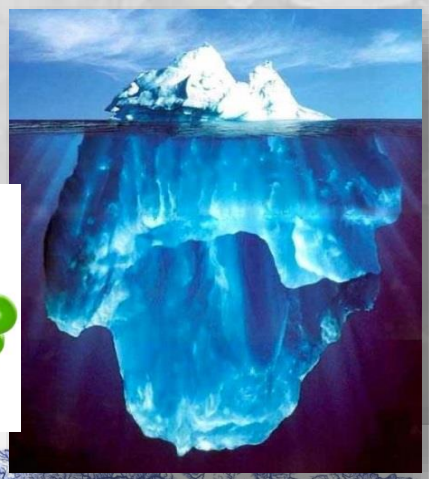
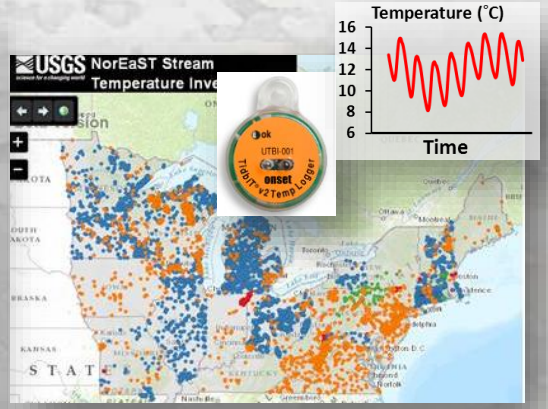
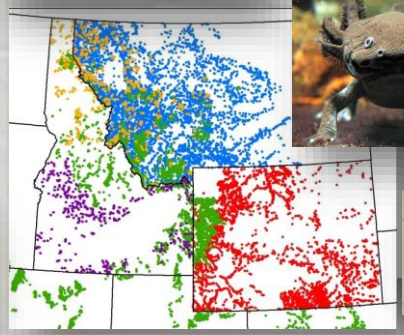
The National Stream Internet

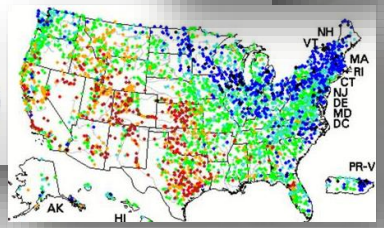
An Analytical Infrastructure for Stream Data

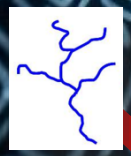
LANDSCAPE
CONSERVATION
COOPERATIVES

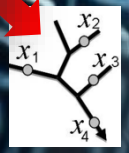






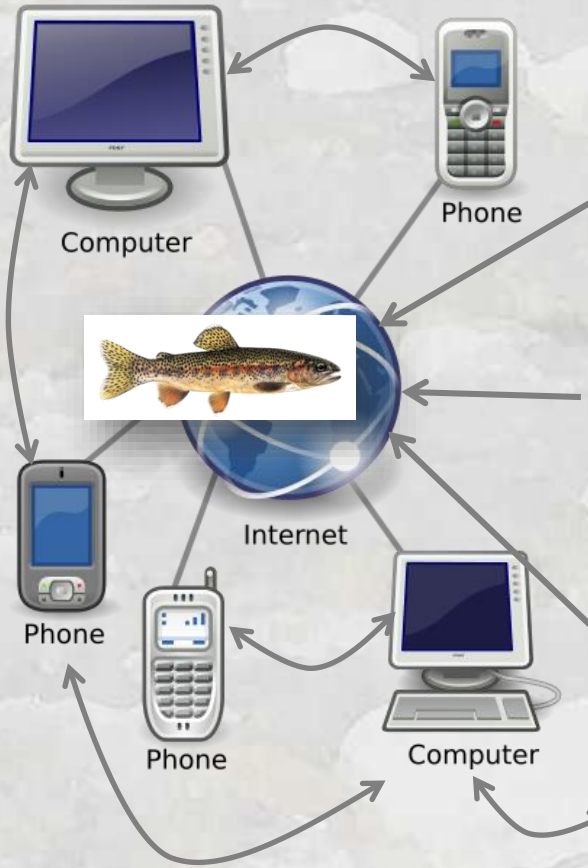






A Stream Internet is…

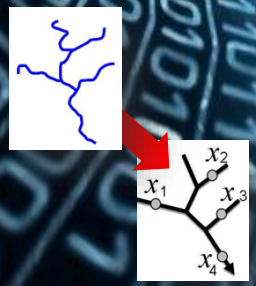
A network of people, databases, digital information systems & analytical techniques that interact synergistically to create & communicate massive amounts of information efficiently

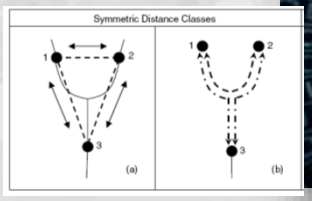


People on landscapes collecting data using standard protocols

Open access, comprehensive databases

Analysis & new information

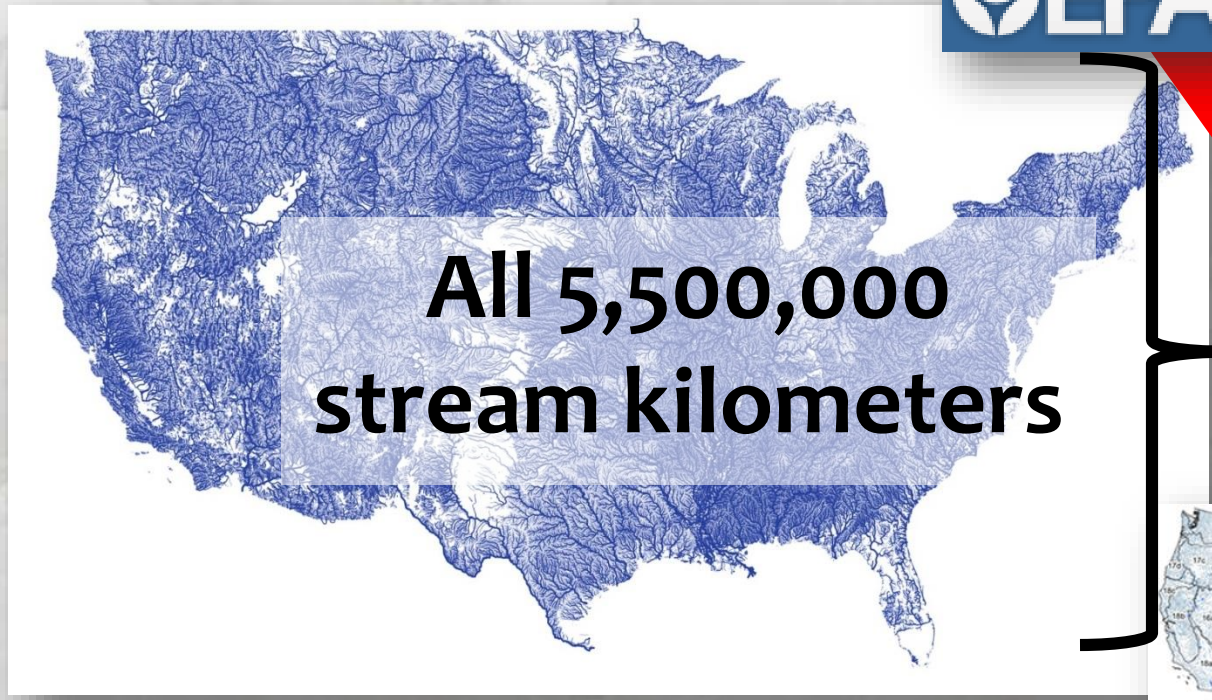




Inter-Compatibility is Key…

Component #1: National Hydrography Dataset

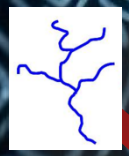
Nationally consistent stream network geodatabase

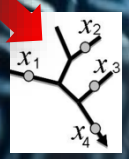


EPA

USGS
science for a changing world

NHDPlus



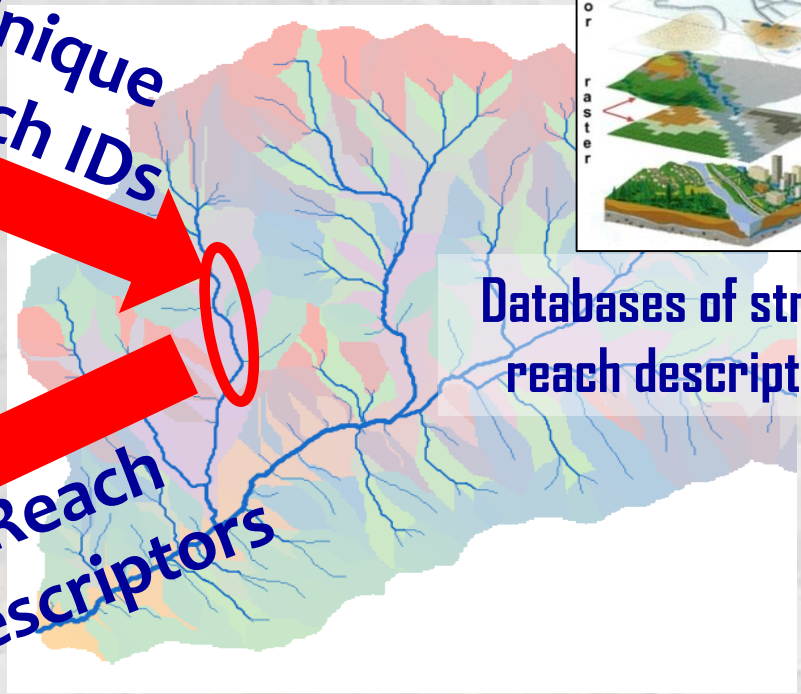


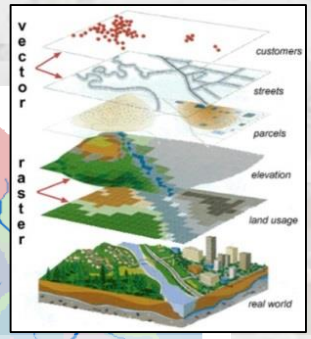
McKay et al. 2015. NHDPlus Version 2: User Guide.
Available at: ftp://ec2-54-227-241-43.compute-1.amazonaws.com/NHDplus/NHDPlusV21/Documentation/NHDPlusV2_User_Guide.pdf

Cooter et al. 2010. A nationally consistent NHDPlus framework for identifying interstate waters: Implications for integrated assessments and interjurisdictional TMDLs. *Environmental Management* **46**:510-524.

Component #2: The "PLUS" part of NHDPlus (Stream Reach Descriptors)

Unique reach IDs





Databases of stream reach descriptors

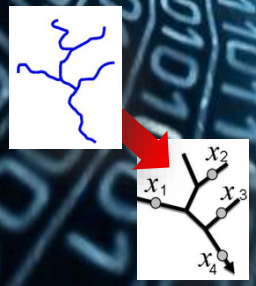
Reach descriptors

- Elevation
- Slope
- %Landuse
- Precipitation

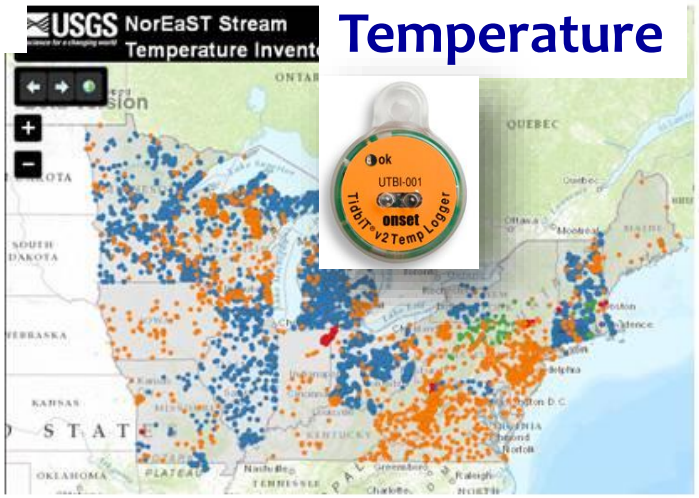
100's more…

Wang et al. 2011. A hierarchical spatial framework and database for the national river fish habitat condition assessment. *Fisheries* **36**: 436-449.
Available at: https://www.researchgate.net/profile/Lizhu_Wang2

Hill et al. In Press. The stream-catchment (StreamCat) dataset: A database of watershed metrics for the conterminous USA. *The Journal of the American Water Resources Association*.
Available at: http://www2.epa.gov/national-aquatic-resource-surveys/streamcat

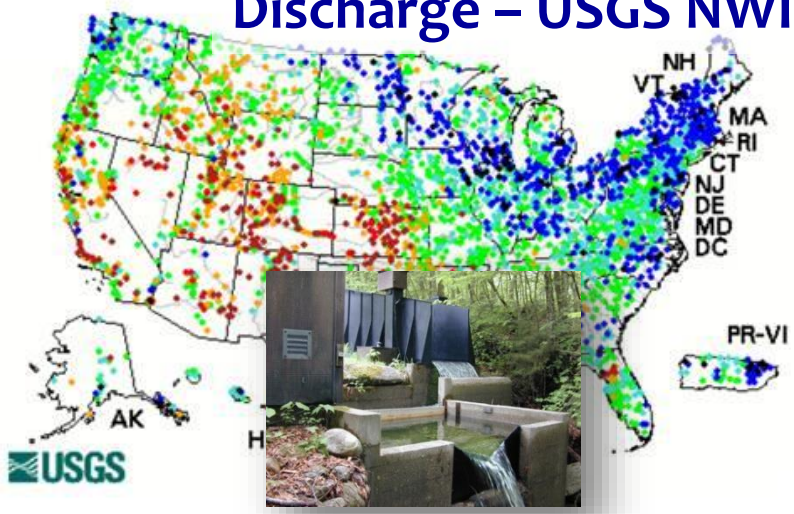


Component #3: Mountains of Data Exist for Information Creation

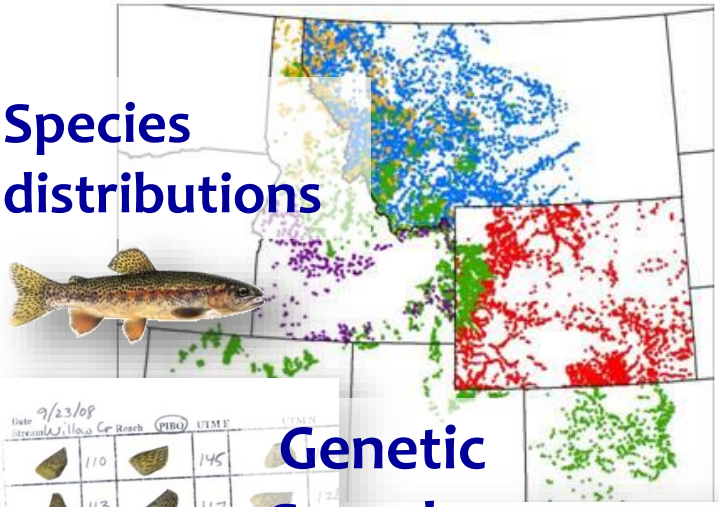


Temperature

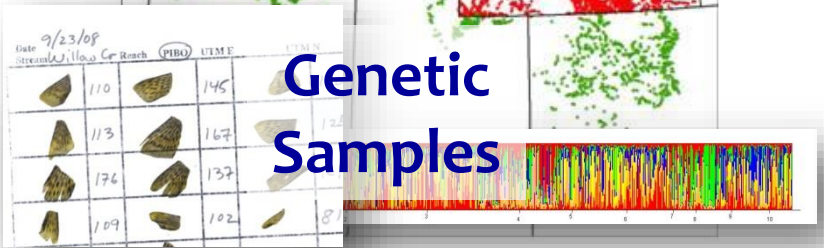
Discharge – USGS NWIS



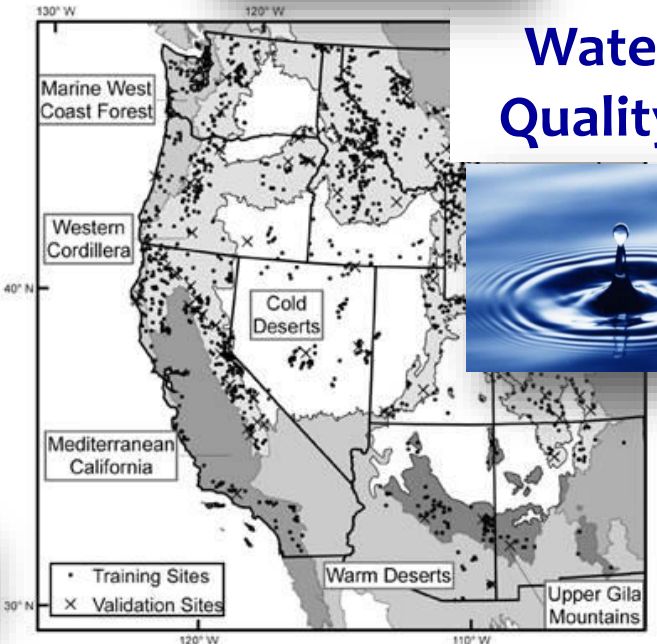
Species distributions

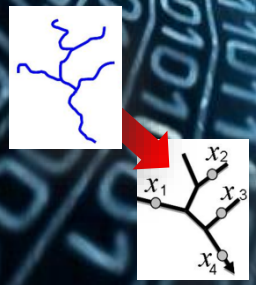


Genetic Samples



Water Quality





Component #4: Statistical Models for Data on Stream Networks… FINALLY!

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

ORIGINAL ARTICLE

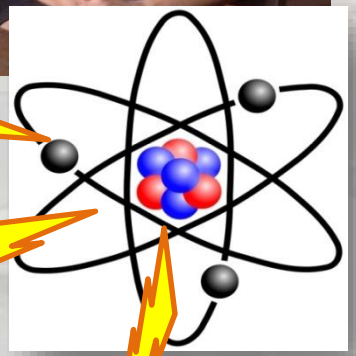
Spatial statistical models that use flow and stream distance

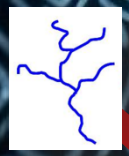
Jay M. Ver Hoef · Erin Peterson · David Theobald

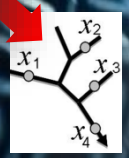
Journal of Statistical Software
January 2014, Volume 56, Issue 3. http://www.jstatsoft.org/

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







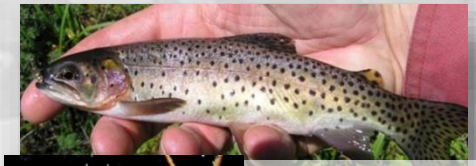
Functional Linkage of Watersheds and Streams (FLoWS)

- ArcGIS Geoprocessing Toolbox written in Python v2.5 for ArcGIS v
- Developed by Dr. Dave Theobald and John Norman at Colorado St

STARMAP
Space-Time Aquatic Resources Modeling and Analysis Program

EPA

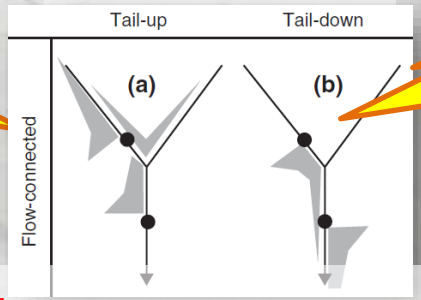
Stream Models are Generalizable…

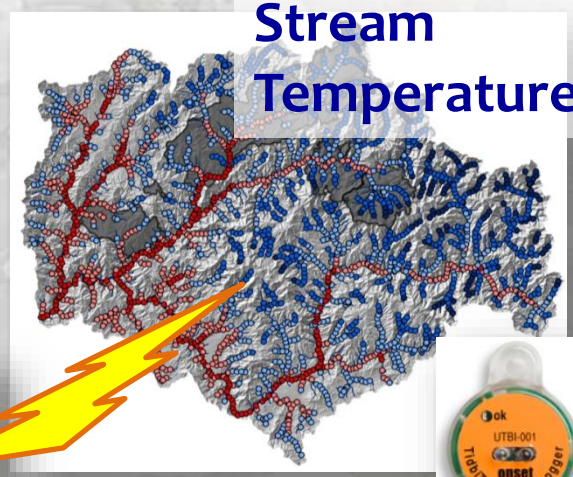


Distribution & abundance

Response Metrics

- Gaussian
- Poissan
- Binomial

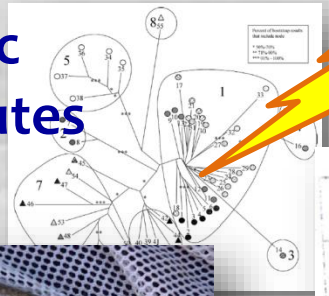


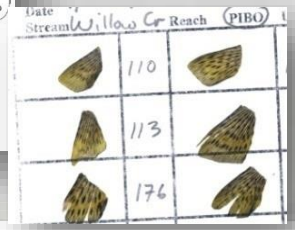


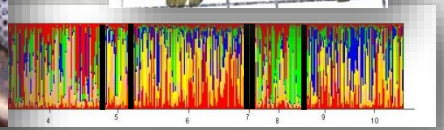
Stream Temperature

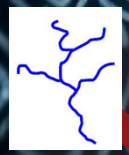
Statistical stream models

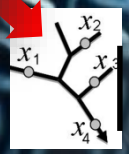
Genetic Attributes





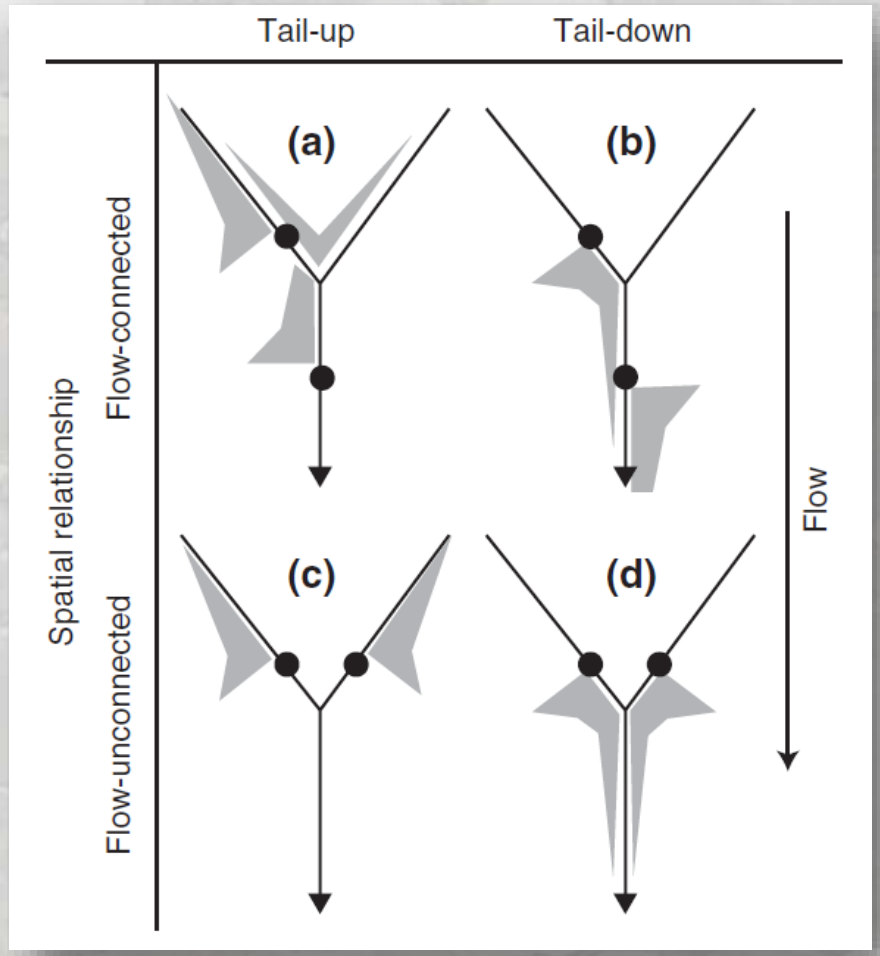


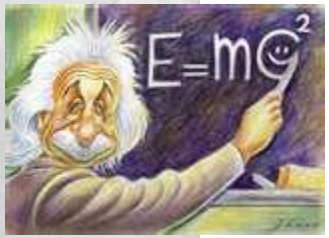


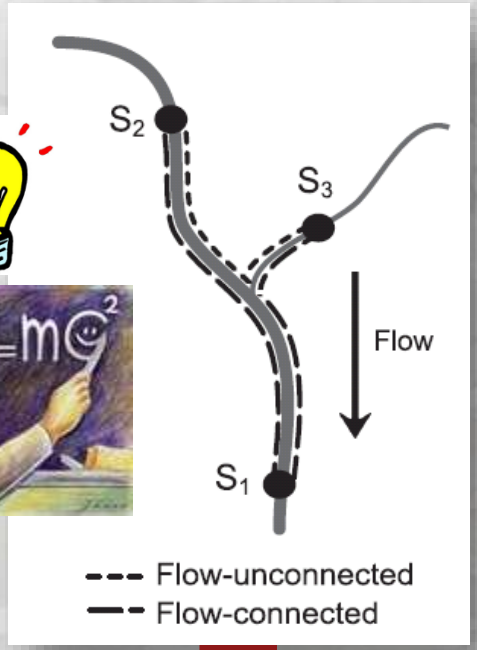


Water Quality Parameters

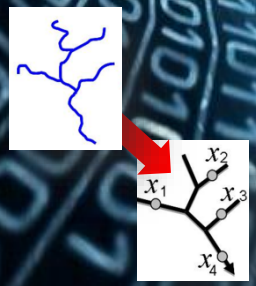
Key Innovation is Covariance Structure Based On Network Structure







- **Models "understand" how information moves among locations**
- **Models account for spatial autocorrelation among observations**



Peterson et al. 2007. *Freshwater Biology* **52**:267-279;
Peterson & Ver Hoef. 2010. *Ecology* **91**:644-651.

Component #5: NSI Network for SSN analysis is Derived from the NHD Network

★ **SSN analysis requires specific network topology**

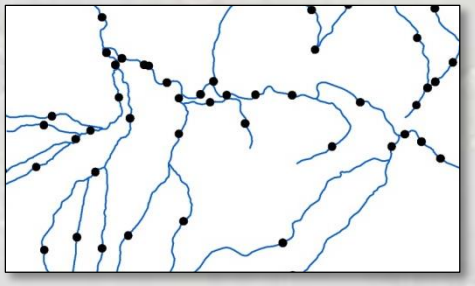
NSI Network Created by Addressing…

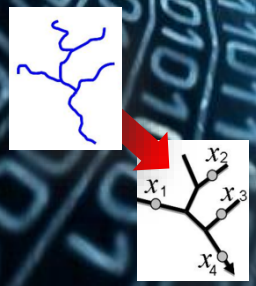
- Uninitialized flow
- Braids and diverging flow
- Converging flow
- Complex confluences
- Outlets and sinks

★ **Back compatibility with NHD-Plus is preserved**

Bonus!

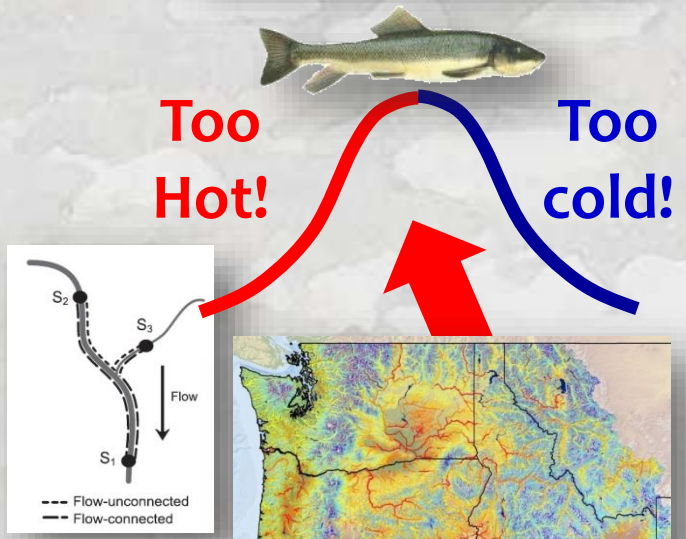
- Prediction points created for NSI network



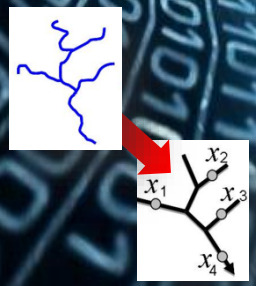


Component #6: SSN Model "Killer Apps"

- Parameter estimation & prediction
- Status & trend assessments
- Efficient monitoring designs
- Block-kriging for reference site comparisons & fish population estimates
- Mining of BIG DATA databases
  - Climate scenarios
  - Temperature criteria
  - Species distribution models

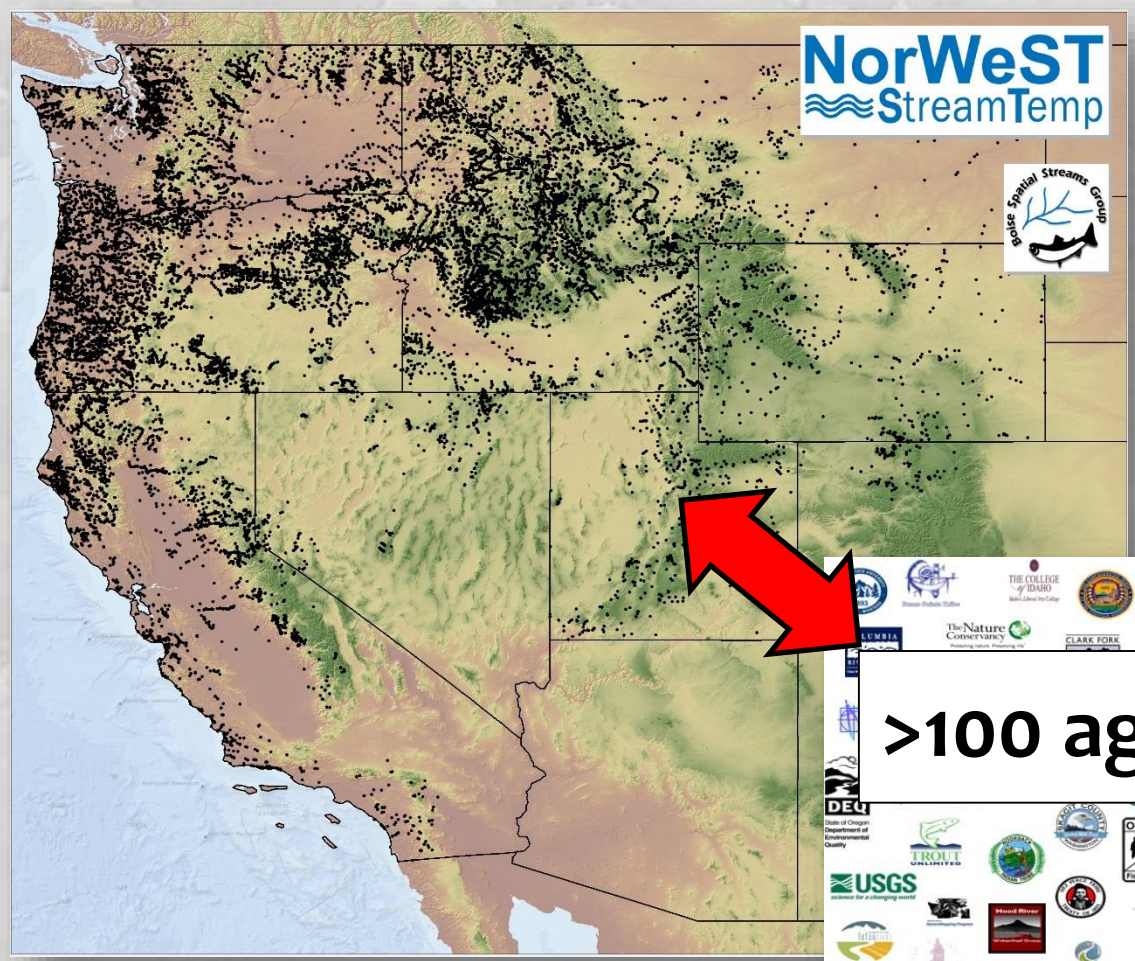


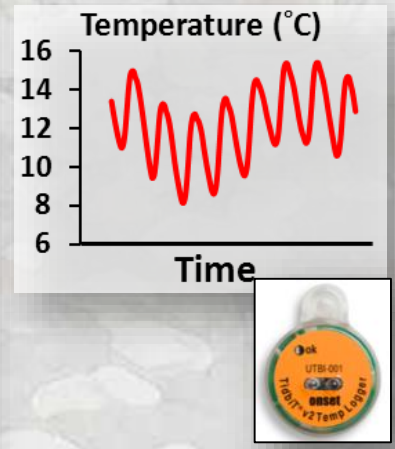
$$Y = b_0 + b_1(x_1) + €$$



Isaak et al. 2014. Applications of spatial statistical network models to stream data. *Wiley Interdisciplinary Reviews - Water* **1**:277-294.

Developing a Comprehensive Database



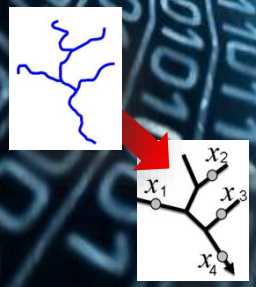


>100 agencies

>150,000,000 hourly records

>20,000 unique stream sites

$10,000,000 of "free" data

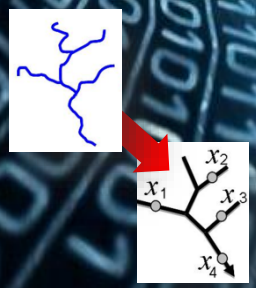


Spatial vs Non-Spatial Temperature Model

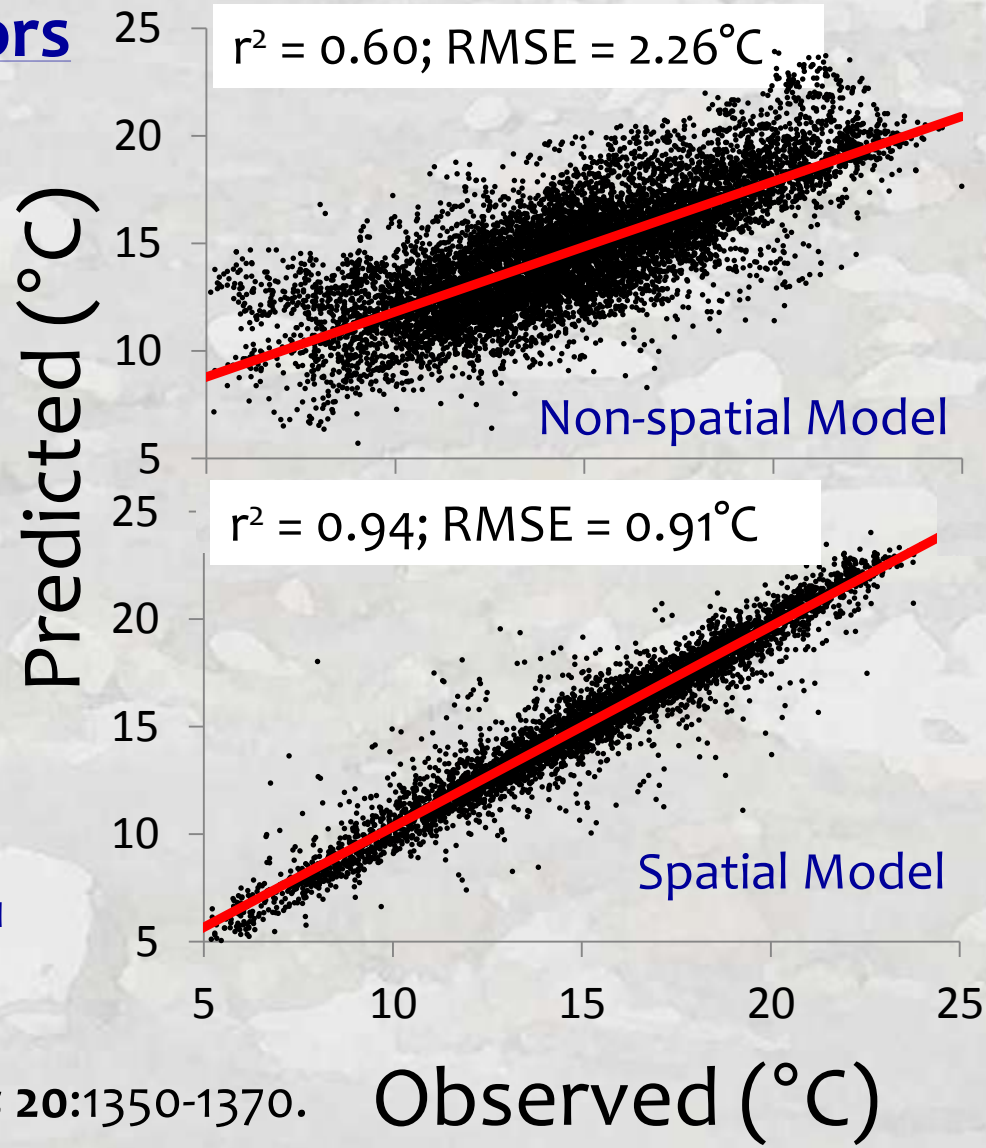
Covariate Predictors

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. Glacier (%)

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

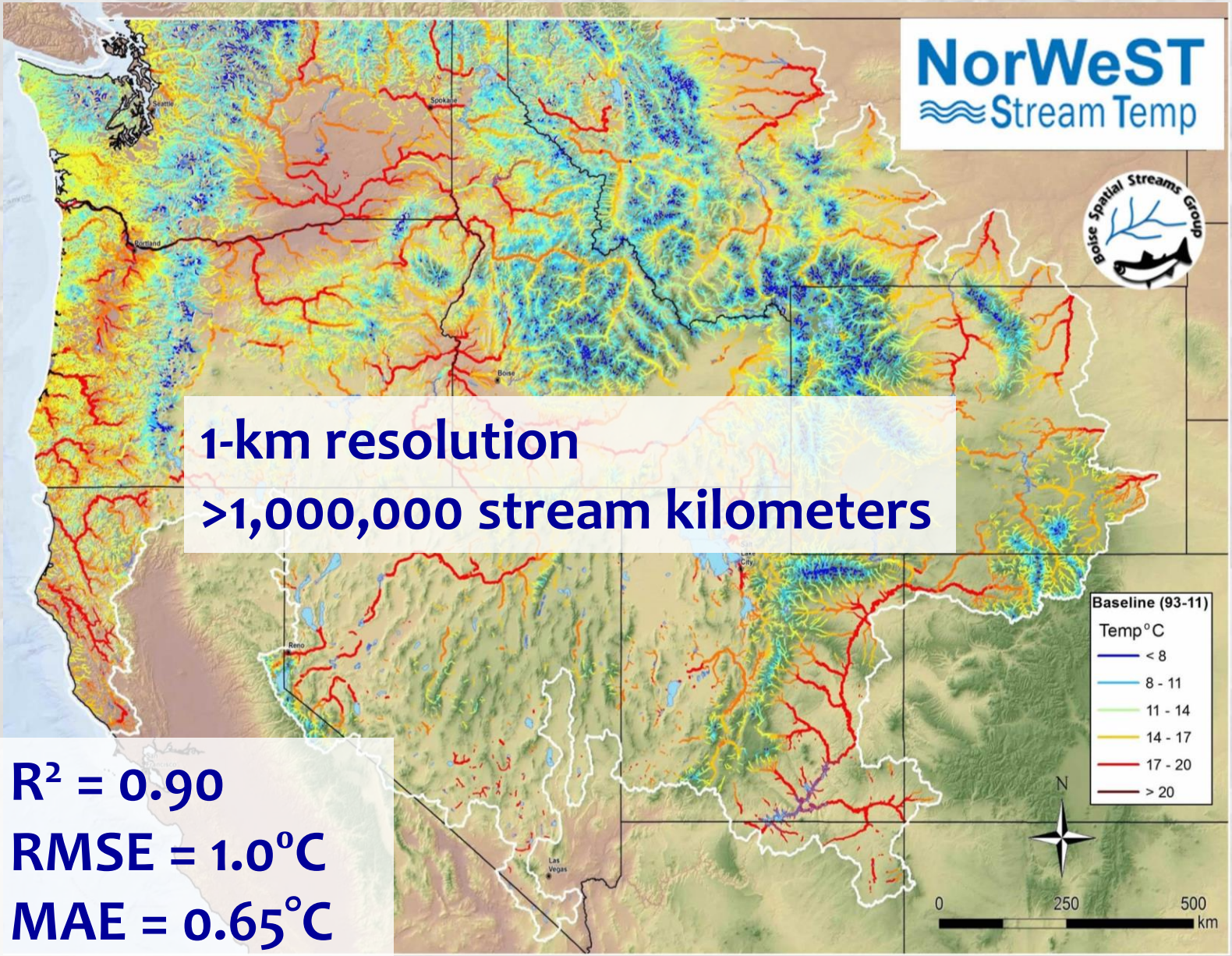


Mean August Temperature



Isaak et al. 2010. *Ecol. Apps* **20**:1350-1370.

Accurate Stream Scenarios from Model Interpolations



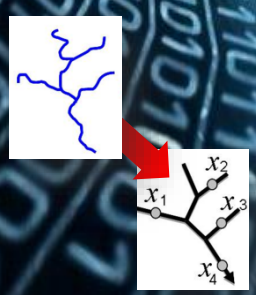
1-km resolution

>1,000,000 stream kilometers

R^2 = 0.90

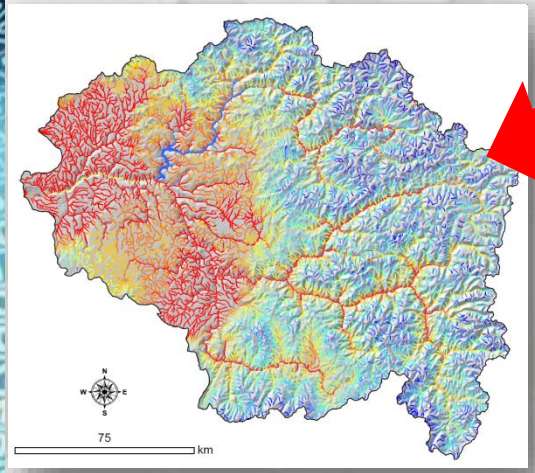
RMSE = 1.0°C

MAE = 0.65°C

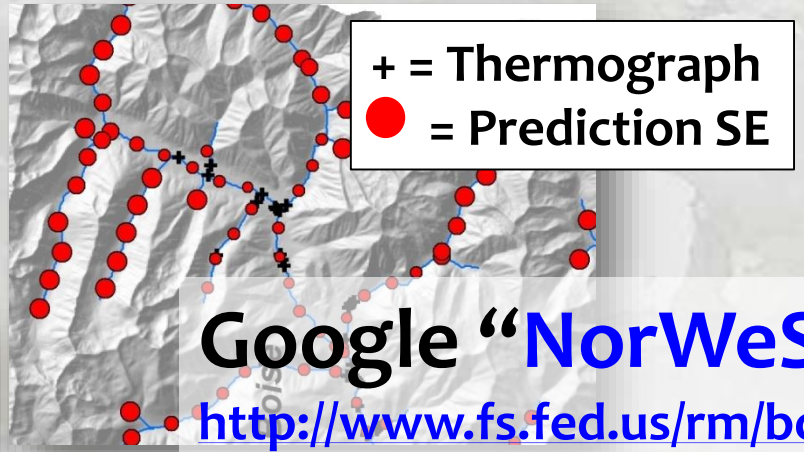


Website: Distributes Information in Useful Digital Formats (ArcGIS & .pdfs & Excel)

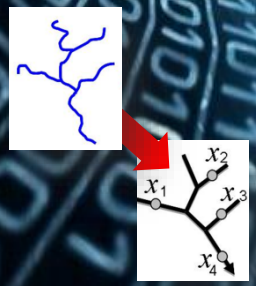
1) GIS shapefiles of stream temperature scenarios



2) GIS shapefiles of stream temperature model prediction precision



3) Temperature data summaries

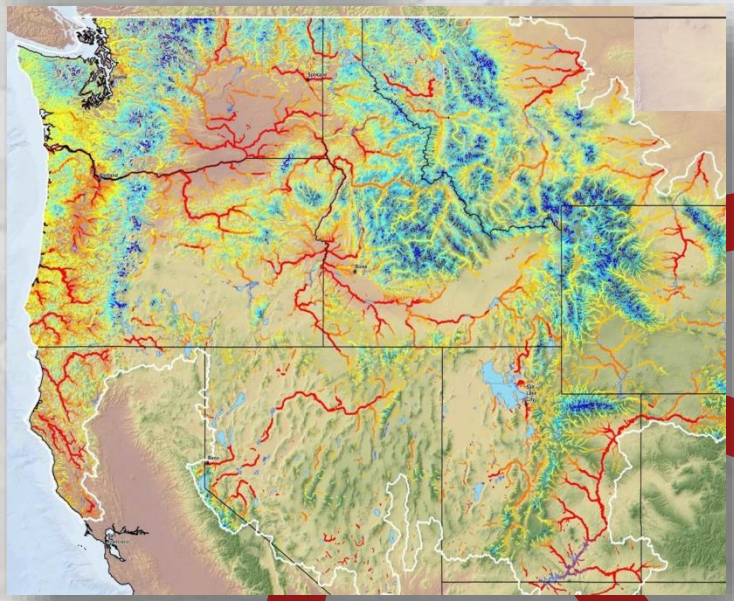


Google "NorWeST" or go here…

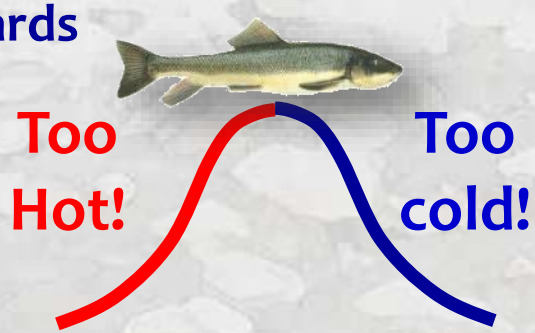
http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml

NorWeST Stream Temp

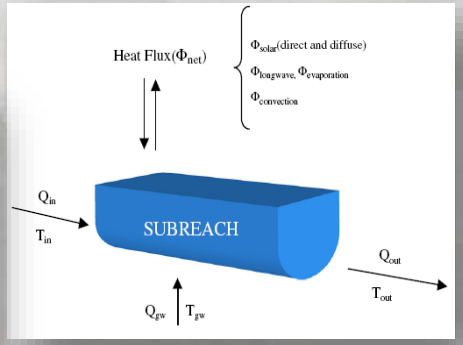
Temperature Applications

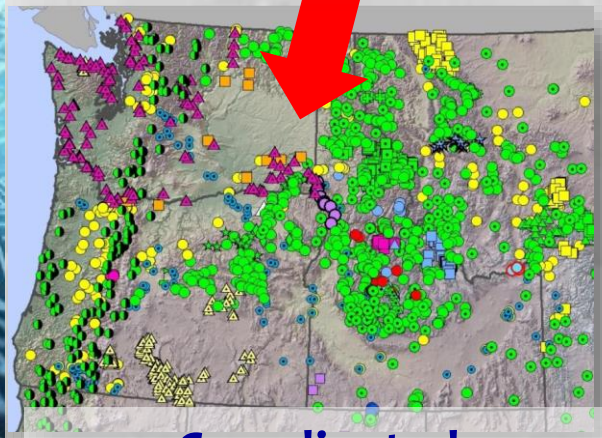


Regulatory temperature standards

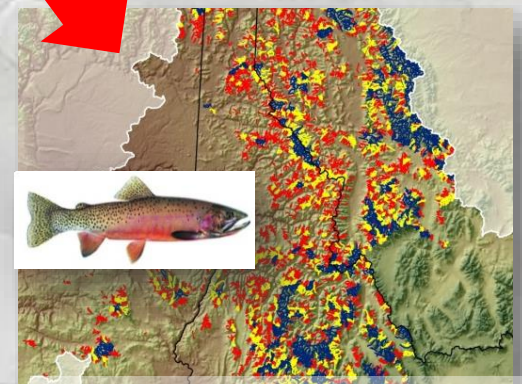


Data access accelerates temperature research

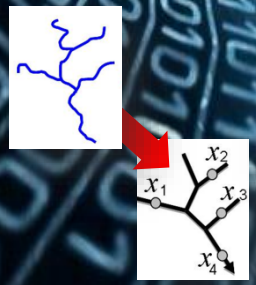




Coordinated Interagency monitoring



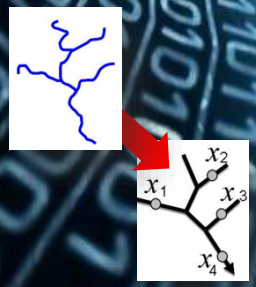
Species distribution models & climate assessments

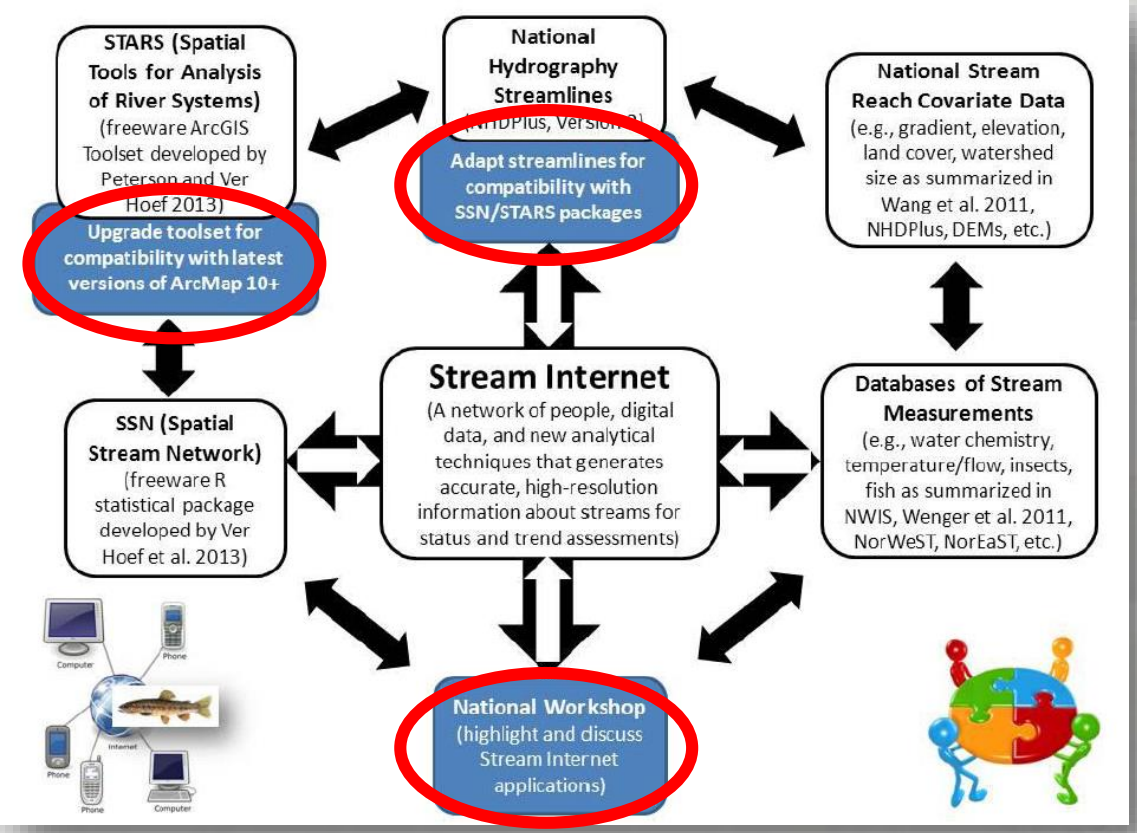


Stream Internet Project Objectives

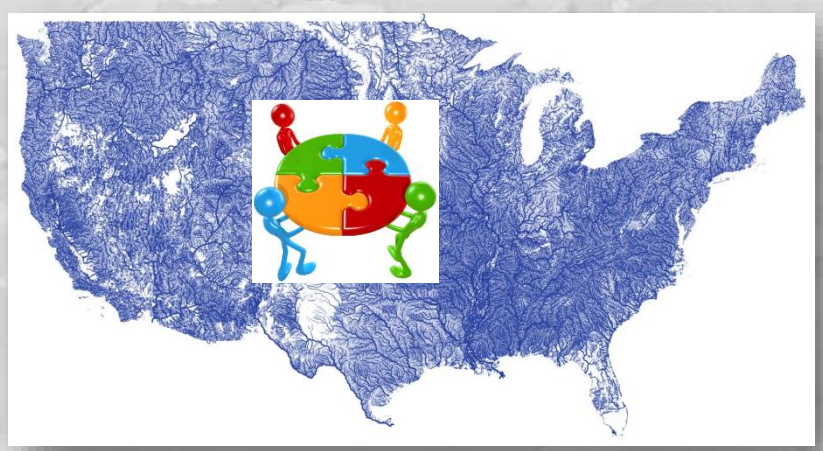
1) Develop compatibility between spatial stream analysis tools, national hydrography layer (NHDPlus, v2) & ArcMap 10.2
2) Host national workshop in 2015 to engage key researchers & leaders from aquatic programs (i.e., power-users)
3) Develop a grassroots user base with technical expertise

- **BIG DATA mining Projects like NorWeST done routinely**
- **Incentives exist for database aggregation**





Website: The National Stream Internet Project



LANDSCAPE CONSERVATION COOPERATIVES

NOAA

ACEMS

Boise Spatial Streams Group

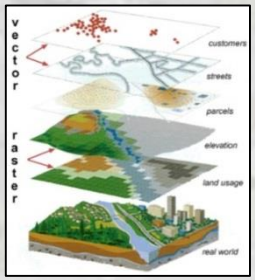
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

USGS

NSI Resources

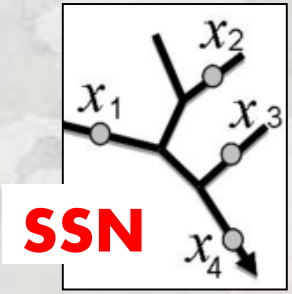
Workshop & presentations

NSI hydrography network (shapefiles)



Databases of stream reach descriptors

Databases of stream measurements

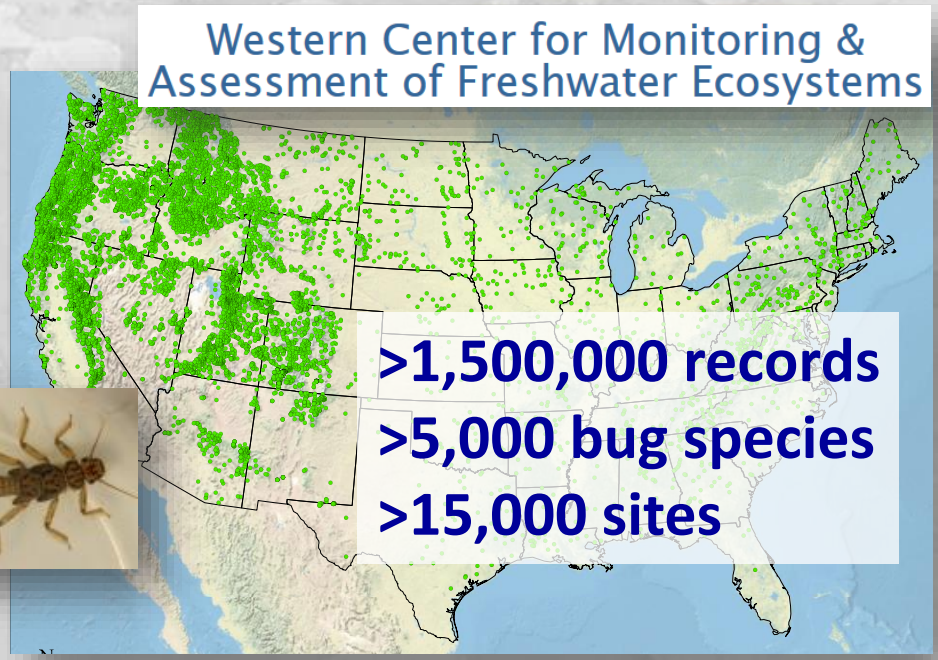


Spatial stream-network models

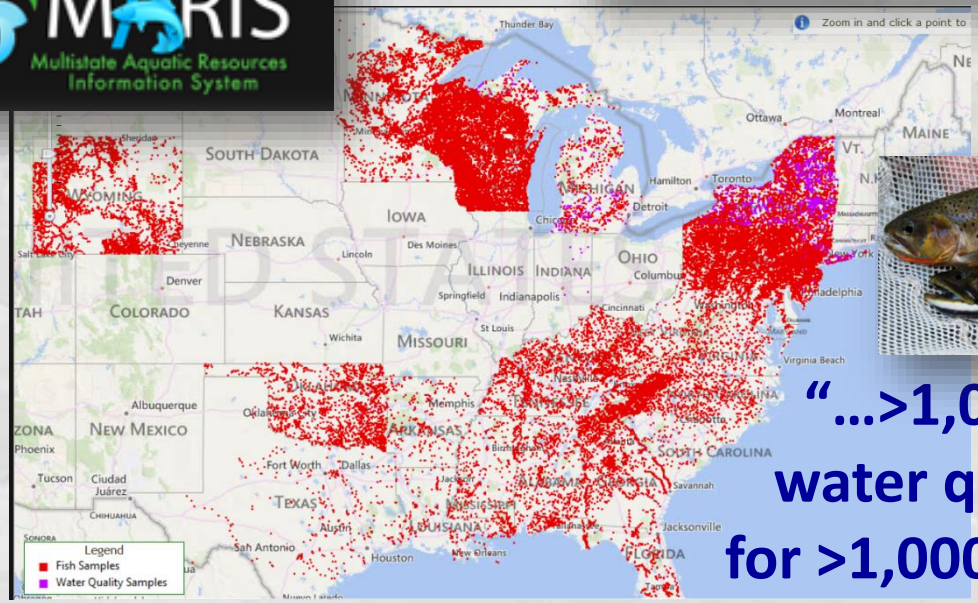
Ideas → Data → Analysis → Information

NSI Website is a "Hub" for Stream Data

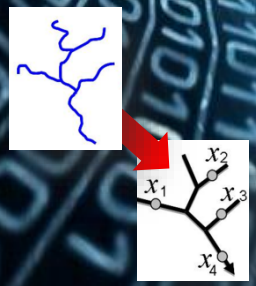
Databases of stream measurements



MARIS
Multistate Aquatic Resources Information System

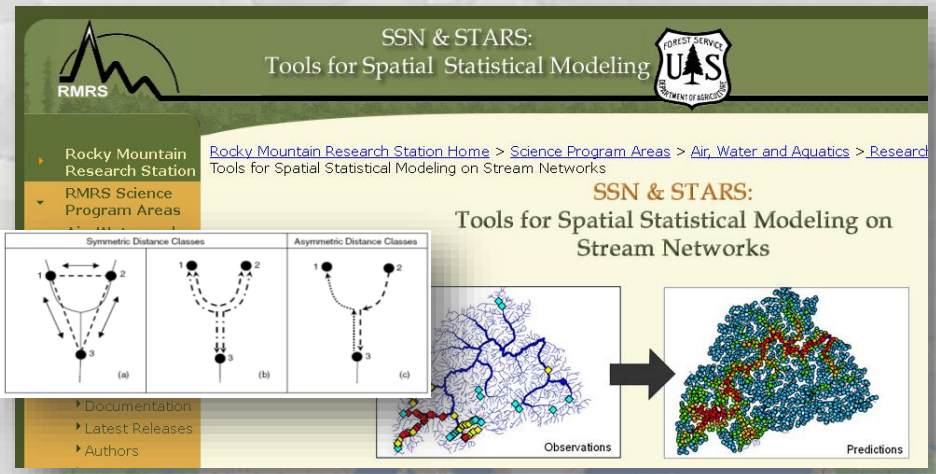


"…>1,000,000 fish & water quality records for >1,000 fish species"



Component #7: Growing User Community

SSN/STARS Website



>28,500 website visits in first 3.5 years

Free, high-quality software

>1,000 software downloads

Locations of visits to SSN/STARS website in last month

Building a Grassroots Technical Army

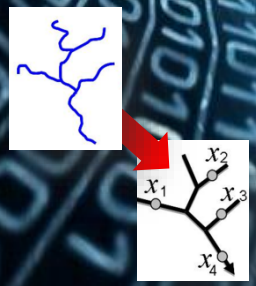
Annual Stream Statistics Training Workshop

waiting list to get in…

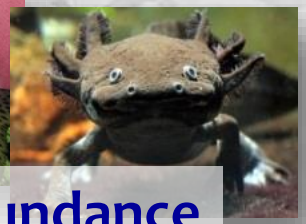
3 day workshop

1st day: overview of spatial stream models (webinar)

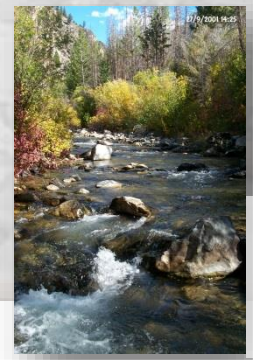
2nd/3rd days: work 1-on-1 with Jay/Erin to model your data



Develop a Database & Do It!



Distribution & abundance



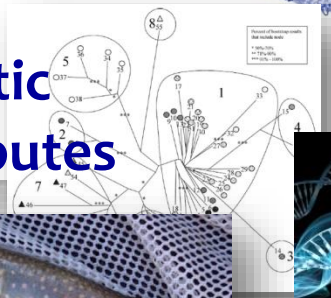
Habitat condition

Anywhere!

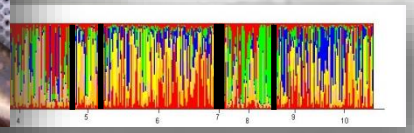
Everywhere!

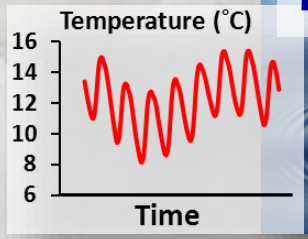
For Anything!

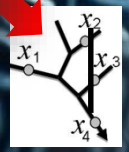
Water Quality Parameters



Genetic Attributes

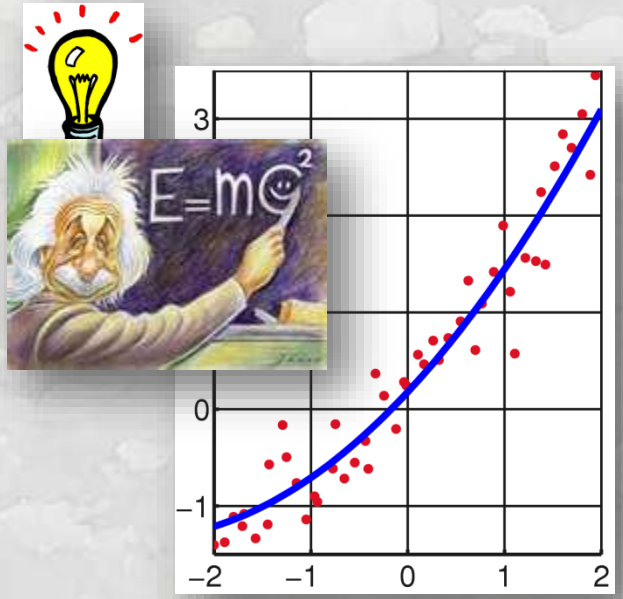


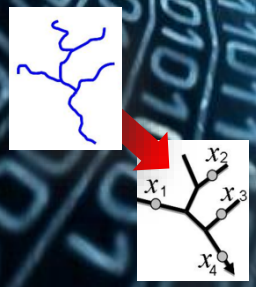




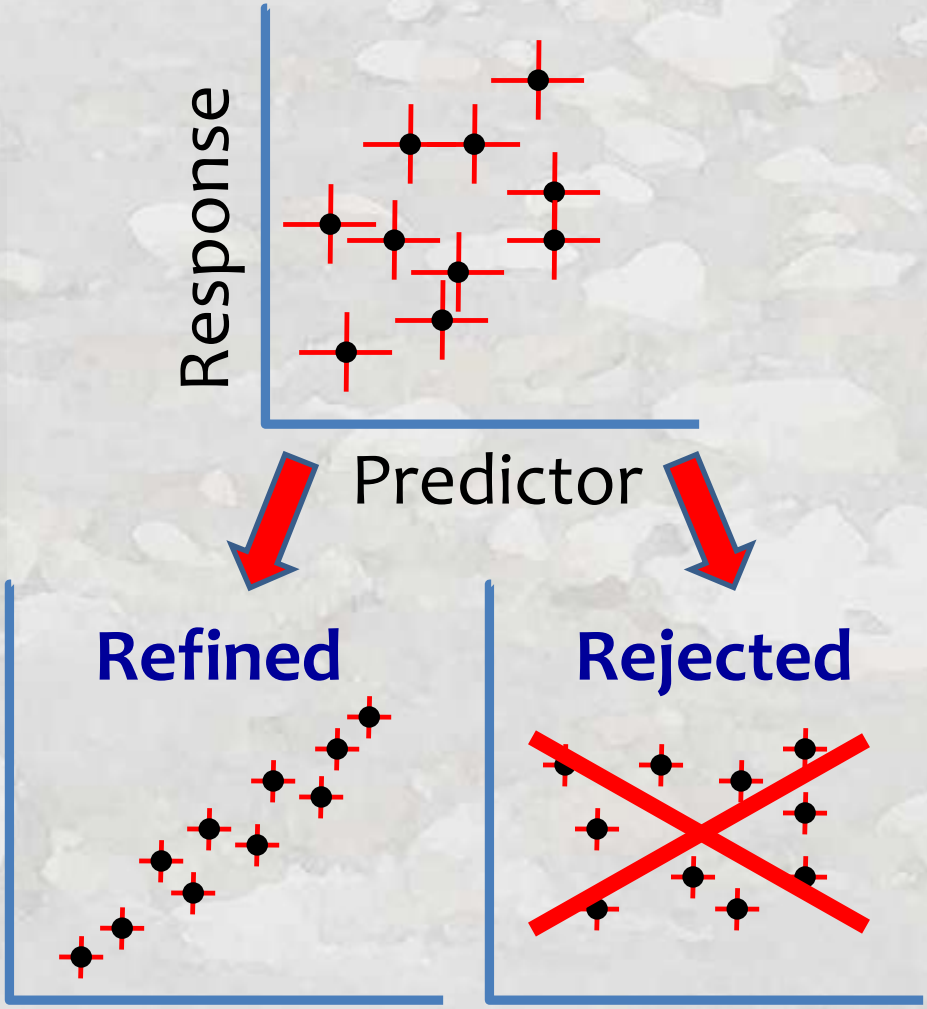
A New Era of Better Prediction & Understanding for Stream Things…

New relationships described



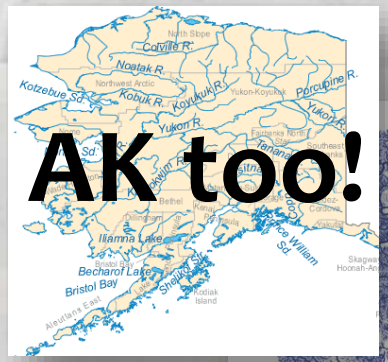


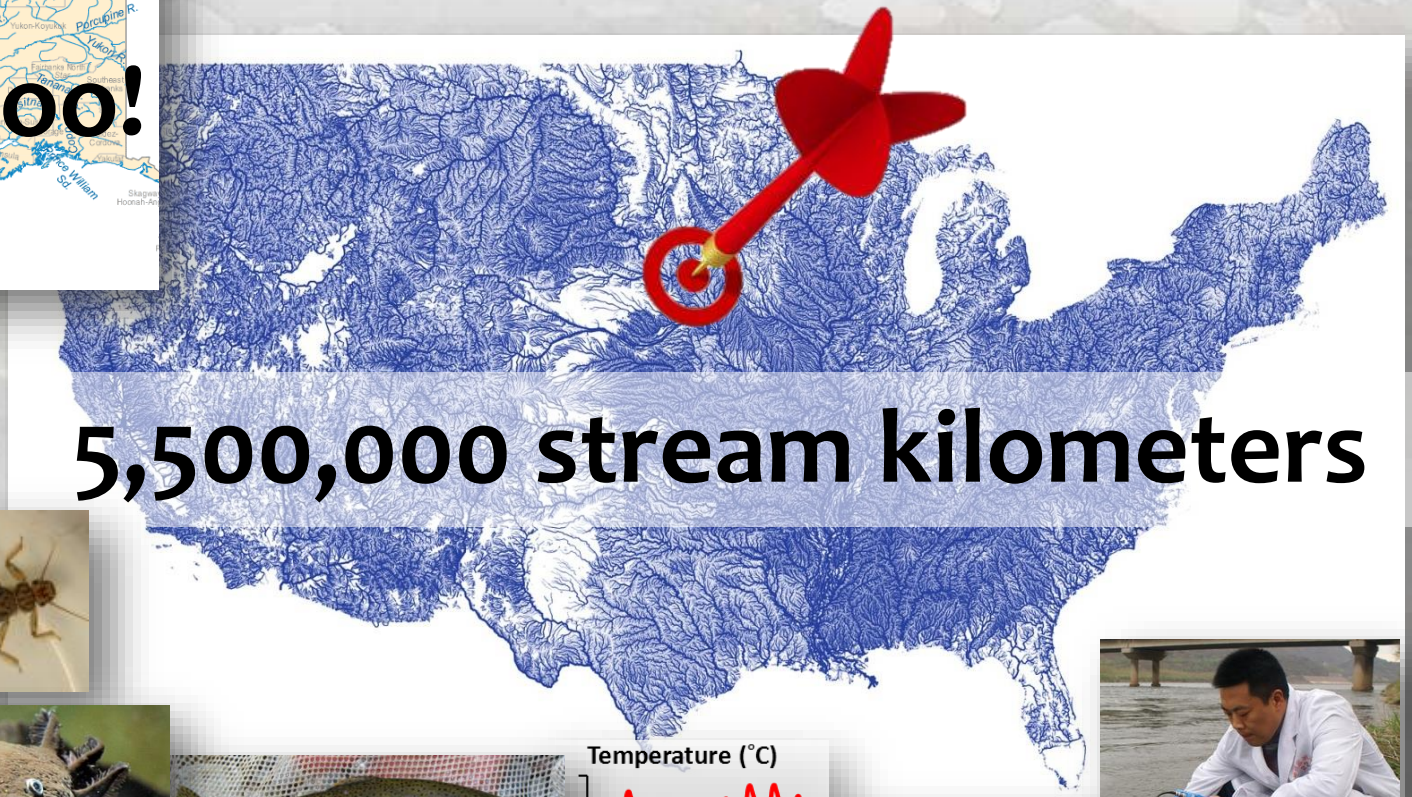
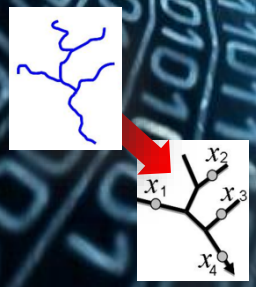
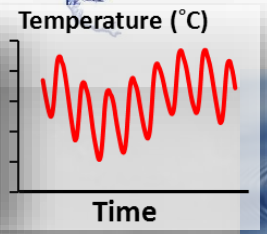
Old relationships tested



Vision: TSI (Total Stream Information) through the NSI

High-resolution information for all stream things in all reaches across the country





5,500,000 stream kilometers