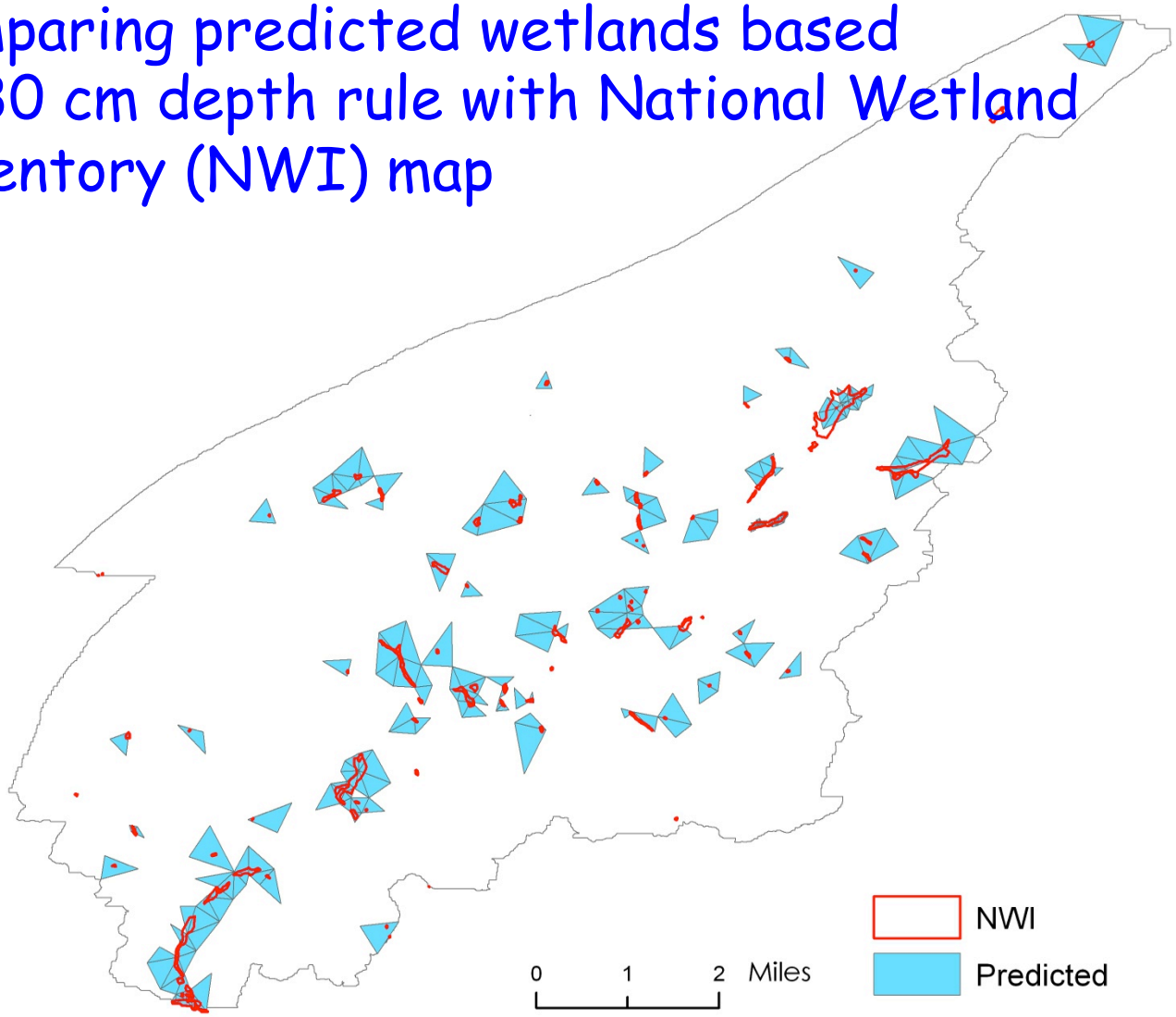
Wetlands & Climate Change

Nested Grid to resolve wetland

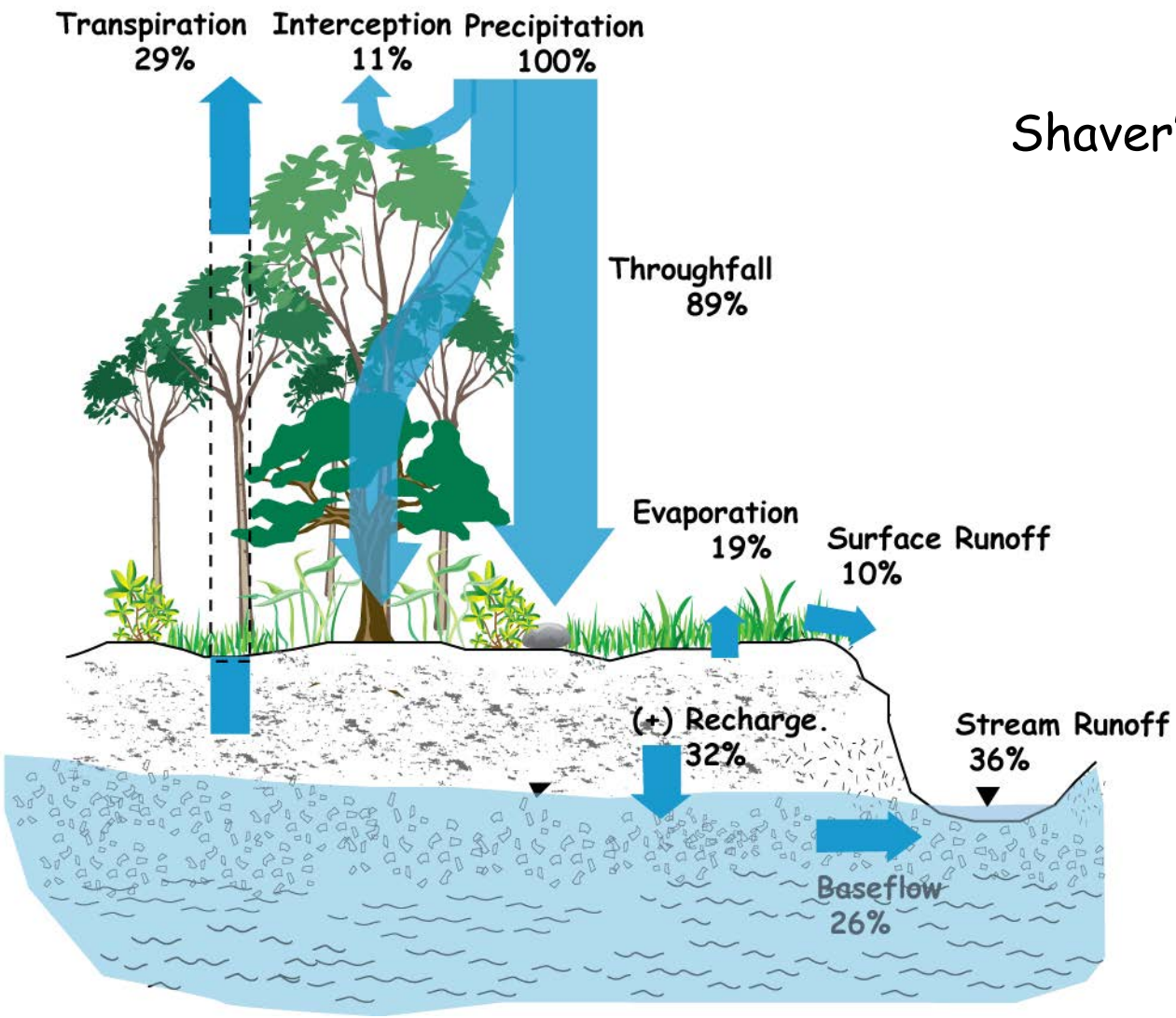


1986 TINs

Comparing predicted wetlands based on 30 cm depth rule with National Wetland Inventory (NWI) map



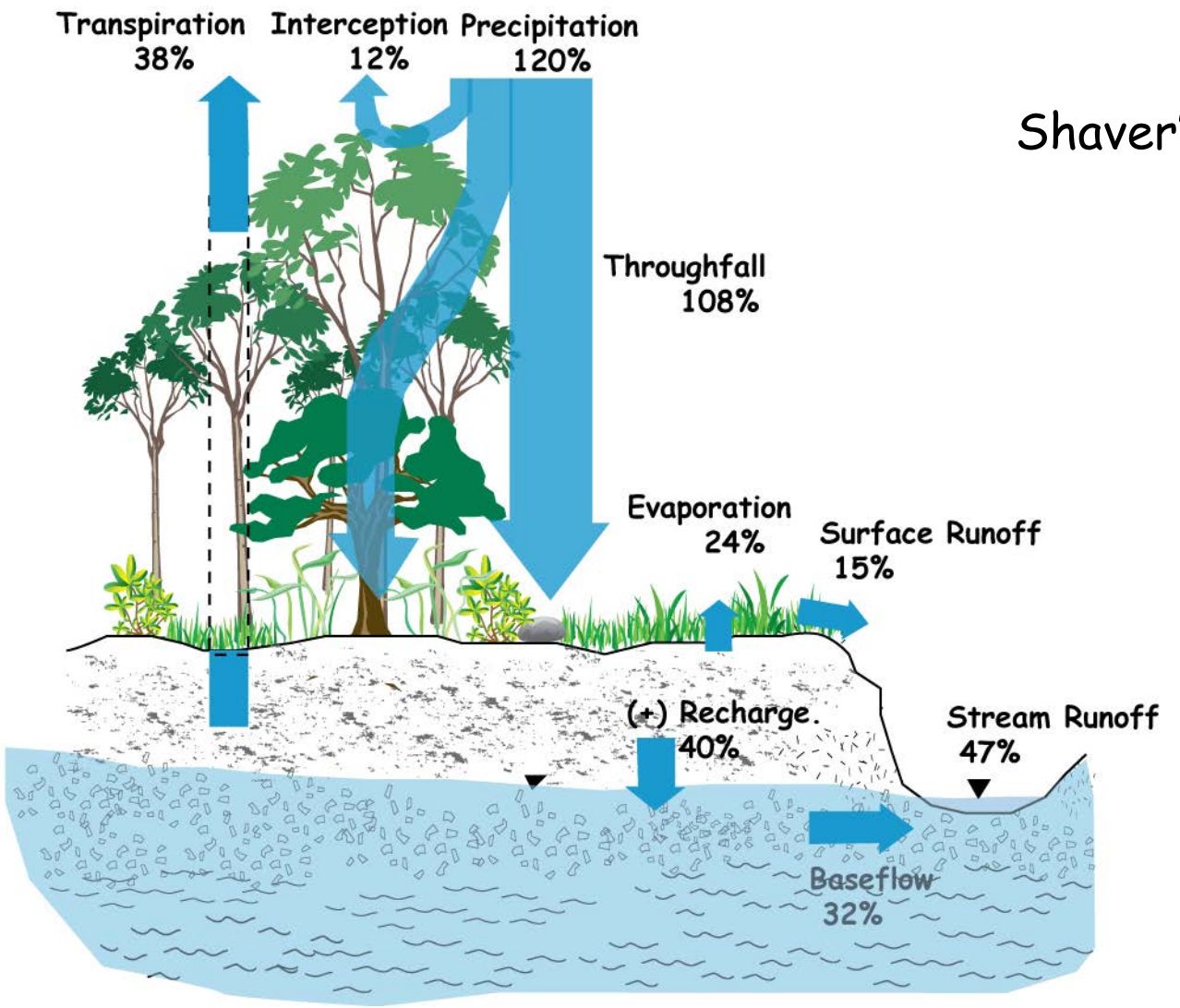
1979-1988 Annual Water Budget
As a percentage of precipitation



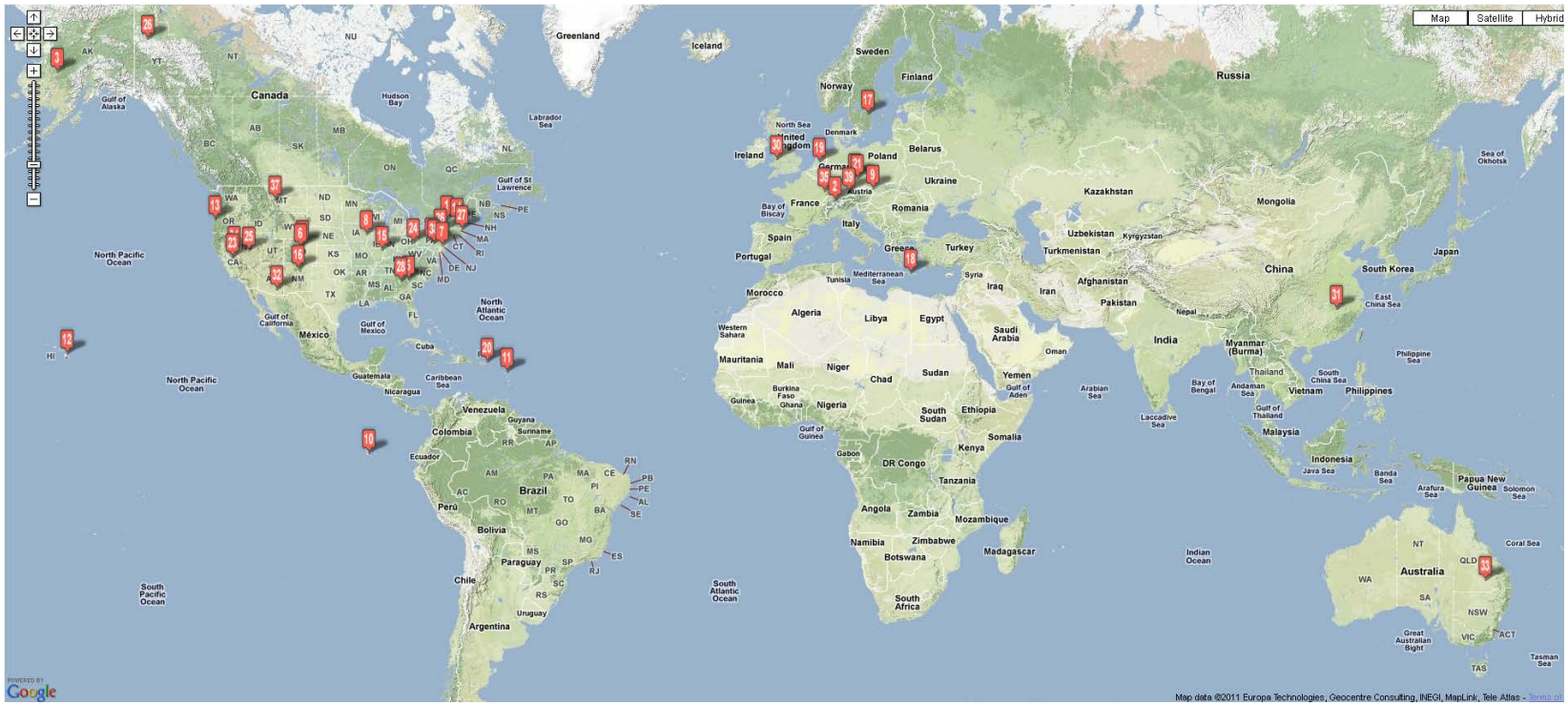
Shaver's Creek

2056-2065 Annual Water Budget from IPCC
Estimated as a % relative to 1979-1988

Shaver's Creek



Critical Zone Observatories: Global Testbeds for Implementing Models at Catchment Scales



International network CZO of testbeds for models and data is growing……..