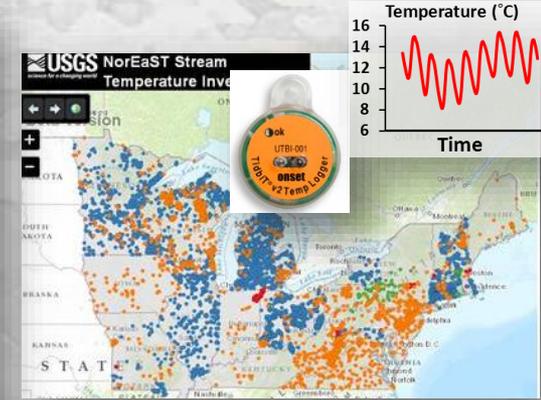
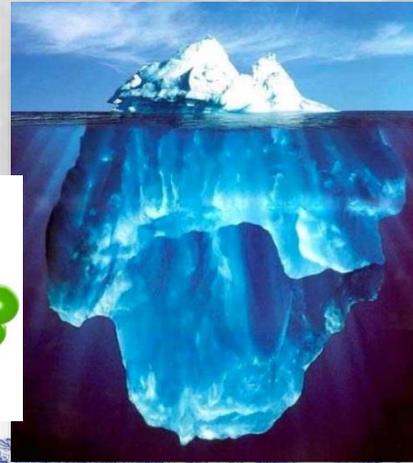
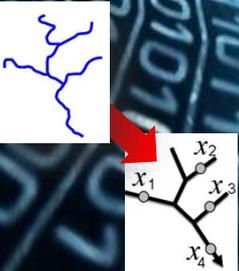
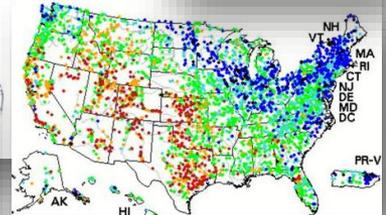
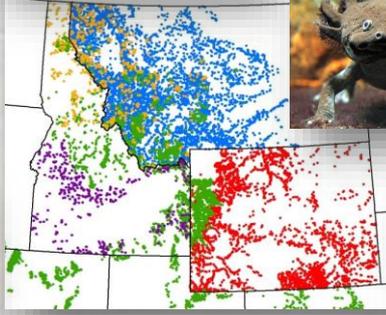


The National Stream Internet

An Analytical Infrastructure for Stream Data



BIG DATA = BIG Possibilities



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

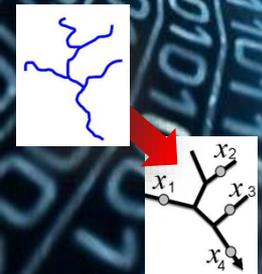
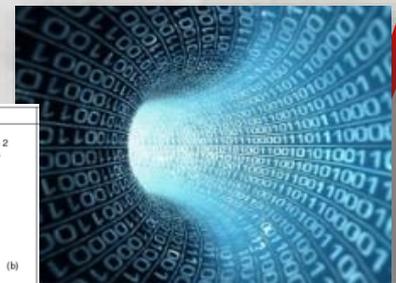
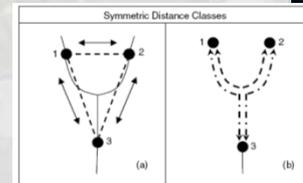


Open access, comprehensive databases



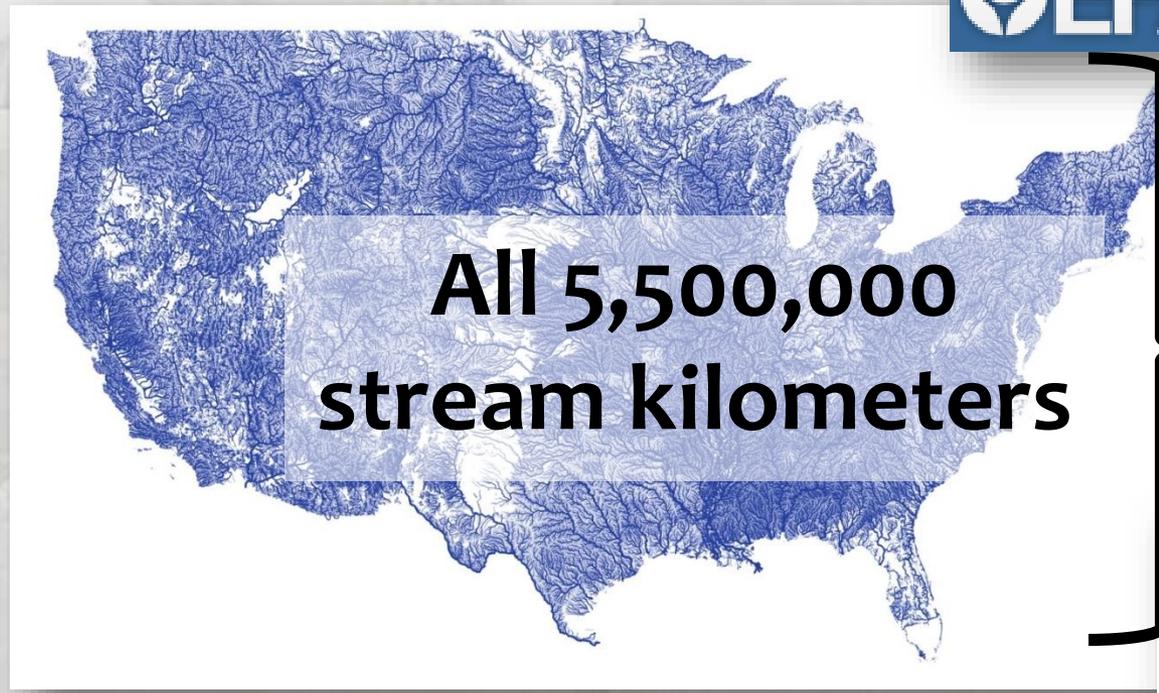
Analysis & new information

Inter-Compatibility is Key...



Component #1: National Hydrography Dataset

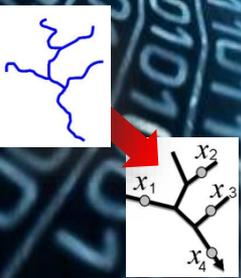
Nationally consistent stream network geodatabase



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.



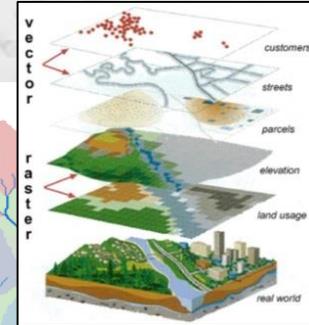
Component #2: The “PLUS” part of NHDPlus (Stream Reach Descriptors)



Unique reach IDs

Reach descriptors

- Elevation
 - Slope
 - %Landuse
 - Precipitation
- 100's more...



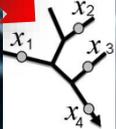
Databases of stream reach descriptors

Wang et al. 2011. A hierarchical spatial framework and database for the national river fish habitat condition assessment. *Fisheries* 36: 436-449.

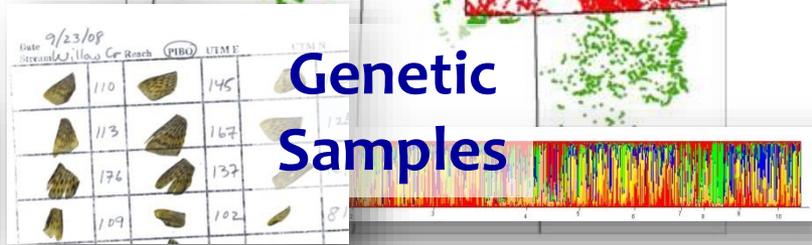
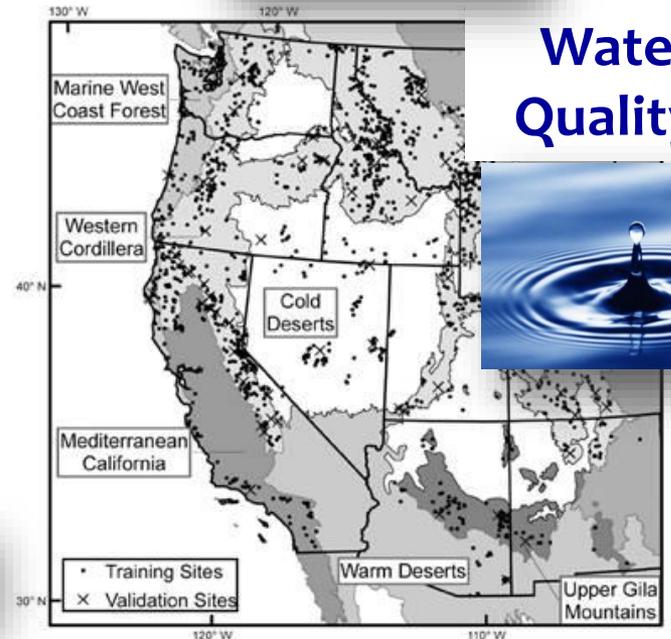
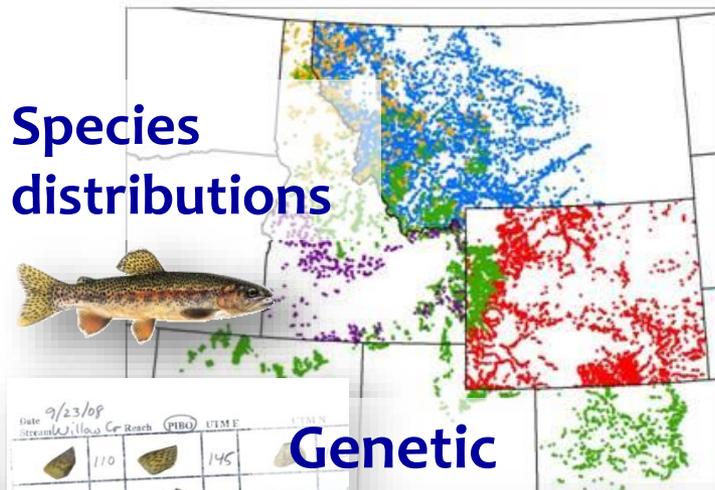
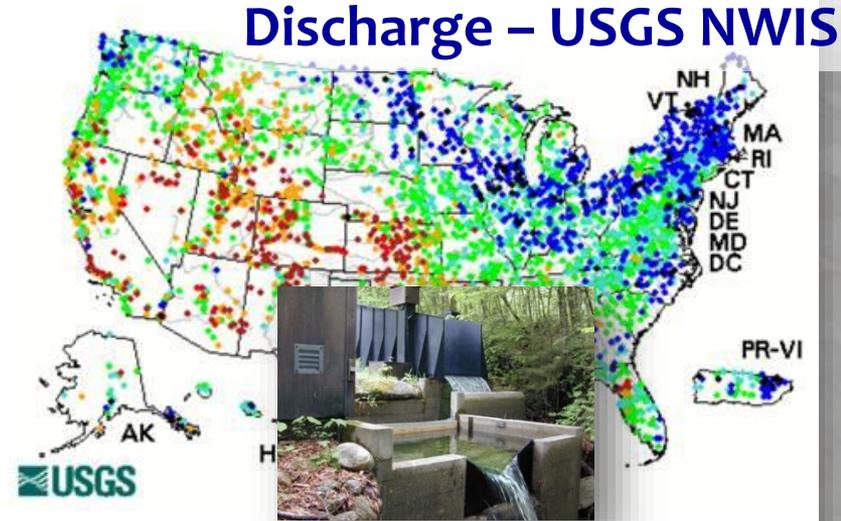
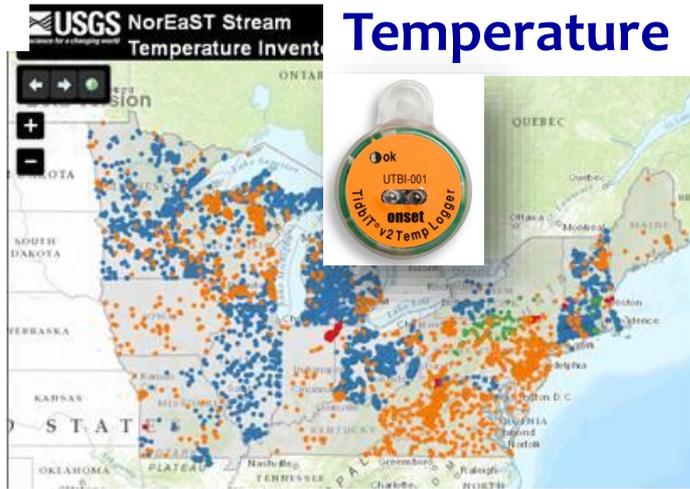
Available at: https://www.researchgate.net/profile/Lizhu_Wang2

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



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



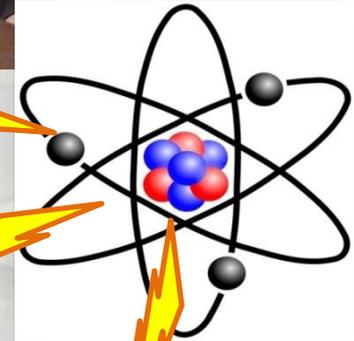
Journal of Statistical Software

January 2014, Volume 56, Issue 3.

<http://www.jstatsoft.org/>

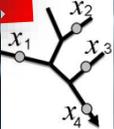
SSN: An R Package for Spatial Statistical Modeling on Stream Networks

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



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



Stream Models are Generalizable...

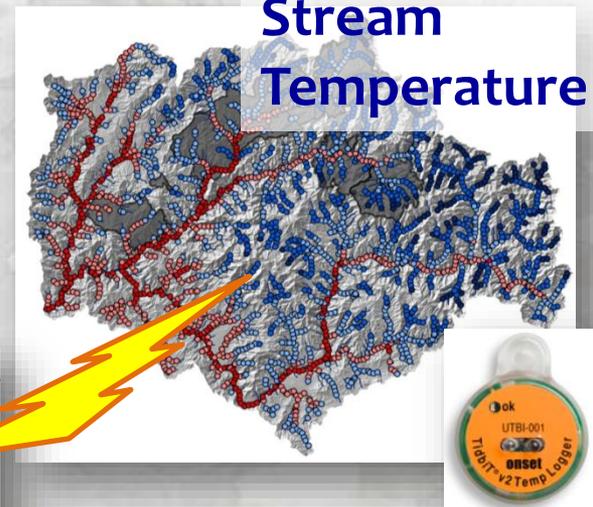


Distribution & abundance

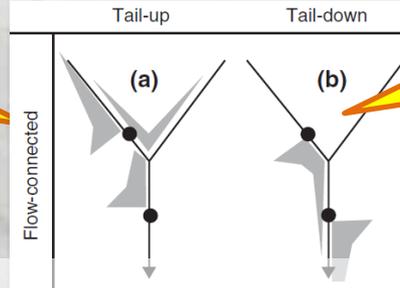


Response Metrics

- Gaussian
- Poisson
- Binomial

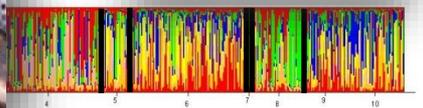
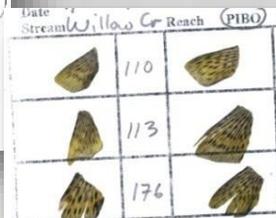
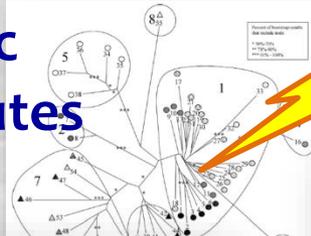


Stream Temperature

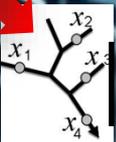
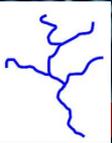


Statistical stream models

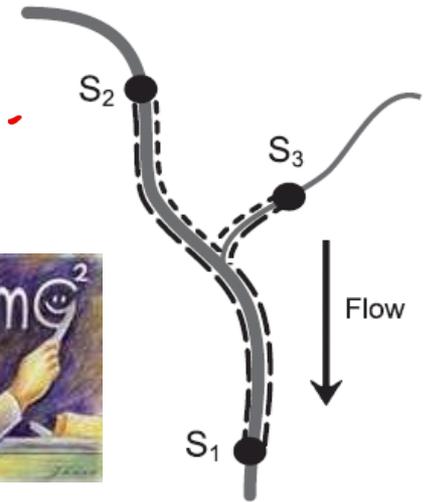
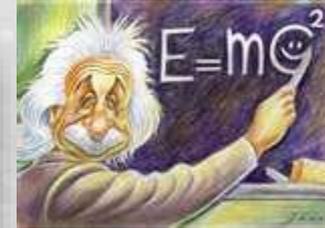
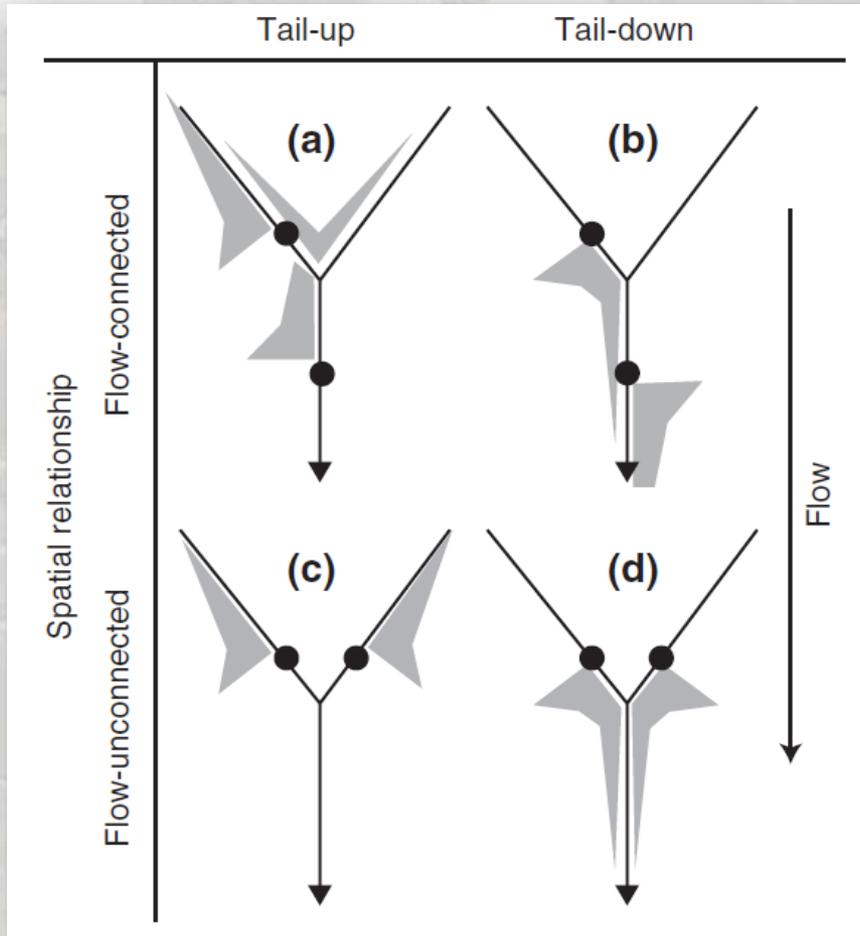
Genetic Attributes



Water Quality Parameters



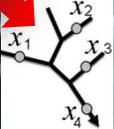
Key Innovation is Covariance Structure Based On Network Structure



- 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...

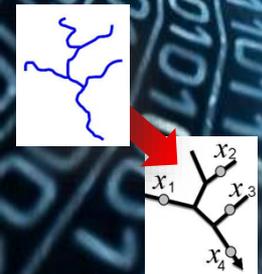
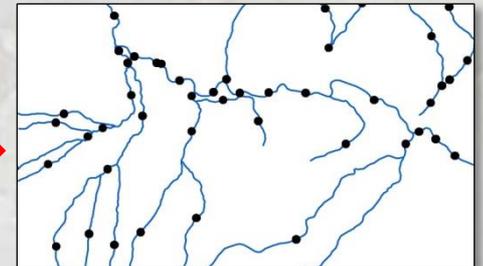
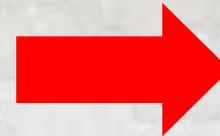
- Uninitialized flow
- Braids and diverging flow
- Converging flow
- Complex confluences
- Outlets and sinks



★ Back compatibility with NHD-Plus is preserved

Bonus!

- Prediction points created for NSI network



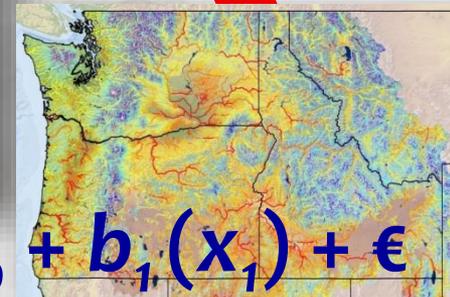
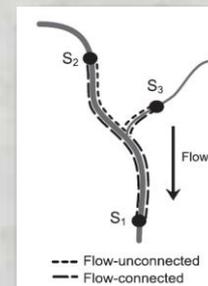
Component #6: SSN Model “Killer Apps”

- 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



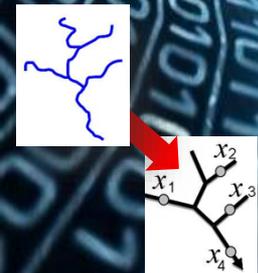
Too Hot!

Too cold!

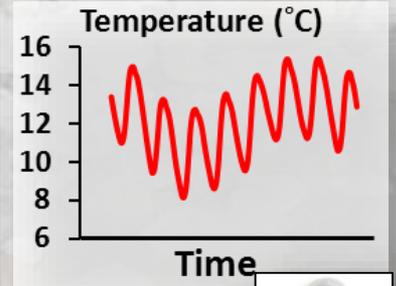
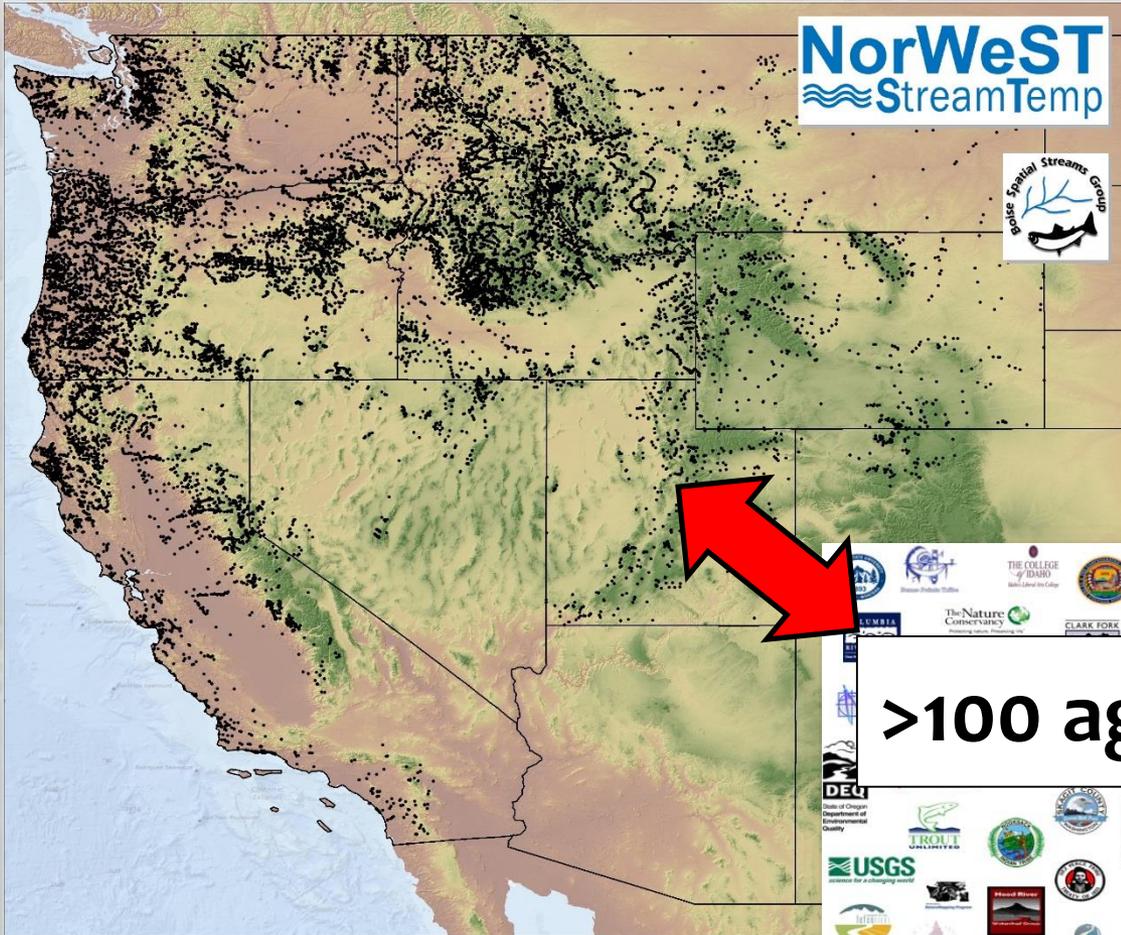


$$Y = b_0 + b_1(x_1) + \epsilon$$

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

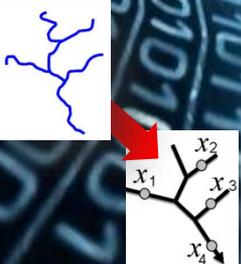


Developing a Comprehensive Database



>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 (km²)
9. Glacier (%)

10. Discharge (m³/s)

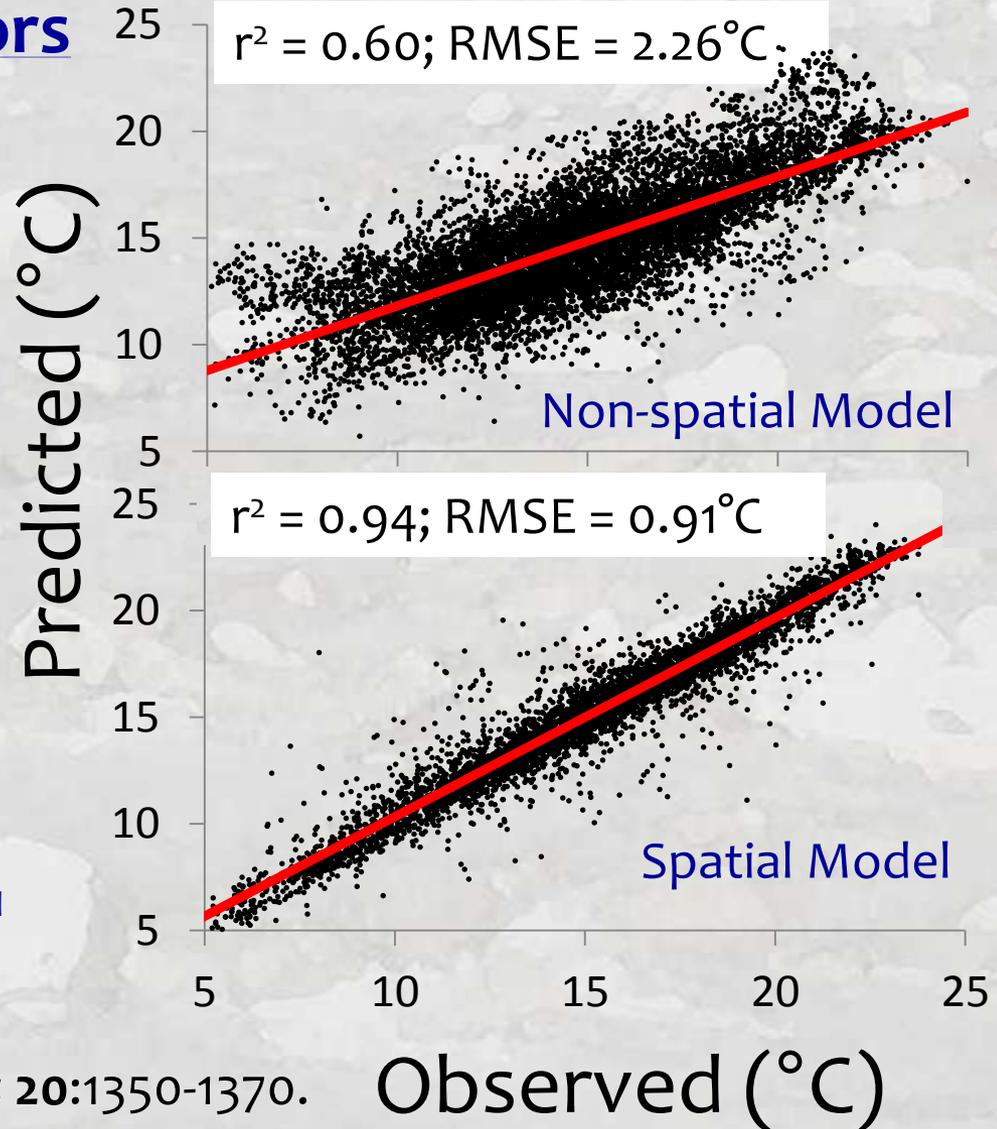
USGS gage data

11. Air Temperature (°C)

RegCM3 NCEP reanalysis

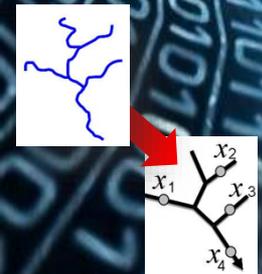
Hostetler et al. 2011

Mean August Temperature

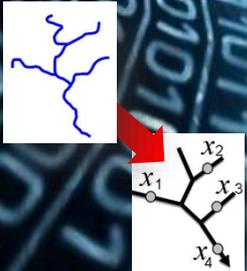
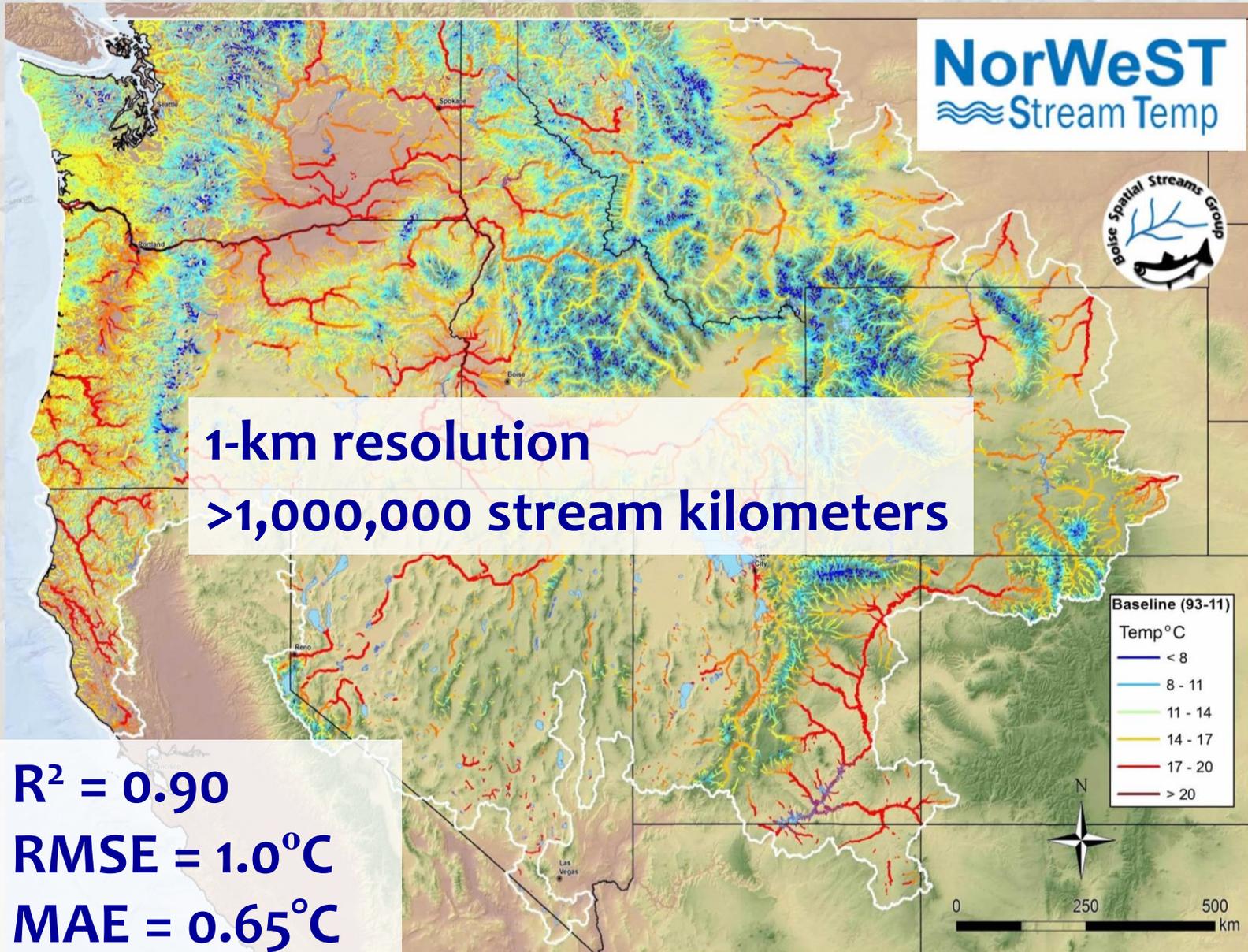


Isaak et al. 2010. *Ecol. Apps* 20:1350-1370.

Observed (°C)

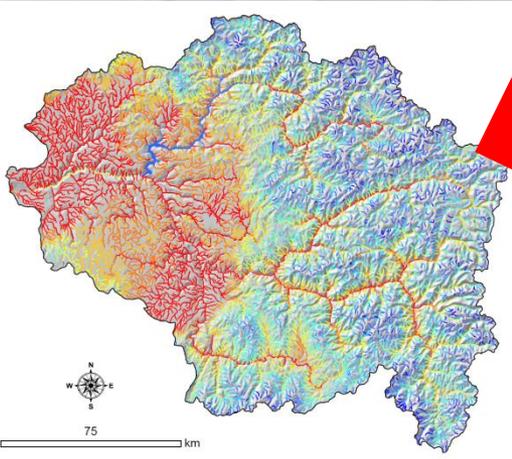


Accurate Stream Scenarios from Model Interpolations



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

1) GIS shapefiles of stream temperature scenarios

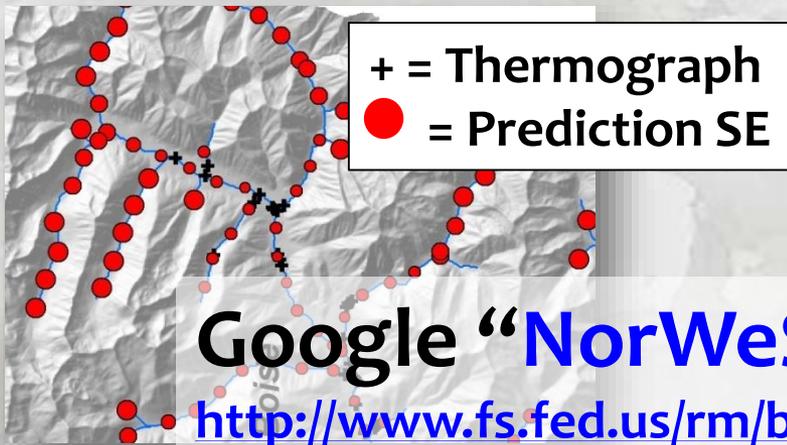


NorWeST
Stream Temp

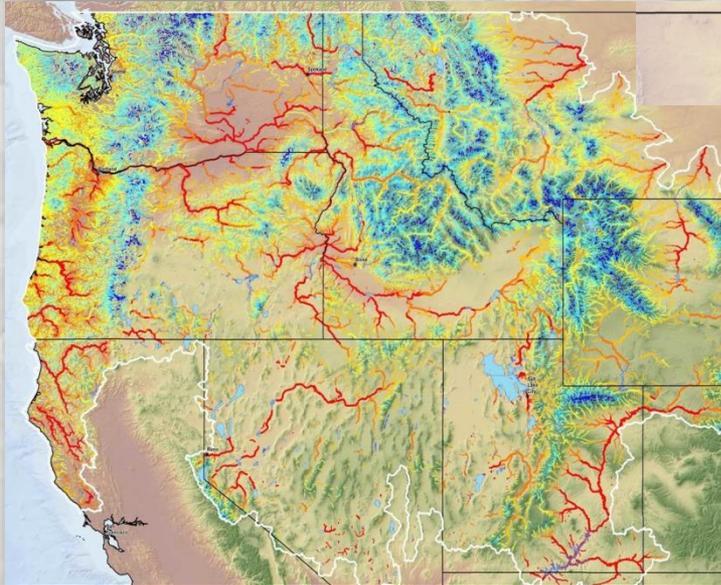
Regional Database and Modeled Stream Temperatures

3) Temperature data summaries

2) GIS shapefiles of stream temperature model prediction precision



Temperature Applications

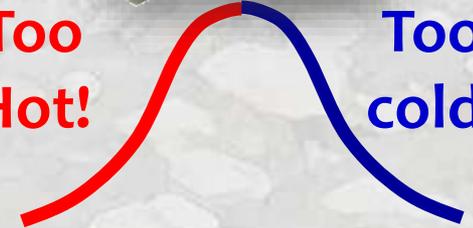


Regulatory temperature standards

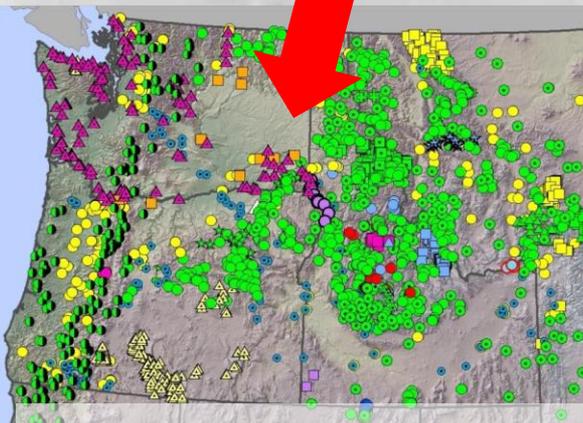


Too Hot!

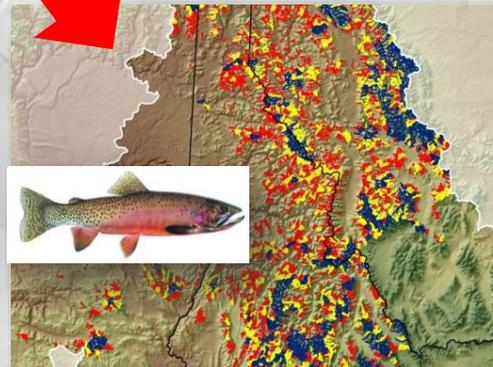
Too cold!



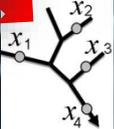
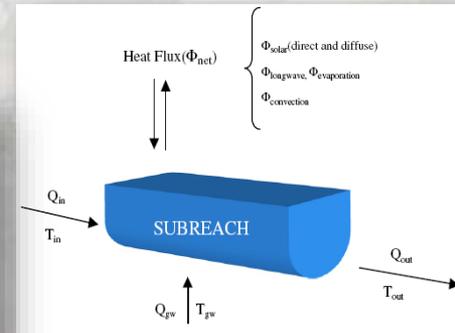
Data access accelerates temperature research



Coordinated Interagency monitoring



Species distribution models & climate assessments

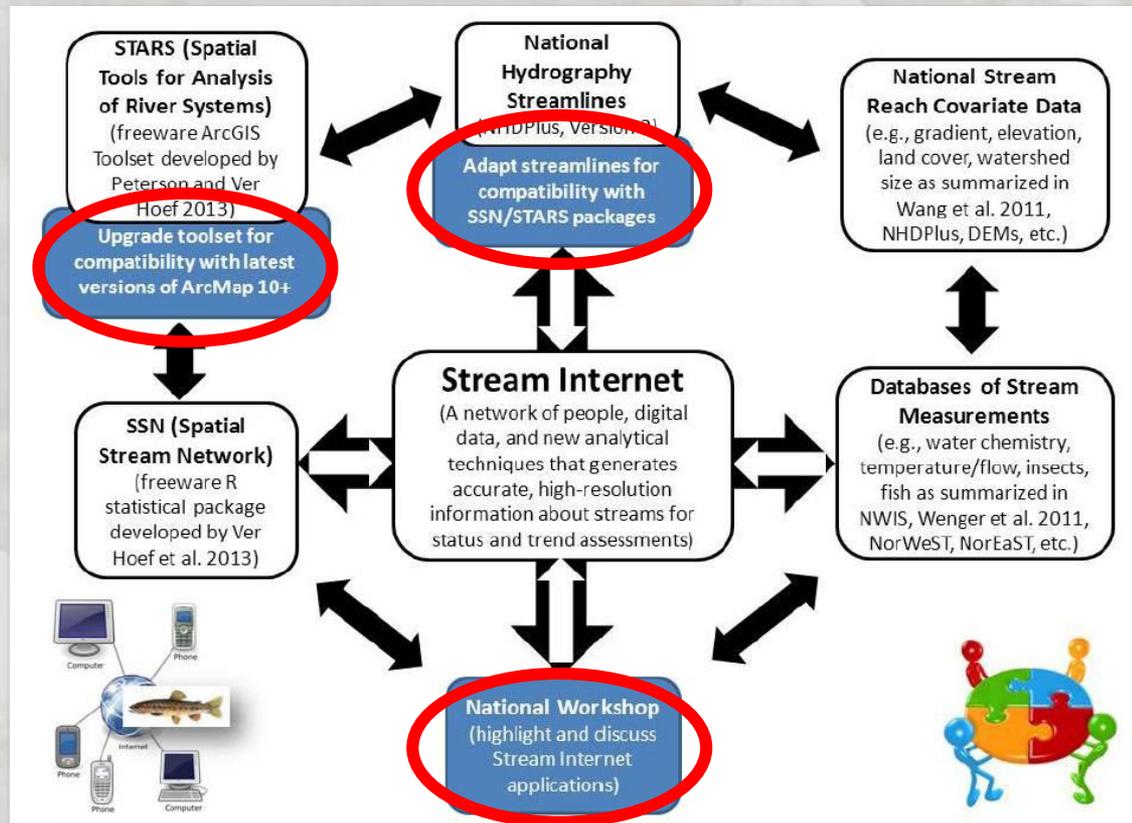


Stream Internet Project Objectives

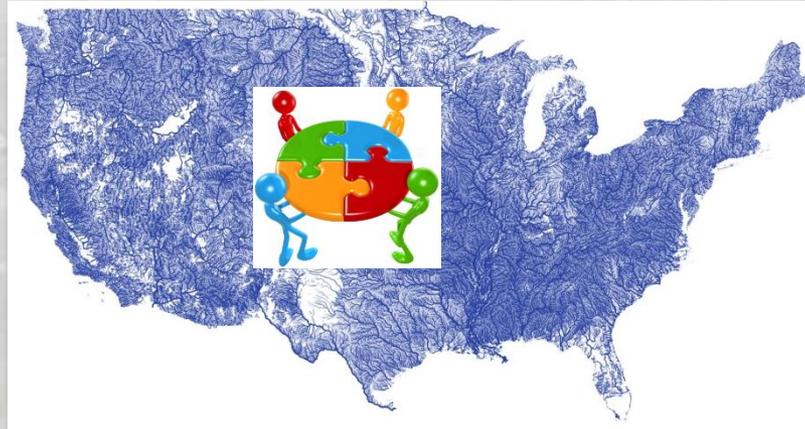
- 1) Develop compatibility between spatial stream analysis tools, national hydrography layer (NHDPlus, v2) & ArcMap 10.2
- 2) Host national workshop in 2015 to engage key researchers & leaders from aquatic programs (i.e., power-users)
- 3) Develop a grassroots user base with technical expertise

- **BIG DATA** mining
Projects like NorWeST done routinely

- Incentives exist for database aggregation



Website: The National Stream Internet Project



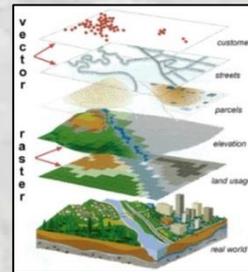
NSI Resources



Workshop & presentations



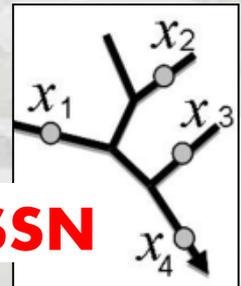
NSI hydrography network (shapefiles)



Databases of stream reach descriptors



Databases of stream measurements



Spatial stream-network models

Ideas



Data



Analysis



Information

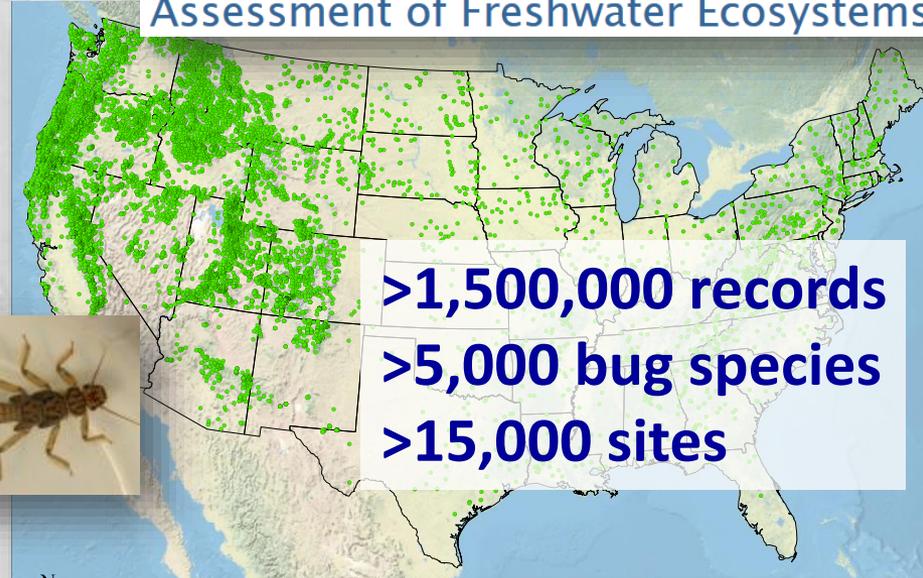
NSI Website is a “Hub” for Stream Data



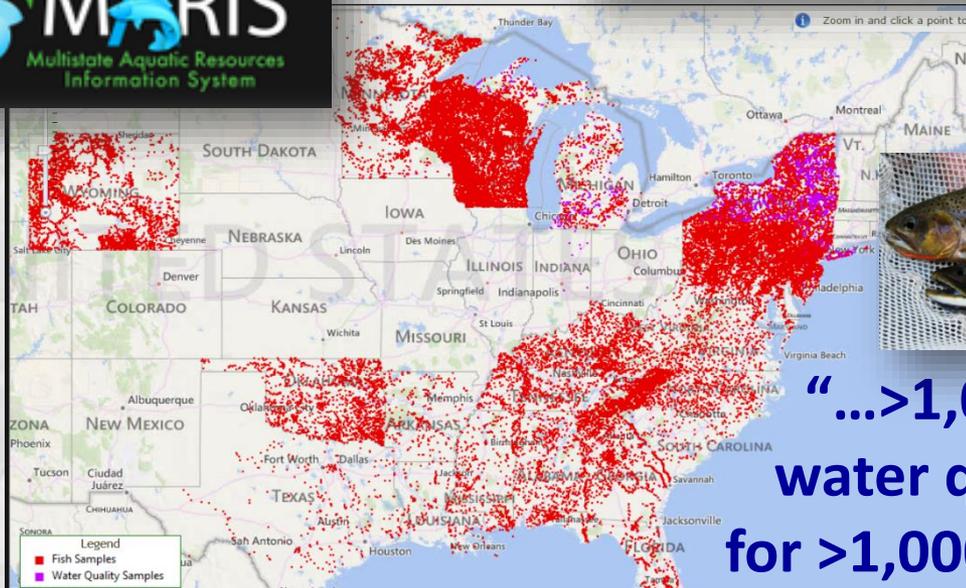
Databases of stream measurements



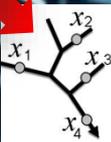
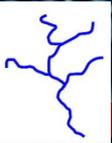
Western Center for Monitoring & Assessment of Freshwater Ecosystems



>1,500,000 records
>5,000 bug species
>15,000 sites



“...>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

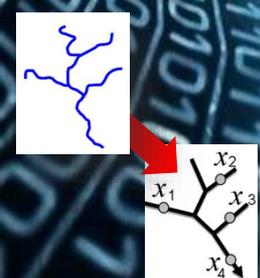
>1,000 software
downloads



A screenshot of the SSN & STARS website. The header includes the RMRS logo, the text 'SSN & STARS: Tools for Spatial Statistical Modeling', and the U.S. Forest Service logo. The main content area features a navigation menu on the left with 'Rocky Mountain Research Station' and 'RMRS Science Program Areas'. The central text reads 'SSN & STARS: Tools for Spatial Statistical Modeling on Stream Networks'. Below this, there are diagrams for 'Symmetric Distance Classes' (a, b) and 'Asymmetric Distance Classes' (c, d), a map of 'Observations' (a stream network), and a map of 'Predictions' (a colored stream network). A sidebar on the left contains links for 'Documentation', 'Latest Releases', and 'Authors'.



Locations of visits to SSN/STARS website in last month



Develop a Database & Do It!



Distribution & abundance



Habitat condition

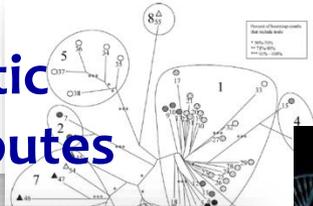


Anywhere!

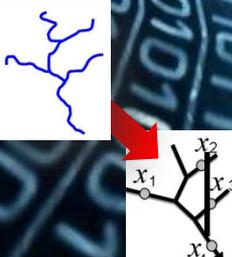
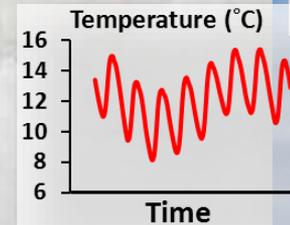
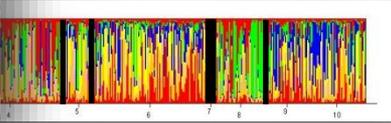
Everywhere!

For Anything!

Genetic Attributes

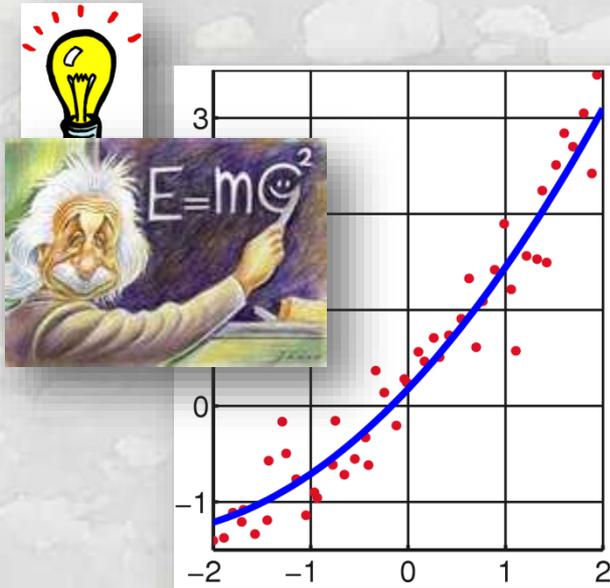


Water Quality Parameters

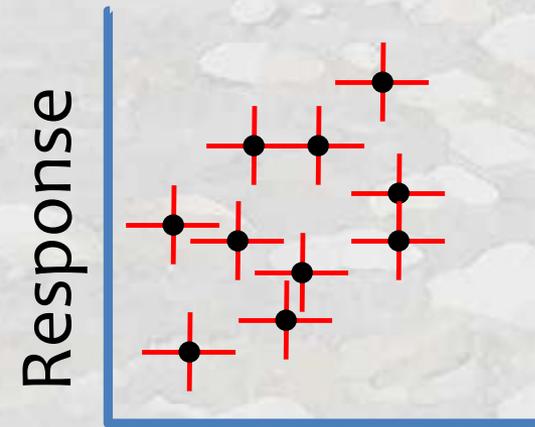


A New Era of Better Prediction & Understanding for Stream Things...

New relationships described

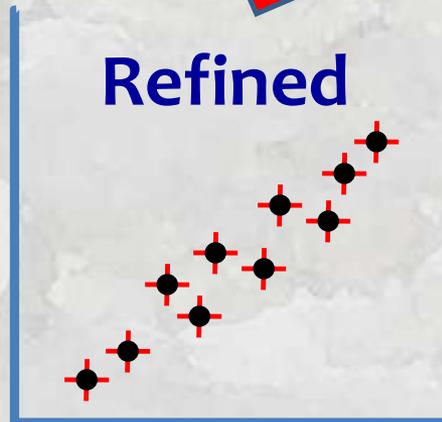


Old relationships tested

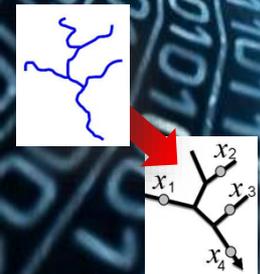


Predictor

Refined



Rejected



Vision: TSI (Total Stream Information) through the NSI

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

