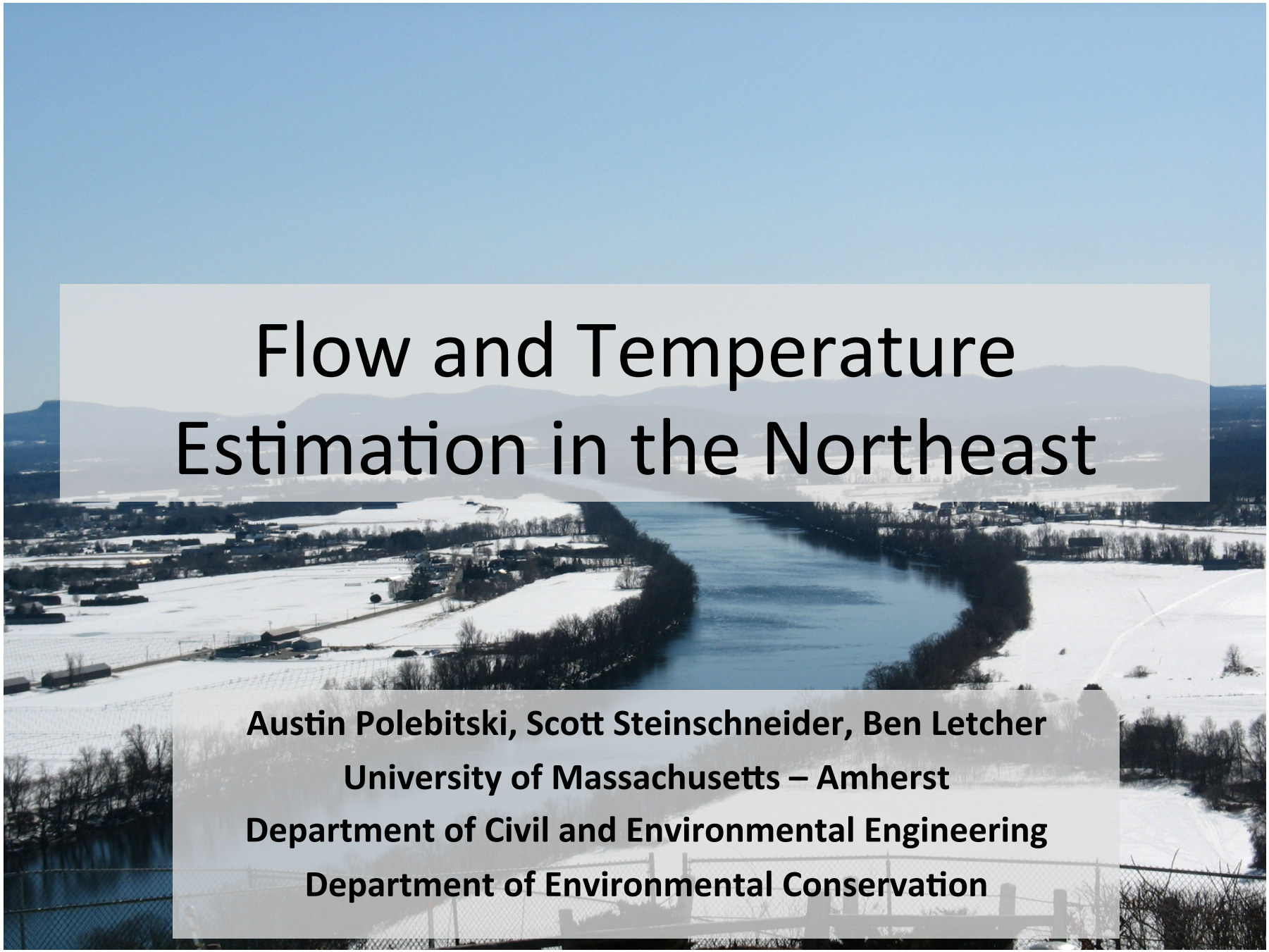


Flow and Temperature Estimation in the Northeast

Austin Polebitski, Scott Steinschneider, Ben Letcher

University of Massachusetts – Amherst

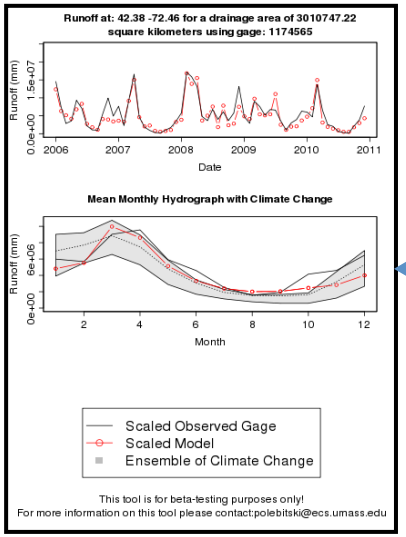
Department of Civil and Environmental Engineering

Department of Environmental Conservation

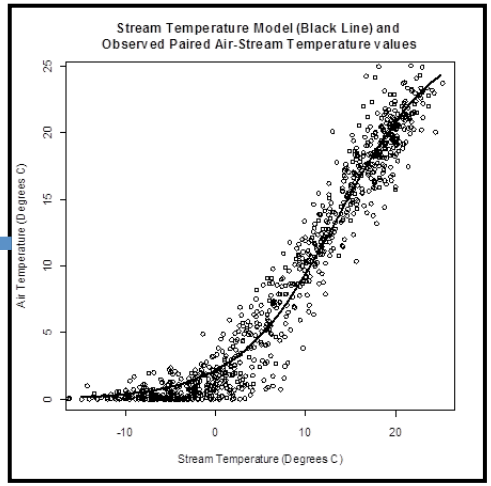
Community Driven Data Gathering and Collection

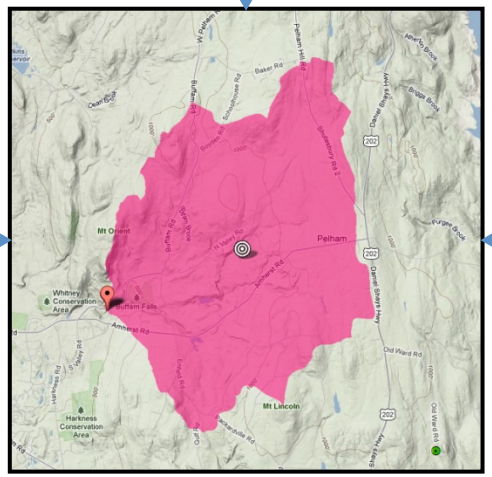
Online Portal/Database for Housing and Querying Data

User Generated Results



User Developed Models



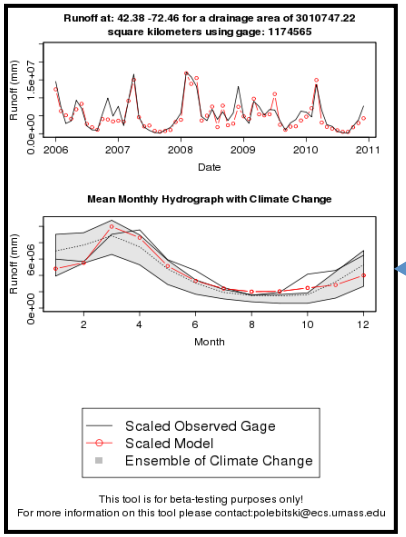


Web-based Applications Linking Models to Data

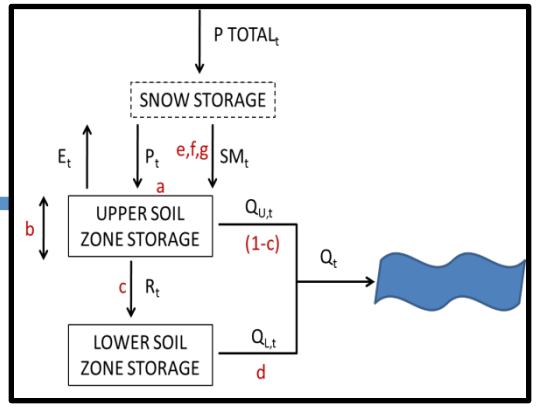
USGS and State Flow Gages

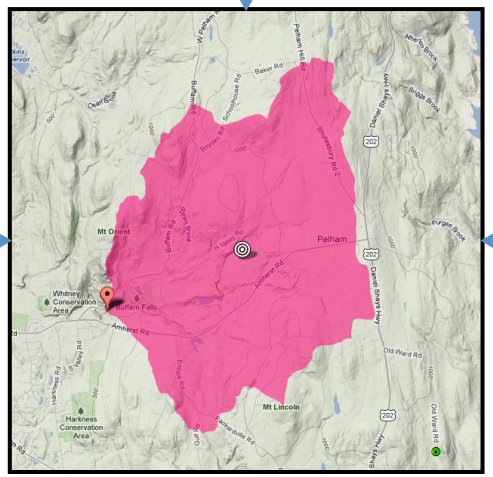
National Water Information System

User Generated Results



ABCDE/VIC Hydrology Models

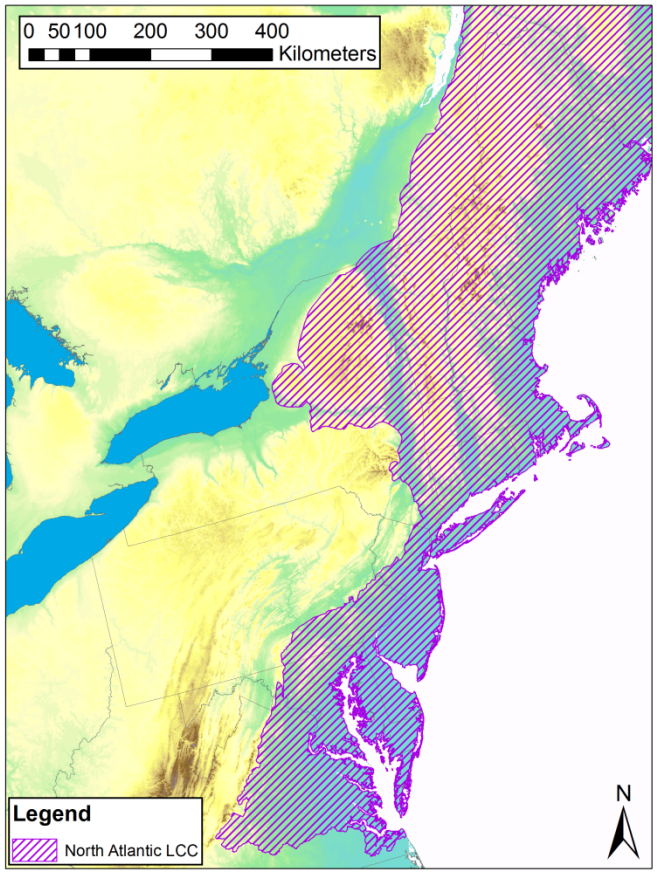




Web-based Applications Linking Models to Data

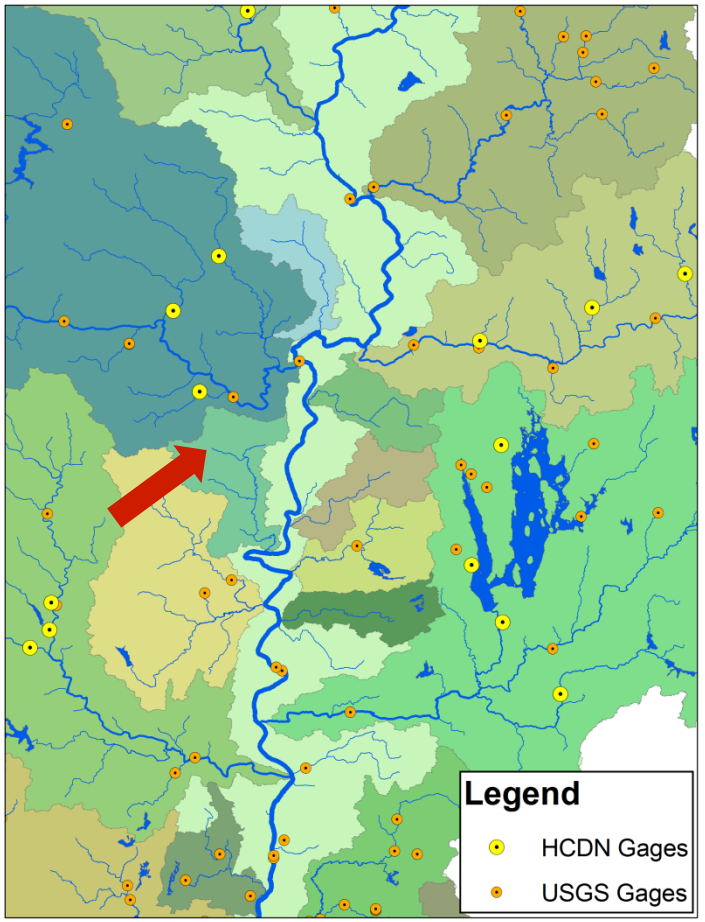
The Challenge with Estimating Streamflow Anywhere

- NALCC project requires estimating streamflow over large spatial extents with varying physical attributes of basins and climatology
- Challenges using deterministic models:
  - Challenge to calibrate
  - Tradeoff between computation requirements and model spatial scale
- Challenges using statistical models:
  - Hard to regionalize
  - Require observed data in close proximities
  - Often do not factor in climate as dominate variable



Estimating Streamflow Anywhere

- Age old issue in hydrology – **Ungaged Basin Prediction**
- Many methods have been proposed
  - Hydrology model regionalization
  - Statistical mapping (MOVE and SYE)
- Our proposed methods for streamflow are two different **combined regionalization** approaches

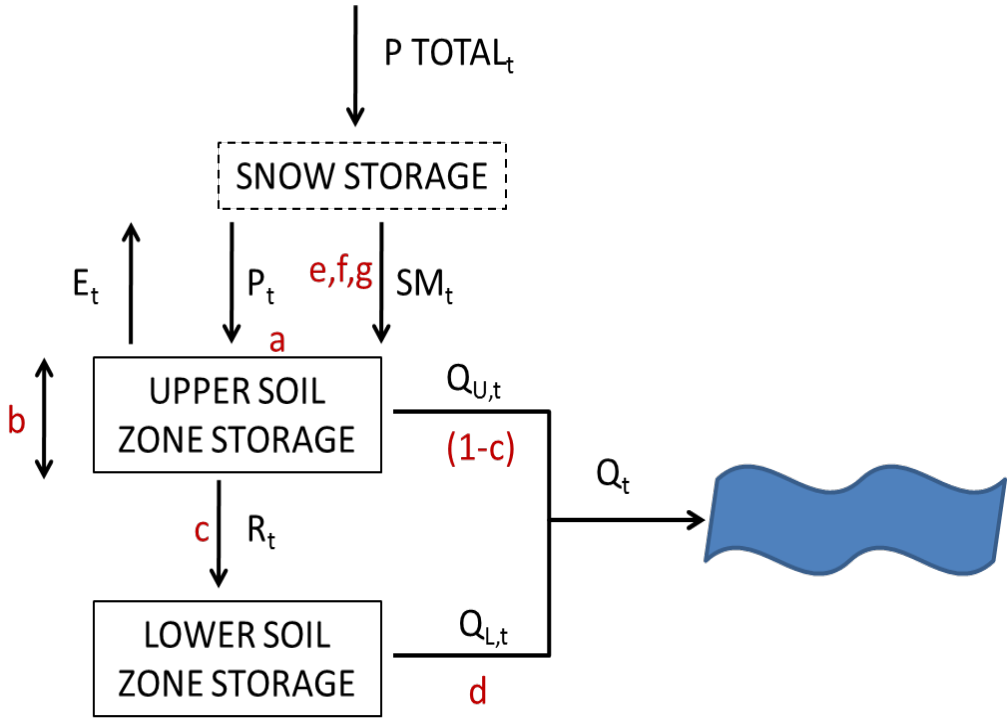


ABCDE Model

- We use the ABCD (and EFG) model
  - A conceptual, (pseudo) physically-based, lumped parameter model
- It is employed in a hierarchical Bayesian framework
- Generates monthly streamflow time series given precipitation and temperature (ET) signals
- **Scalable, parsimonious,** and **flexible hydrology model** seeking **stream temperature** similar qualities

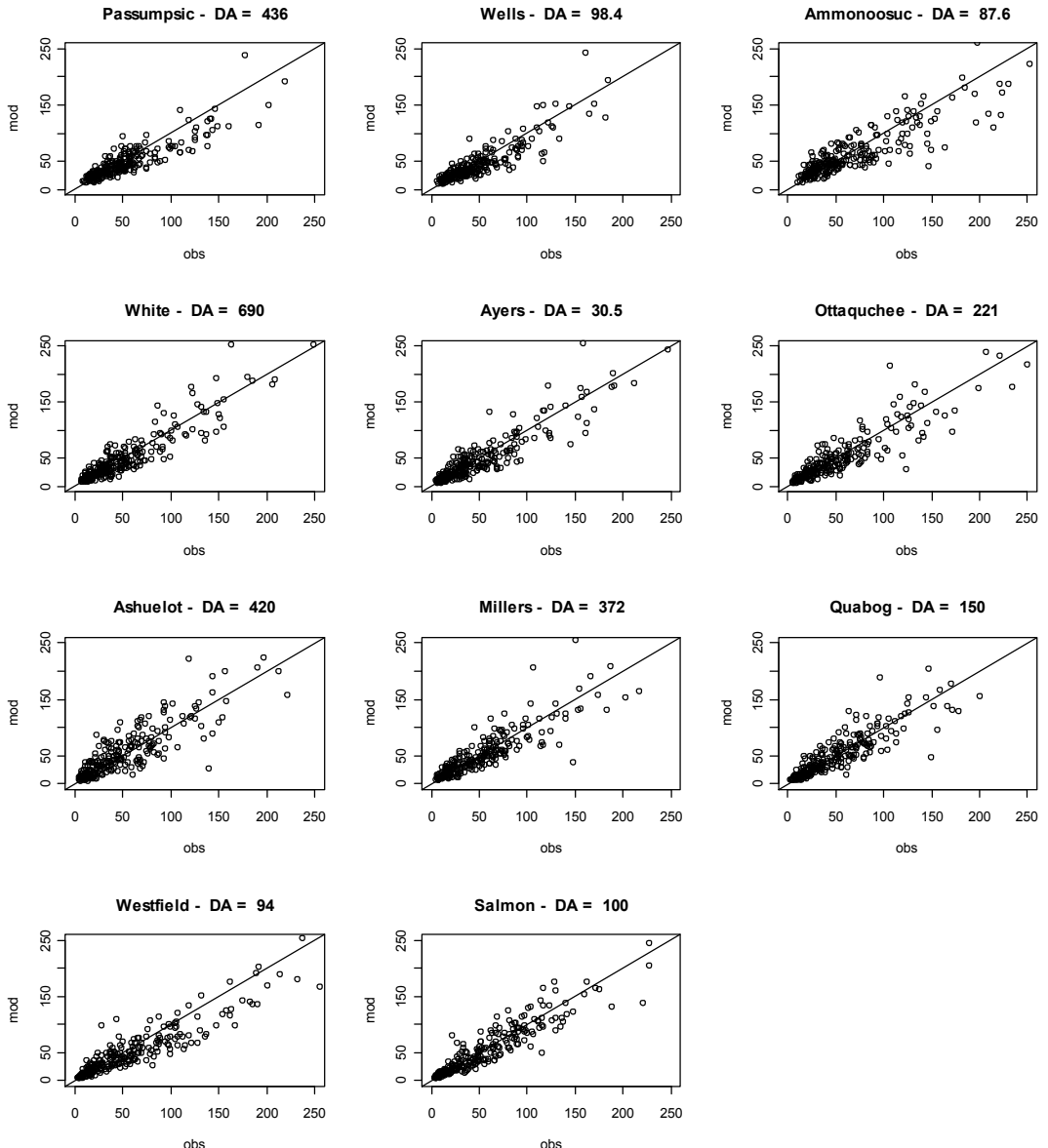
ABCD Model Components

- Conceptually represents major components of hydrological system
- Reflects snow and soil moisture storage mechanisms (physically-based)
- Basins take a single value for each parameter (lumped)



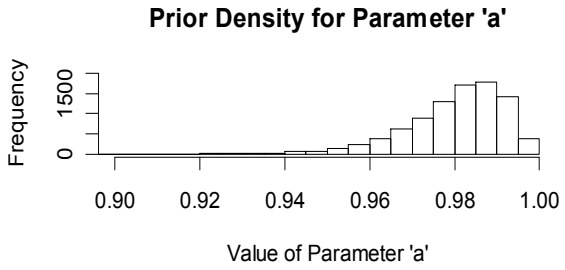
ABCD Model Results

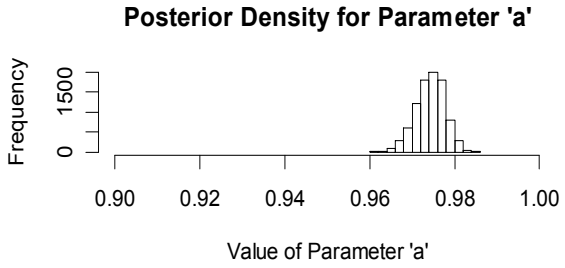
- Model reproduces hydrologic signal well across multiple basin sizes, climatology, and physical characteristics
- Initial study has focused on CT River basins
- Is being expanded to entire Northeast

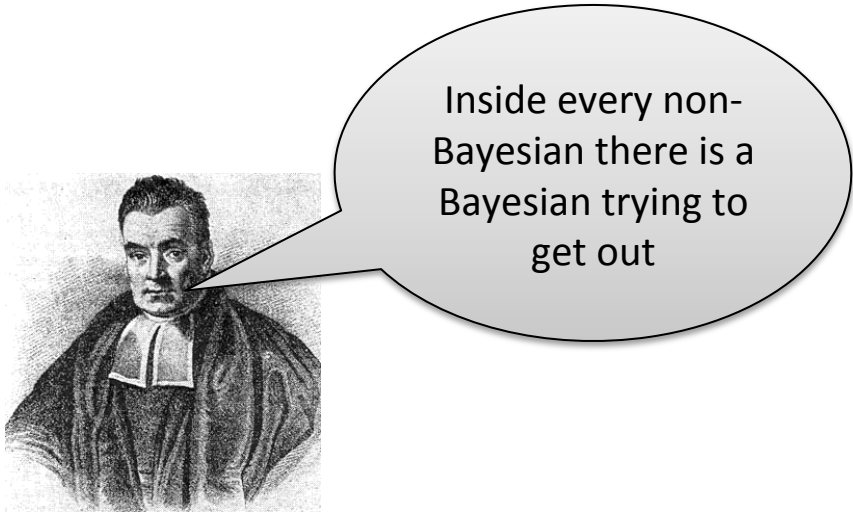


Bayesian Framework

- Bayesian methods provide a formal mechanism to:
  - Allow prior information regarding each parameter value to be incorporated into model calibration
  - Characterize model error from uncertainties in model parameterization, structure, and calibration data

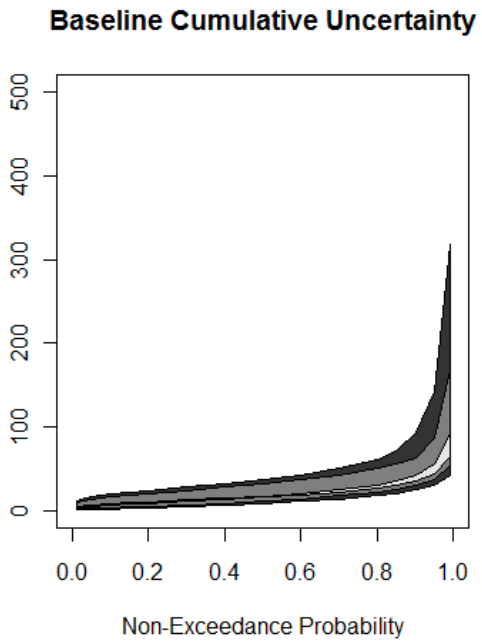


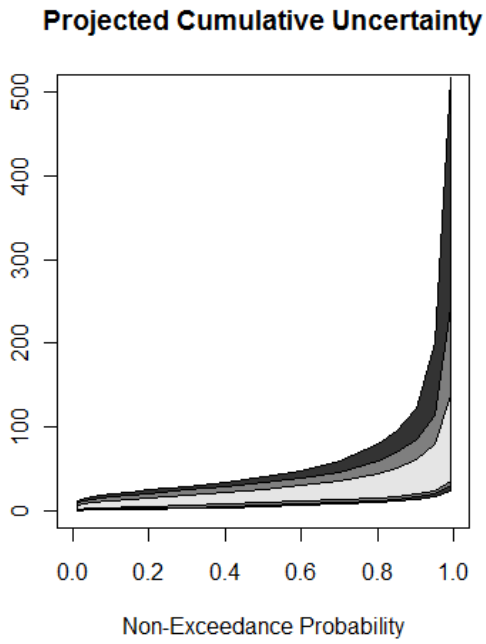




Model Uncertainty - Sandwiches

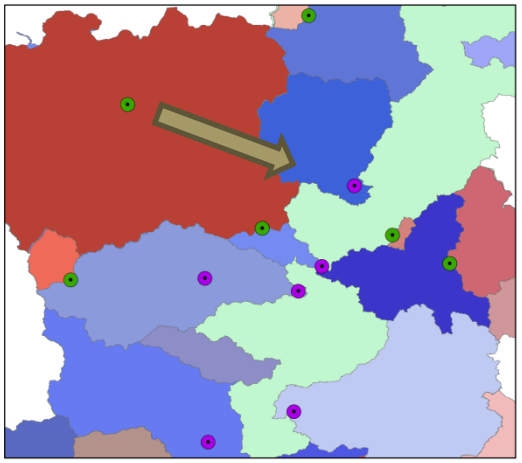
- Where does uncertainty stem from?
- Propagate Through to Fish Models, etc.
- Inform end-user of quality of model!

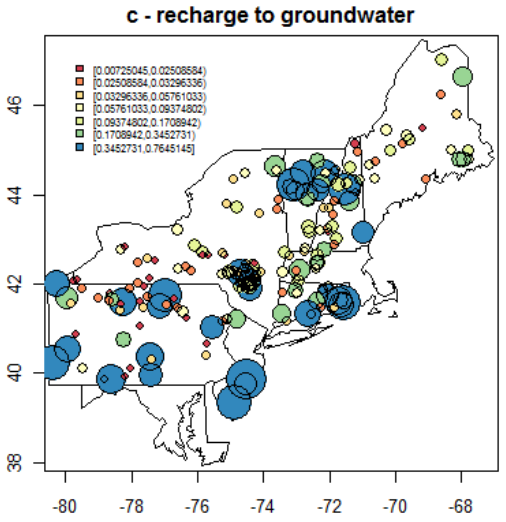




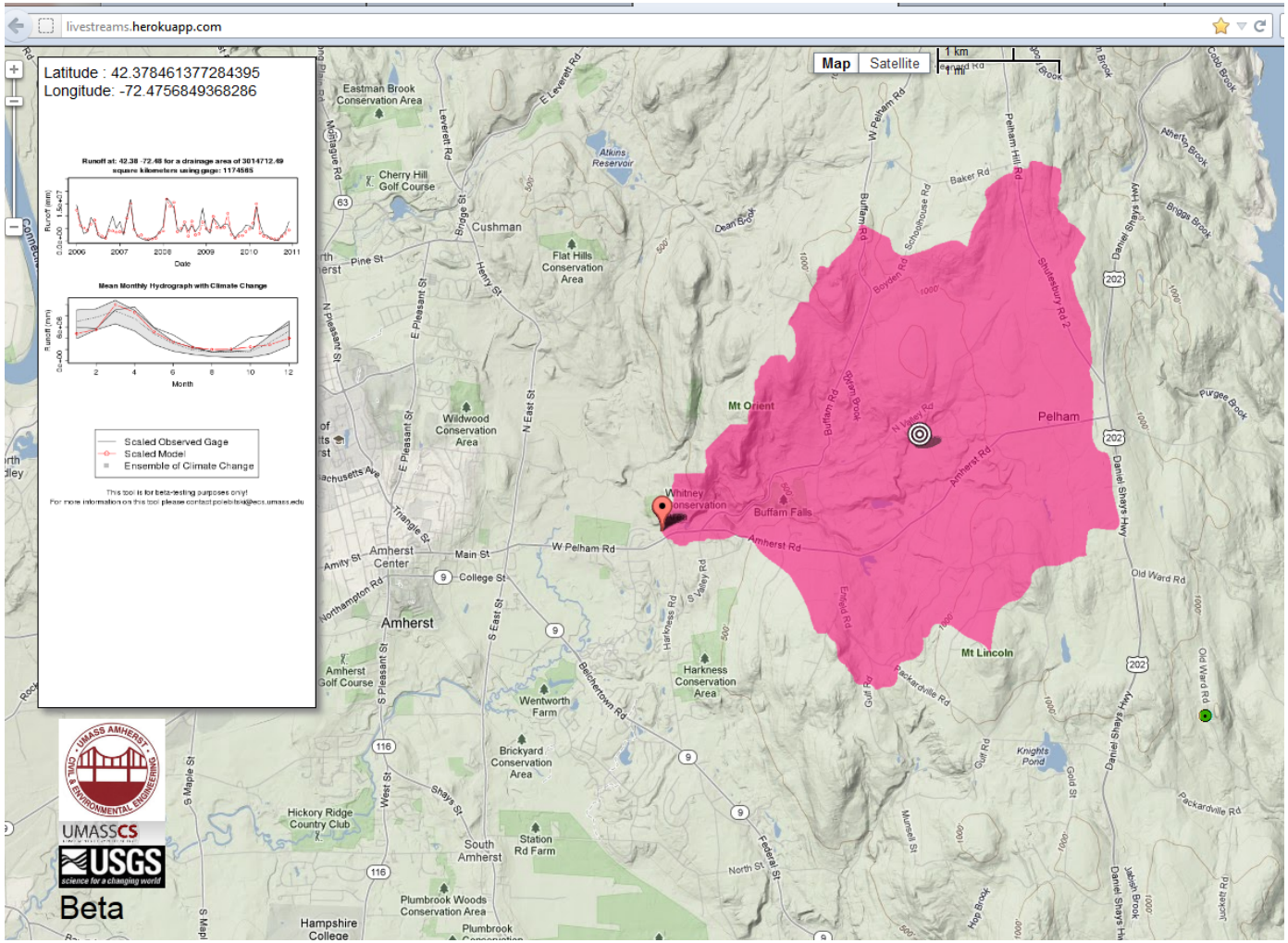
Regionalization– Getting at the Ungaged Basin Problem

- Two primary methods:
  - Regionalize through streamflow transfer (Scheme 1)
  - Regionalize through model parameterization (Scheme 2)
- Both have distinct advantages and challenges and require extensive validation
  - Selecting index site
  - Physical meaning in paramteres

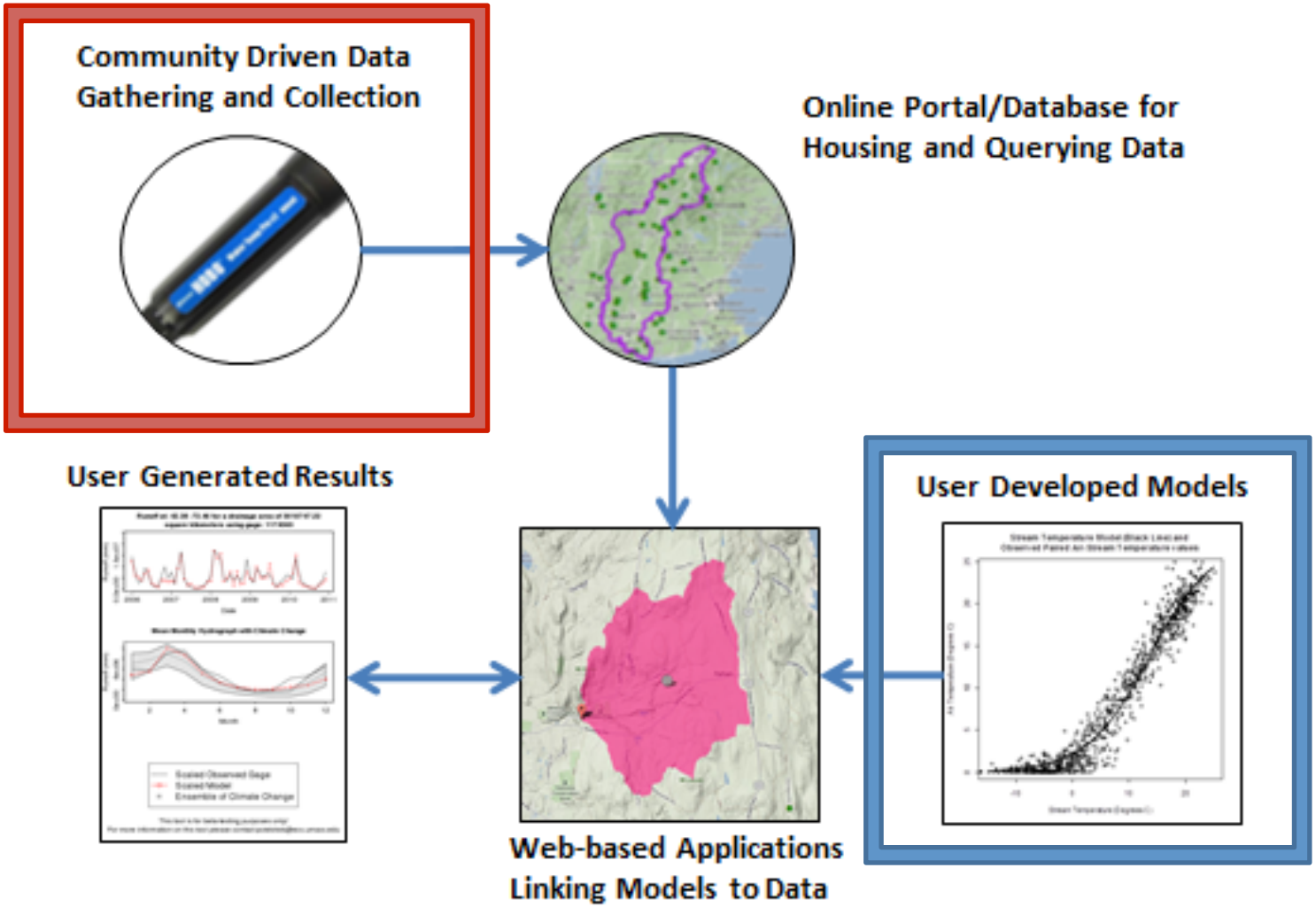




Where are we at with Streamflow?



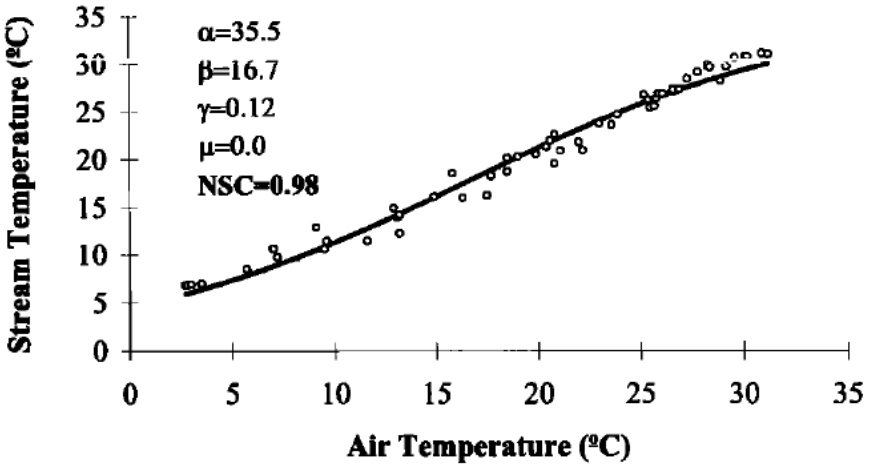
Where are we headed with Stream Temperature?



Current Stream Temperature Model

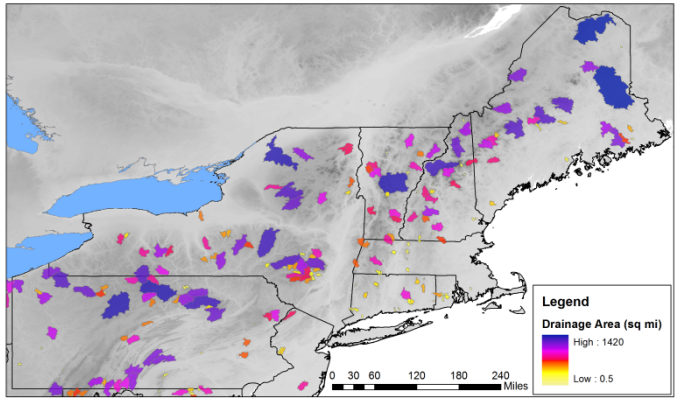
- Nonlinear Regression developed by Mohseni et al. 1998
- Function fit using maximum and minimum stream temperature and air temperature
- Works very well on weekly time step
- Fit using Bayesian framework allows scalability to areas lacking data

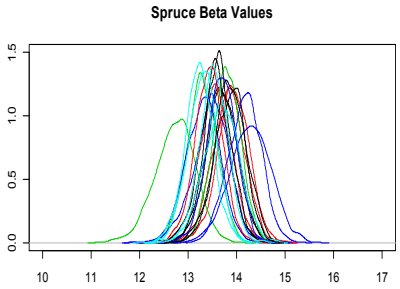
$$T_s = \mu + \frac{\alpha - \mu}{1 + e^{\gamma(\beta - T_a)}}$$

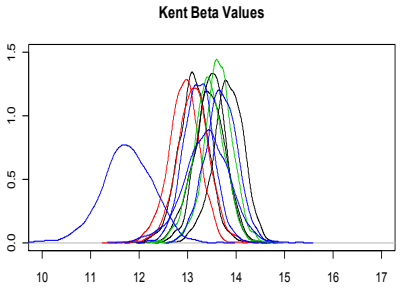


Regionalizing Stream Temperature Models

- Stream temperature modeling challenging as temperature is reach dependent and not necessarily additive
- Potentially use similar methods for regionalizing as streamflow
  - May need to incorporate reach specific effects/ aggregation

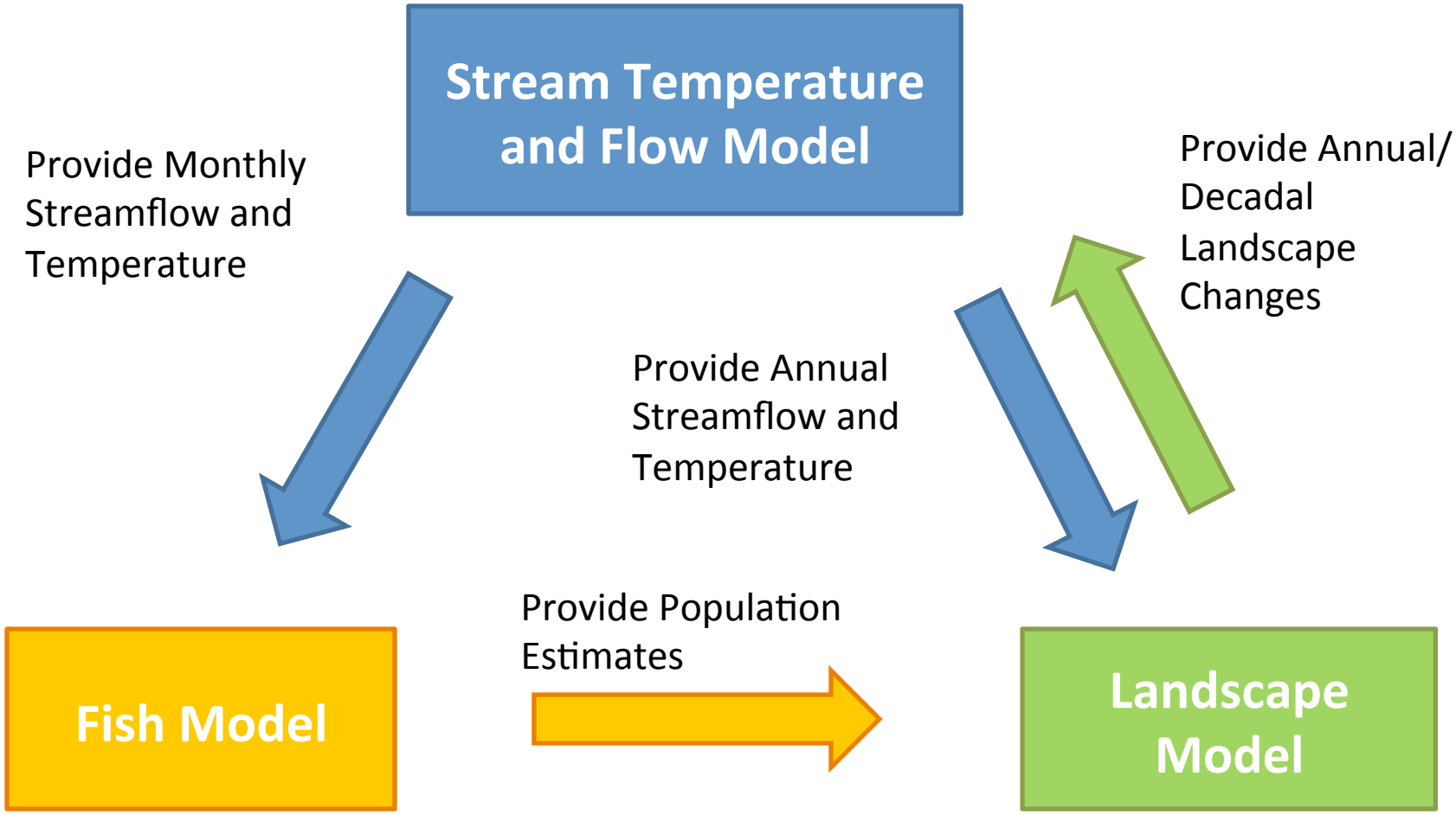




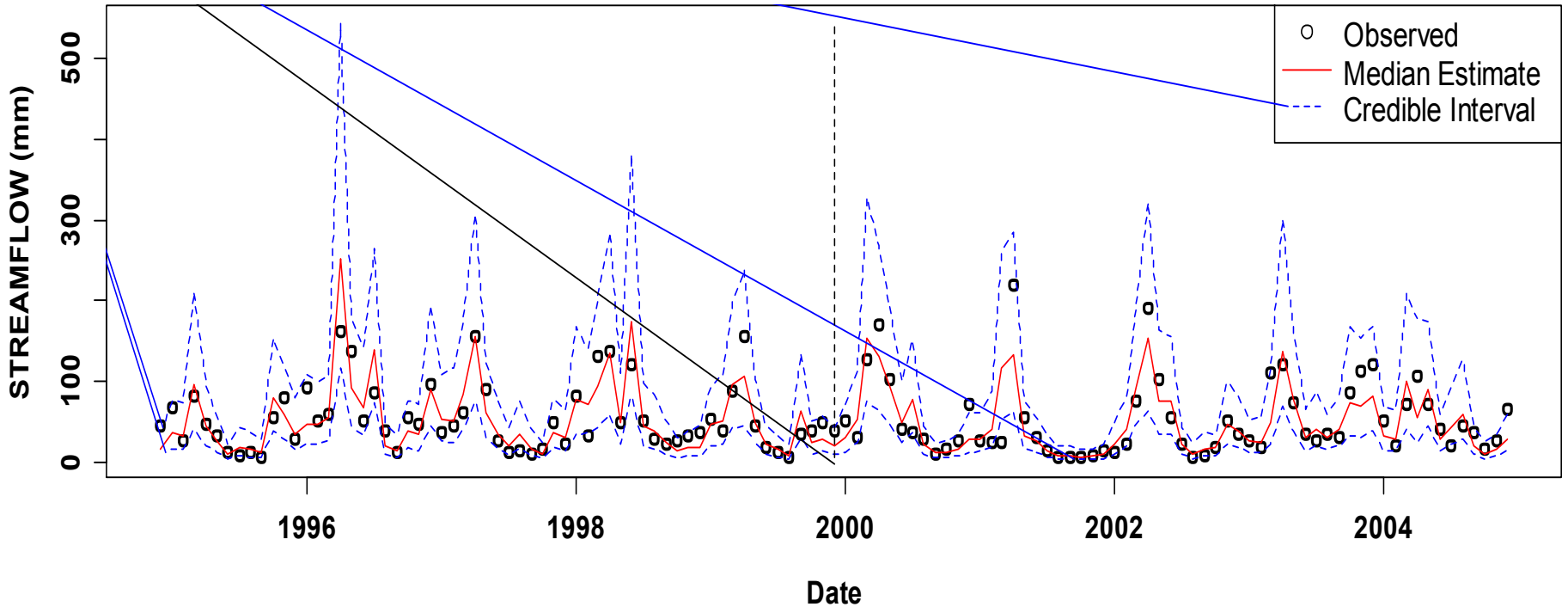


Thank you!

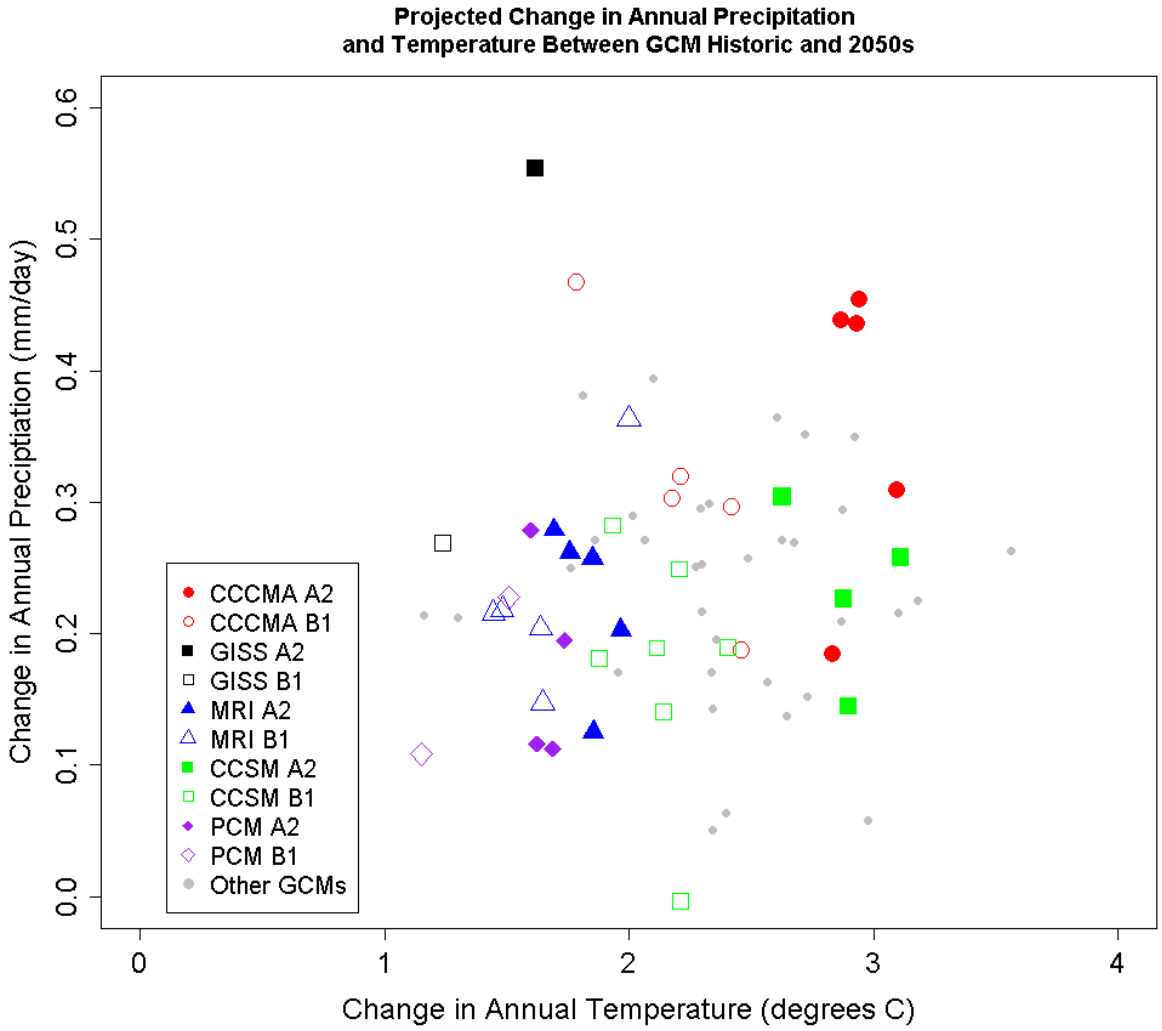
NALCC Streamflow/Temperature Project



Cool Things About ABCDE - Model Uncertainty

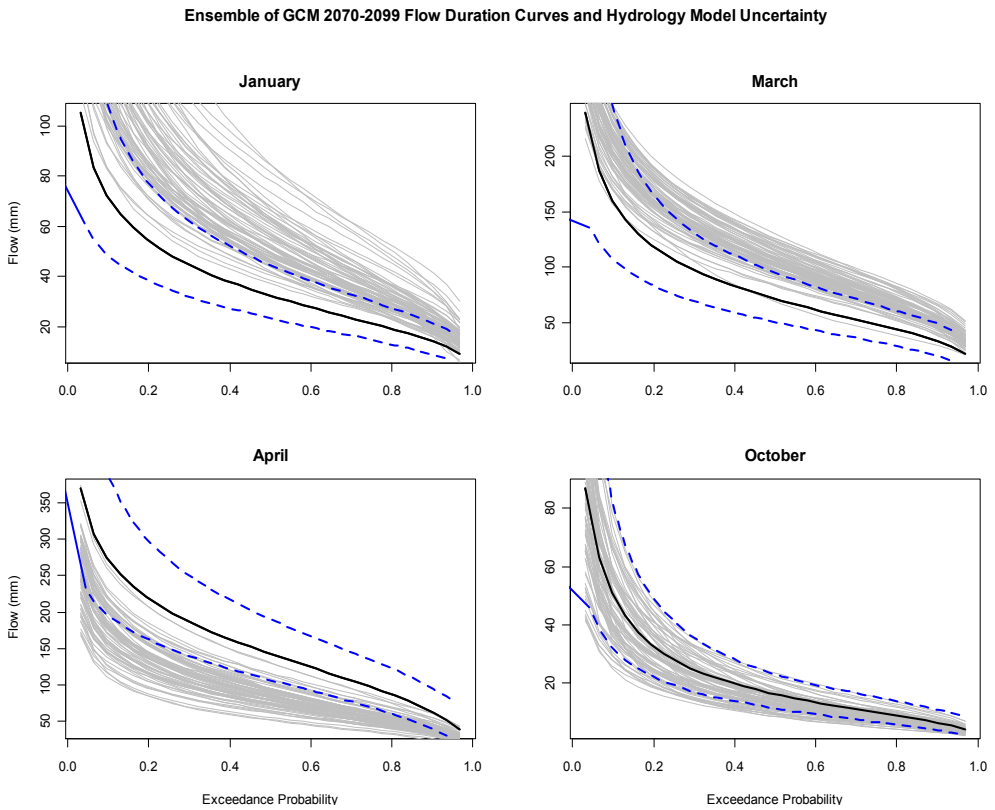


Model Uncertainty – Climate Change



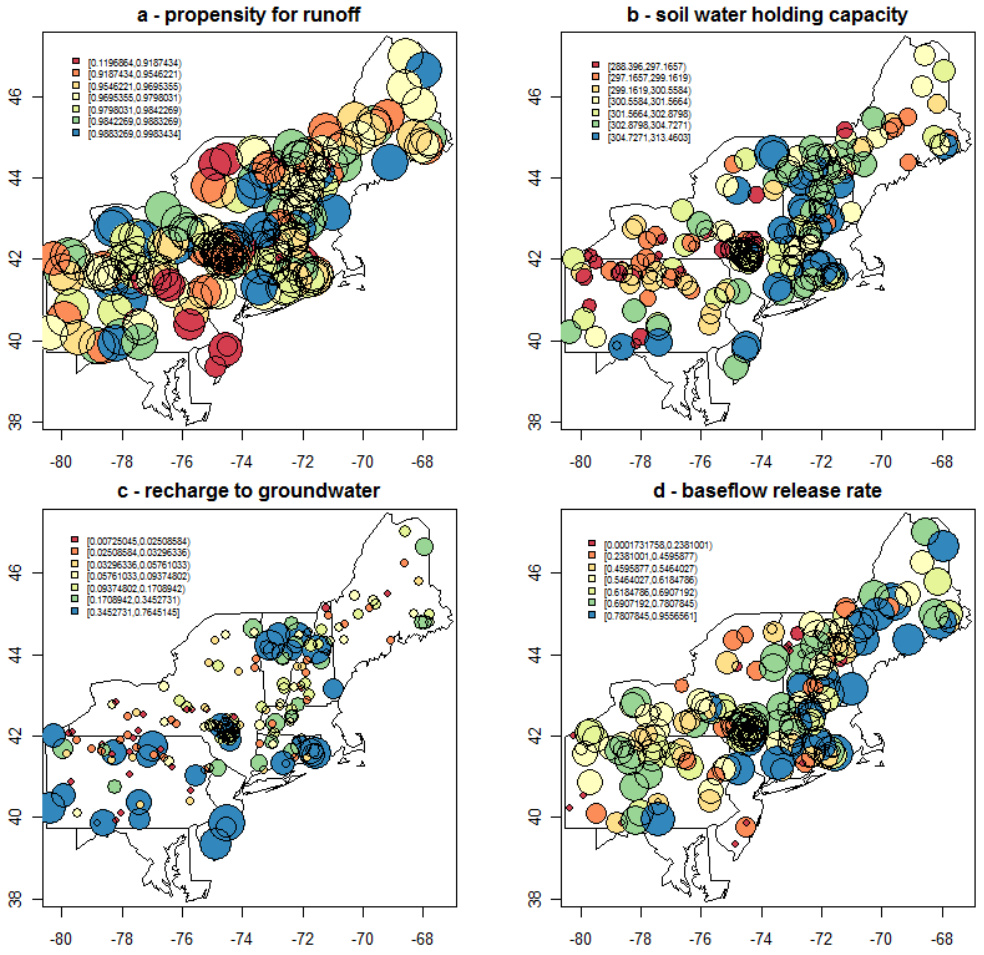
Model Uncertainty – Climate Change

- Compare uncertainty in climate change scenarios to hydrologic model uncertainty
- More ‘certain’ in shift in hydrograph during winter and spring months
- Less ‘certain’ about impacts during fall



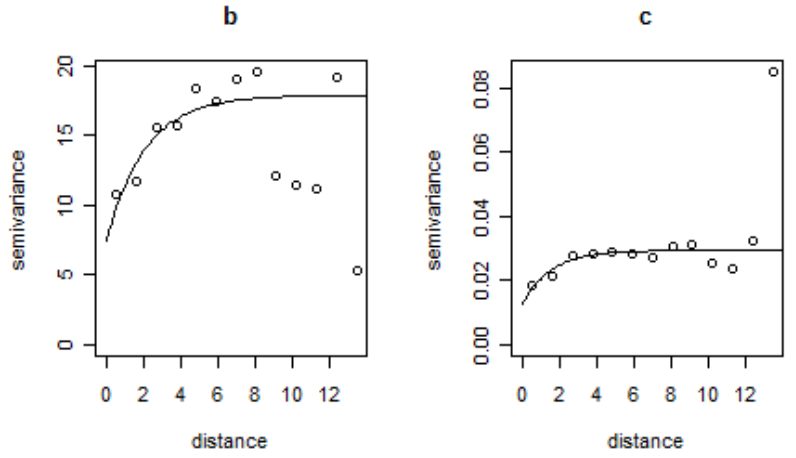
Parameter Spatial Correlation

- Use spatial statistics to create more robust parameter estimates at ungaged locations
- Even after regionalization relationships defined, spatial patterns will exist



Parameter Spatial Correlation

- Use variogram models to fit spatial correlation after regionalization
- Purely a function of distance
- Condition estimate of parameter ‘b’ at ungaged location using:
  - Regression result
  - Values at nearby gages (conditional distribution)



$$C(\mathbf{0}) = \mathrm{Cov}(Z(\mathbf{u}), Z(\mathbf{u})) = \mathrm{Var}(Z(\mathbf{u}))$$

$$\rho(\mathbf{h}) = C(\mathbf{h})/C(\mathbf{0})$$

$$\gamma(\mathbf{h}) = C(\mathbf{0}) - C(\mathbf{h})$$

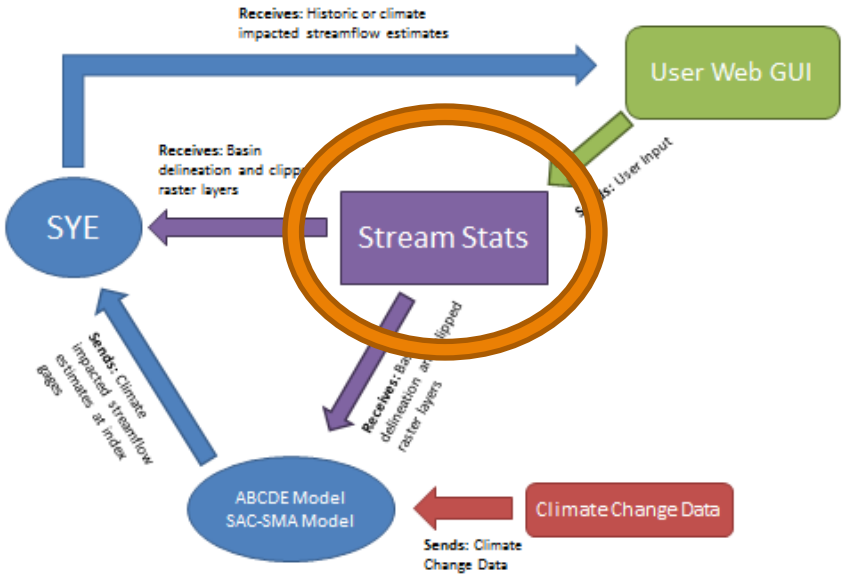
$$Y|X = x \sim \mathcal{N}\left(\mu_Y + \frac{\sigma_Y}{\sigma_X}\rho(x - \mu_X), (1-\rho^2)\sigma_Y^2\right).$$

What is the big picture?

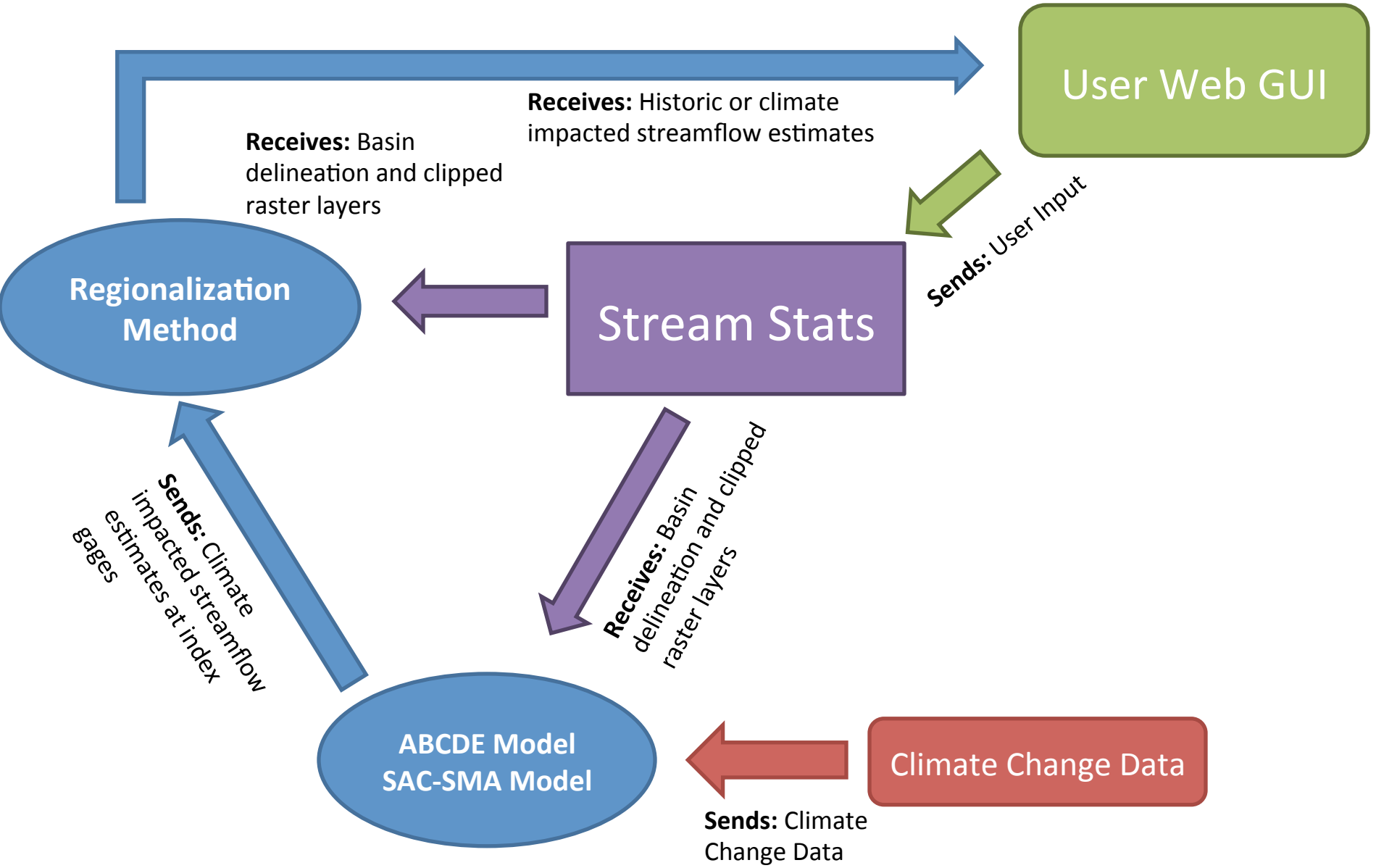
StreamStats

A Model For Other Applications?

- Use StreamStats as a central linking element
- Each new application a 'plug-in' feature to StreamStats
  - streamflow, stream temperature, fish population, flood frequency, etc…
- Open framework built upon a familiar tool
- Baby Steps - Won't happen over night, but we have a really good demo here to try/beta test idea

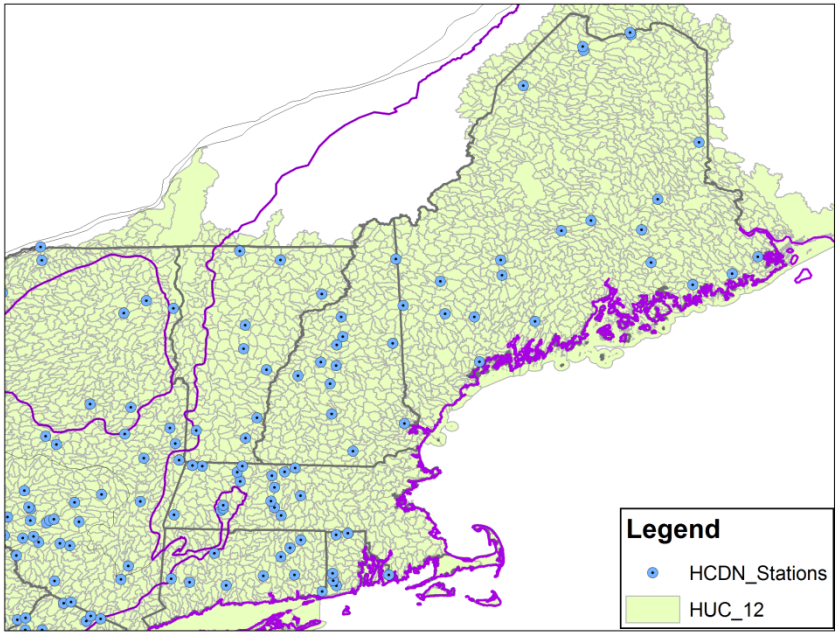


Linking Climate Change with Users!



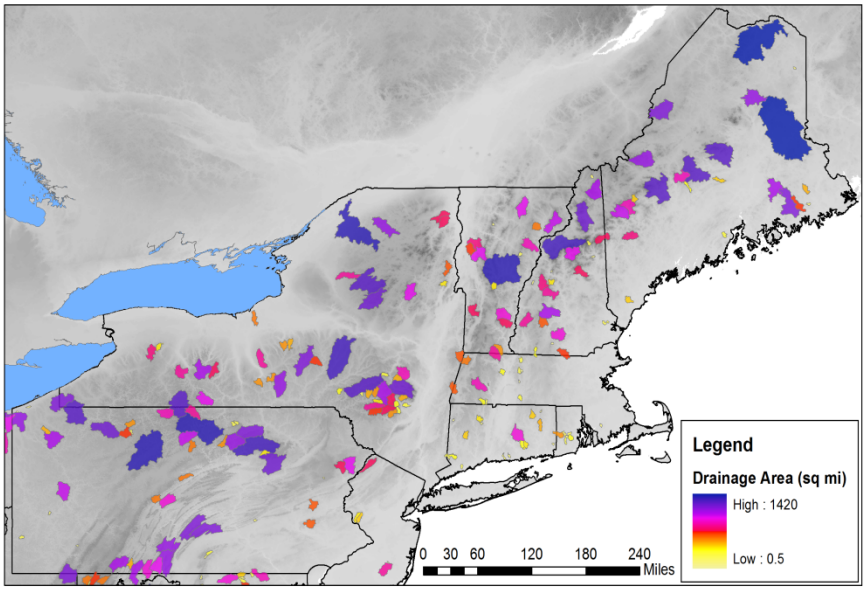
Final Products - Streamflow

- Eventually develop framework for online GIS-based streamflow generator
  - We would like to use StreamStats to dynamically delinate basins
  - Need to define important variables for regionalization and ensure spatially continuous maps exist
  - Ensure transfer scheme maintains important streamflow moments, including under climate change conditions
  - Preferable to embed entire system in StreamStats



Regionalization Scheme 1

- Calibrate hydrology models to index gage sites (VIC, ABCDE, SAC-SMA, PRMS, etc)
- Use MOVE, DAR, WAVE, or SYE to extend model results to ungaged locations
- Substitute index gage with climate altered streamflow – climate change streamflow anywhere!



Scheme 2 – Regionalize Model Parameters

- Estimate streamflow at ungaged locations using regionalization relationships by relying on spatially continuous maps of important variables (rasters)
- Build on work of Vogel and others
  - Previous studies have shown promise
- Bayesian framework can address some concerns of past studies
  - Multicolinearity (among abcd)
  - Account for uncertainty in ‘b’ in our regional regressions
- **Direct linkage with output from Landscape project**