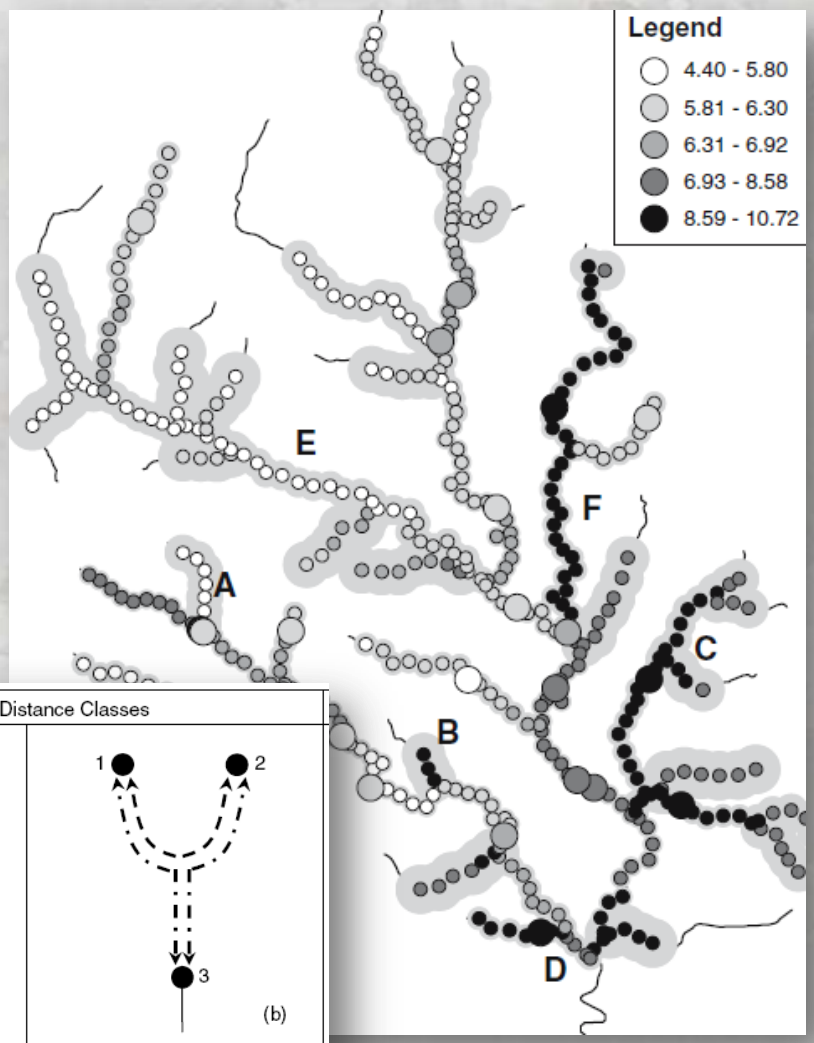
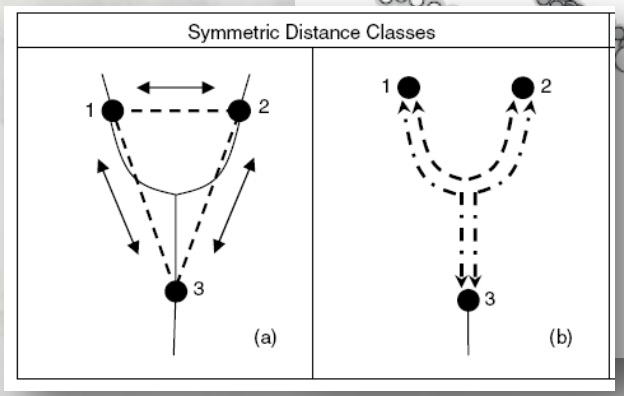
A New Class of Spatial Statistical Model for Data on Stream Networks: Overview and Applications

Jay Ver Hoef

Erin Peterson

Dan Isaak





Spatial Statistical Models for Stream Networks

Environ Ecol Stat (2006) 13:449–464
DOI 10.1007/s10651-006-0022-8

ORIGINAL ARTICLE

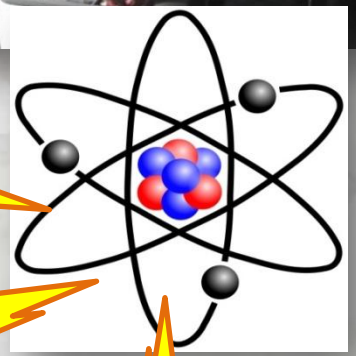
Spatial statistical models that use flow and stream distance

Jay M. Ver Hoef · Erin Peterson · David Theobald

Freshwater Biology (2007) 52, 267–279 doi:10.1111/j.1365-2427.2006.01686.x

Geostatistical modelling on stream networks: developing valid covariance matrices based on hydrologic distance and stream flow

ERIN E. PETERSON,* DAVID M. THEOBALD† AND JAY M. VER HOEF‡



Functional Linkage of Water basins and Streams (FLoWS) v1 User's Guide:

ArcGIS tools for Network-ba

Contact info:

Authors:
David M. Theobald
John B. Norman
E. Peterson
S. Ferraz
A. Wade
M.R. Sherburne

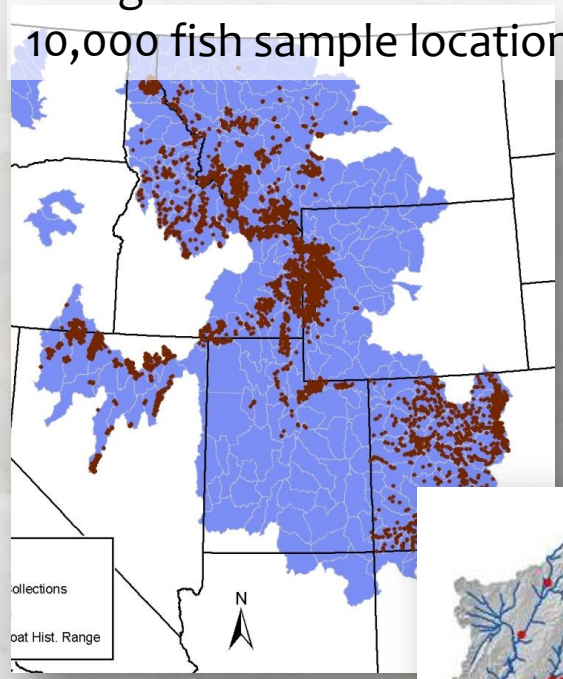
Spatial modelling and prediction on river networks: up model, down model or hybrid?

Vincent Garreta[1*,†], Pascal Monestiez[2] and Jay M. Ver Hoef[3]

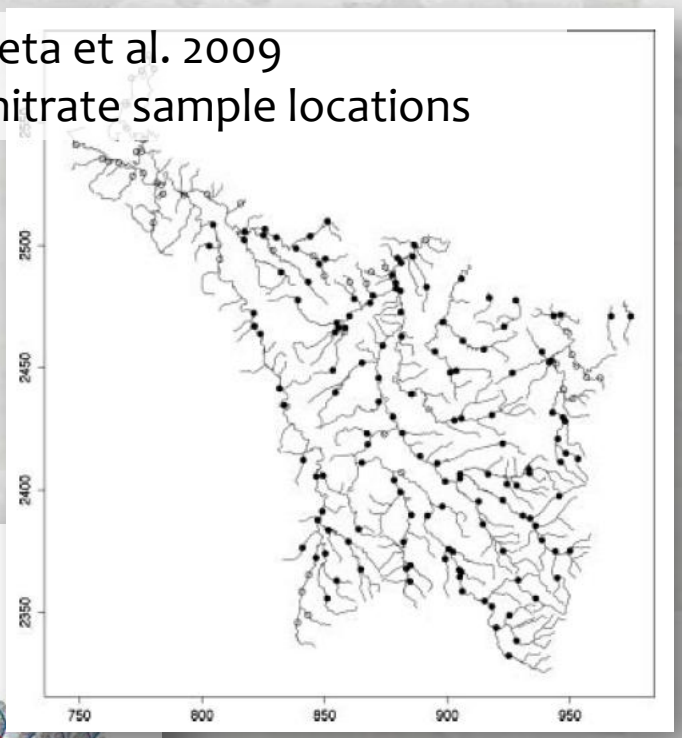
[1]*CEREGE, UMR 6635, CNRS, Université Aix-Marseille, Europôle de l'Arbois, 13545 Aix-en-Provence, France*
[2]*INRA, Unité de Biostatistique et Processus spatiaux, Domaine St Paul, Site Agroparc, 84914 Avignon Cedex 9, France*
[3]*NOAA National Marine Mammal Lab, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA*

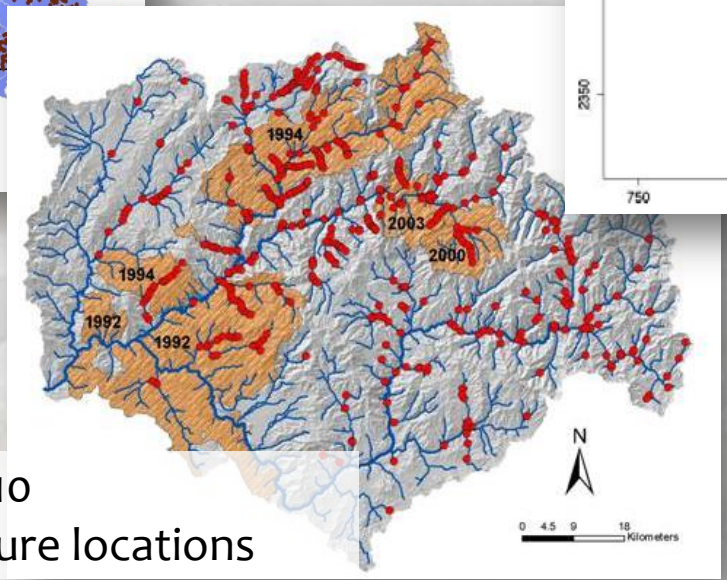
Examples of Autocorrelated Data on Stream Networks

Wenger et al. 2011
10,000 fish sample locations



Garreta et al. 2009
187 nitrate sample locations

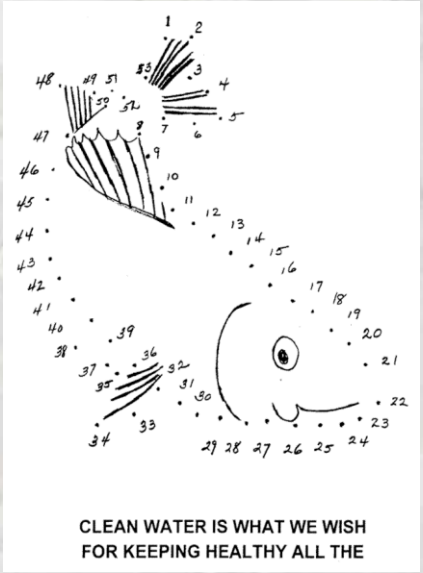




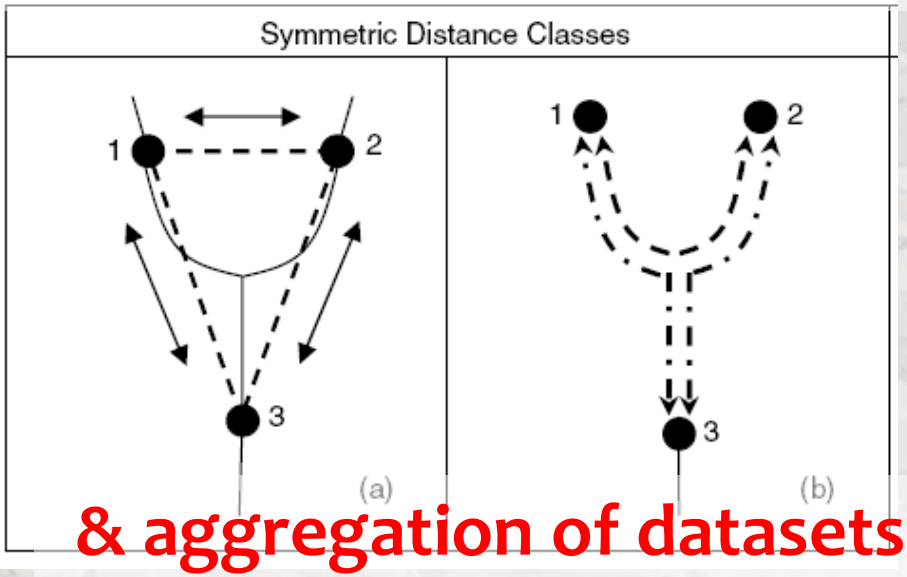
Isaak et al. 2010
780 temperature locations

Observations are not independent

Spatial Statistical Models are Dot Connectors



Valid interpolation on networks



& aggregation of datasets

Advantages:

-flexible & valid autocovariance structures that accommodate network topology

-weighting by stream size

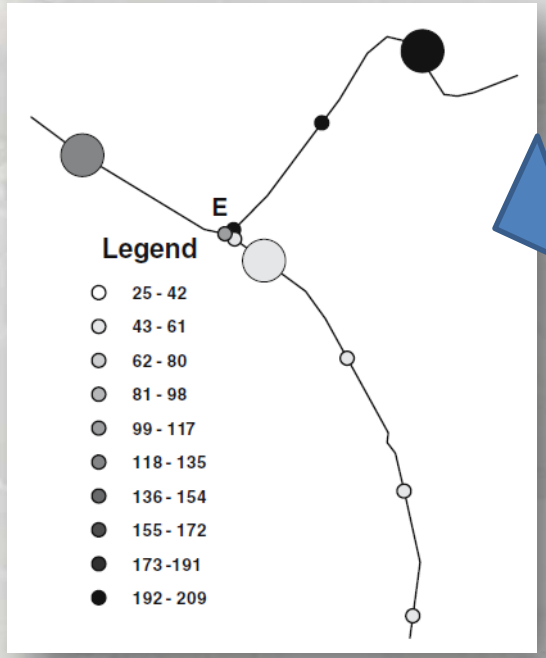
-improved predictive ability & parameter estimates relative to non-spatial models

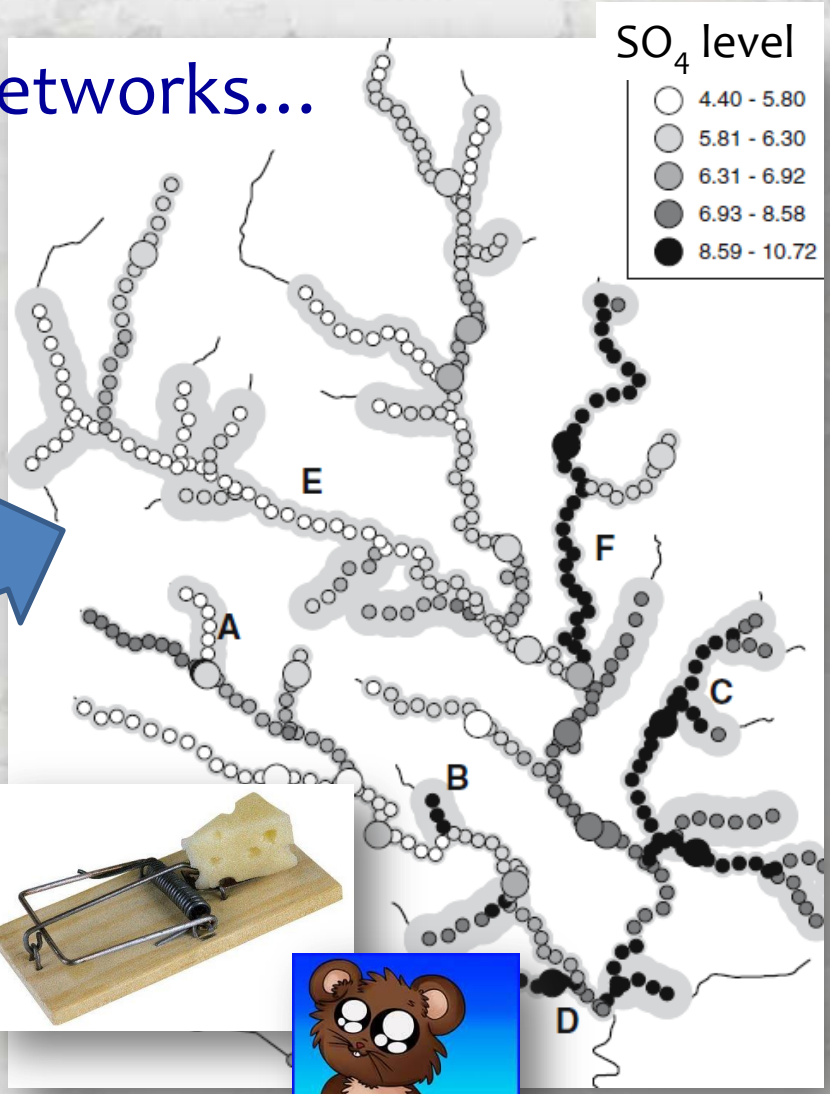
Peterson et al. 2006; Ver Hoef et al. 2006; Ver Hoef and Peterson 2010

Spatial Statistical Network Models Work the Way that Streams Do

Gradual trends within networks…

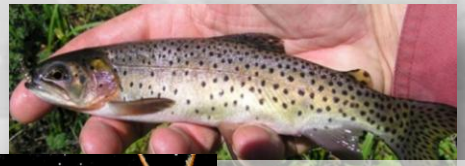
…but also changes at tributary confluences





…& are significantly better mousetraps

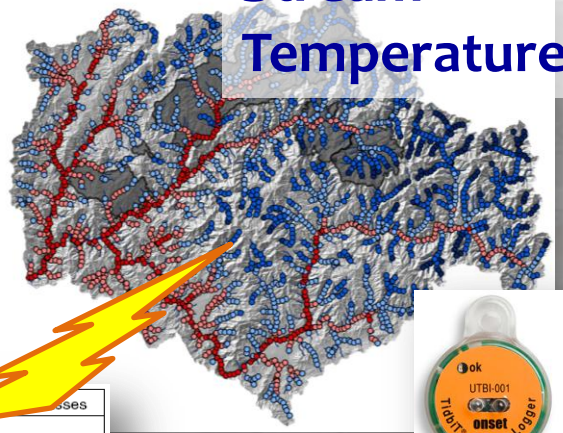
Stream Models are Generalizable

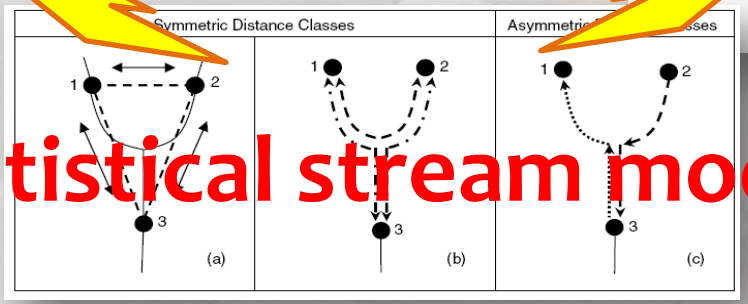


Distribution & abundance

Response Metrics
- Gaussian
- Poissan
- Binomial

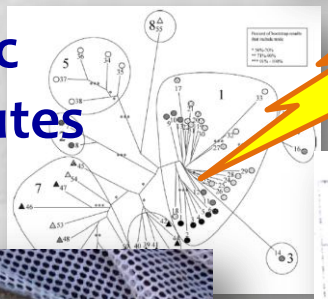
Stream Temperature

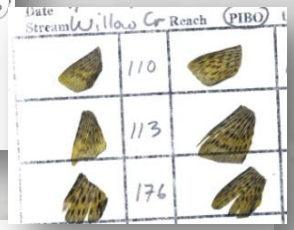


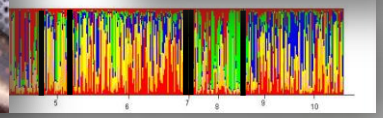


Statistical stream models

Genetic Attributes



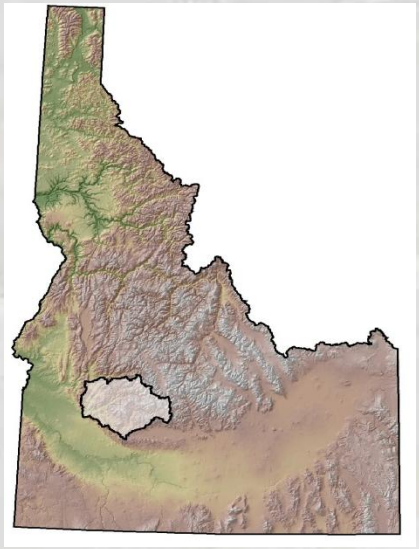




Water Quality Parameters

An Example in the Boise River Basin

Stream Temperature Database
14 year period (1993 – 2006)
780 observations
518 unique locations



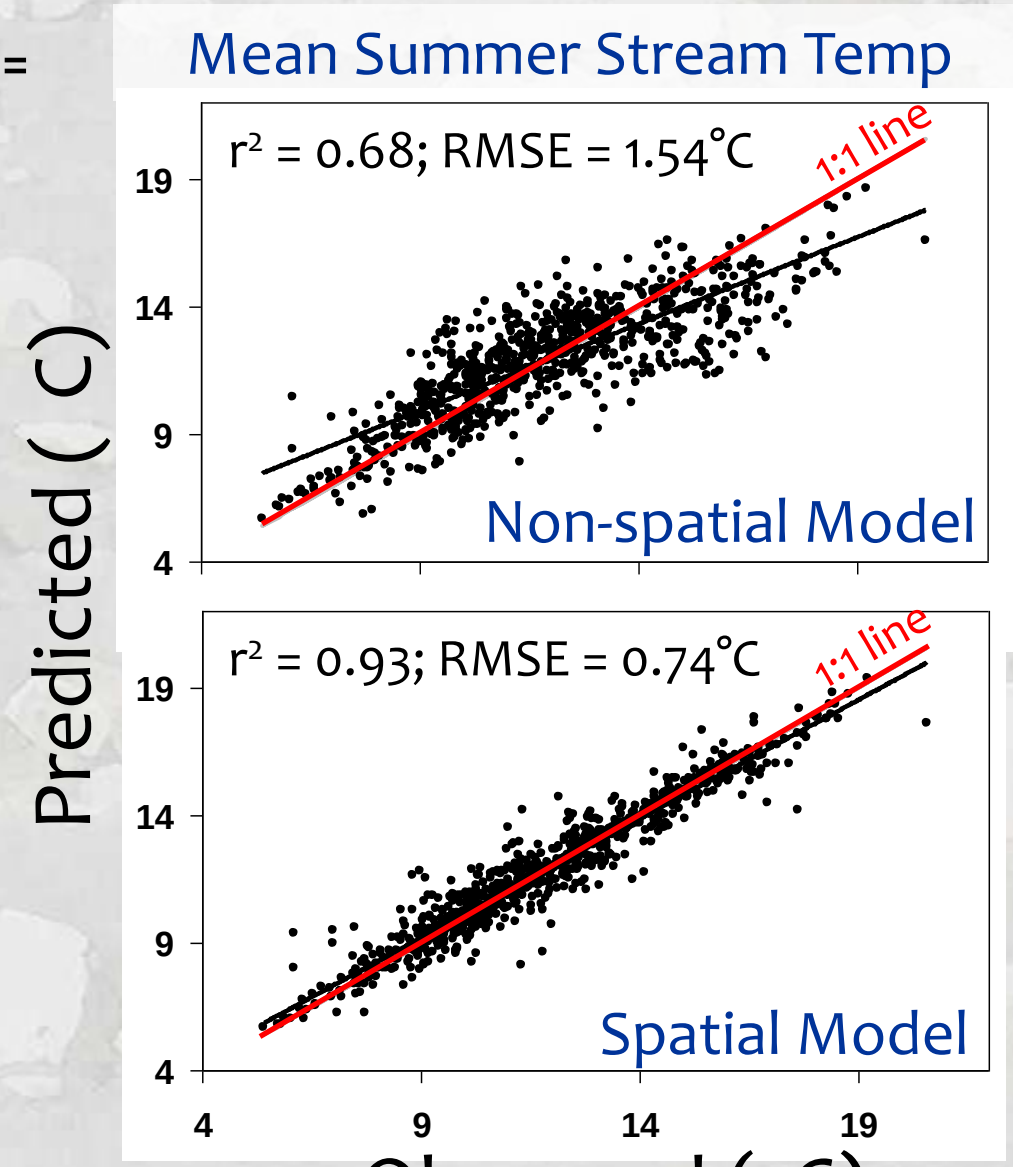
Watershed Characteristics
Elevation range 900 – 3300 m
Fish bearing streams ~2,500 km
Watershed area = 6,900 km^2

Boise River Temperature Model

Non-spatial Stream Temp =
– 0.0064*Elevation (m)
+ 0.0104*Radiation
+ 0.39*AirTemp (°C)
– 0.17*Flow (m^3/s)

Parameter estimates are different because of autocorrelation in database

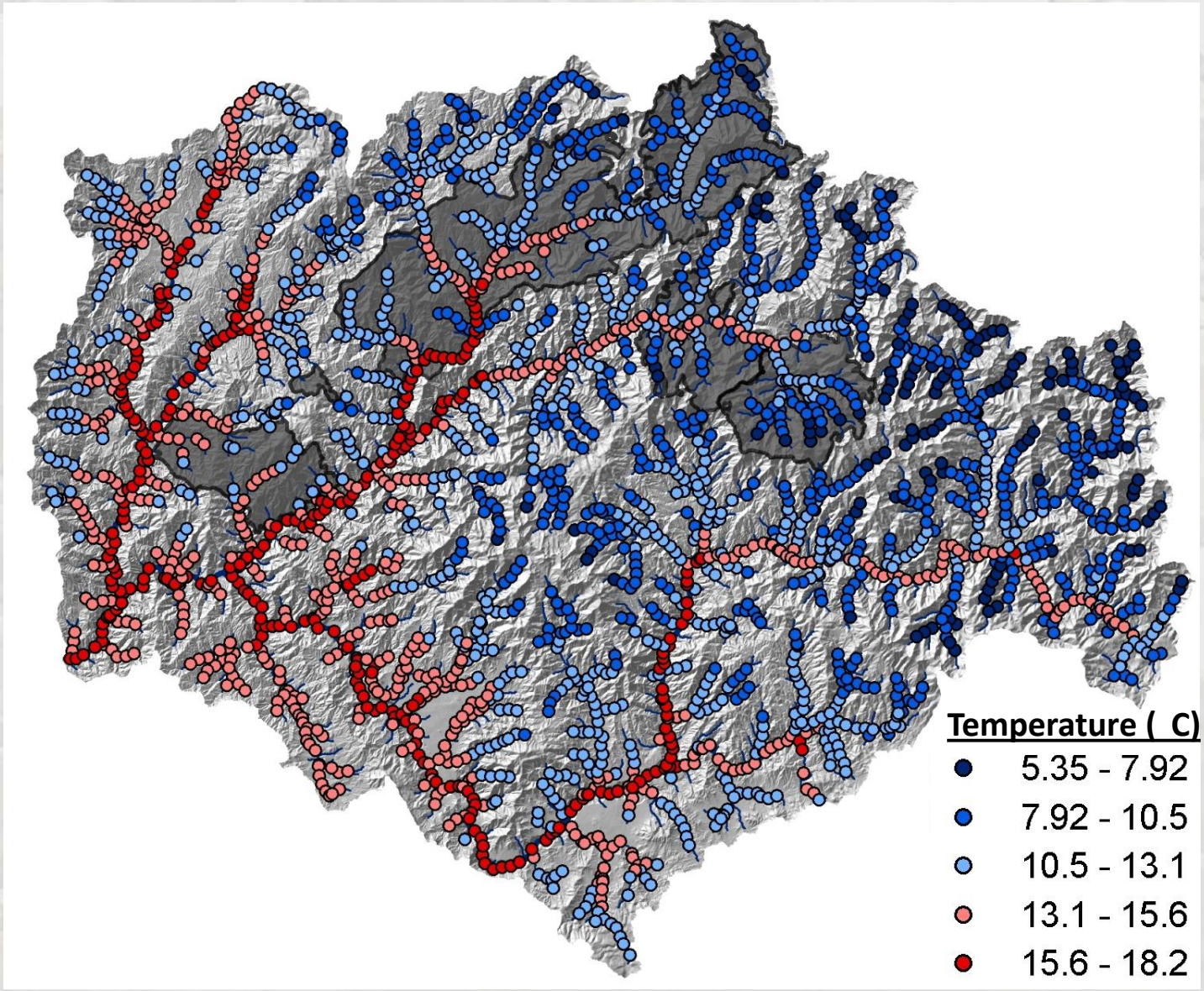
Spatial Stream Temp =
– 0.0045*Elevation (m)
+ 0.0085*Radiation
+ 0.48*AirTemp (°C)
– 0.11*Flow (m^3/s)



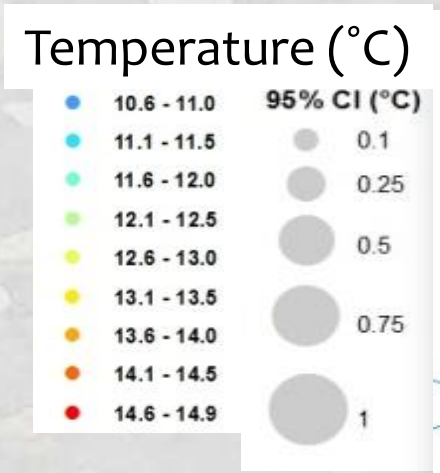
Isaak et al. 2010. *Ecol. Apps.* 20:1350-1371

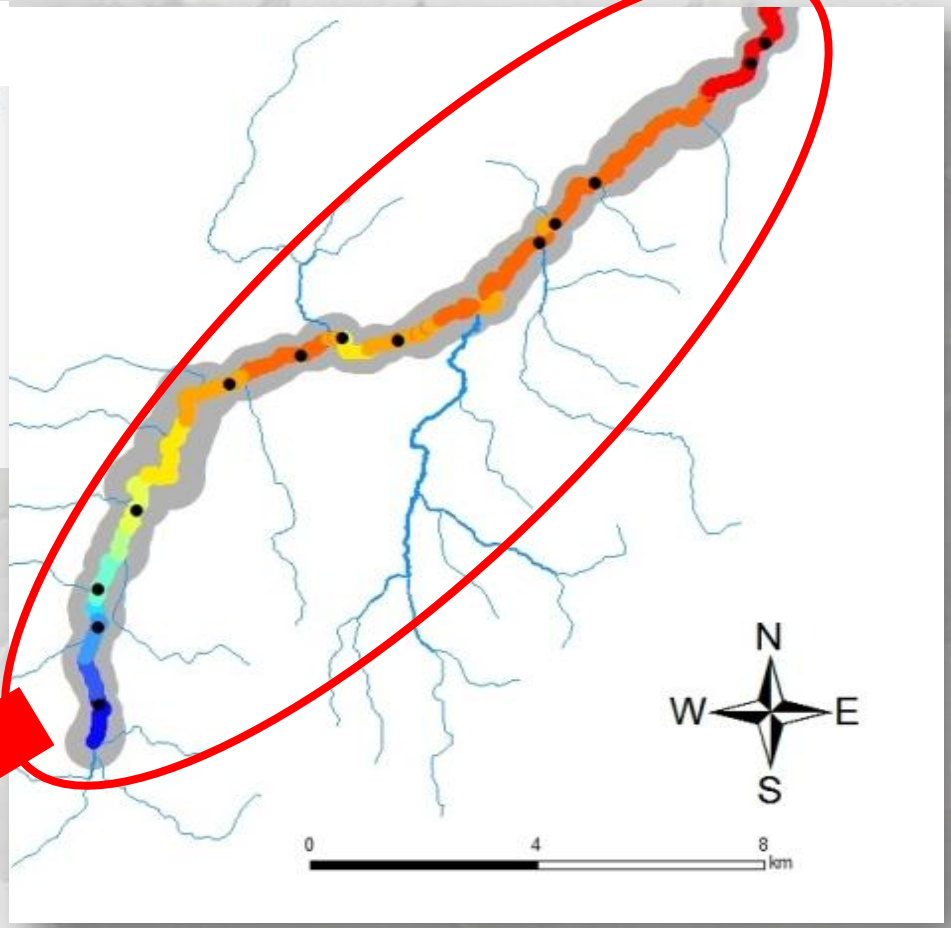
A Kriged River Temperature Map

2006 Mean Summer Temperatures

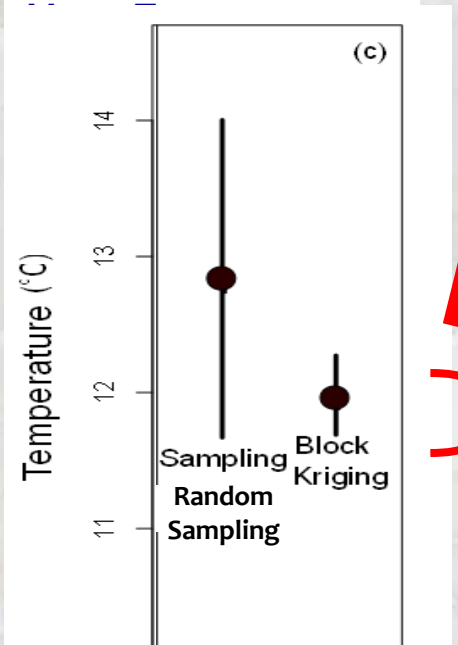


Block-Kriging for Estimates at User-Defined Scales



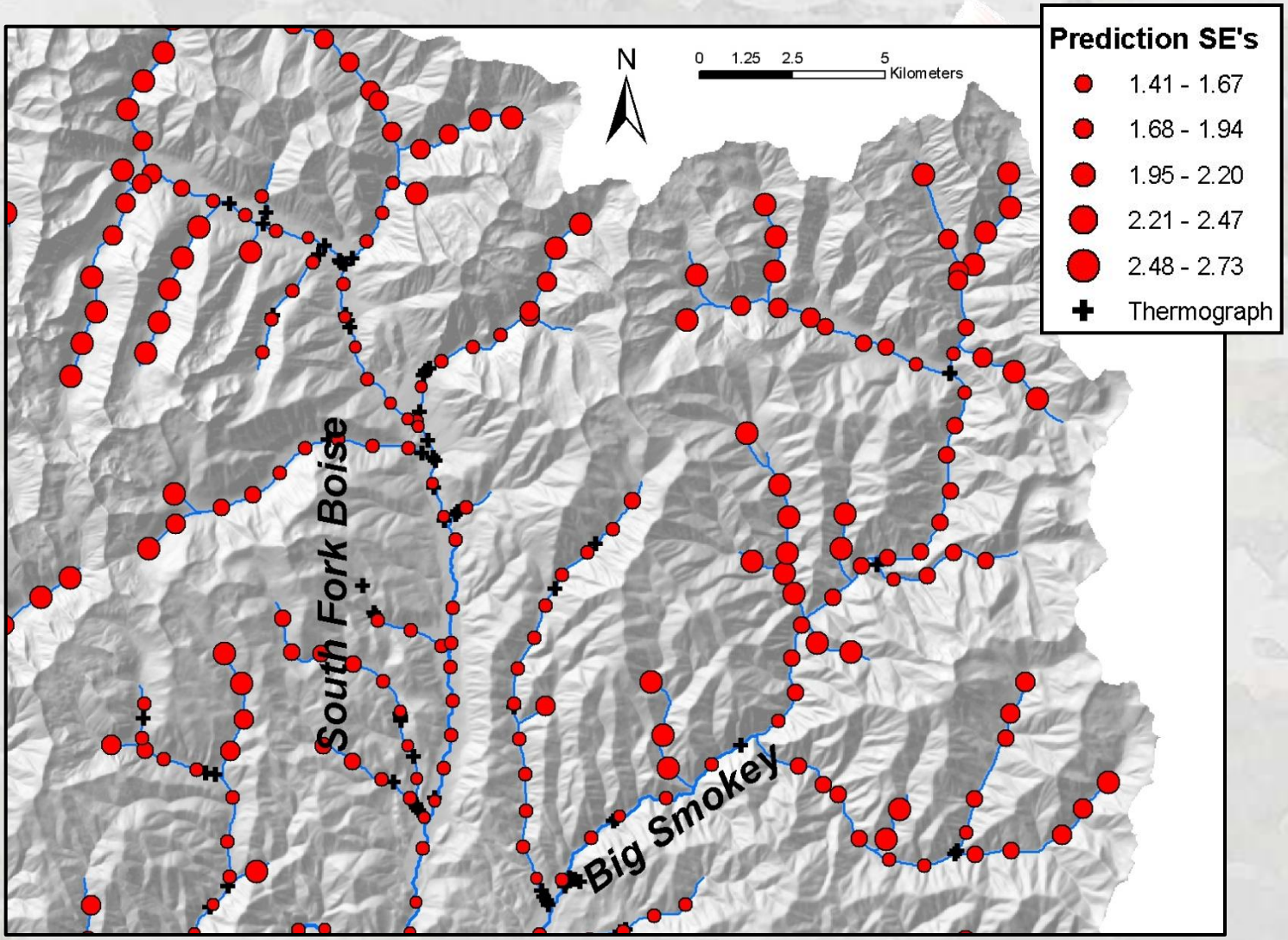


Bear Valley Creek

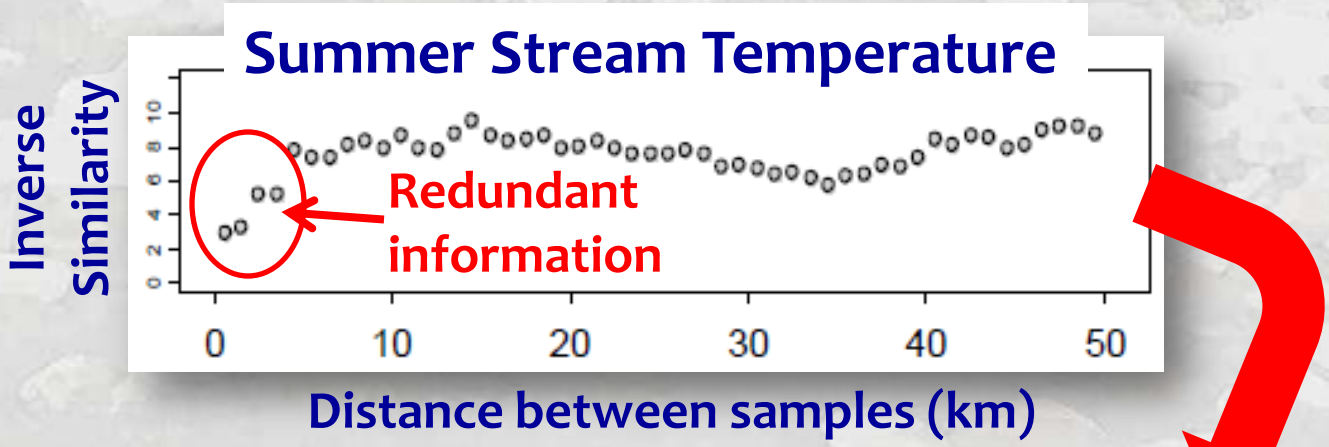


Spatial estimates are less biased & more precise

Spatial Variation in Prediction Precision



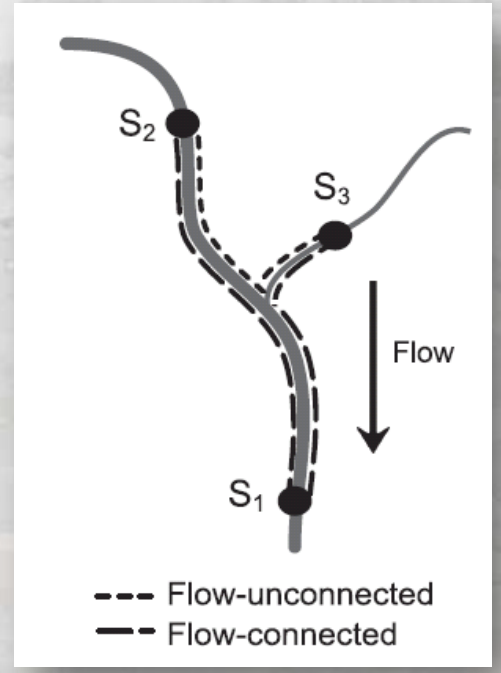
Models Describe Autocorrelation Distances

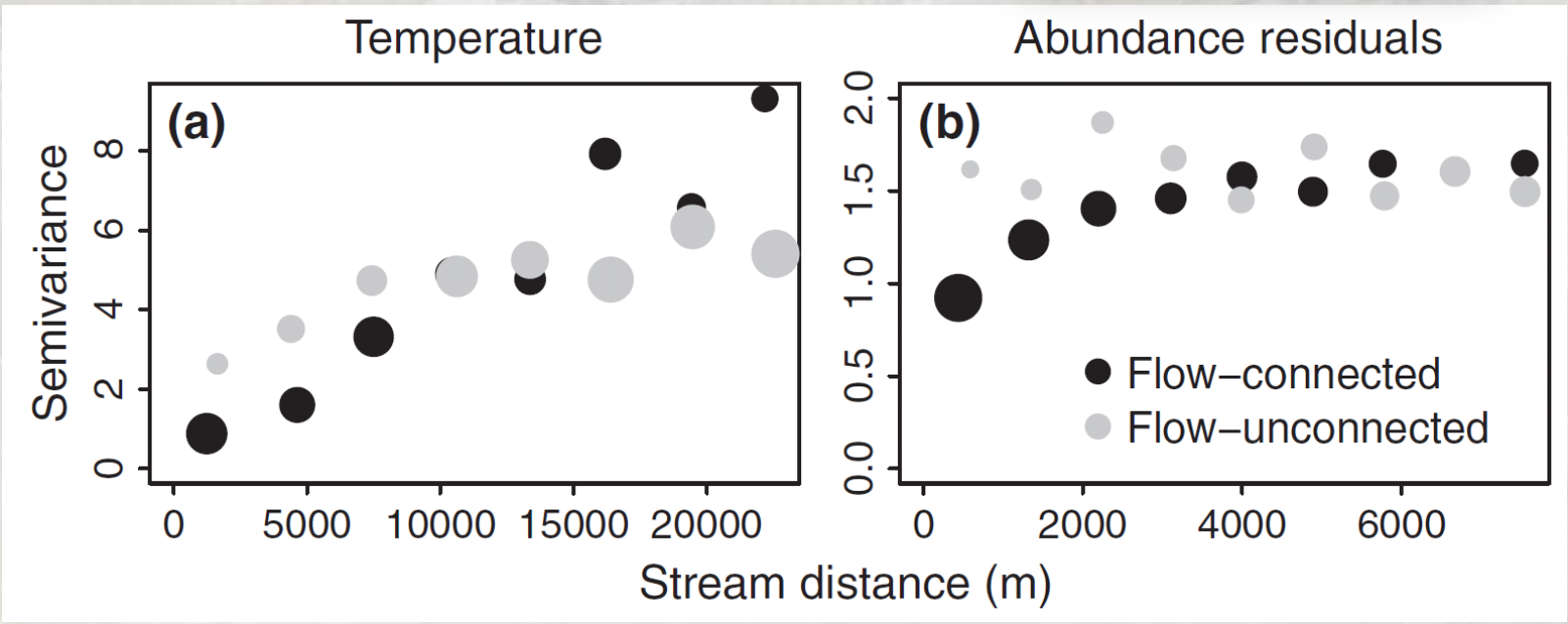


Efficient Monitoring Designs

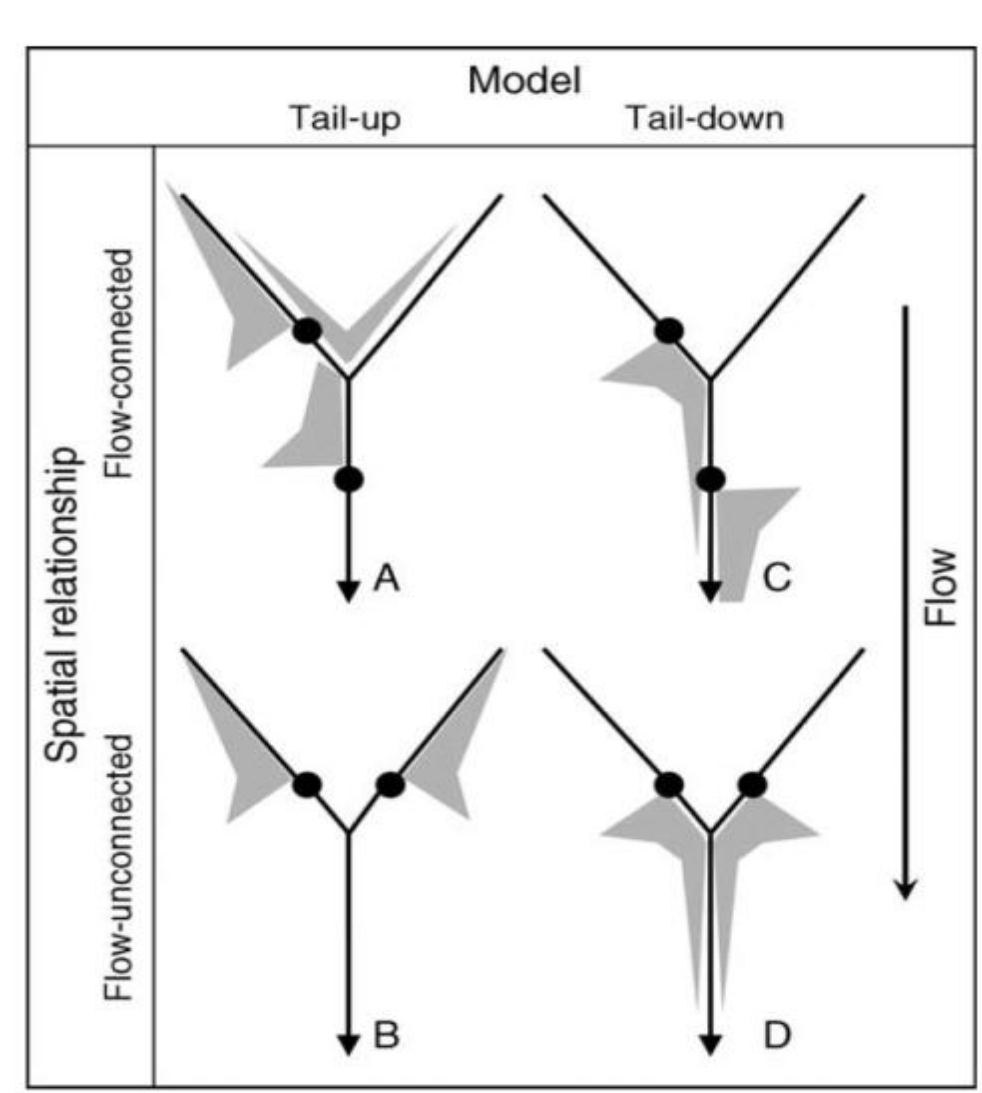
Autocorrelation Type & Distance Depends on Network Topology

Are sites flow connected or unconnected?

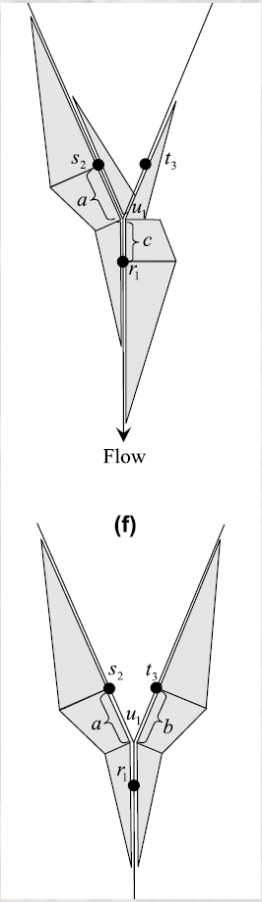




Autocovariance Structures for Stream Models



Mixed



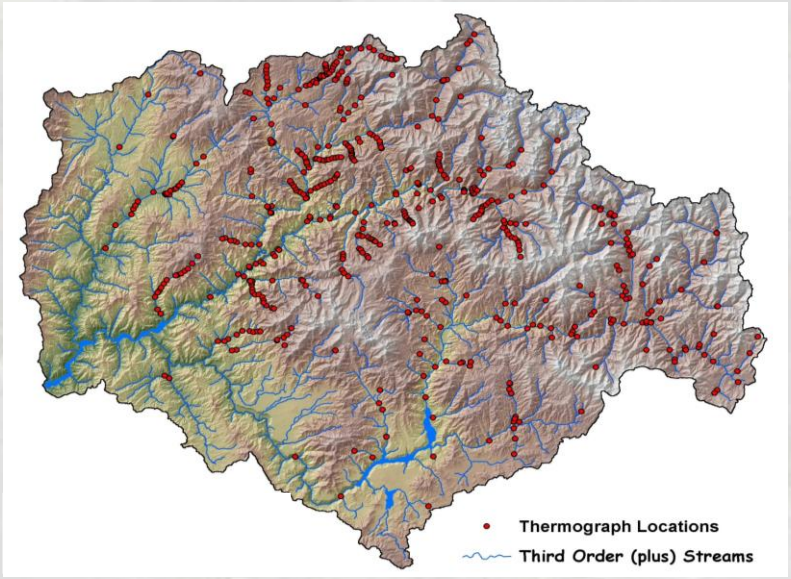
Ver Hoef & Peterson. 2010. *J American Statistical Association* **105**:6-18.

Sample size & computational requirements

Minimum sample size ~ n ≥ 50 / 100

-more parameters with autocovariance

-spatial clustering needed



FROM Site

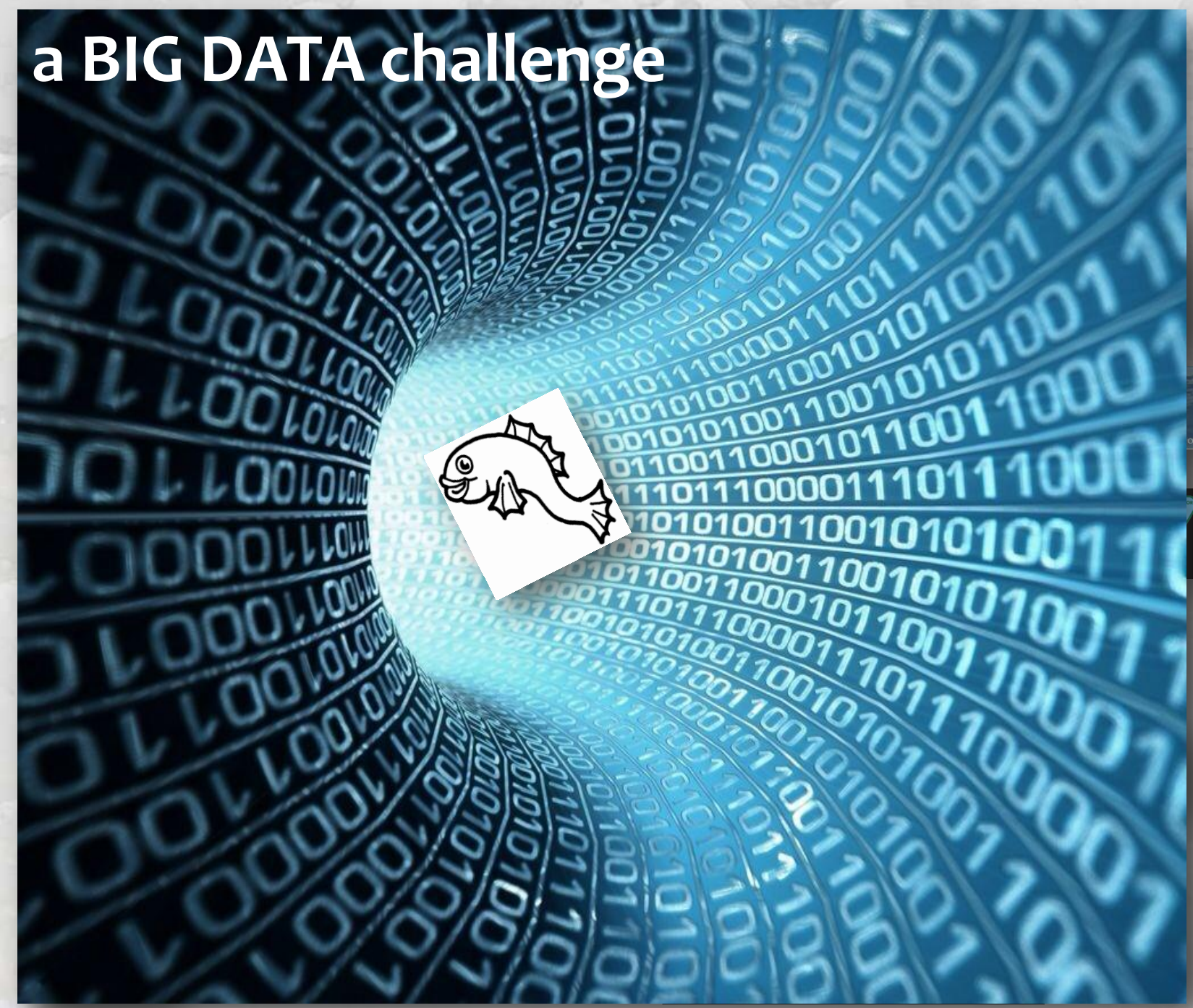
TO site	A	B	C	D
A	0	28	30	0
B	0	0	15	0
C	0	13	0	0
D	0	0	0	0

Distance matrix

Maximum sample size ~ n < 10,000

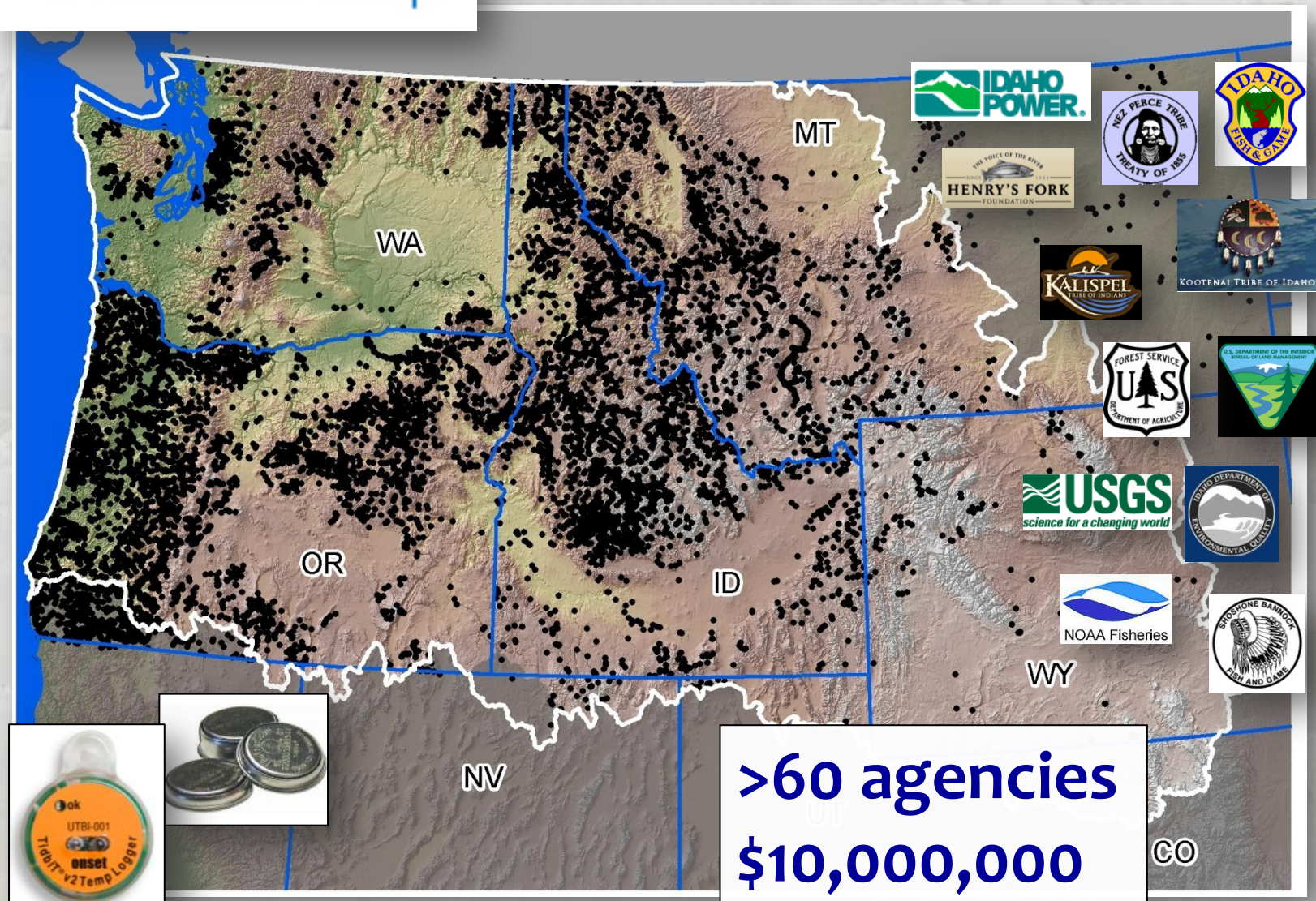
-inversion of n x n matrix

a BIG DATA challenge



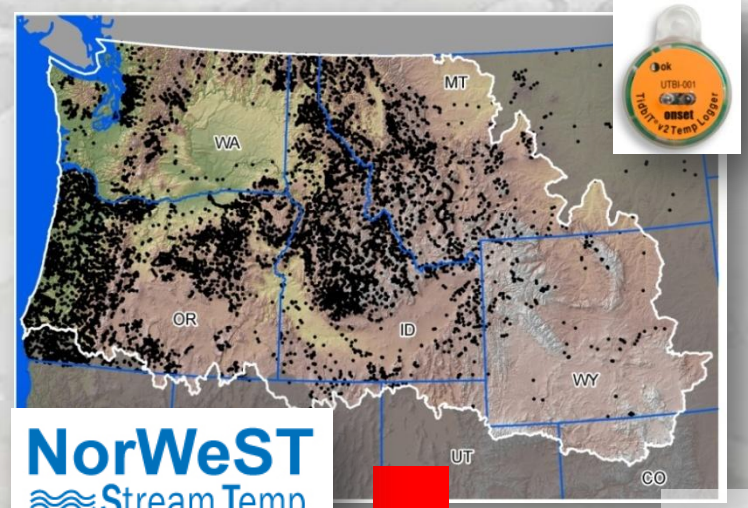
NorWeST Stream Temp

>45,000,000 hourly records
>15,000 unique stream sites



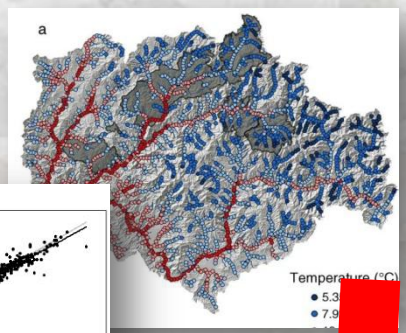
>60 agencies
$10,000,000

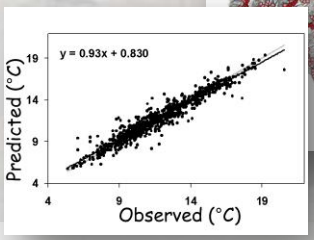
Regional Temperature Model



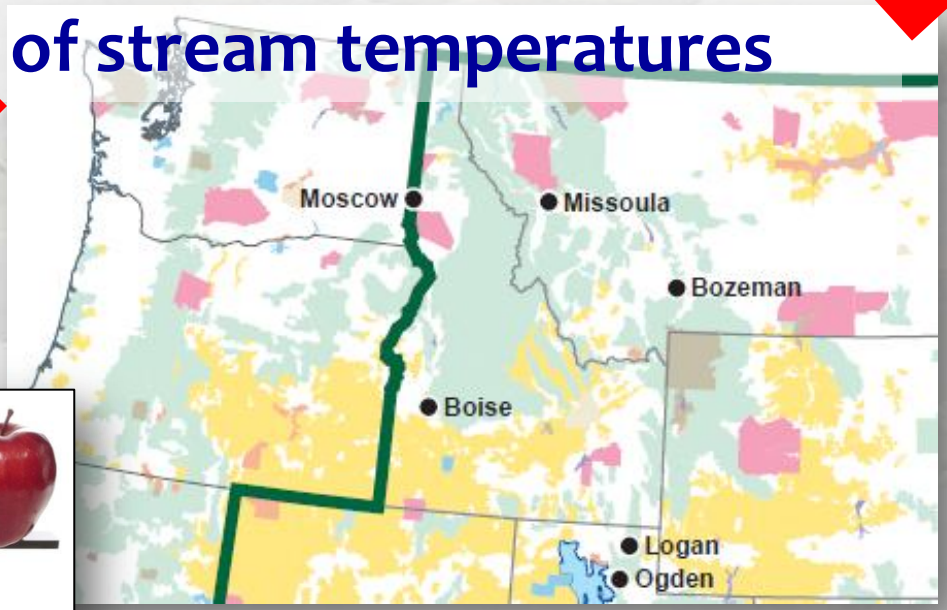
NorWeST Stream Temp

Accurate temperature models

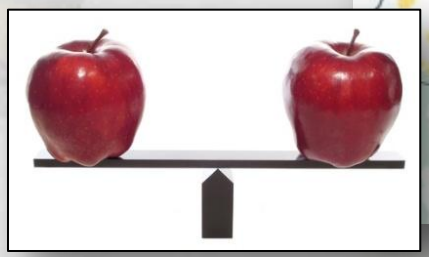




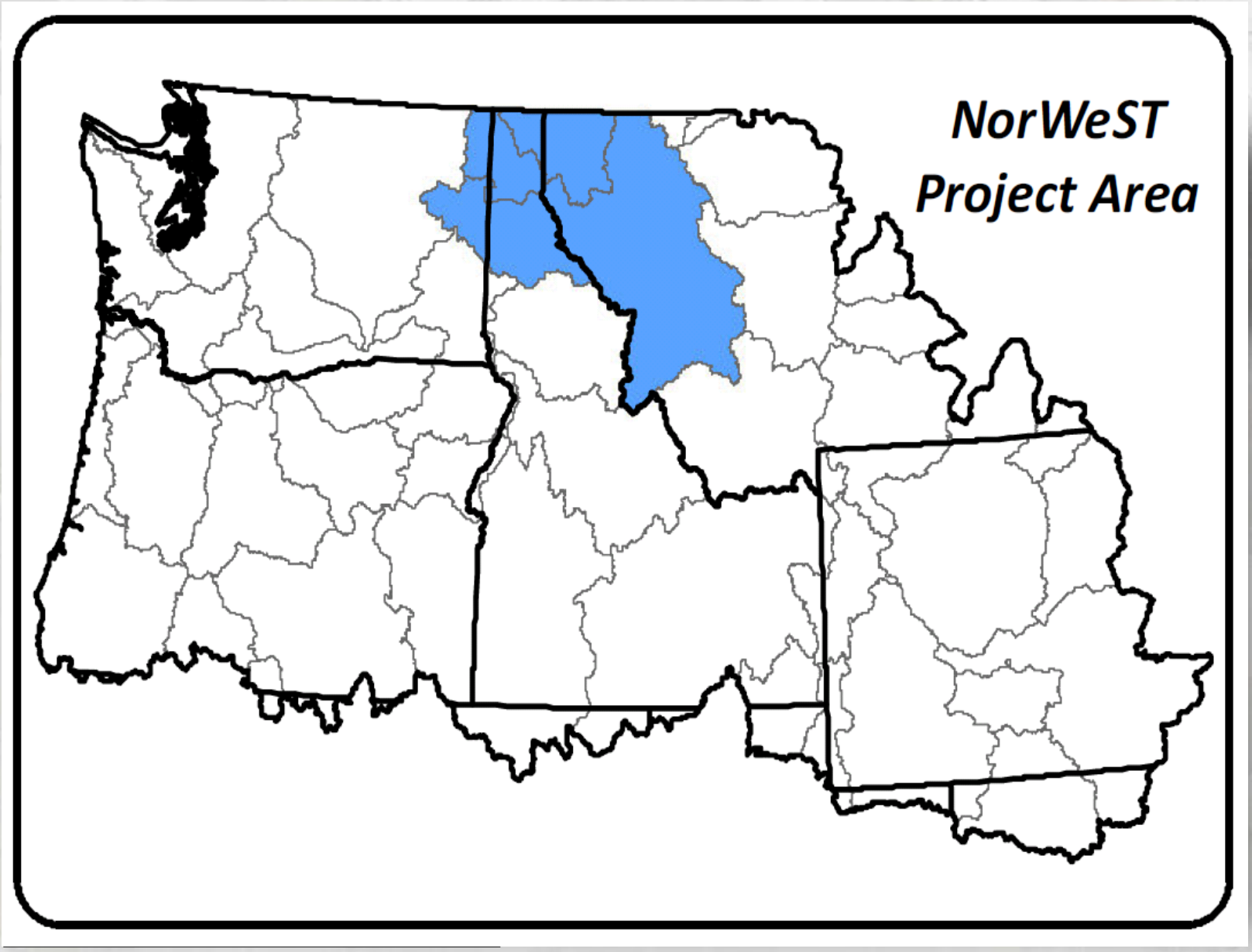
Cross-jurisdictional "maps" of stream temperatures



Consistent planning across 350,000 stream kilometers

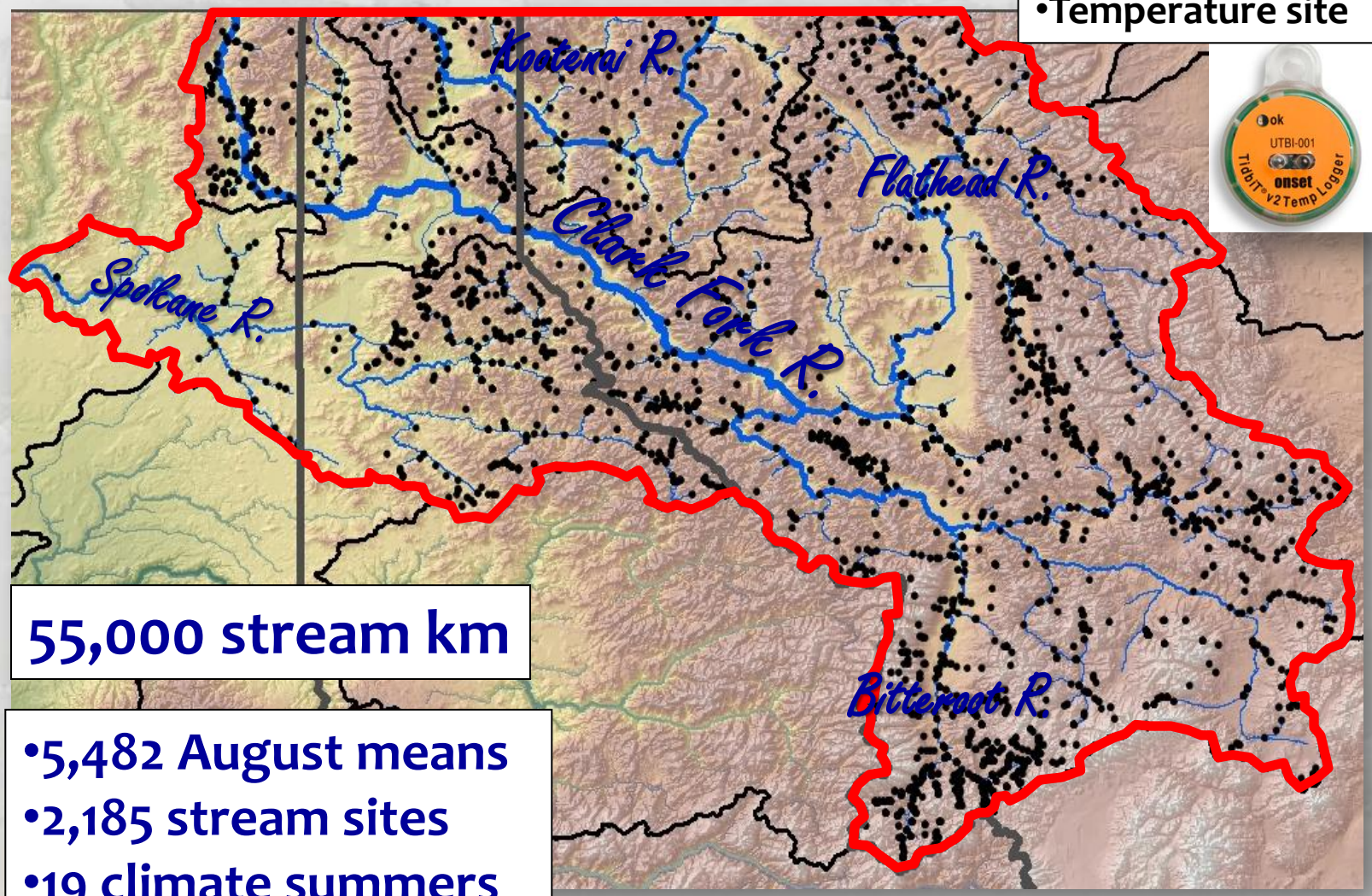


Example: SpoKoot River Basins



Example: SpoKoot River Basins

Data extracted from NorWeST



SpoKoot River Temp Model

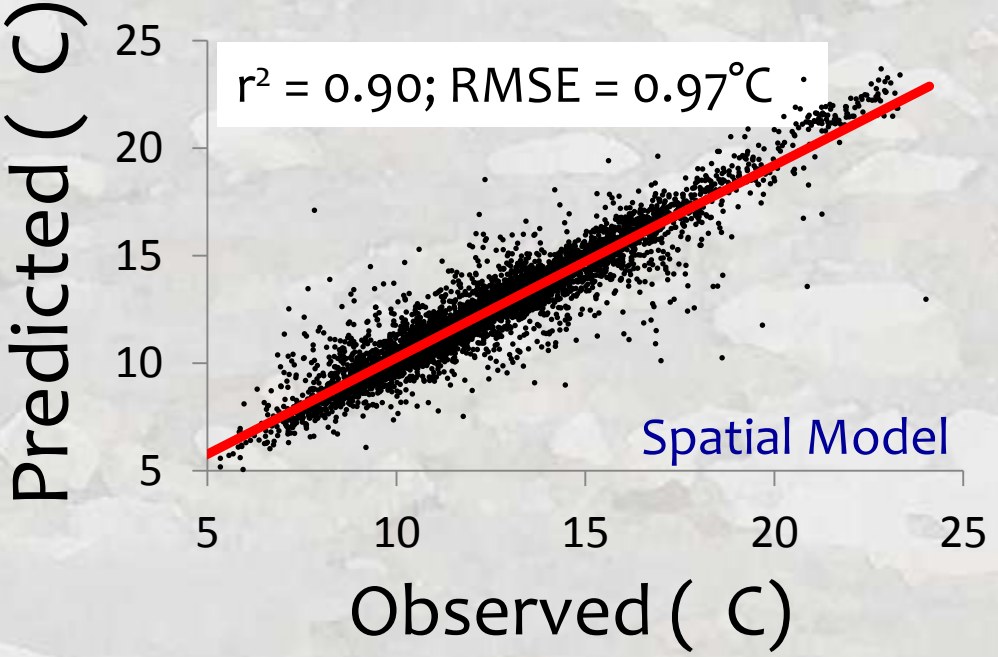
n = 5,482

Covariate Predictors

1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Baseflow Index
8. Watershed size (km^2)

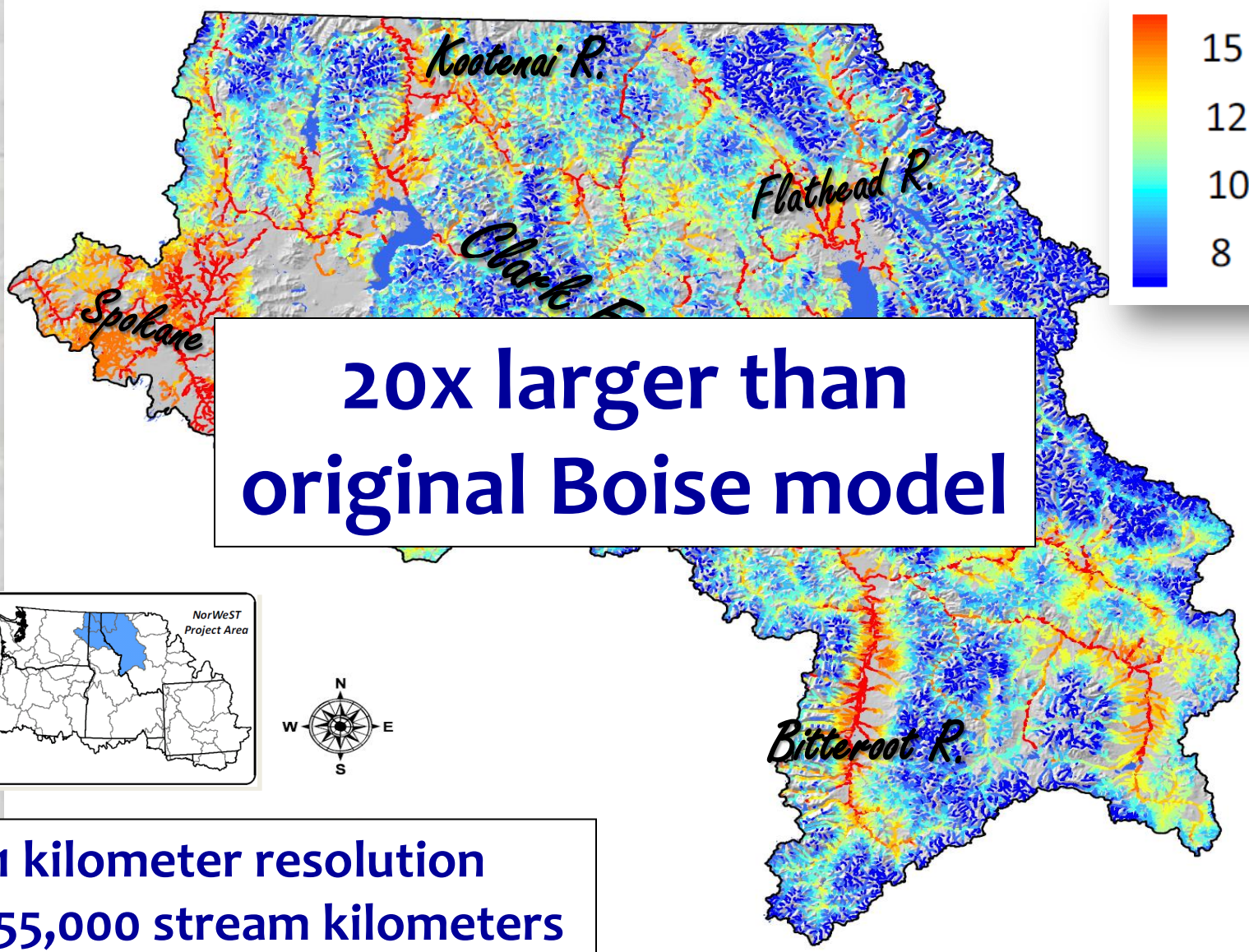
9. Discharge (m^3/s)
   USGS gage data
10. Air Temperature (˚C)
    RegCM3 NCEP reanalysis
    Hostetler et al. 2011

Mean August Temperature



Kriged Prediction Map of Climate Scenario

1993-2011 mean August temperatures

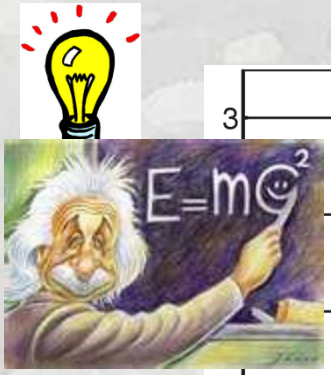


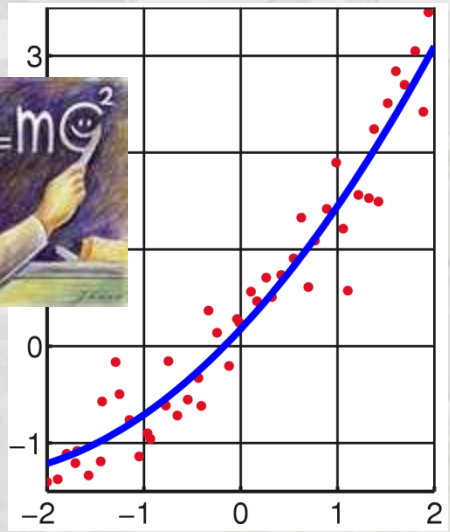
20x larger than original Boise model

1 kilometer resolution
55,000 stream kilometers

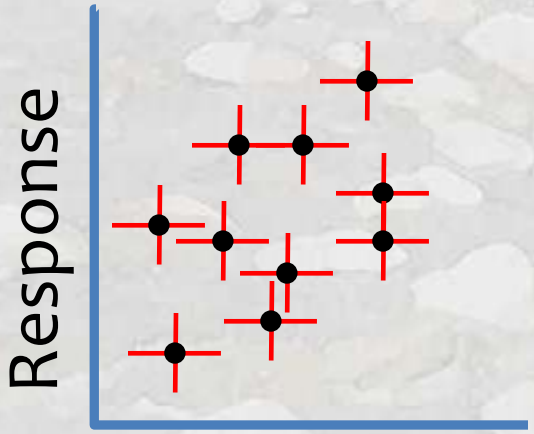
Better Understanding & Prediction for Streams

New relationships described

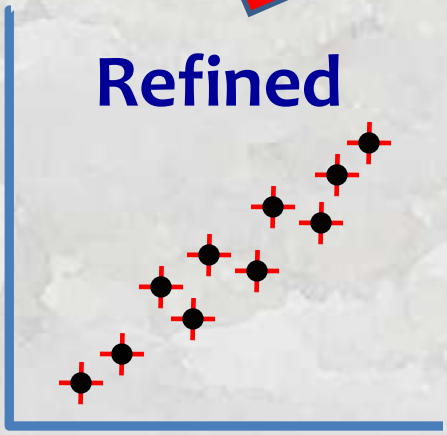




Old relationships tested



Refined



Rejected

Key References – Theory

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Ver Hoef, J.M., and E.E. Peterson. 2010. A moving average approach for spatial statistical models of stream networks. *J American Statistical Association* **105**:6-18.

Ver Hoef, J.M., E.E. Peterson, and D.M. Theobald. 2006. Spatial statistical models that use flow and stream distance. *Environmental and Ecological Statistics* **13**:449–464.

Garreta, V, Monestiez P, and Ver Hoef JM. 2010. Spatial modeling and prediction on river networks: up model, down model or hybrid? *Environmentrics* **21**:439-456.

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Isaak DJ, Luce CH, Rieman BE, Nagel DE, Peterson EE, Horan DL, Parkes S, Chandler GL. 2010. Effects of climate change and recent wildfires on stream temperature and thermal habitat for two salmonids in a mountain river network. *Ecological Applications* **20**:1350-1371.

Money E, Carter G, and Serre M. 2009. Modern space/time geostatistics using river distances: data integration of turbidity and *E. coli* measurements to assess fecal contamination along the Raritan River in New Jersey. *Environ. Science and Technology* **43**:3736–3742.

Money E, Carter G, and Serre M. 2009. Using river distances in the space/time estimation of dissolved oxygen along two impaired river networks in New Jersey. *Water Research* **43**:1948–1958.

Peterson, EE, Merton AA, Theobald DM, and Urquhart NS. 2006. Patterns of spatial autocorrelation in stream water chemistry. *Environmental Monitoring and Assessment* **121**:569–594.

Peterson, EE, and Urquhart NS. 2006. Predicting water quality impaired stream segments using landscape-scale data and a regional geostatistical model: a case study in Maryland. *Environmental Monitoring and Assessment* **121**:615–638.

Ruesch AS, Torgersen CE, Lawler JJ, Olden JD, Peterson EE, Volk CJ, and Lawrence DJ. 2012. Projected climate-induced habitat loss for salmonids based on a network model of stream temperature. *Conservation Biology* **26**:873-882.

SSN (Spatial Stream Networks) R Package on CRAN

SSN: Spatial Modeling on Stream Networks

Geostatistical modeling for data on stream networks, including models based on in-strea
models, including covariates, can be fit with ML or REML. Mapping and other graphical fun

Version:	1.1
Depends:	R (≥ 2.10), methods, maptools, RSQLite, igraph (≥ 0.6), MASS, sp, BH
LinkingTo:	BH
Published:	2013-04-06
Author:	Jay Ver Hoef and Erin Peterson
Maintainer:	Jay Ver Hoef <ver.hoef at SpatialStreamNetworks.com>
License:	GPL-2
NeedsCompilation:	yes
Citation:	SSN citation info
CRAN checks:	SSN results

Downloads:

Package source:	SSN_1.1.tar.gz
MacOS X binary:	SSN_1.1.tgz
Windows binary:	SSN_1.1.zip
Reference manual:	SSN.pdf
Vignettes:	Model Introduction and SSN User Manual GIS Information and STARS User manual
Old sources:	SSN archive

Related packages

SSN/STARS Website

FreeWare Tools, Example Datasets, & Applications

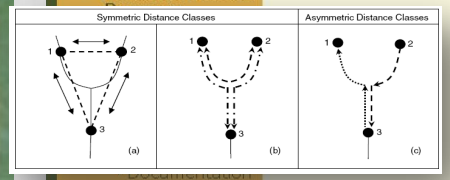
SSN & STARS:
Tools for Spatial Statistical Modeling

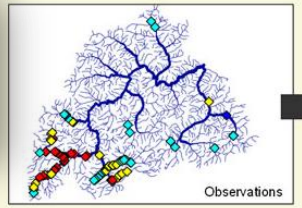
RMRS

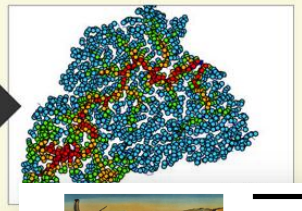
Rocky Mountain Research Station
RMRS Science Program Areas
Air, Water and Aquatics Science
Latest Releases
Authors

Rocky Mountain Research Station Home > Science Program Areas > Air, Water and Aquatics > Research
Tools for Spatial Statistical Modeling on Stream Networks

SSN & STARS:
Tools for Spatial Statistical Modeling on Stream Networks







Google "SSN/STARS"

Analytical Stream Ecosystem is Growing

ECOLOGY LETTERS

Ecology Letters, (2013) doi: 10

Modelling dendritic ecological networks in space: an integrated network perspective

Journal of Statistical Software
MMMMMM YYYY, Volume VV, Issue II. http://www.jstatsoft.org/

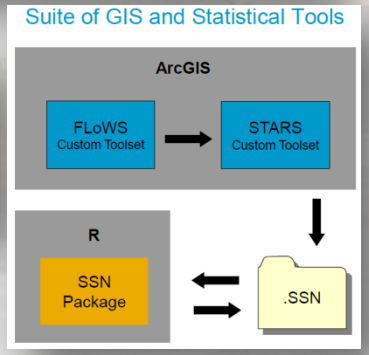
SSN: An R Package for Spatial Statistical Modeling on Stream Networks

Jay M. Ver Hoef, NOAA National Marine Mammal Laboratory
Erin E. Peterson, CSIRO, Brisbane
David Clifford, CSIRO, Brisbane
Rohan Shah, CSIRO, Brisbane

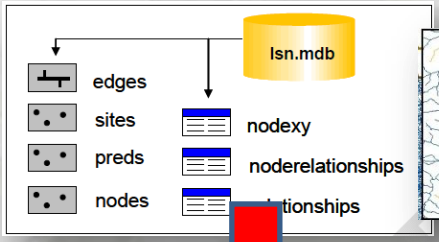
A Moving Average Approach for Spatial Statistical Models of Stream Networks

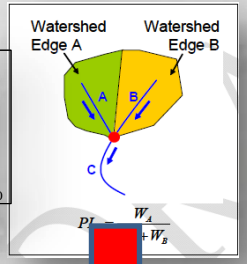
Jay M. VER HOEF and Erin E. PETERSON

STARS: An ArcGIS toolset used to calculate the spatial data needed to fit spatial statistical models to stream network data

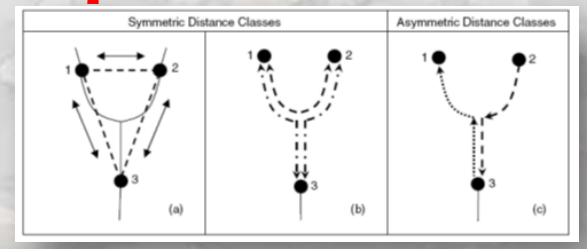


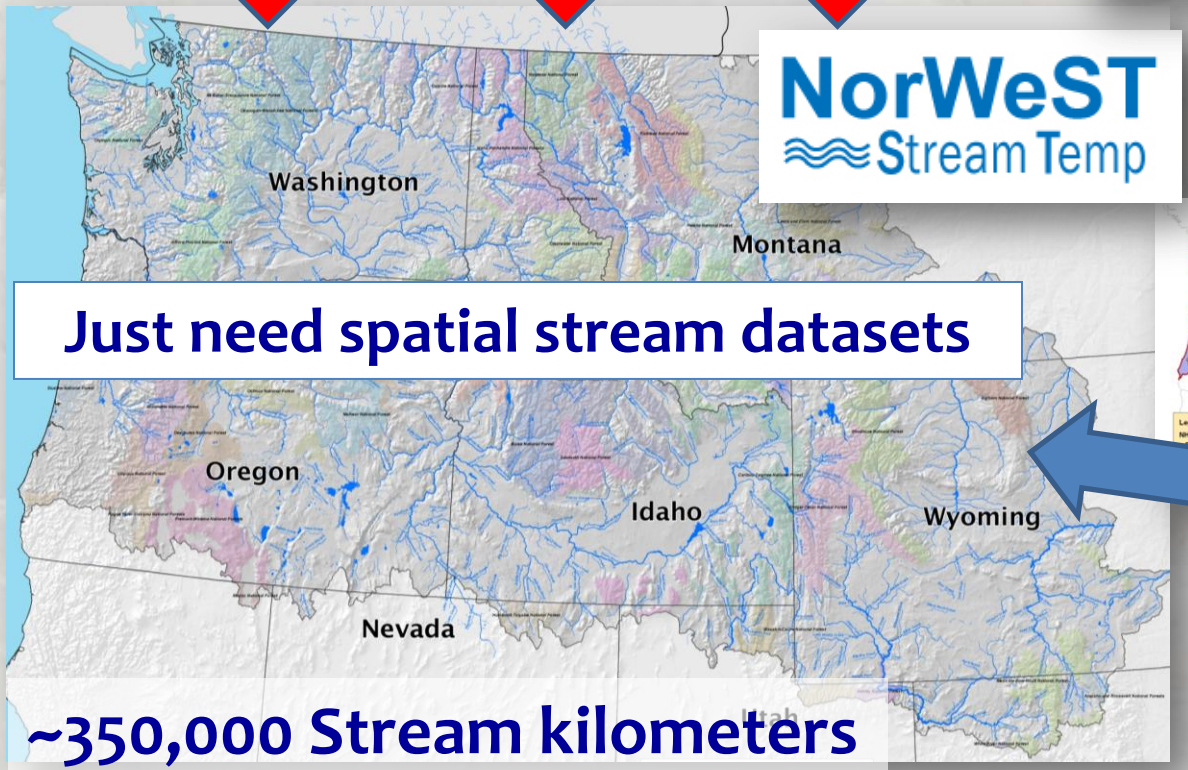
Digital Preprocessed Stream Networks also Available Through SSN/STARS





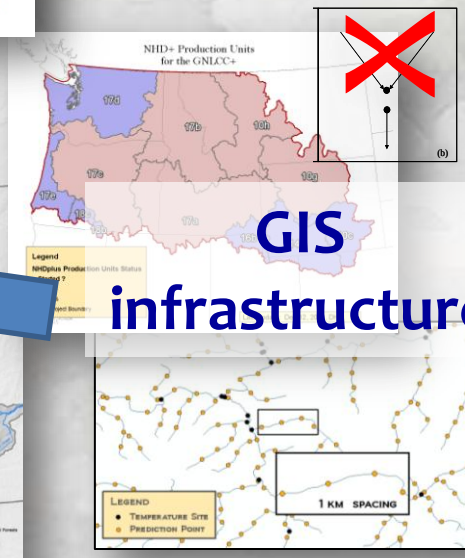
Spatial models





NorWeST Stream Temp

Just need spatial stream datasets

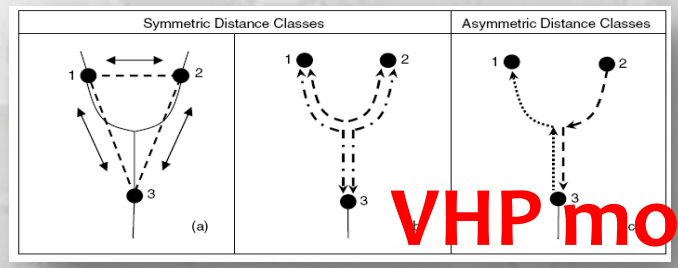


GIS infrastructure

~350,000 Stream kilometers

User Community is Growing

>7,000 Visits to SSN/STARS Website in last 9 months

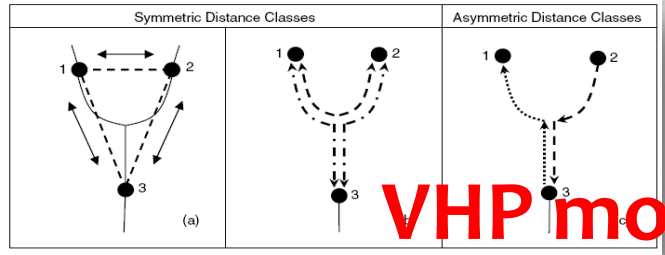


VHP models

National

User Community is Growing

>7,000 Visits to SSN/STARS Website in last 9 months



VHP models

Global


The End