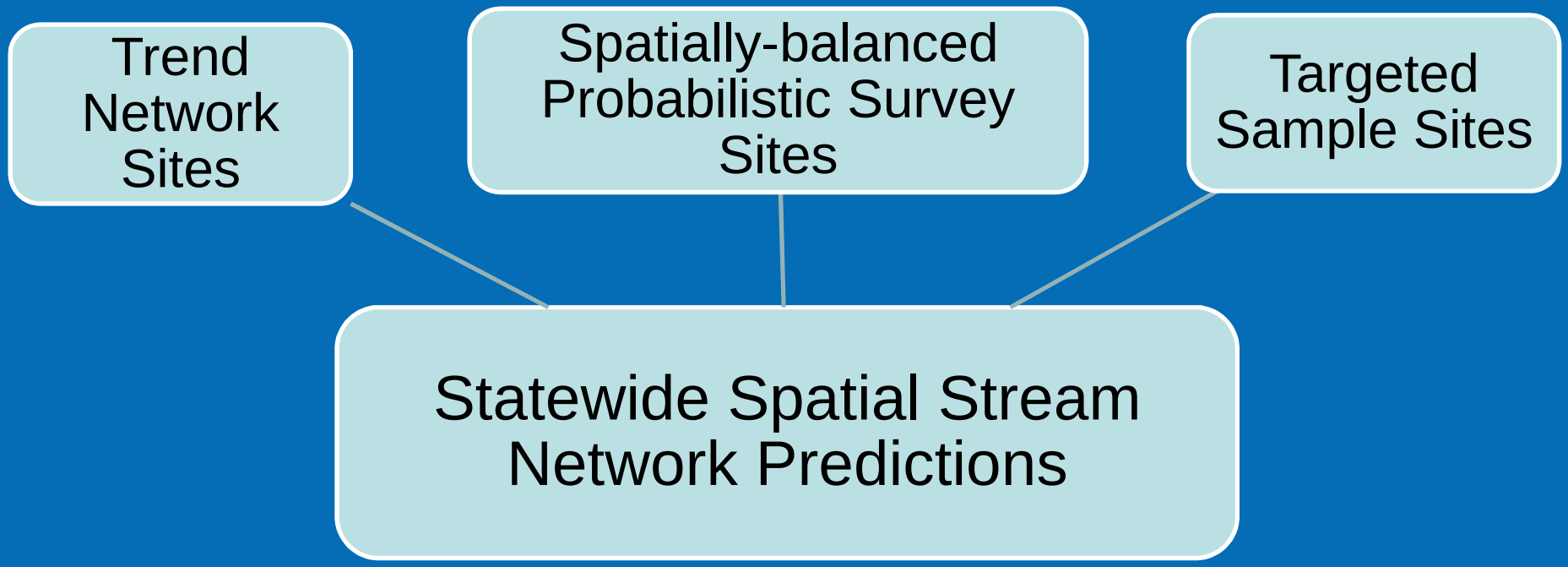
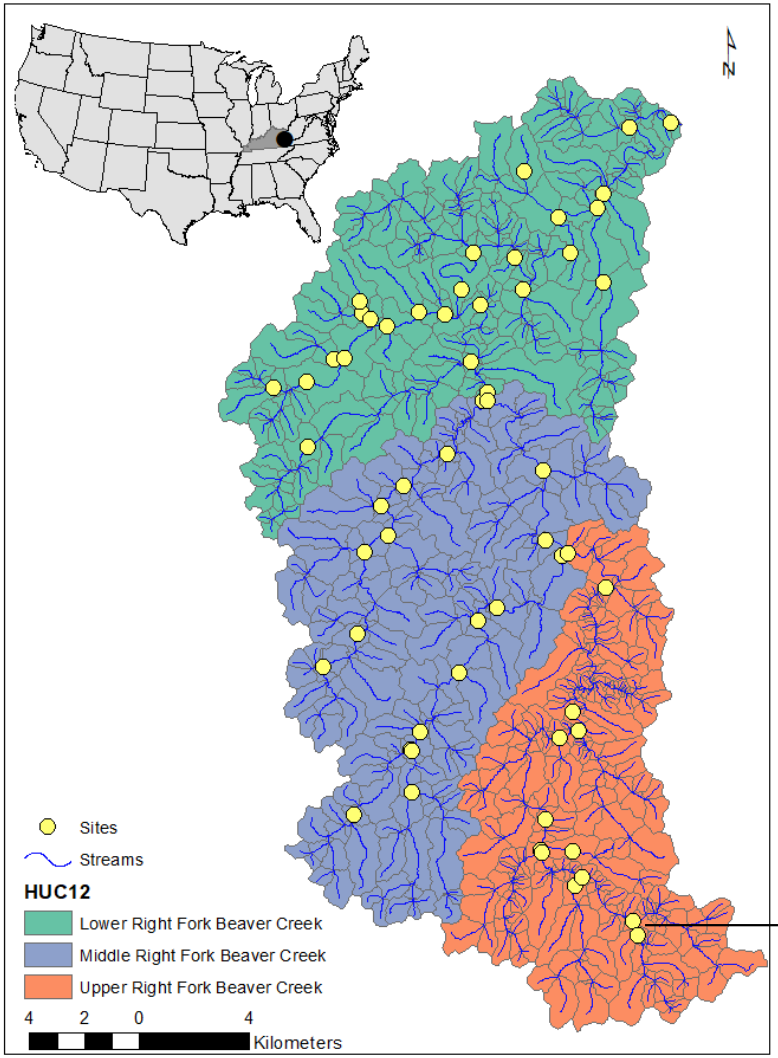
Versatility of Spatial Stream Network Modeling for Watershed Predictions of Conductivity

Michael G. McManus – EPA National Center for Environmental Assessment



The views expressed in this presentation are those of the authors and do not necessarily reflect the views and polices of the U.S. Environmental Protection Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Versatility to Achieve 3 Goals



- Relate a response variable to covariates
- Predict at unsampled locations
- Compare predictions geographically and to a benchmark

Site ARF

Photo by Jerry Ackerman, EPA R4

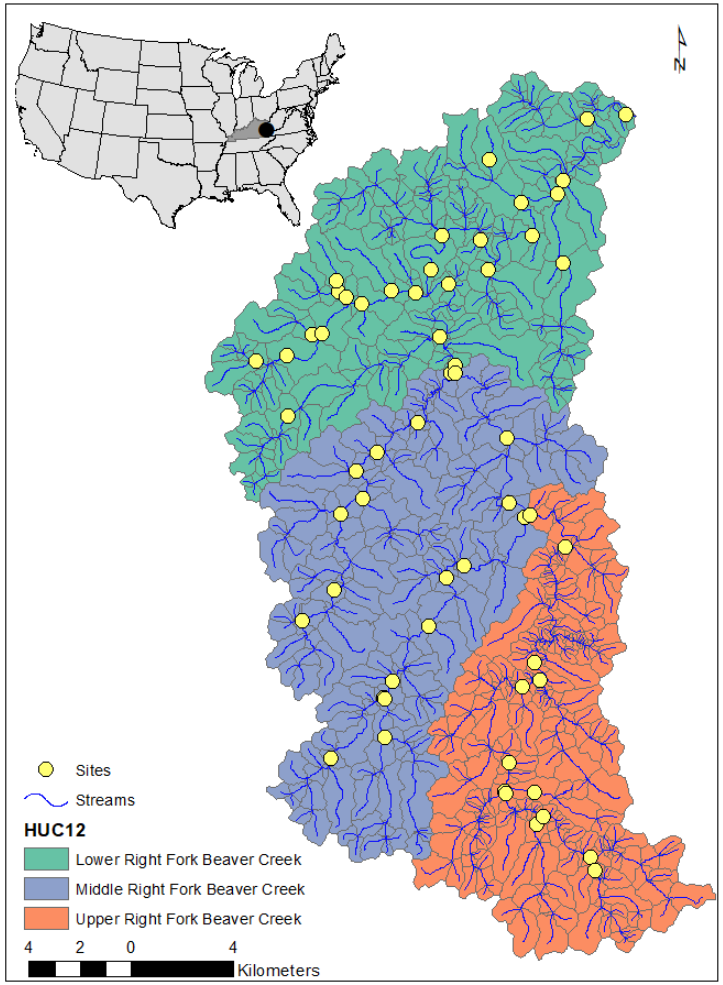
Cumulative Impact of Mining in Eastern Kentucky (CIMEK)

Watershed Research Questions

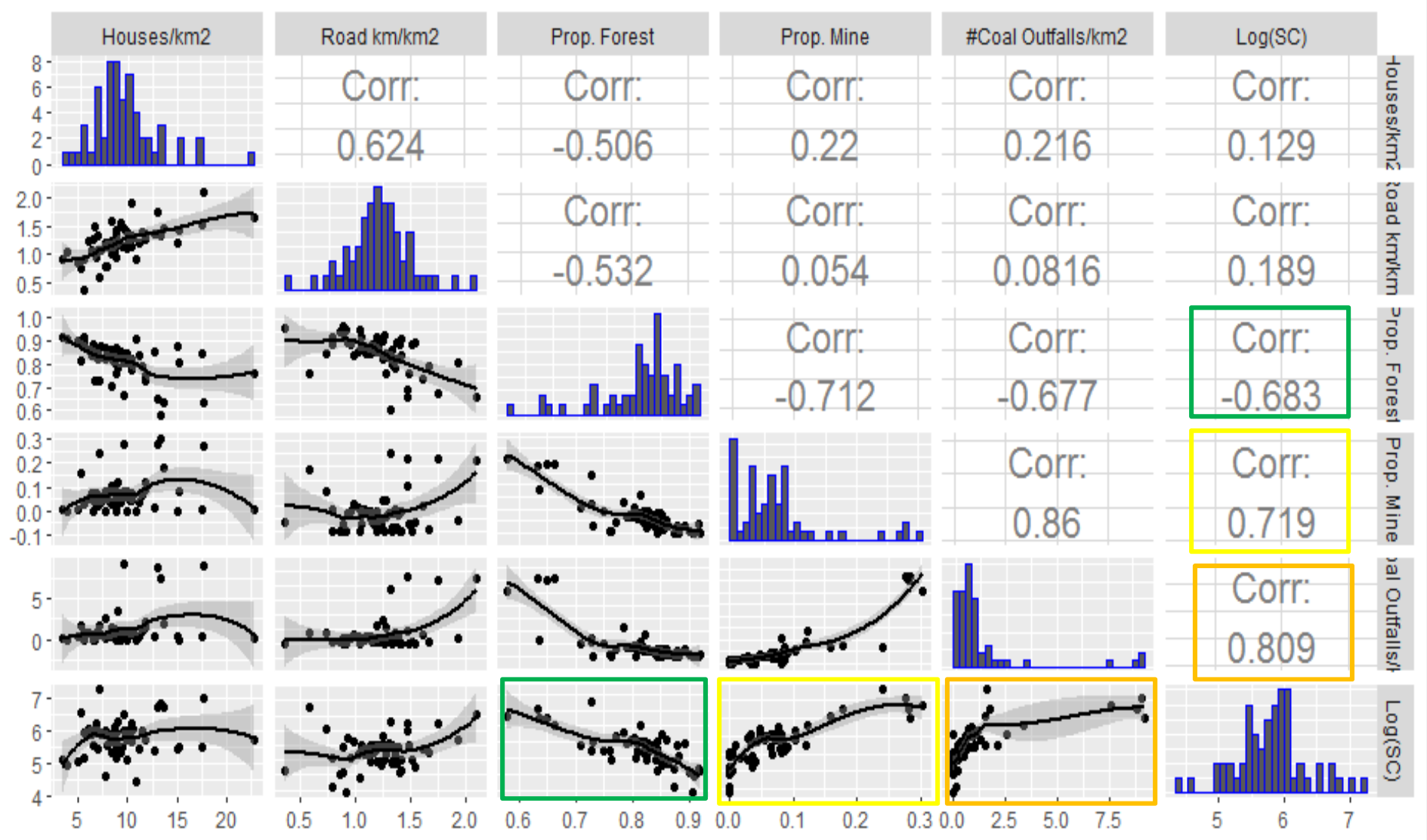
- How does hydrologic variability alter the nature and degree of autocorrelation in specific conductivity (SC)?
- What portions of the stream network have consistently low or high average predictions of conductivity relative to a benchmark meant to protect stream biota?

Study Area and Design

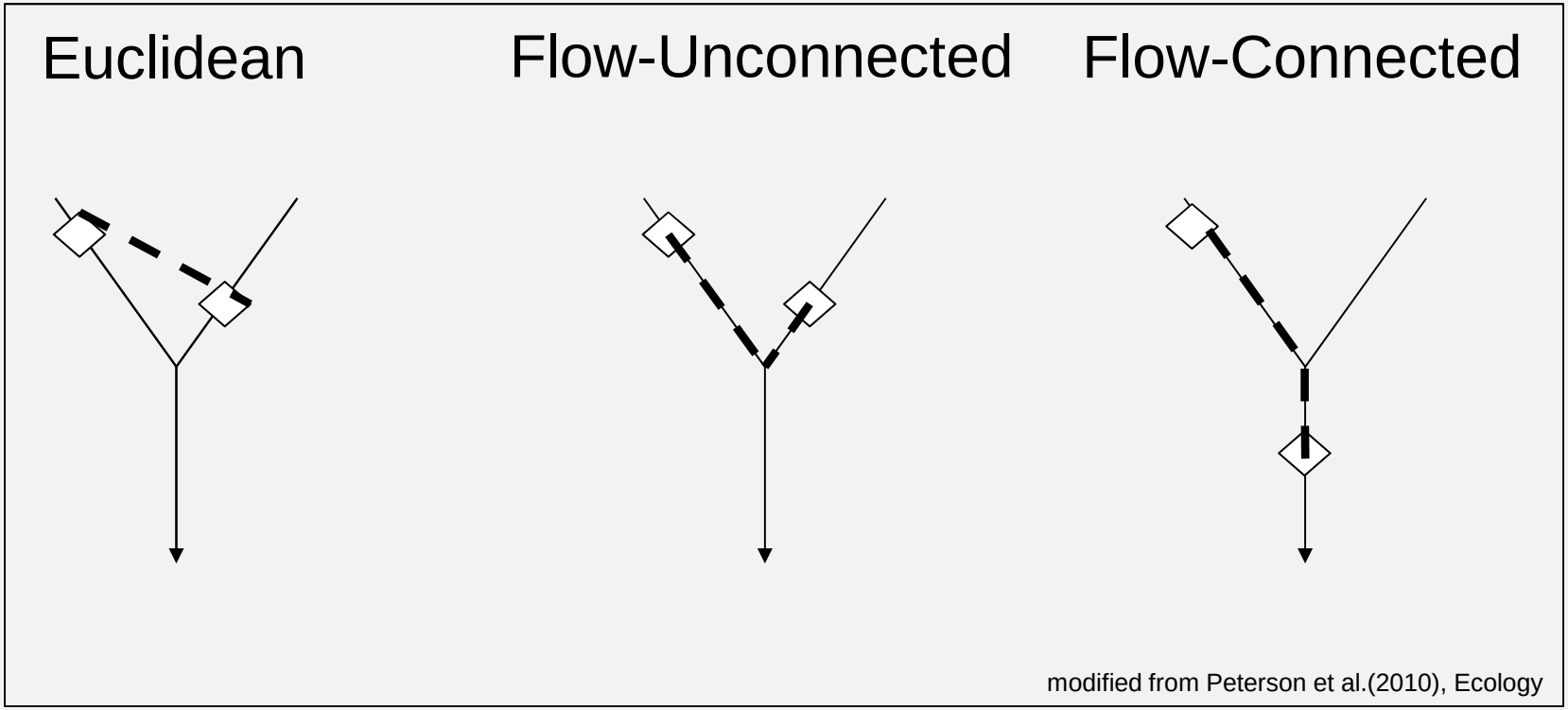
- Right Fork of Beaver Creek Watershed, 400 km^2 (Eastern Kentucky)
- 60 Sites on the mainstem, tributaries and headwaters
- Sampled quarterly for 2 years by in situ measurements
- Response variable: Specific Conductivity (SC), (µS/cm)



Covariates & Conductivity Dec 2012



Distance Relationships

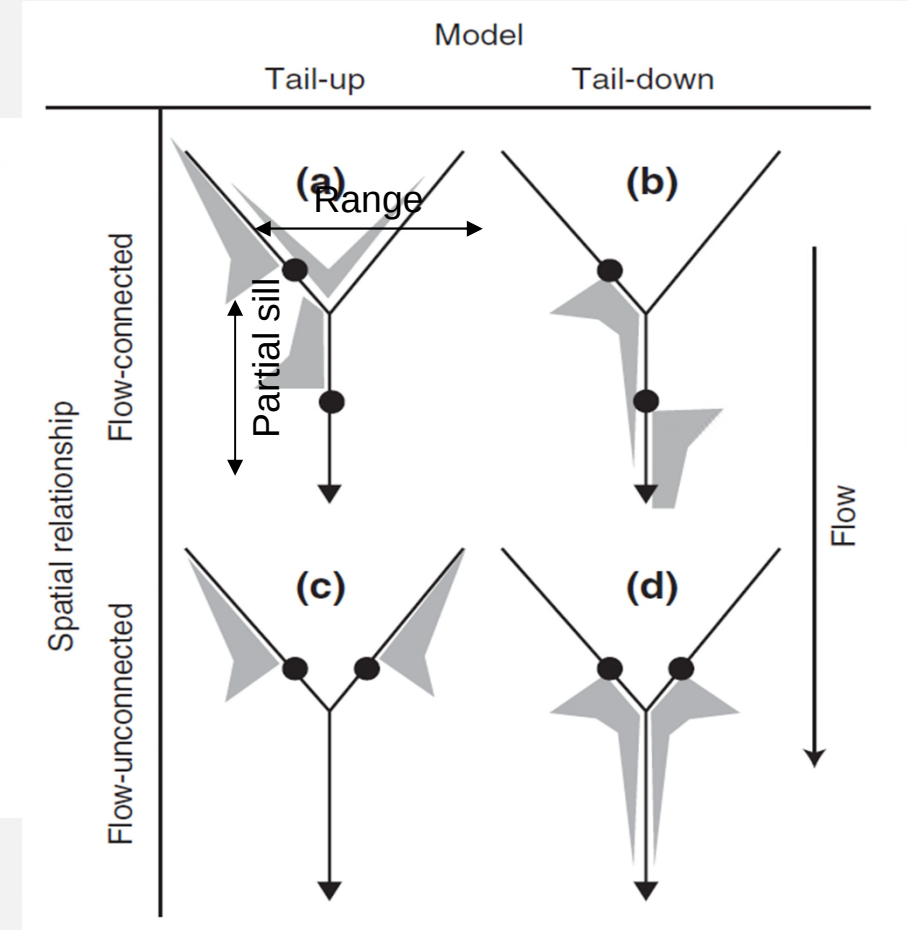


Sites correlated through Euclidean or flow-unconnected relationships suggest landscape influences on conductivity.

Sites correlated through flow-connected relationships suggest downstream flow and longitudinal transport affect conductivity.

Spatial Autocovariances

- Spatial autocovariance in SSN models
  - Euclidean space
  - Semivariogram
    - Torgergram – stream distance
  - Spatial stream relationships
    - Network space
      - Flow connected/unconnected
      - Tail-up/tail-down autocovariance



Isaak et al. (2014), *WIREs Water*

Building a spatial stream network model

- Construct non-spatial generalized linear model

Response variable

Covariates

Parameters

Residual error = nugget

$$Y = X\beta + \varepsilon$$

- Construct spatial GLM

Spatial autocovariance structure

- Range
- Partial sill

$$Y = X\beta + \overbrace{z_{TU} + z_{TD} + z_{Euc}} + \varepsilon$$

Model Building Strategy

- Multiple Regression (MLR) Model
  - Select Land Form, Land Use, & Permit Covariates for each Monitoring Period

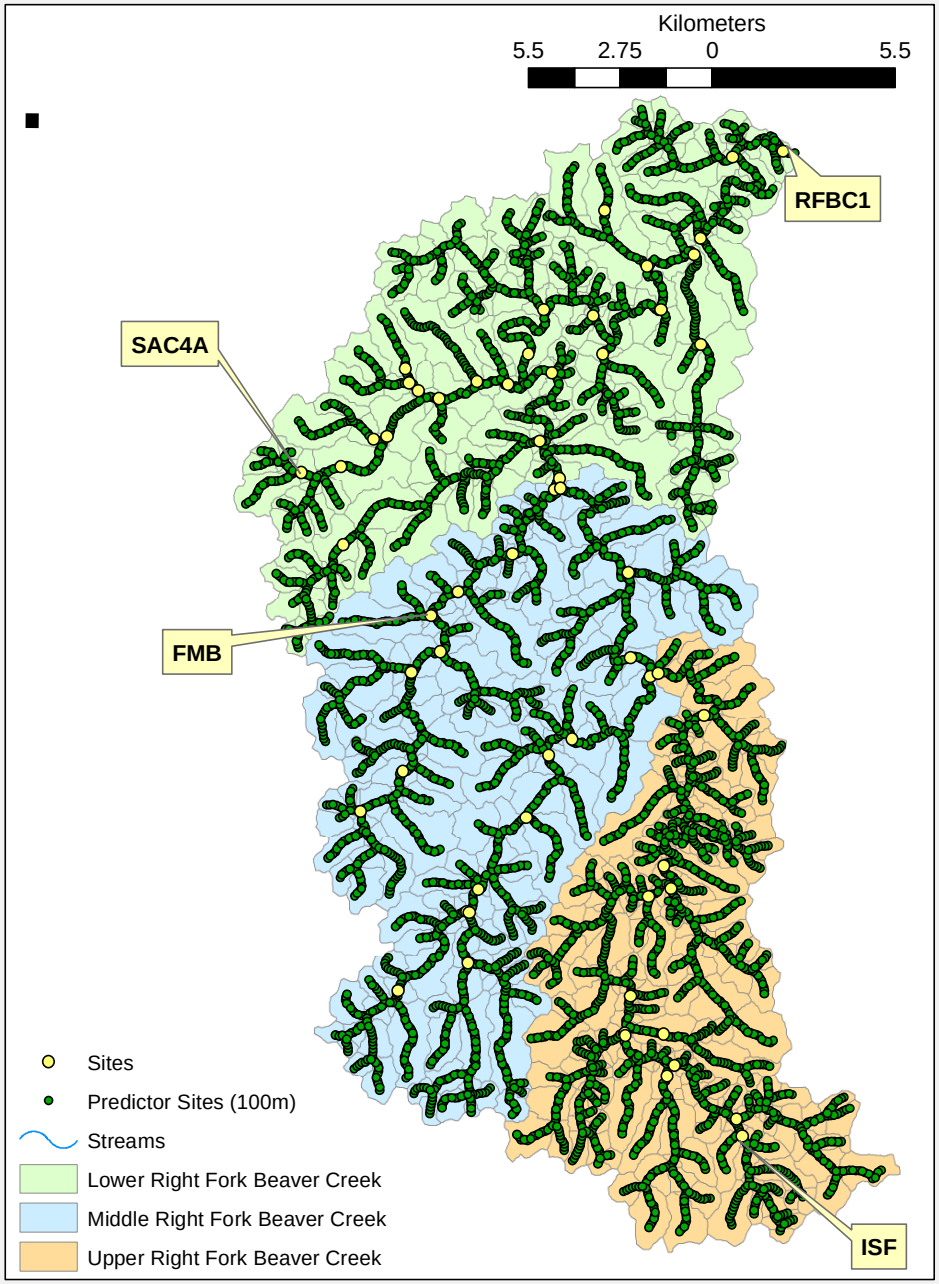
- Spatial Stream Network (SSN) Model
  - Fix the Covariates
  - Select Euclidean, Tail-Up, and Tail-Down Spatial Autocovariances
  - Exponential or Spherical Function

Covariates & Model Fit Year 1

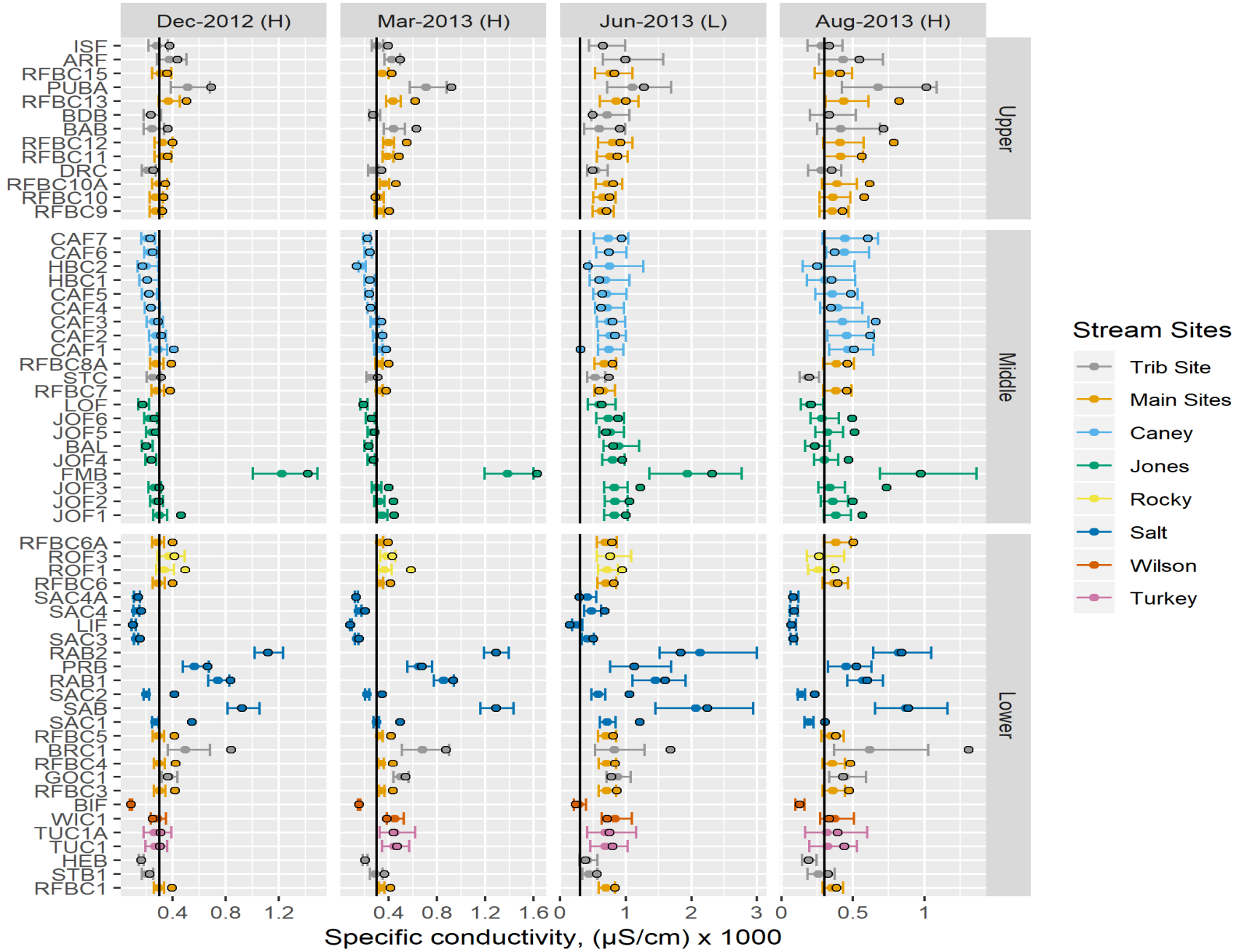
Model Parameters	Dec 2012 (High Q)		Mar 2013 (High Q)		Jun 2013 (Low Q)		Aug 2013 (High Q)	
	SSN	MLR	SSN	MLR	SSN	MLR	SSN	MLR
Intercept	7.3	7.2	7.6	8.4	4.8	4.9	7.4	5.1
Percent Rise								
Abs/Pres NPDES			0.05	-0.22				
House Density							0.004	0.034
Road Density					0.38	0.30		
Prop. Forest	-2.7	-3.2	-2.7	-3.5			-2.5	-2.3
Mean Elevation	1.9×10^{-4}	0.003			0.003	0.003	-4.3×10^{-5}	0.008
Prop. Mine	10.4	9.2	8.7	9.5	10.9	10.7	11.0	15.8
Prop. Mine Quadratic	-22.2	-20.6	-16.2	-23.0	-21.9	-21.4	-23.8	-45.2
Autocovariance	TU, TD		TU, TD		TU		TU, TD	
AIC	-26.71	25.09	-24.53	21.26	34.77	36.19	22.80	67.87
Δ AIC	51.8		45.8		1.4		45.1	
RMSPE	0.16	0.30	0.17	0.31	0.32	0.33	0.28	0.44

Prediction Sites for Block-Kriging

- Modeled at 60 sites (yellow dots)
- Predicted at every 100 m (green dots)
- Obtained average predicted conductivity over different portions of the network



Block-Kriged Predictions Year 1



Research Conclusions

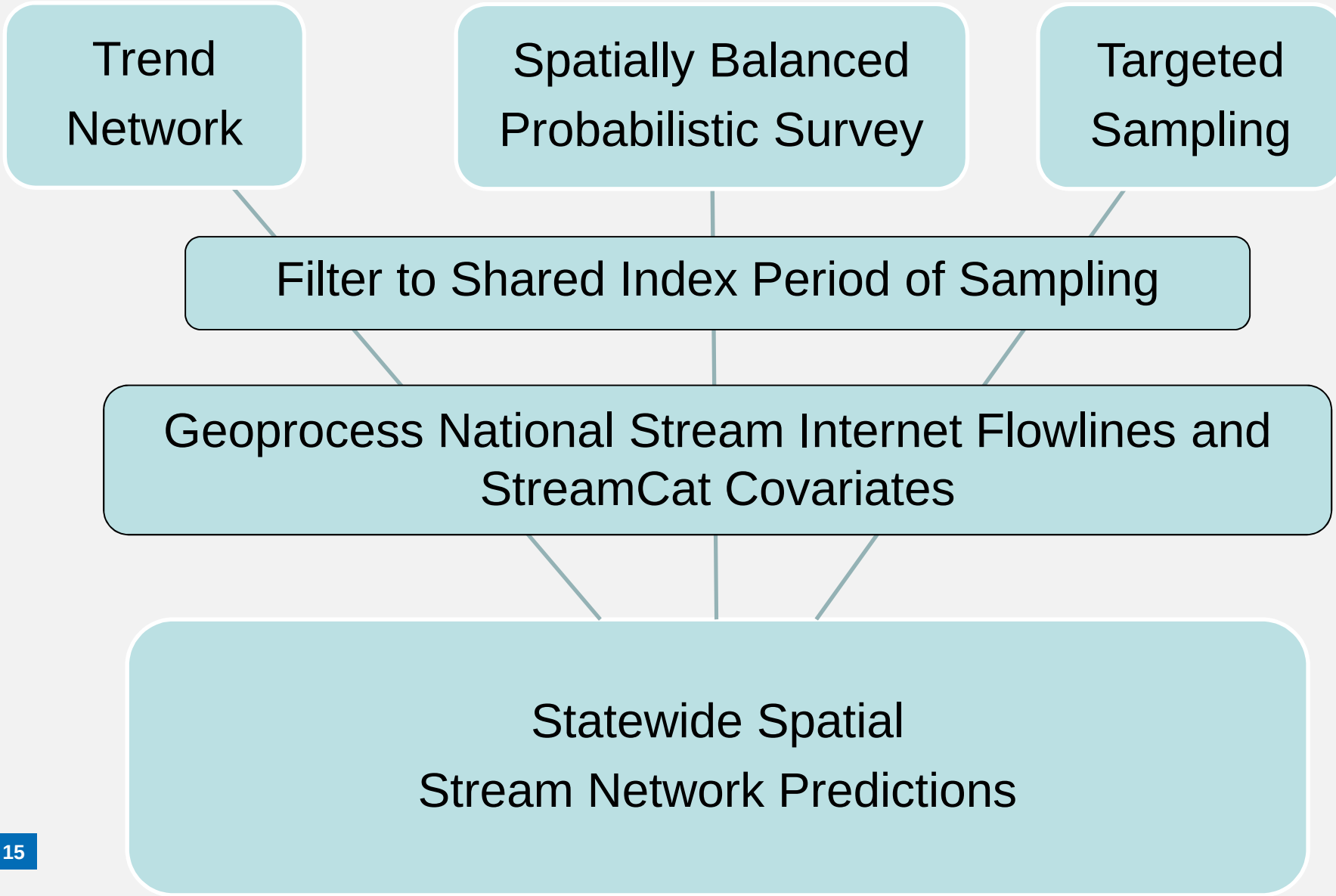
- During high discharge conditions sites have both flow-connected and flow-unconnected network relationship.
- During most low discharge conditions sites have only flow-connected relationships.
- Spatial stream network models tend to have better predictions and smaller nuggets than multiple linear regression models.
- Able to identify portions of the network with high or low conductivities by comparing block-kriged predictions to a benchmark.

Versatility of Spatial Predictions

Versatility	Spatial Stream Network
Relate Response Variable to Covariates	✓
Predict at Unsampled Locations	✓
Predict from Point Support to Block Support	✓

- Examine spatial and statistical distributions of covariates to try and avoid extrapolations (http://freerangestats.info/blog/2016/12/10/extrapolation)
- Covariates derived from local, study-specific, GIS sources can often be better than national sources

Future Direction



Acknowledgements

- Co-authors Ellen D'Amico, Pegasus Technical Support, and EPA R4 scientists: Elizabeth M. Smith, Robyn Polinsky, Jerry Ackerman, and Kip Tyler

- Kristin Broms, Neptune and Company and Mark S. Murphy, CSRA, for statistical and GIS support, respectively

- Field crews and laboratory scientists for collecting and processing the data