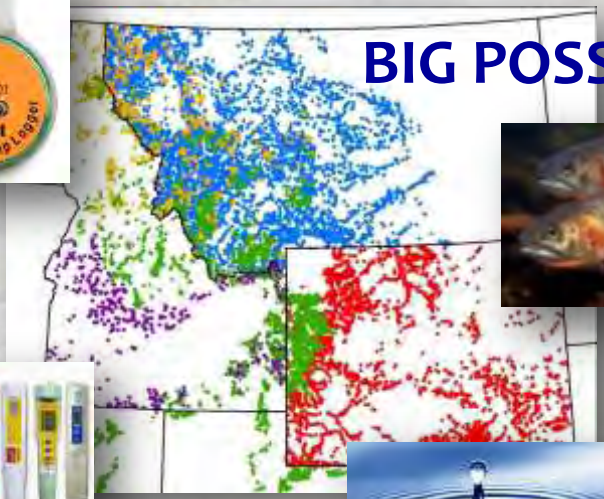
The National Stream Internet Project

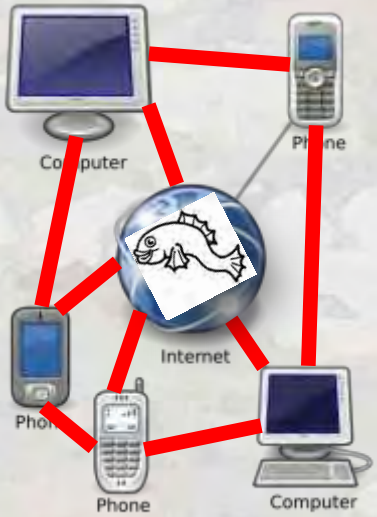
An analytical framework for creating new information from old stream data

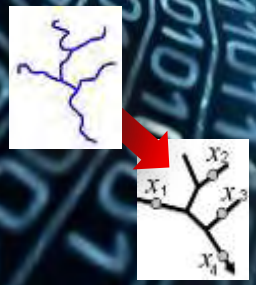
Dan Isaak, Erin Peterson, Dave Nagel, Jay Ver Hoef, Jeff Kershner

BIG DATA =

BIG POSSIBILITIES

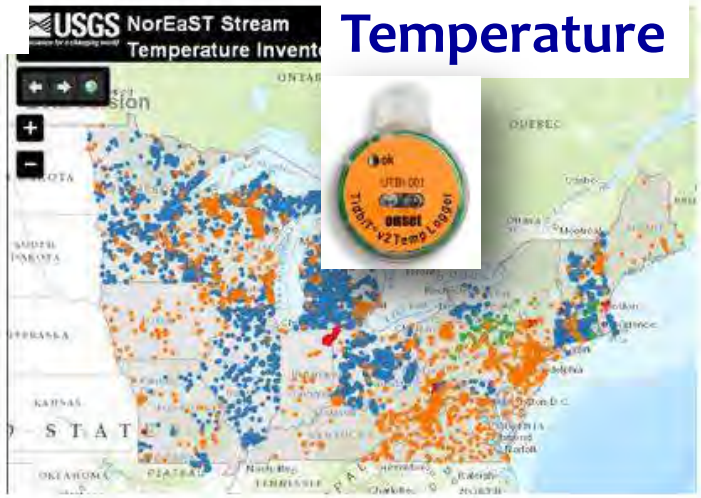


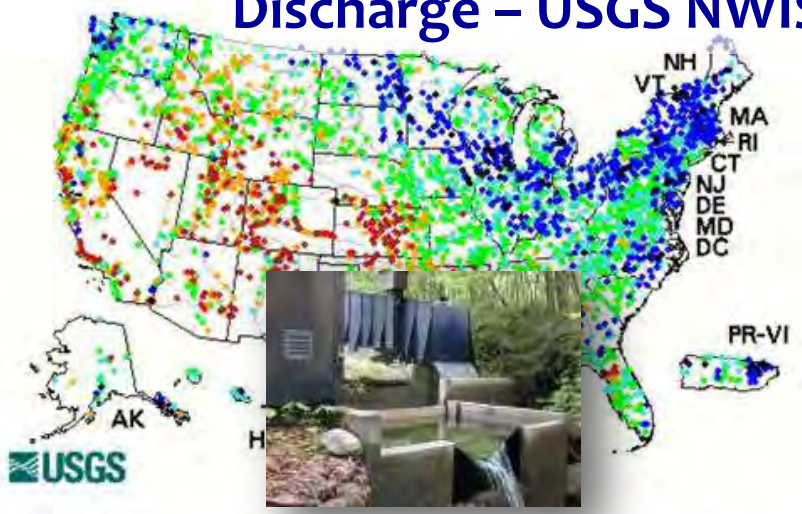


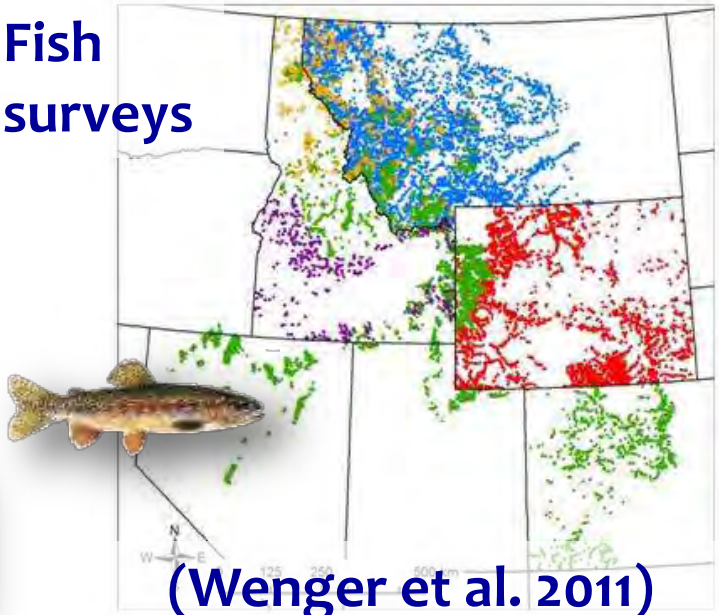


LANDSCAPE CONSERVATION COOPERATIVES

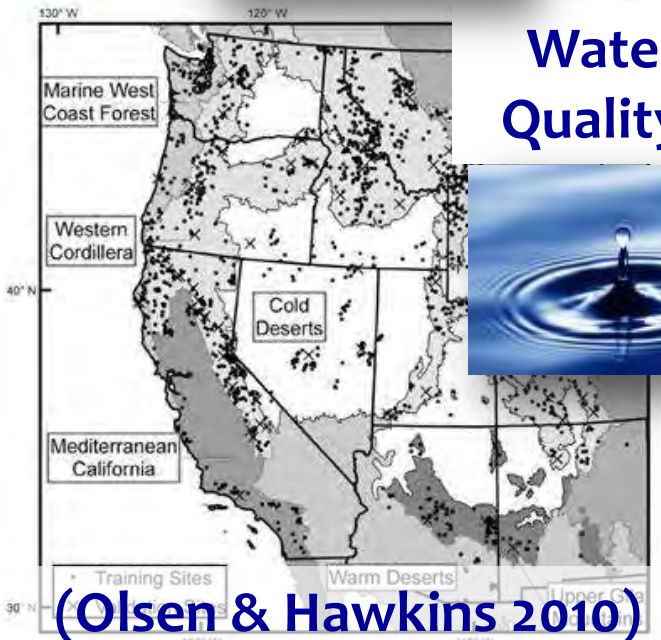
Mountains of Data Could be Mined for Valuable Information







(Wenger et al. 2011)



(Olsen & Hawkins 2010)

Mountains of Data Could be Mined for Valuable Information

Free millions!

Temperature

Discharge – U

Free millions!

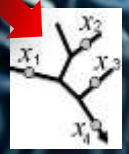
PR-VI

Fish

Free millions!

Water Quality

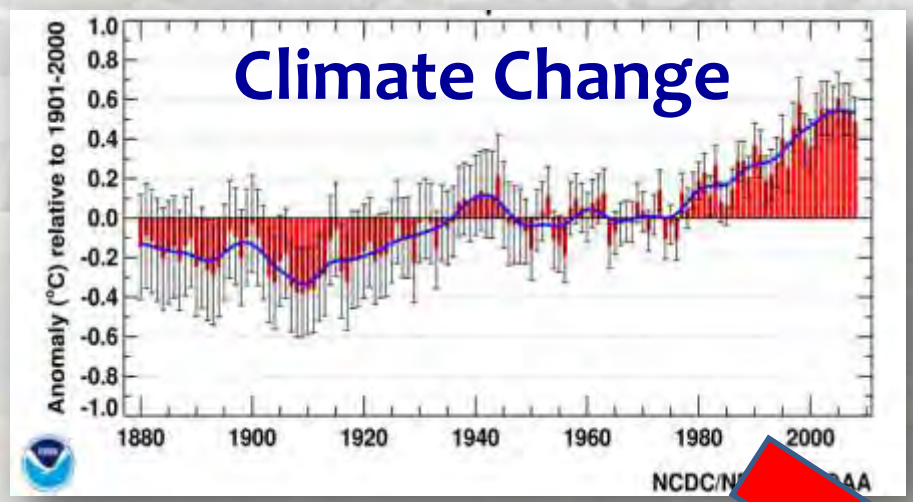
Free millions!



(Wenger et al. 2011)

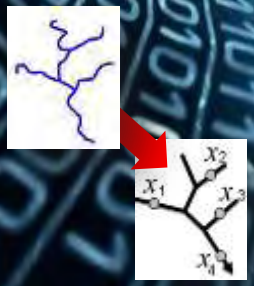
(Olsen & Hawkins 2010)

More Pressure, Fewer Resources



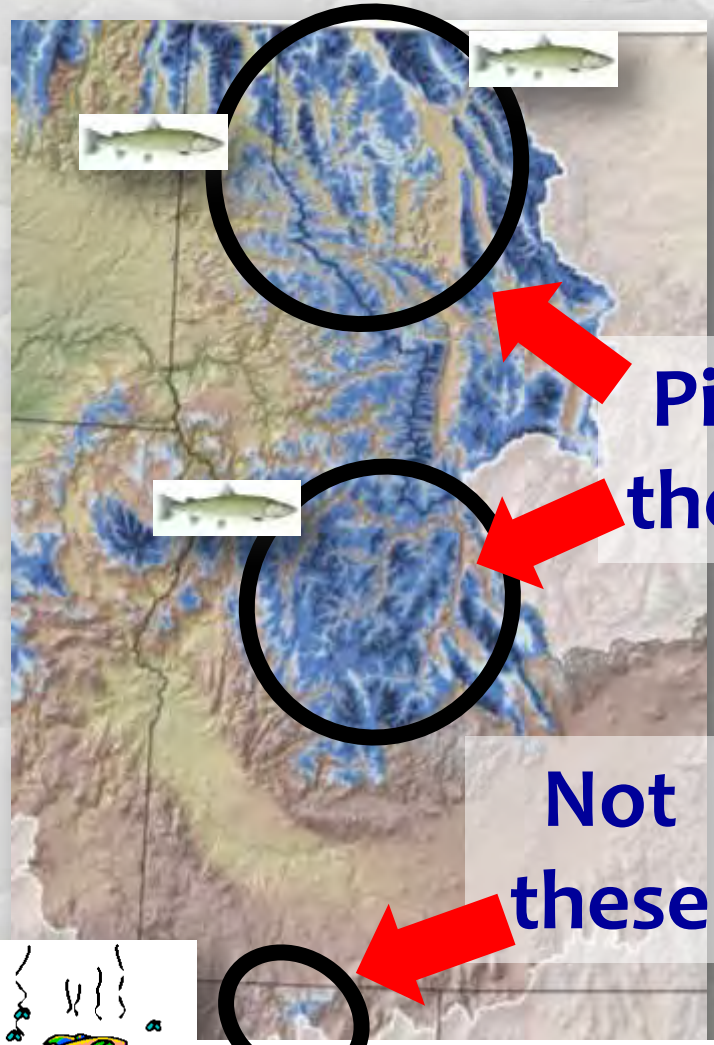
Urbanization & Population Growth

Shrinking Budgets



Need to do more with less

Good Information for Strategic Decision Making Will be Critical

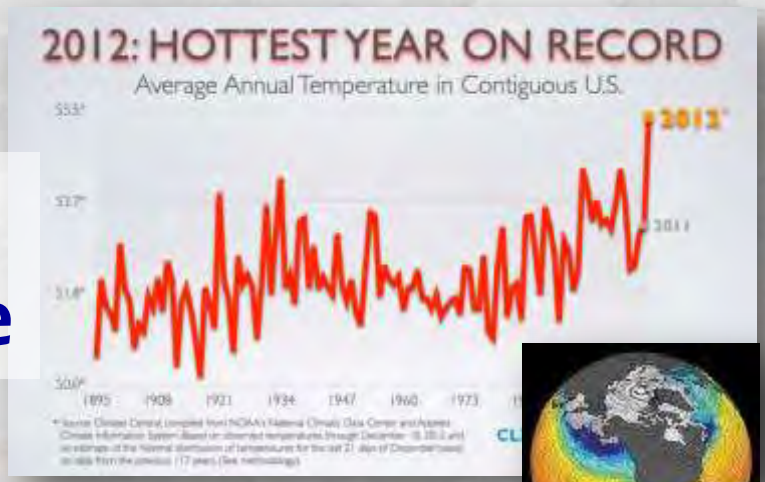


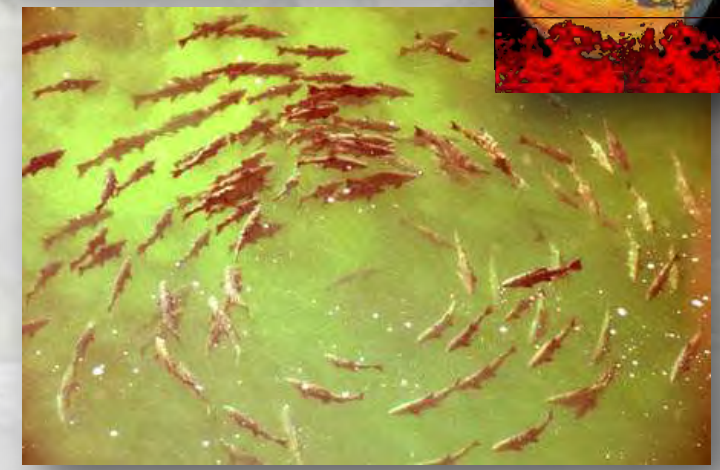
Pick these

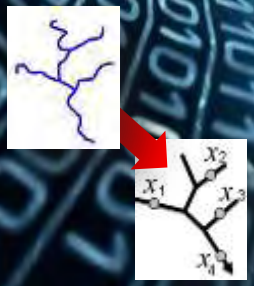
Not these

Sorry Charlie

The 21st-Century will Be a Transitional One

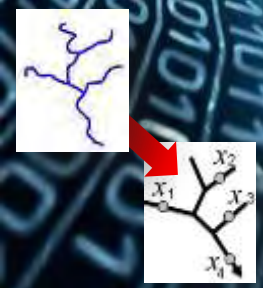




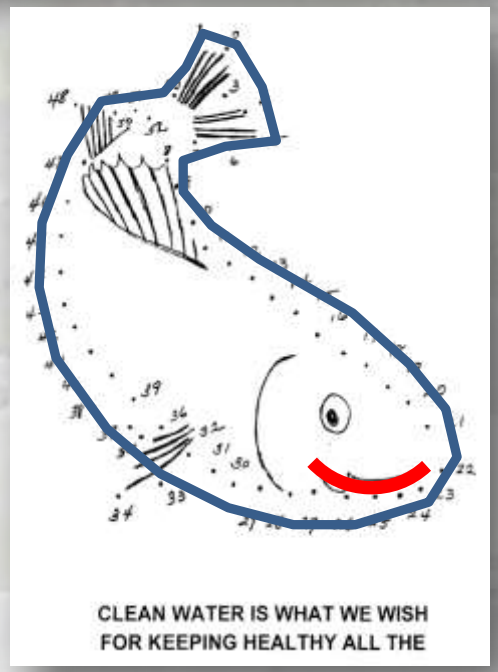


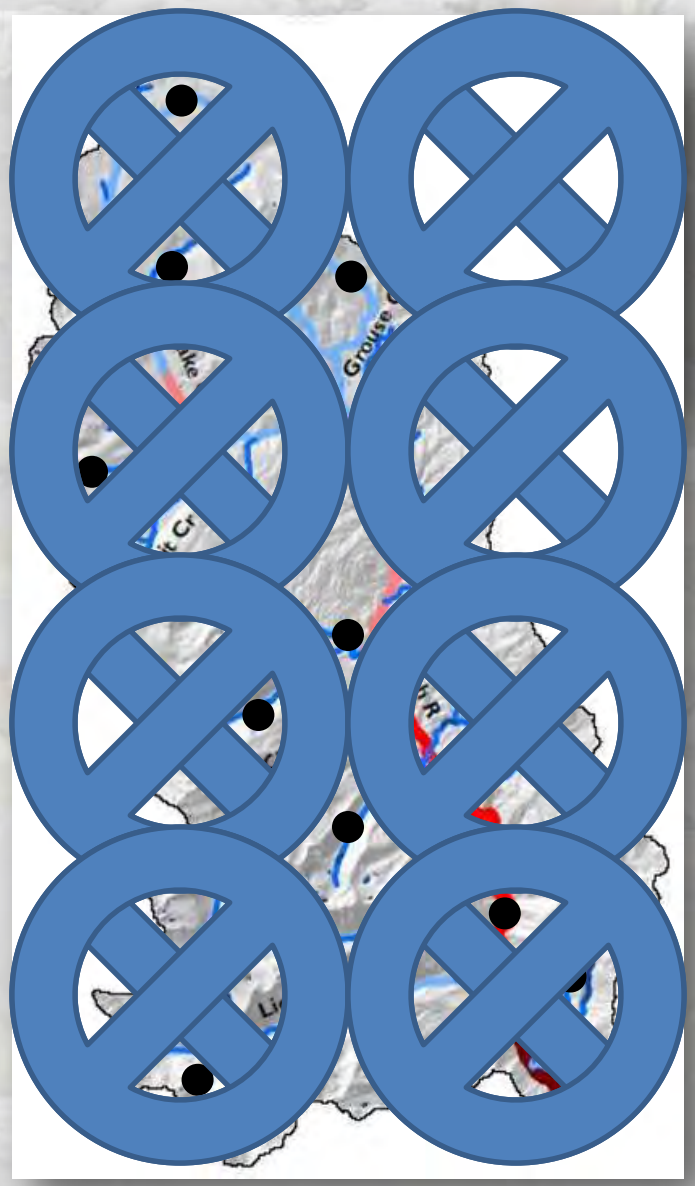
Where do Fish Fit in a Terrestrial World?

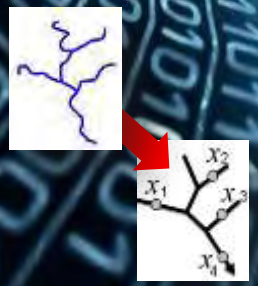
This is a Tree not a Fish



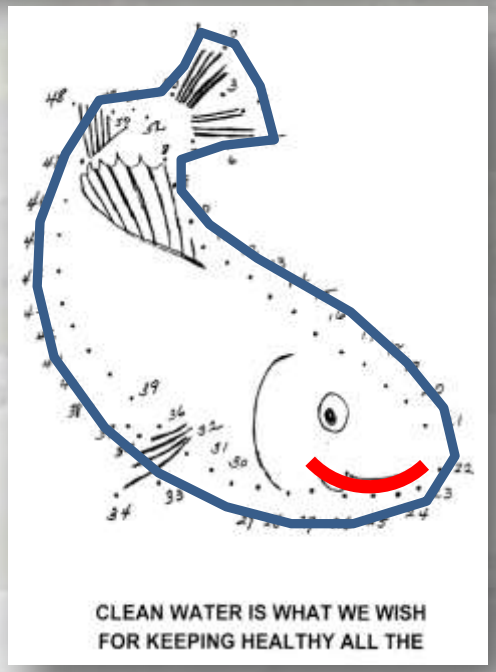
Stop Viewing Streams as Dots

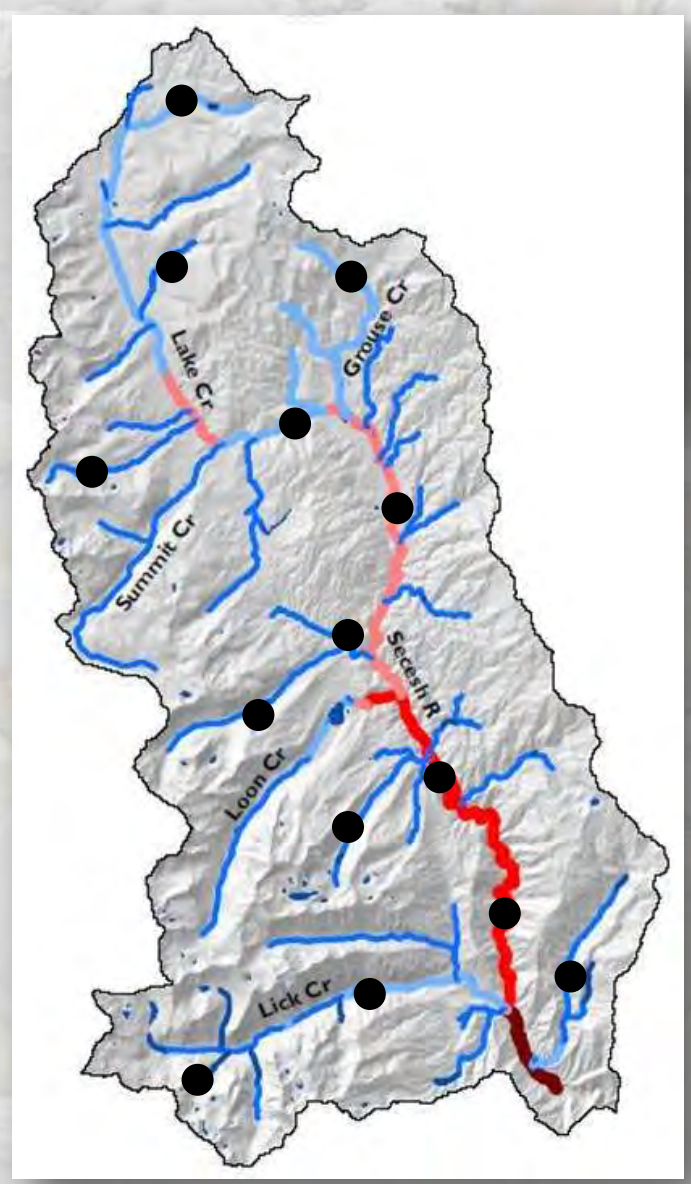


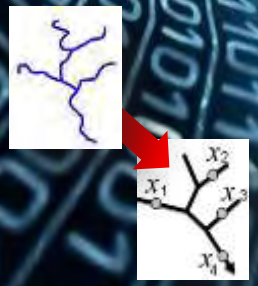




Stop Viewing Streams as Dots





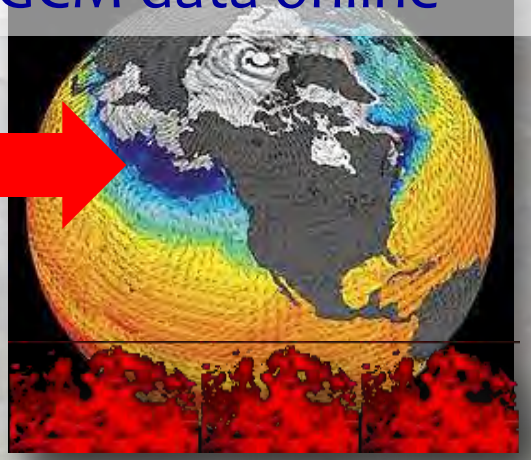


Geospatial Technologies, Digital Databases & Computing Horsepower

Remote Sensing

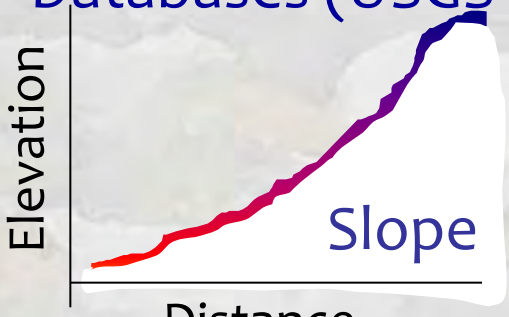
GIS / Computing Capacity

Climate, weather, GCM data online



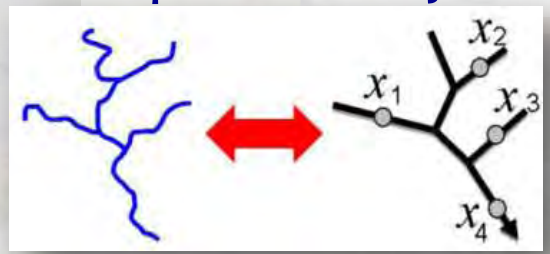
Visualization

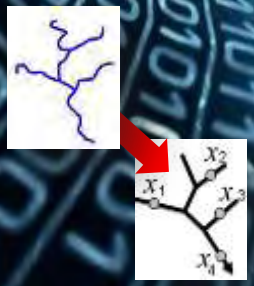
Nationally Consistent Hydrology Databases (USGS NHD+)



Drainage Area

Spatial analyses





A New Type of Statistical Model for Data on Stream Networks

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

ORIGINAL ARTICLE

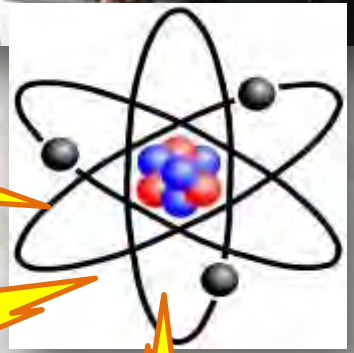
Spatial statistical models that use flow and stream distance

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:

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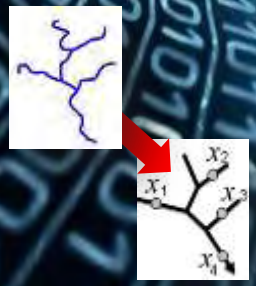
A. Wade
M.R. Sherburne

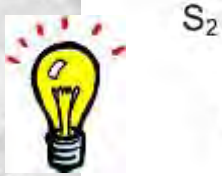
Spatial modelling and prediction on river networks: up model, down model or hybrid?

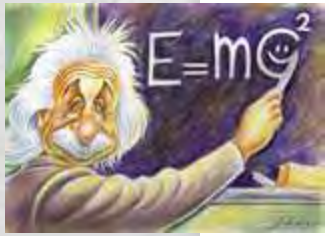
Vincent Garreta[1*,†], Pascal Monestiez[2] and Jay M. Ver Hoef[3]

[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*

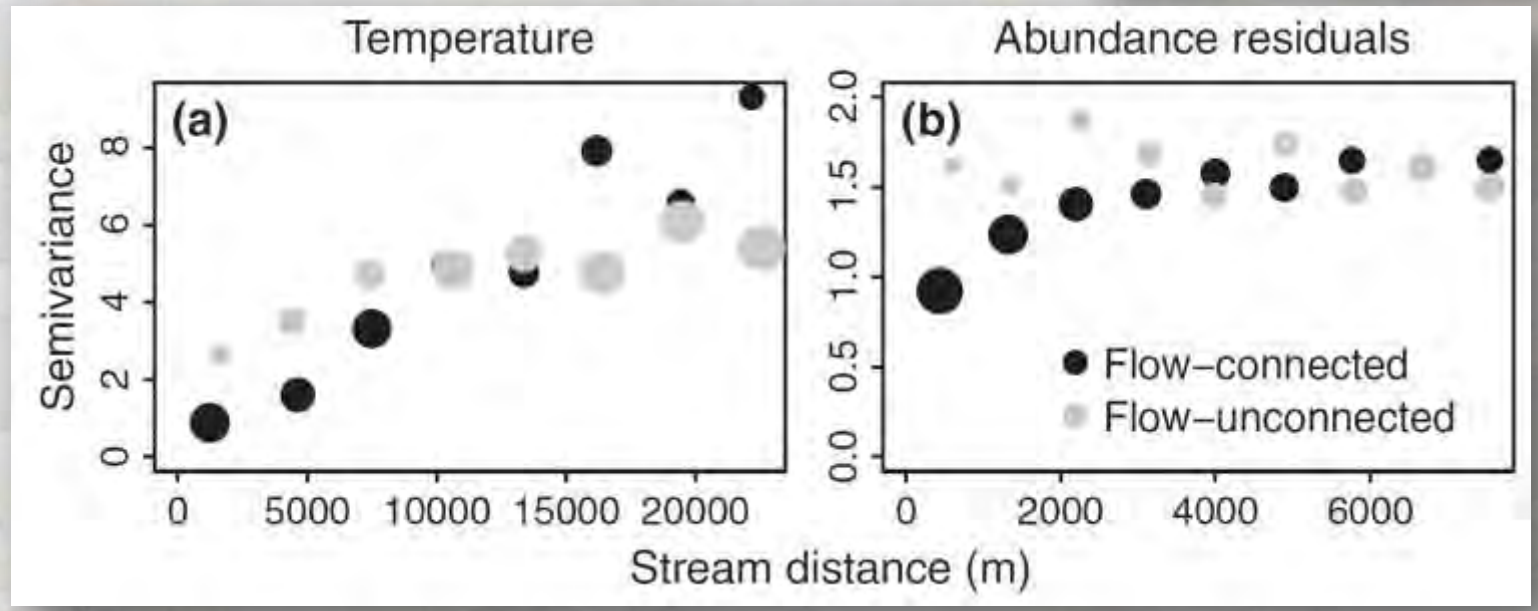


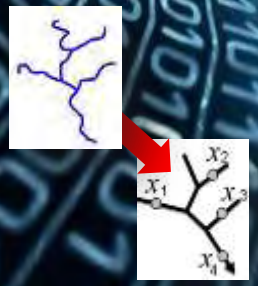
Key Innovation of Stream Models is Covariance Structure Based On Network Structure





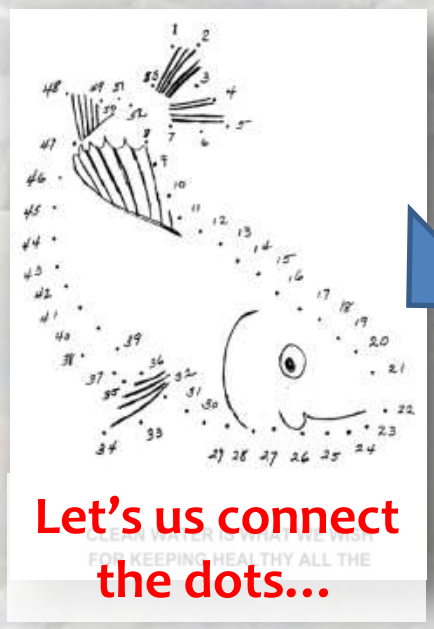
Models "understand" how information moves among locations based on network topology





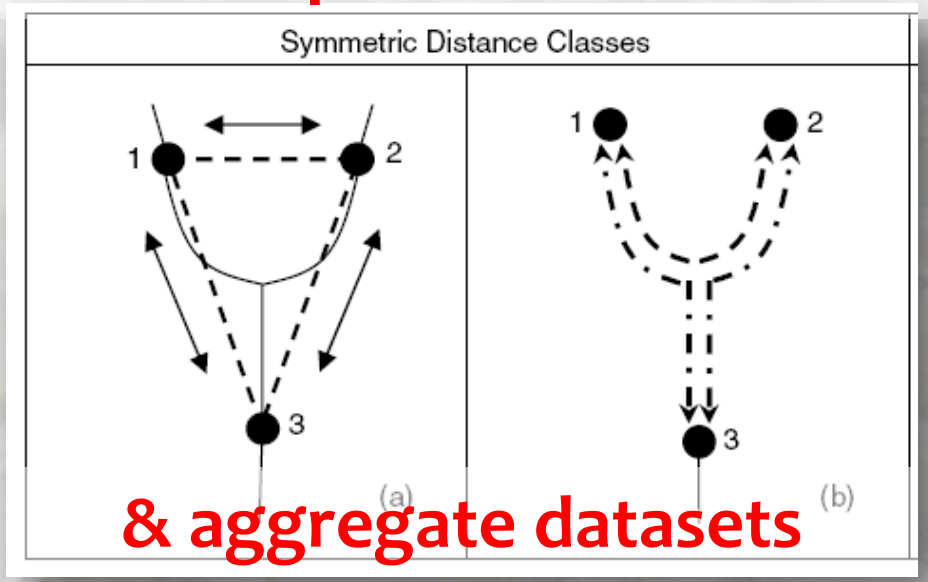
Peterson et al. 2007. *Freshwater Biology* **52**:267-279;
Peterson & Ver Hoef. 2010. *Ecology* **91**:644-651.

Spatial Statistical Network Models



Let's us connect the dots…

Valid interpolation on networks



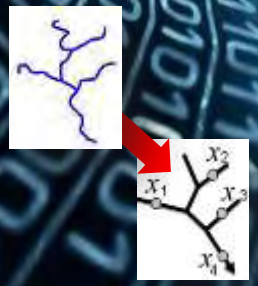
& aggregate datasets

Advantages:

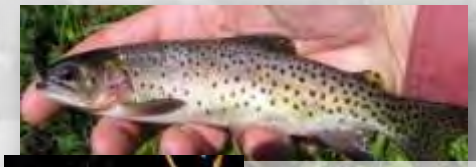
-flexible & valid autocovariance structures that accommodate network topology & non-independence among observations

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

Ver Hoef et al. 2006; Ver Hoef & Peterson 2010; Peterson & Ver Hoef 2013



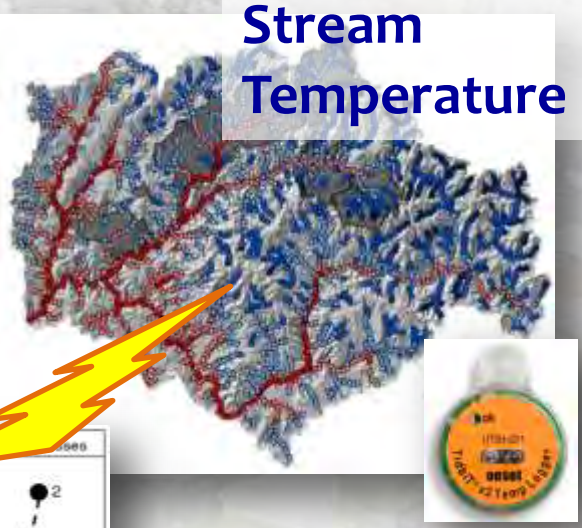
Stream Models are Generalizable…

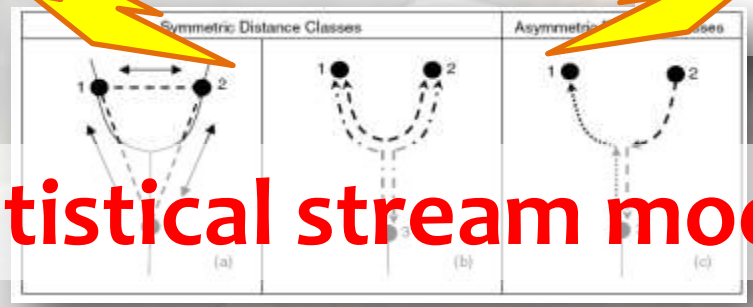


Response Metrics
- Gaussian
- Poissan
- Binomial

Distribution & abundance

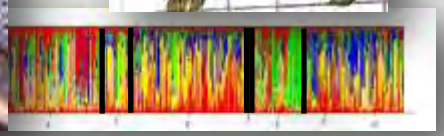
Stream Temperature



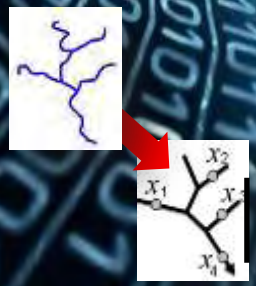


Statistical stream models

Genetic Attributes



Water Quality Parameters



Statistically Valid, Unbiased

Training on left 2007 validation on right Data from 200

Summer Mean

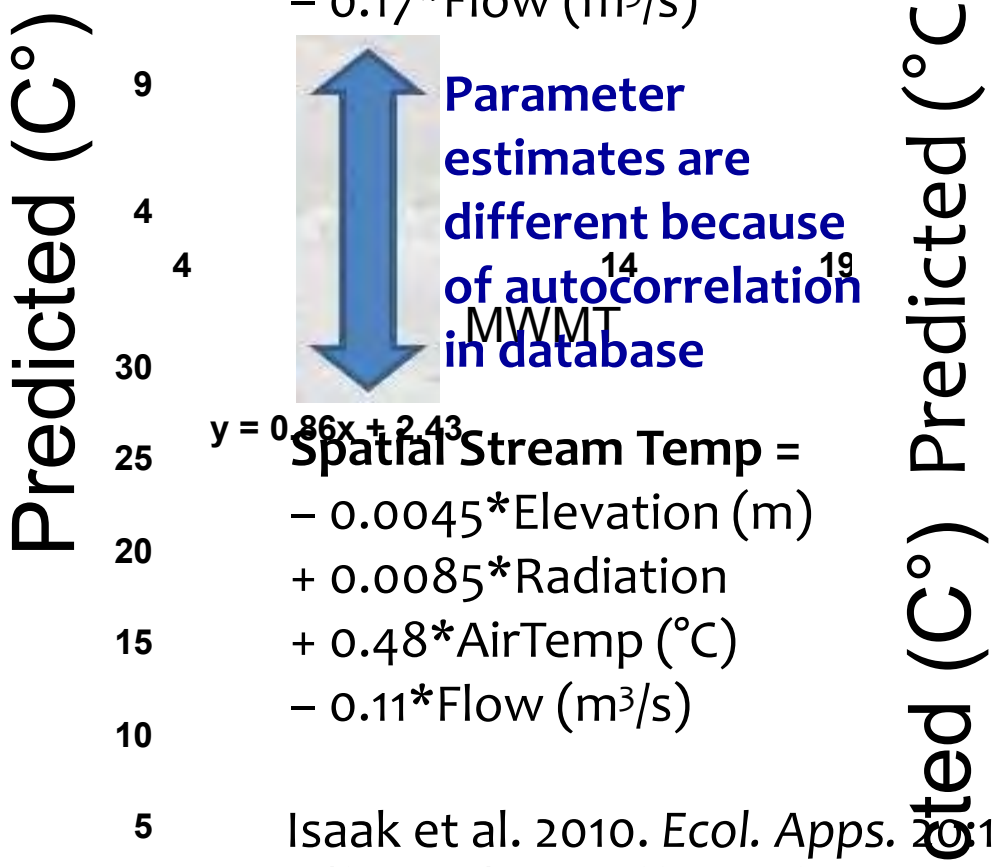
Non-spatial Stream Temp =

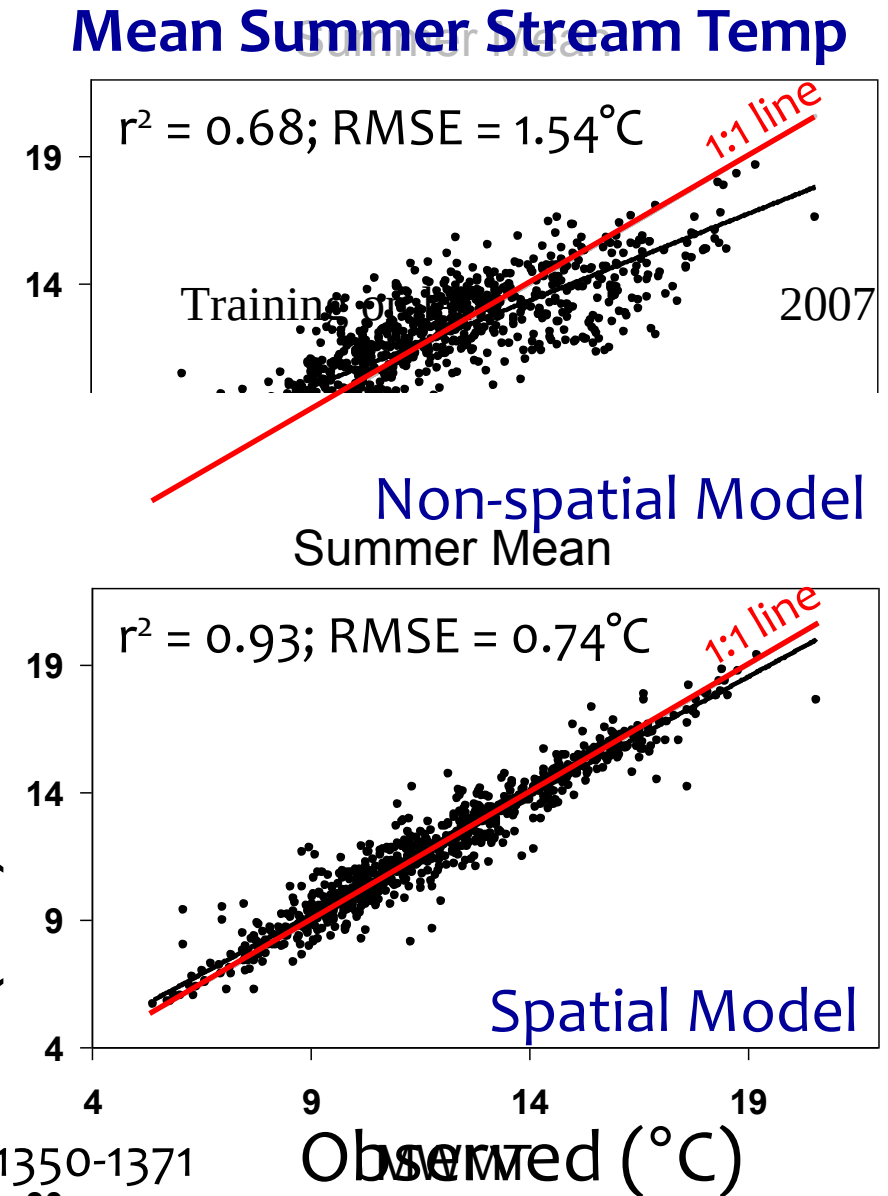
– 0.64*Elevation (m)
+ 0.0104*Radiation
+ 0.39*AirTemp (°C)
– 0.17*Flow (m³/s)

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 (m³/s)



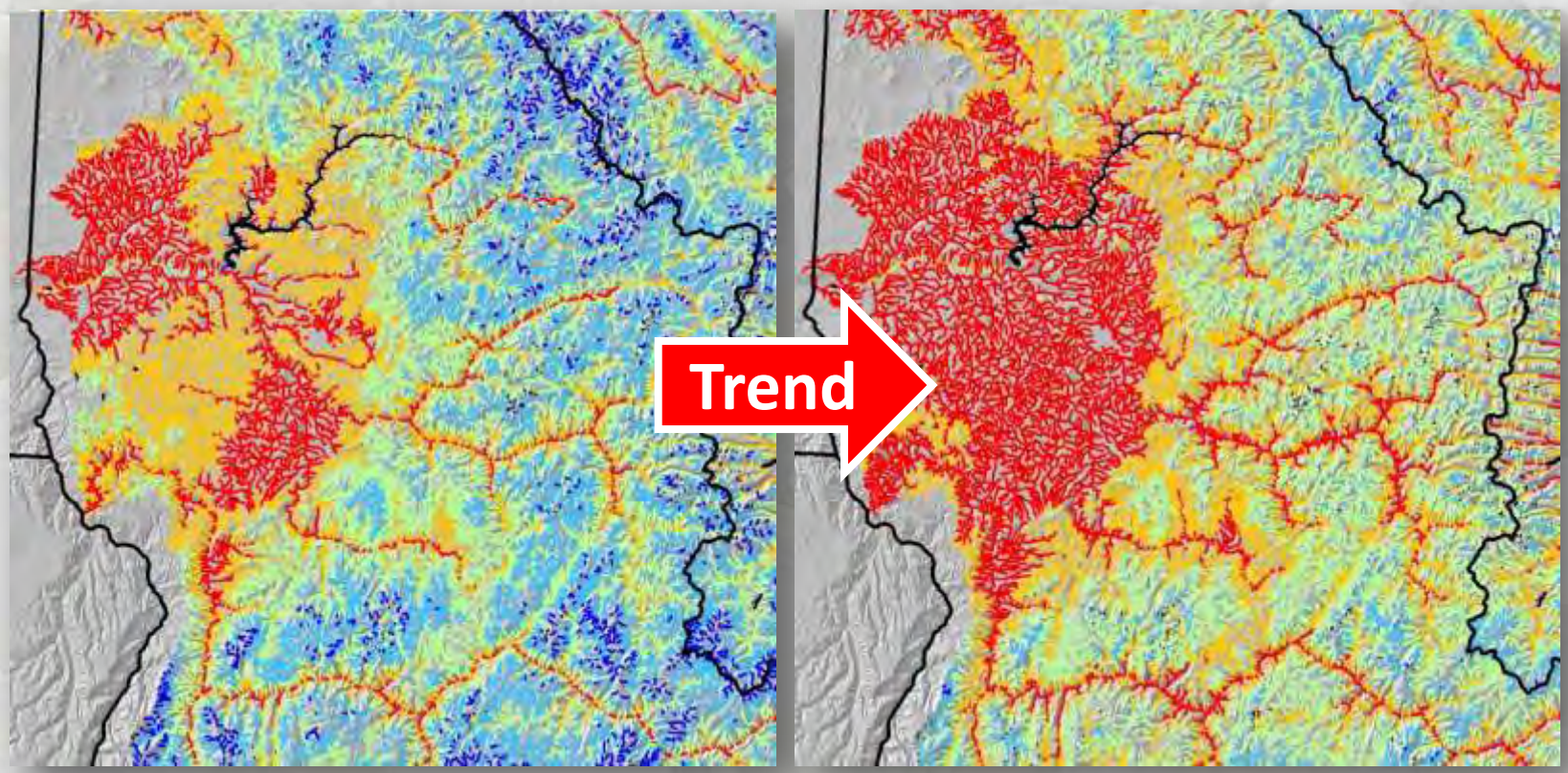


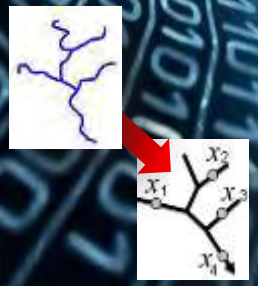
Isaak et al. 2010. *Ecol. Apps.* 20:1350-1371

Accurate Predictions at Sampled (& *Unsampled*) Locations Enable Spatially Continuous *Status* Maps

Time 1

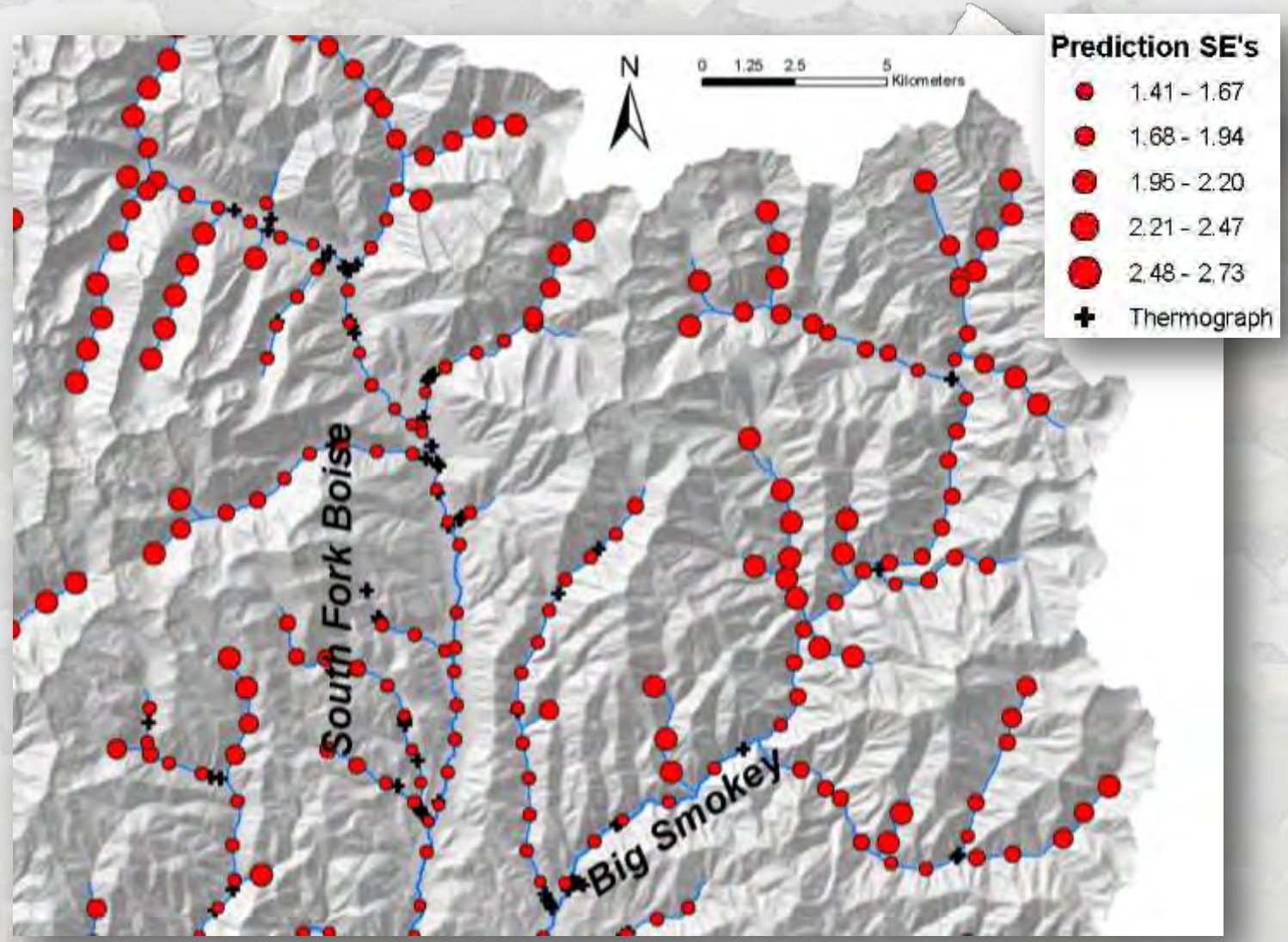
Time 2

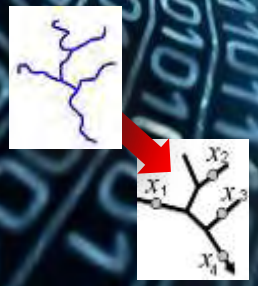




Which then facilitate trend assessments…

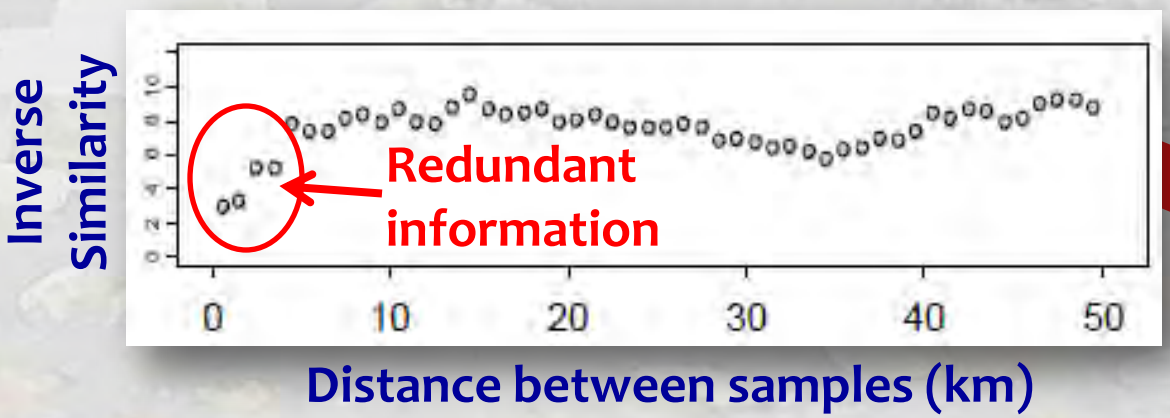
Spatial Variation in Prediction Precision

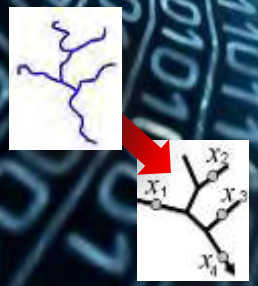




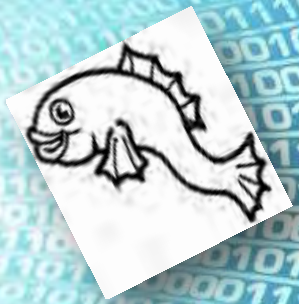
Designing Efficient Monitoring Designs

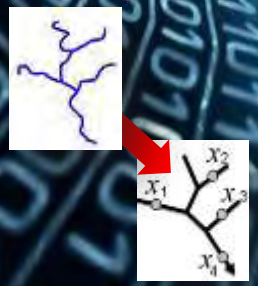
Models Describe Autocorrelation Distances





A BIG DATA challenge

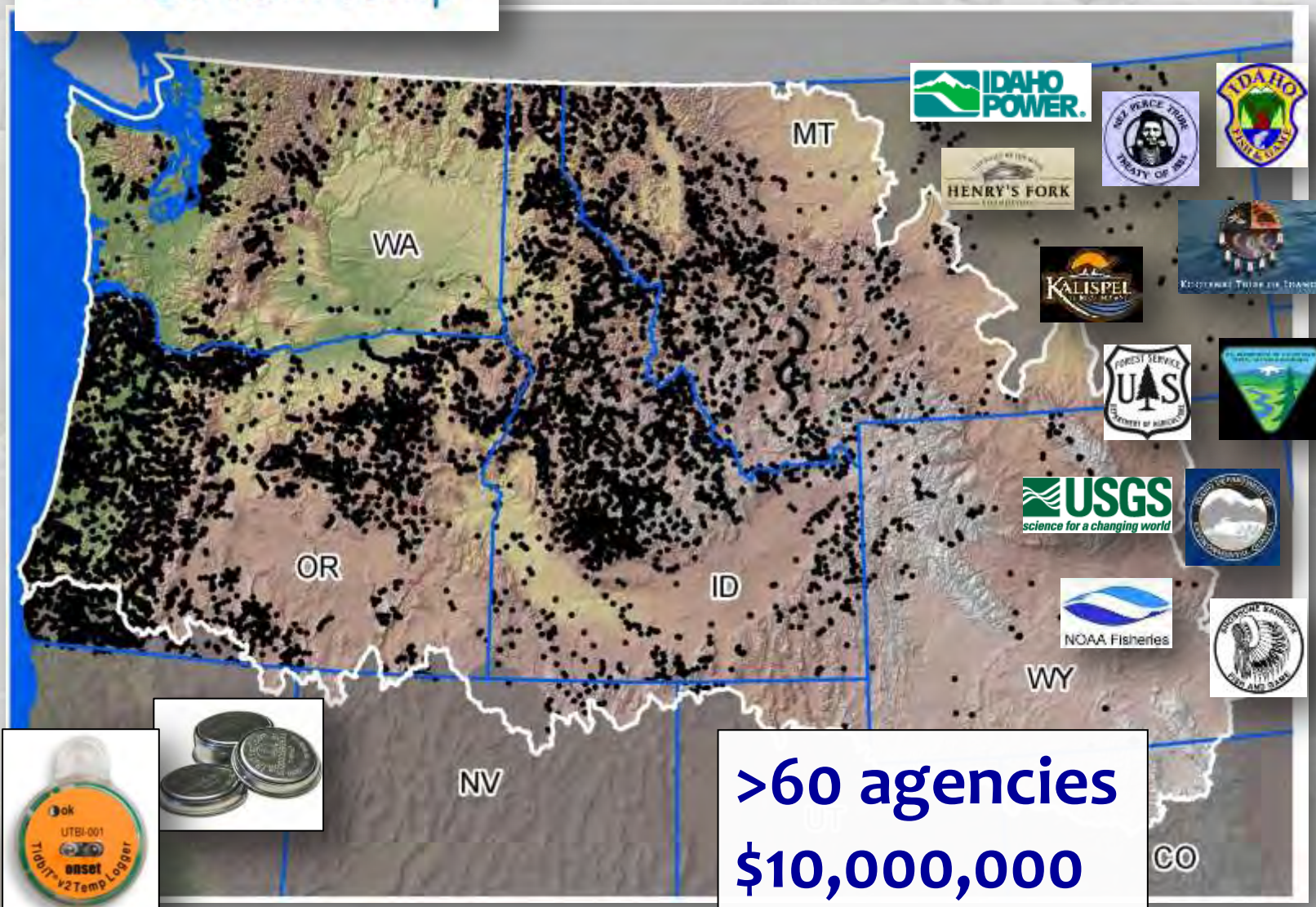




BIG DATA = BIG INFORMATION?

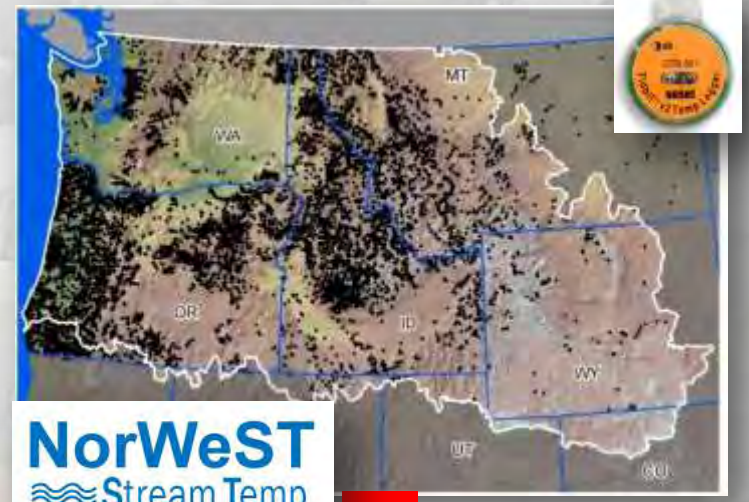
NorWeST Stream Temp

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



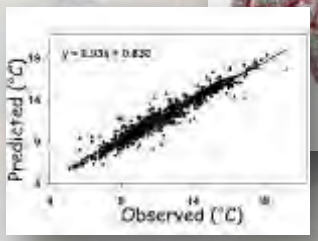
>60 agencies
$10,000,000

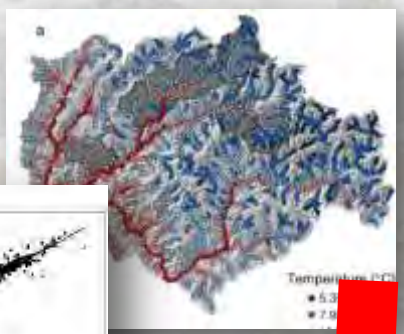
Regional Temperature Model



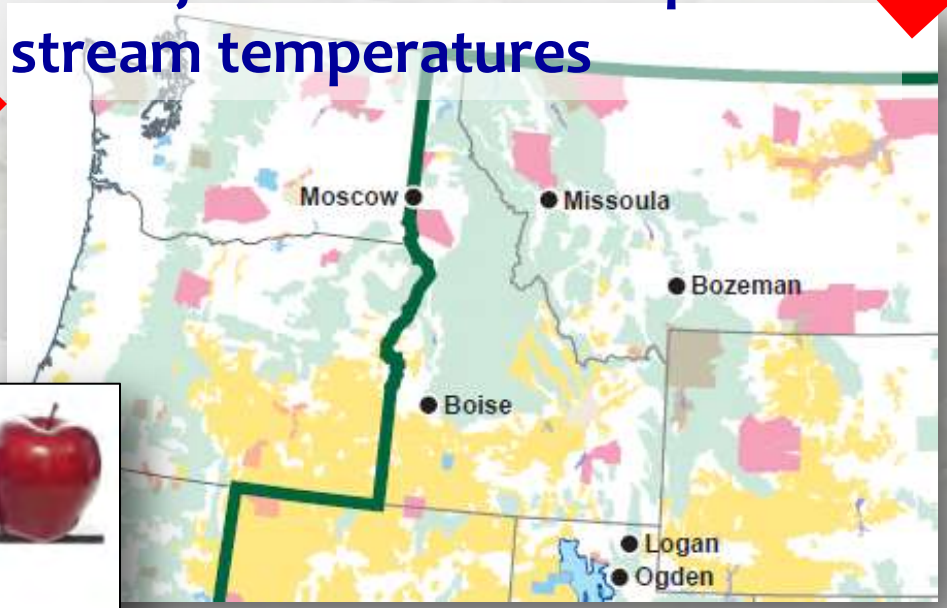
NorWeST Stream Temp

Accurate temperature models

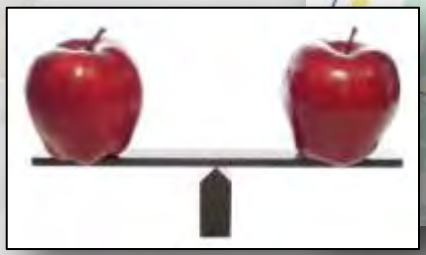


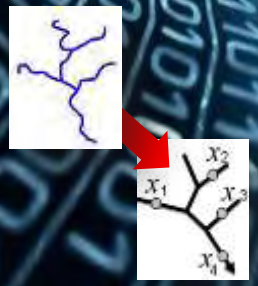


Cross-jurisdictional "maps" of stream temperatures

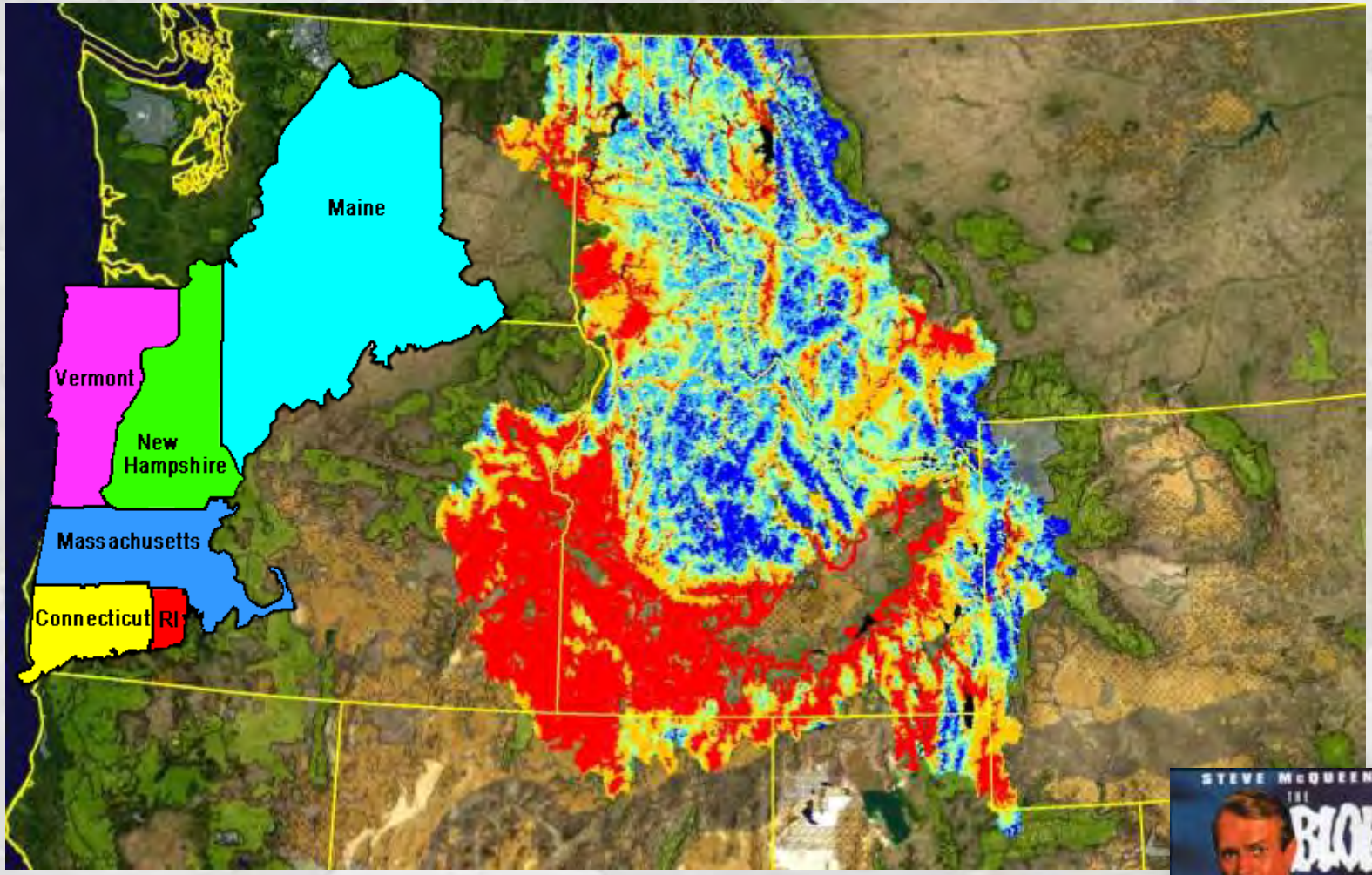


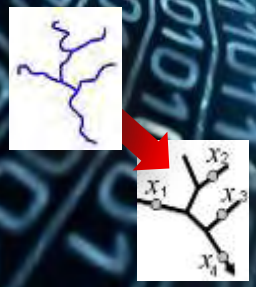
Consistent planning across 500,000 stream kilometers





Stream Thermalscape so Far…

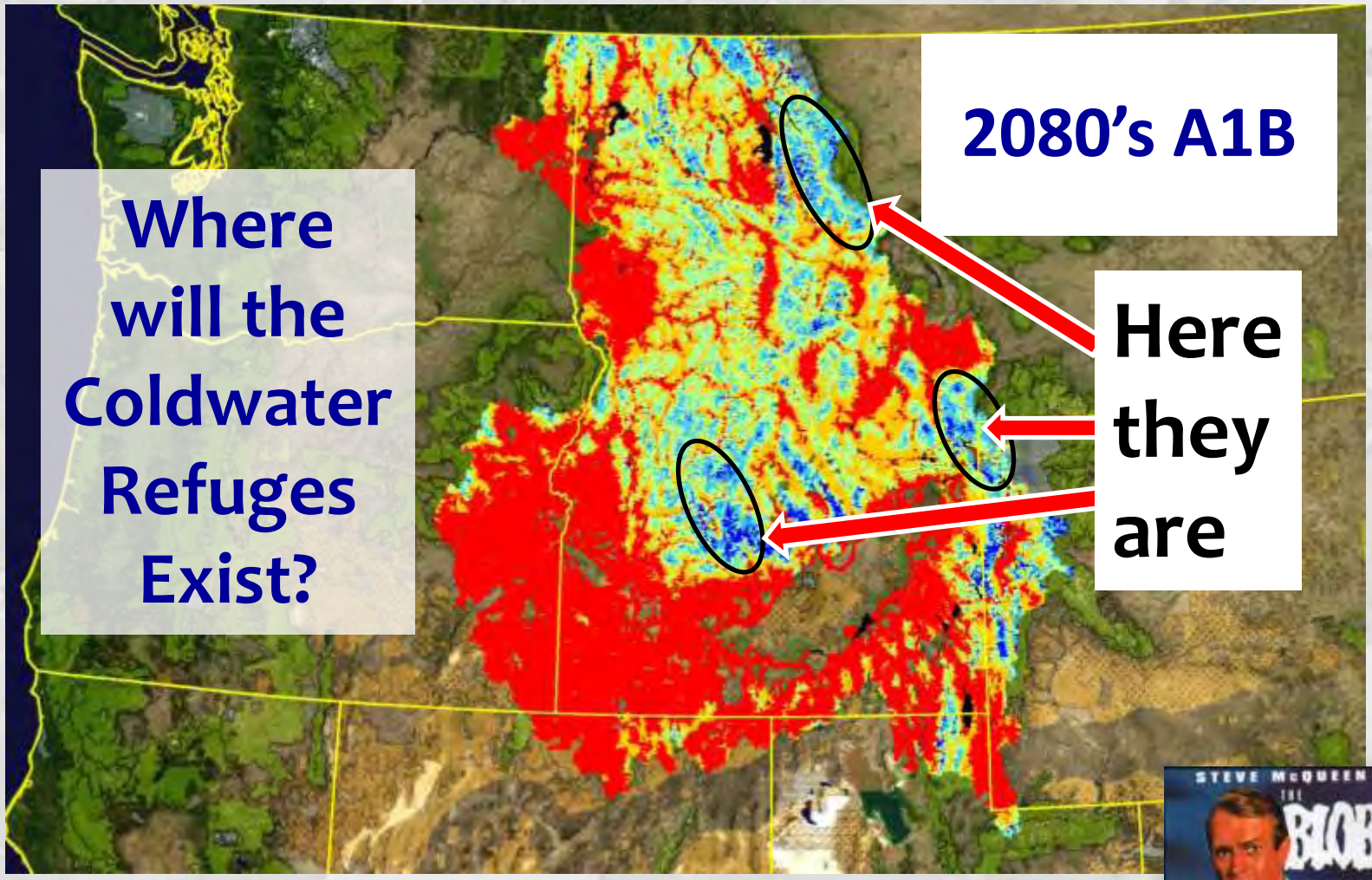


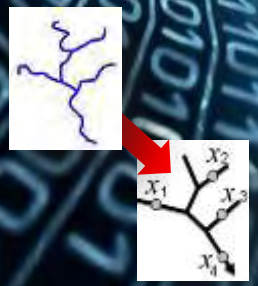


The BLOB… it just keeps growing…

- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed

BLOB Space, but BLOB time too…



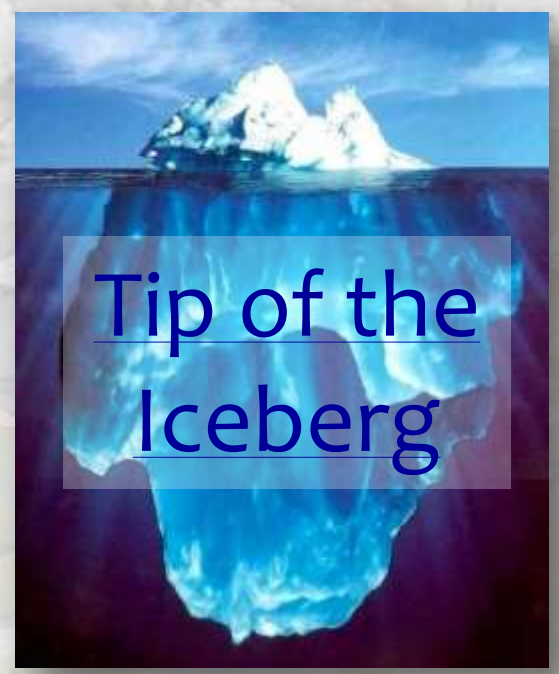


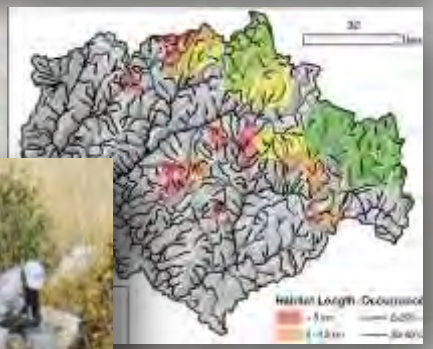
The BLOB… it just keeps growing…

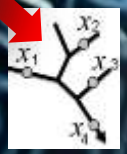
- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed

NorWeST Facilitates Related Projects

- Regional bull trout climate vulnerability assessment (J. Dunham)
- Cutthroat & bull trout climate decision support tools (Peterson et al., 2013)
- Landscape-scale bull trout monitoring protocol (Isaak et al. 2009)
- **Consistent thermal niche definitions (S. Wenger, In Prep.)**
- Efficient stream temperature monitoring designs

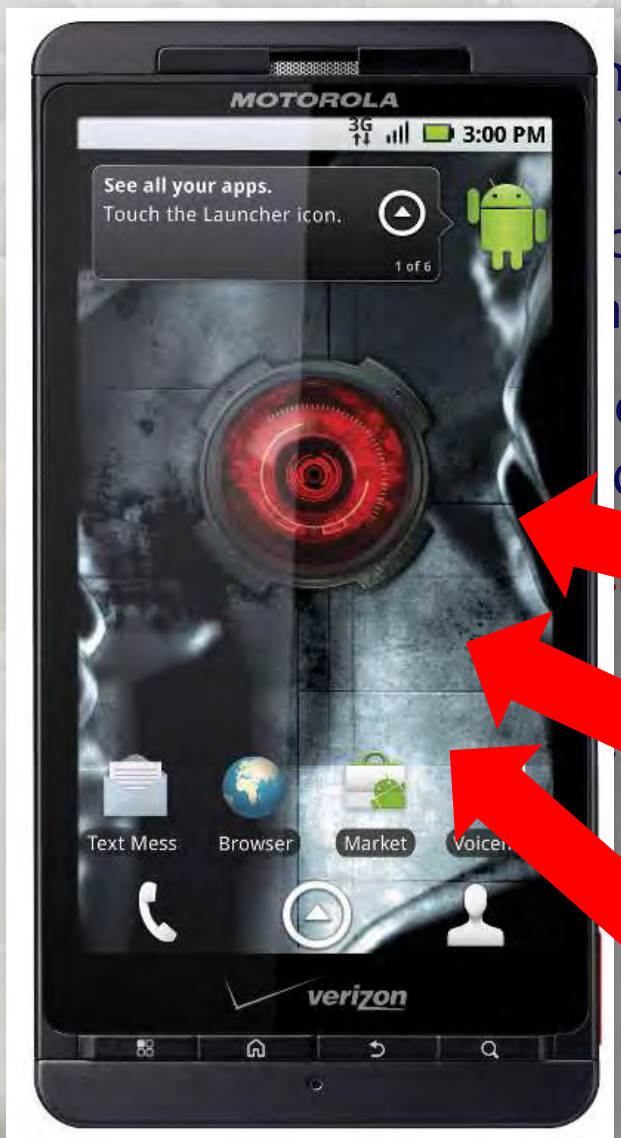


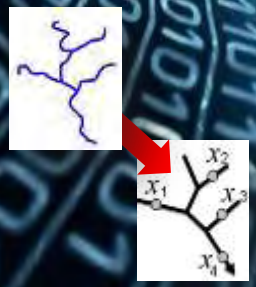


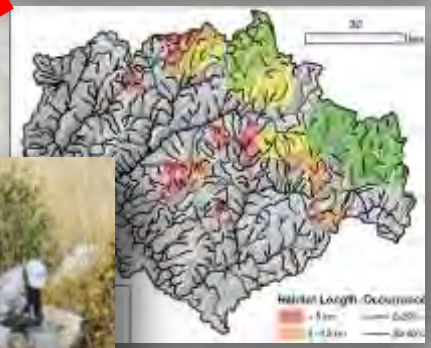


NorWeST Facilitates Related Projects

"Apps" Run on a Consistent Data Network

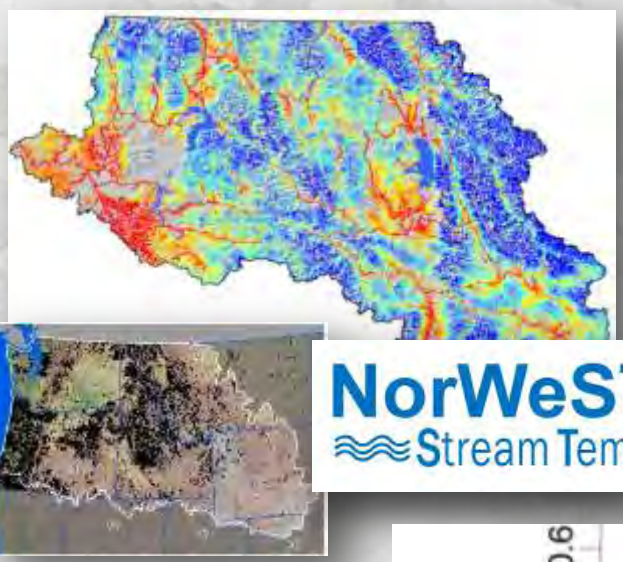






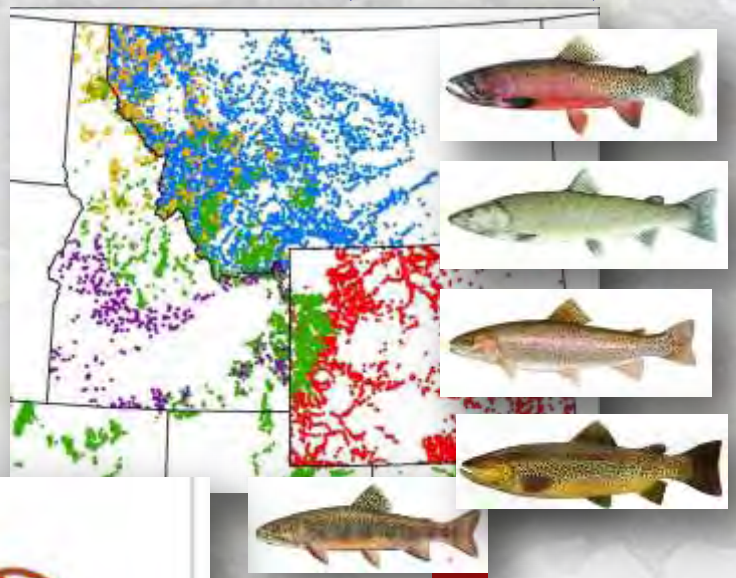
Stream Thermalscape Maps Enable Development of Useful Thermal Criteria

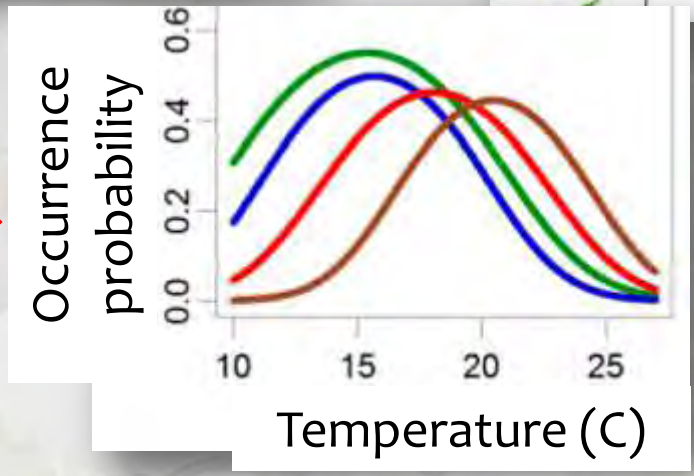
Stream temperature maps

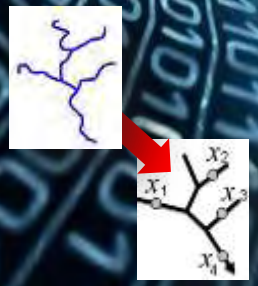


NorWeST Stream Temp

Regional fish survey databases (n ~ 20,000)





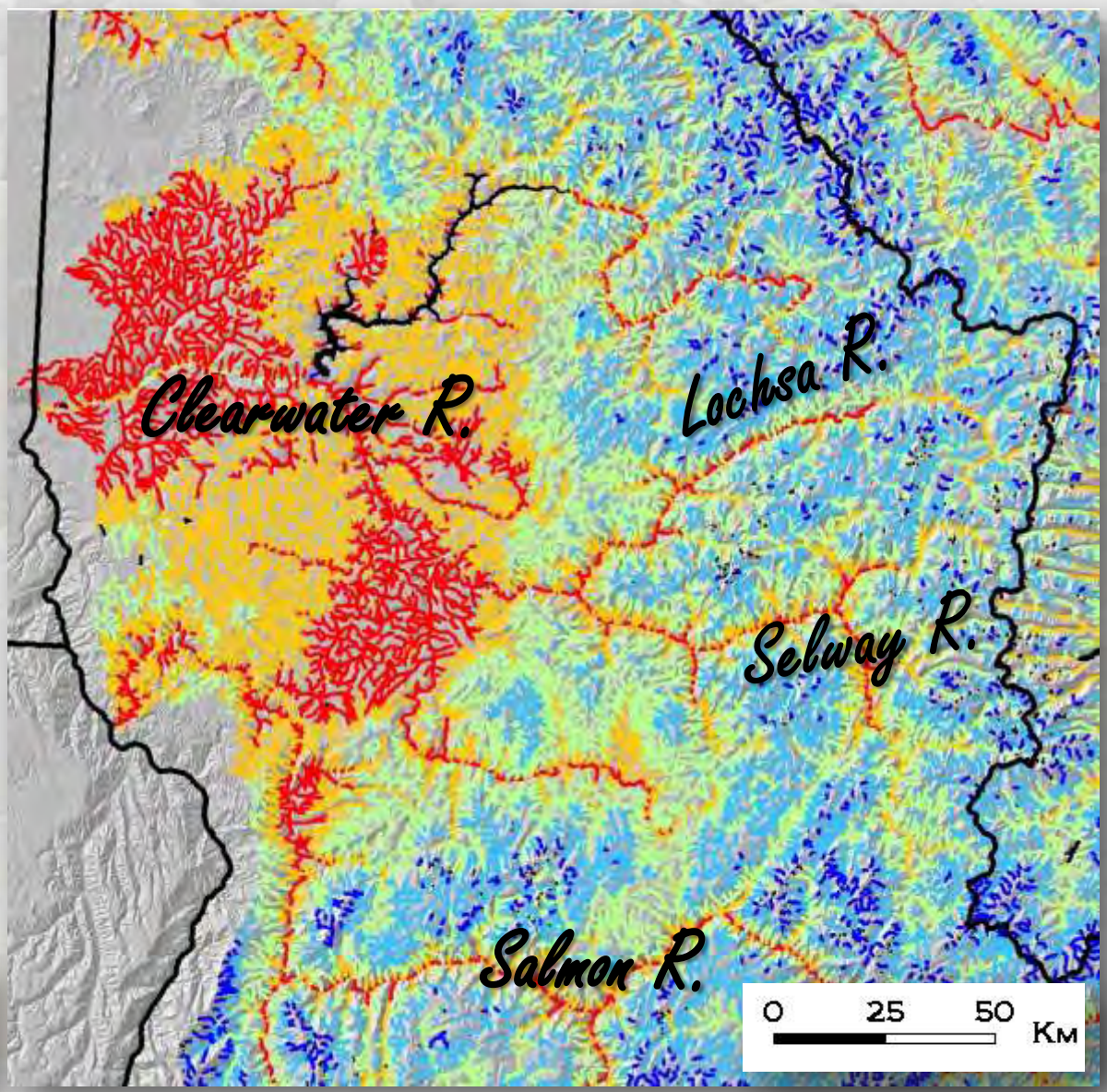


Wenger et al. 2011a. *PNAS* **108**:14175-14180

Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Clearwater Stream Temperature Scenario

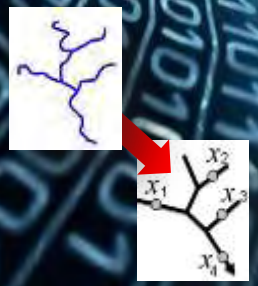
Historic (1993-2011 Average August)



Temperature (°C)

- 0.0 - 8.0
- 8.1 - 10.0
- 10.1 - 12.5
- 12.6 - 15.0
- > 15

1 kilometer resolution



Climate Effects on Bull Trout Thermal Habitat

Historic (1993-2011 Average August)

Suitable

Unsuitable

< 11.0°C

Clearwater R.

Lochsa R.

Selway R.

Salmon R.

Climate Effects on Bull Trout Thermal Habitat

+1.50˚C Stream Temp (~2040s)

Suitable

Unsuitable

< 11.0˚C

Clearwater R.

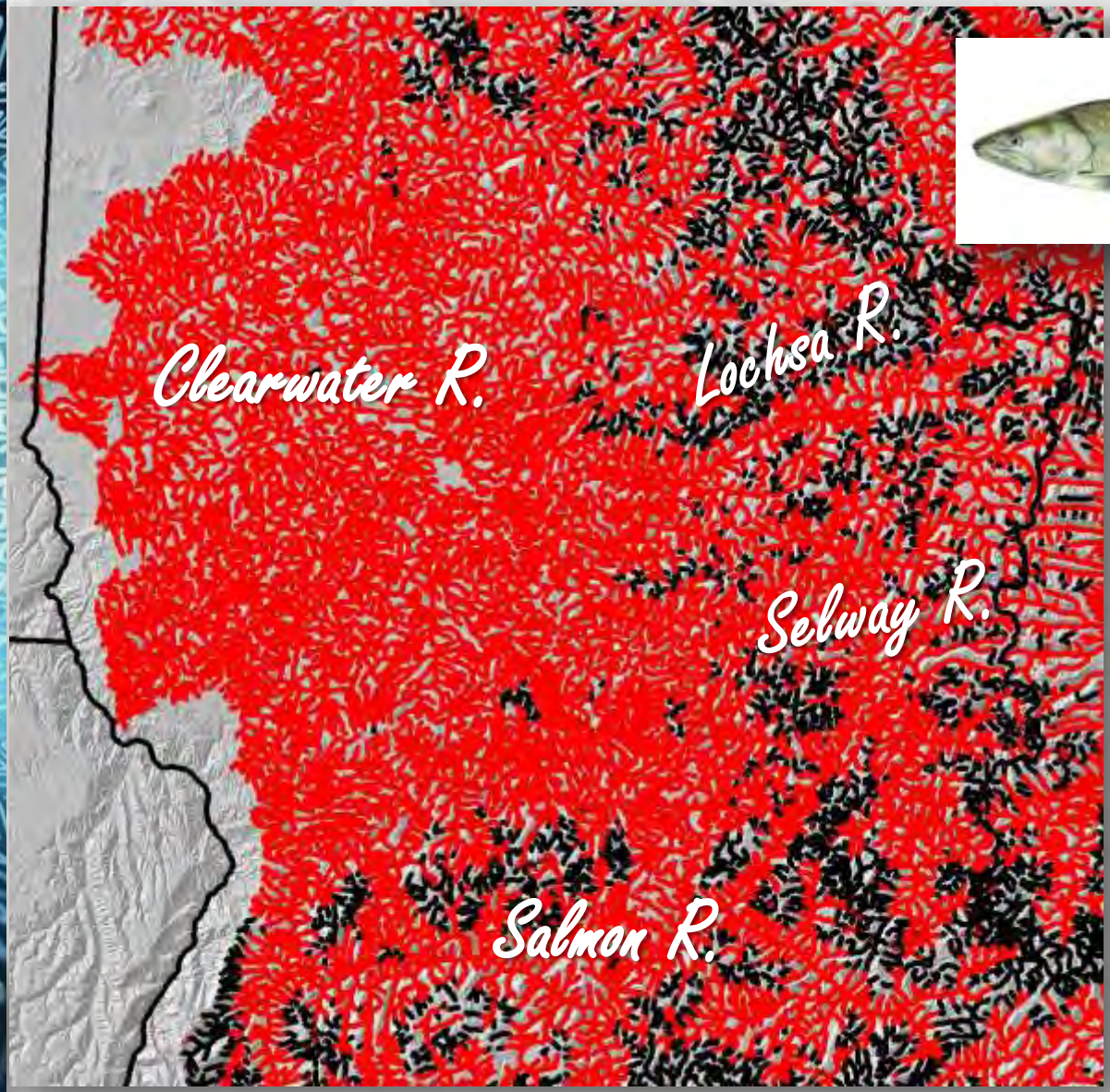
Lochsa R.

Selway R.

Salmon R.

Climate Effects on Bull Trout Thermal Habitat

+3.00˚C Stream Temp (~2080s)



Suitable

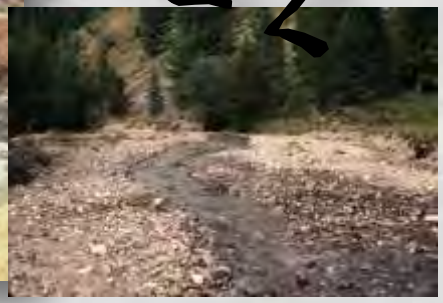
Unsuitable

< 11.0˚C

Strategic Prioritization of Habitat Restoration

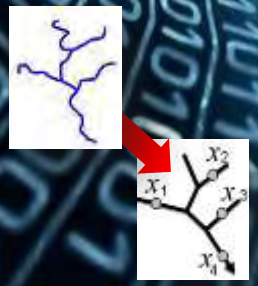
Lots of things we can do…

- Maintaining/restoring flow…
- Maintaining/restoring riparian…
- Restoring channel form/function…
- Prescribed burns limit wildfire risks…
- Non-native species control…
- Improve/impede fish passage…

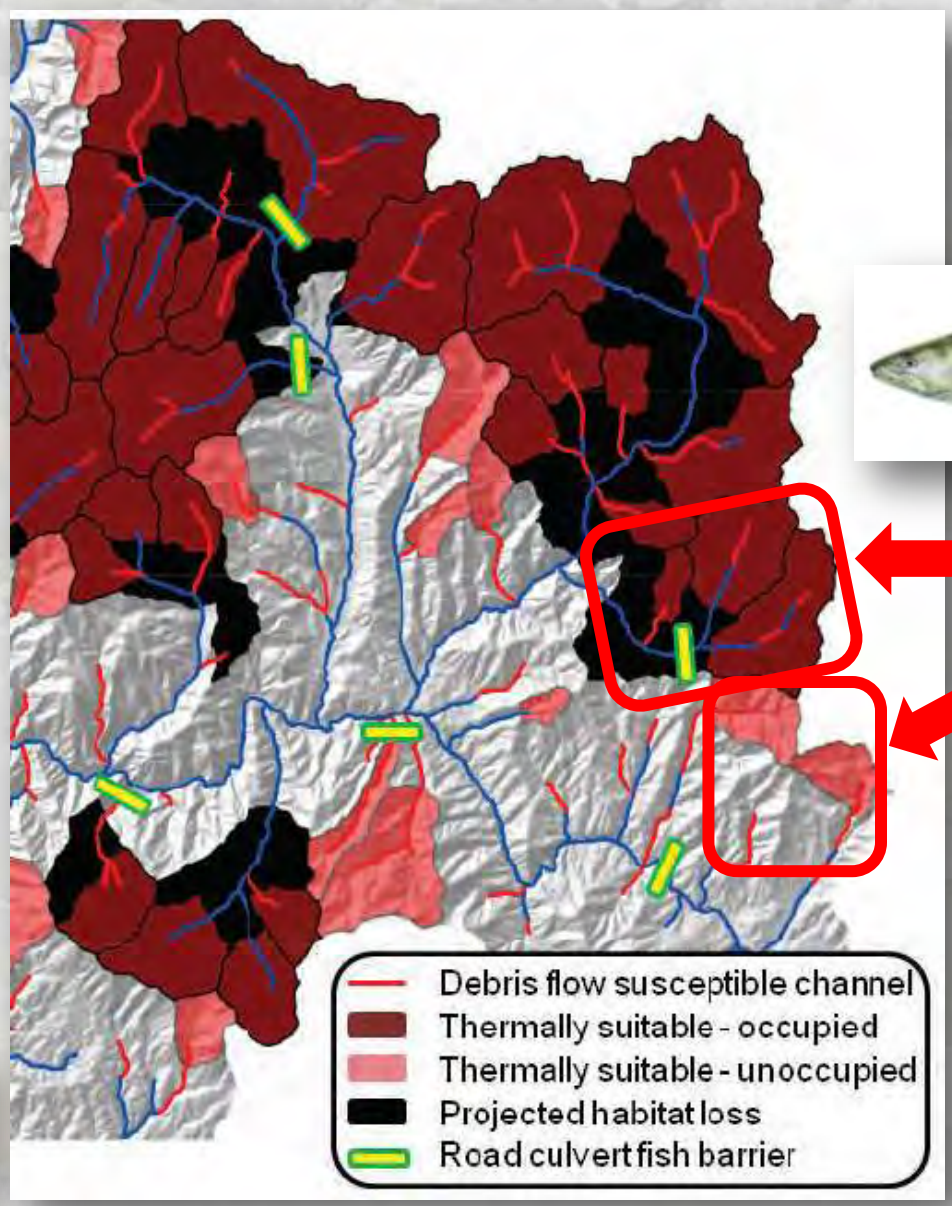


Low Priority

High Priority

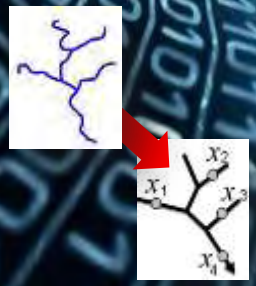


Precise Information Empowers Local Decision Makers & Strengthens Aquatic Social Networks

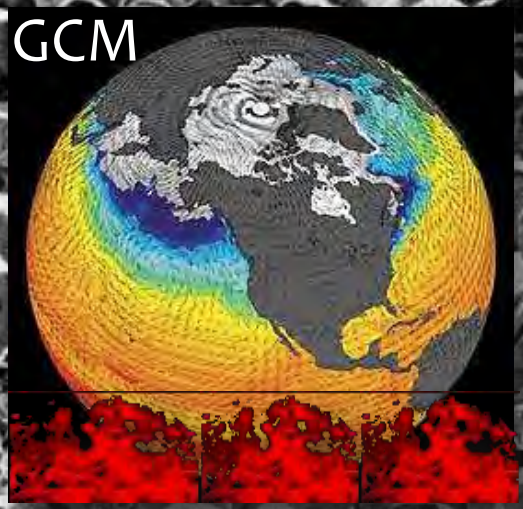


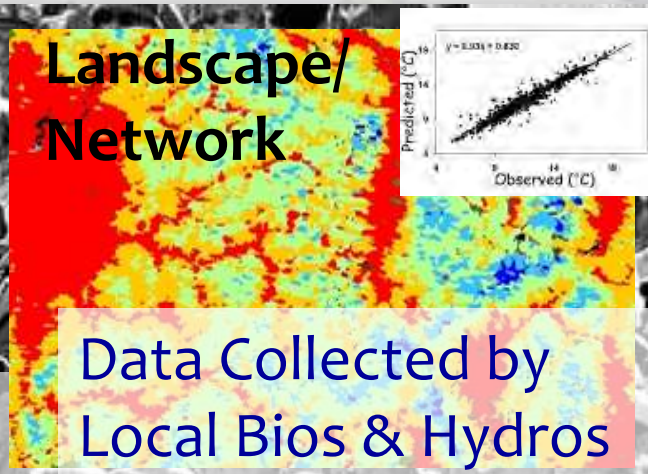
I'm going to invest here…

…instead of here



Everyone's Data is Used, Everyone is Engaged in the Process

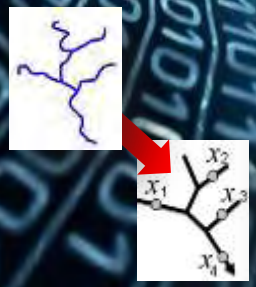




Data Collected by Local Bios & Hydros

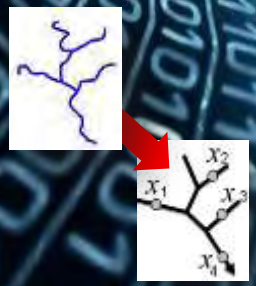
Coordinated, Effective Management Responses

Management Decisions



The BLOB has a dream…

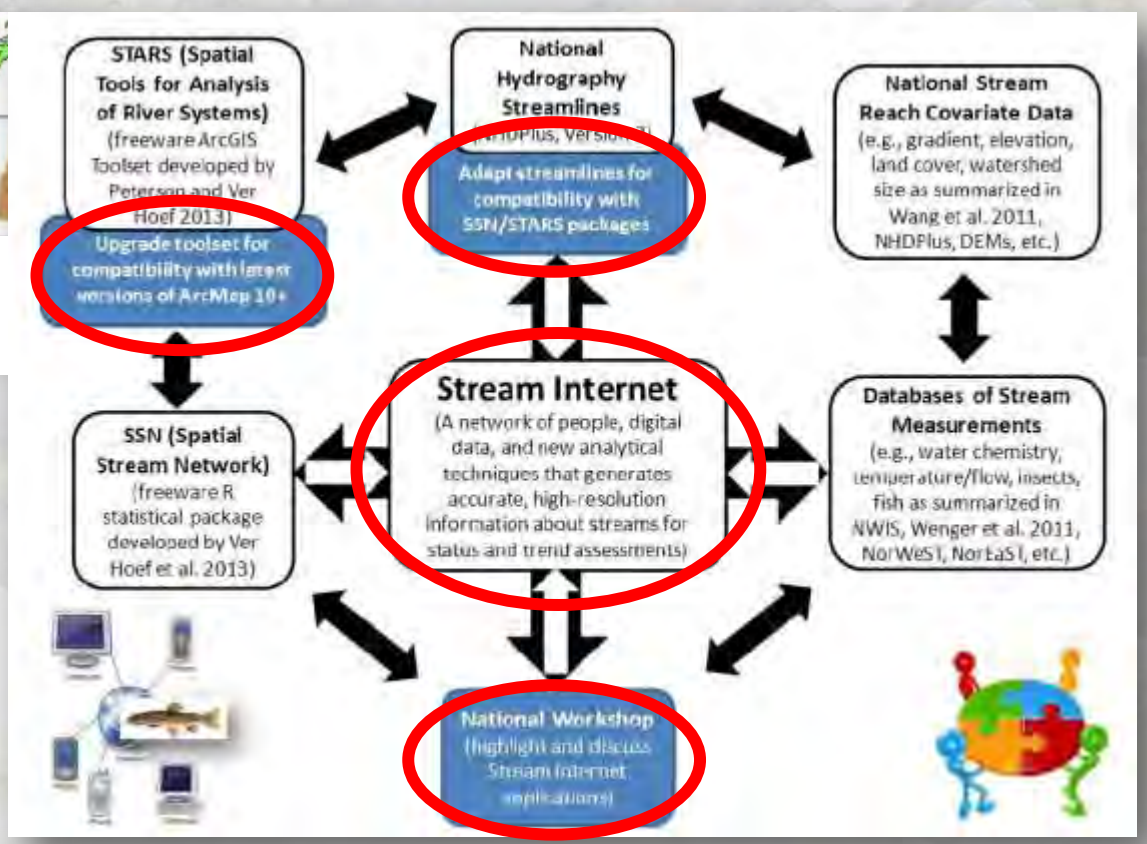
"What if I could eat data everywhere?"



Stream Internet Project Objectives

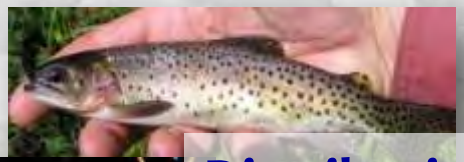
1) Develop compatibility between spatial stream analysis tools and national hydrography layer (USGS NHDPlus, v2)
2) Update STARS stream analysis tools to ArcMap 10.2
3) Host national workshop in 2015 to engage key researchers & leaders from aquatic programs (i.e., power-users)

Projects like NorWeST done routinely & incentives exist for database aggregation

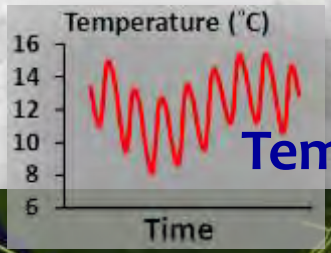


3 Easy Steps to Use the Stream Internet

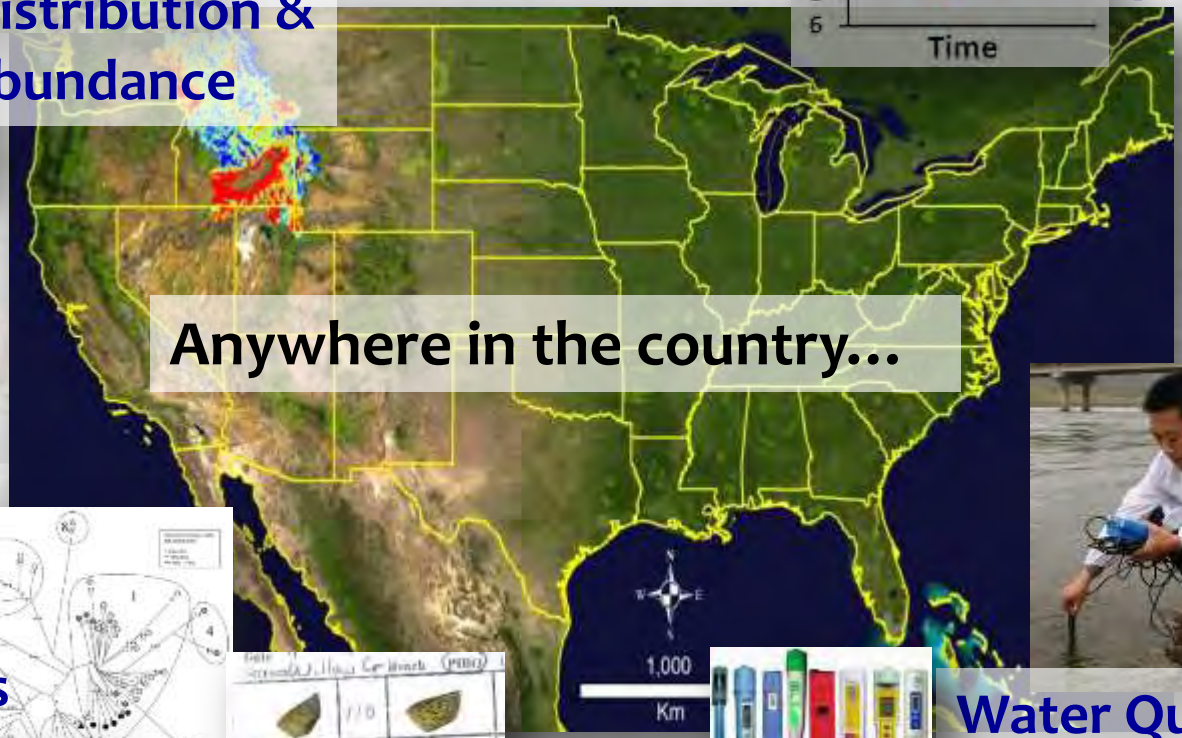
Step 1. Develop a Stream Database…



Distribution & abundance

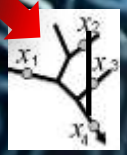


Stream Temperature



Anywhere in the country…

Genetic Attributes



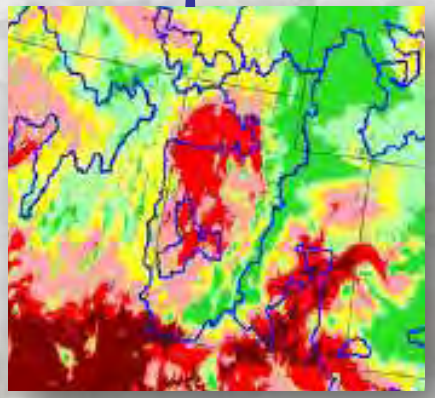
Water Quality Parameters

Step 2. Link to Covariate Predictors

100's are Available (NHDPlus, NLCD, DEMs…)

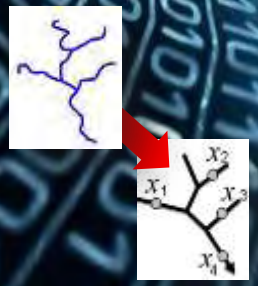
% Landuse

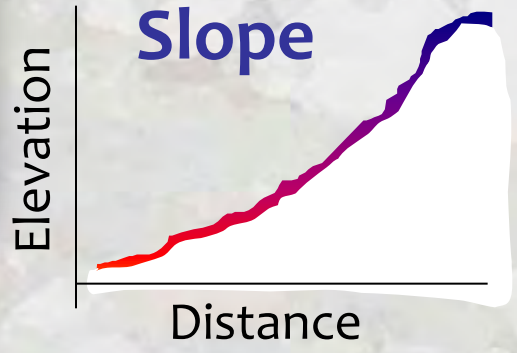
Precipitation



Drainage Area

Elevation

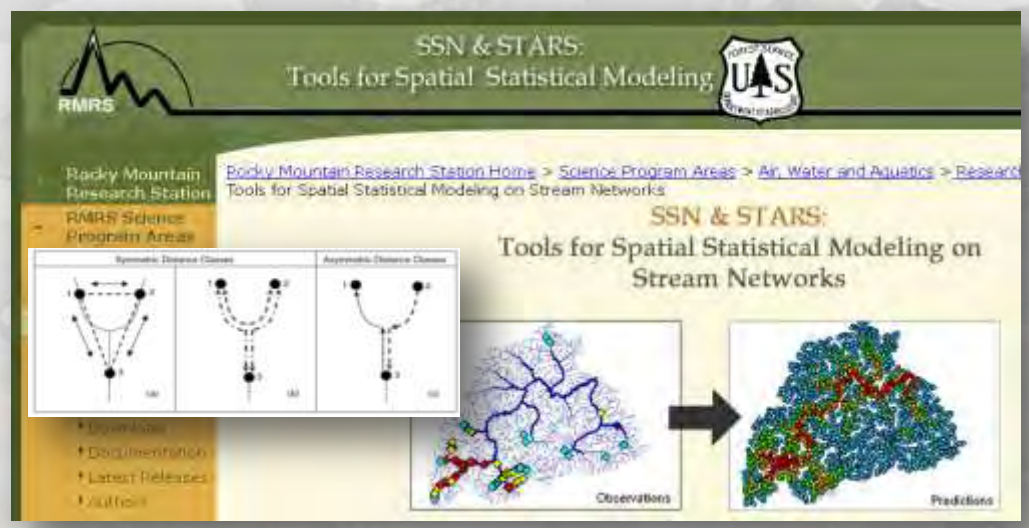




Wang et al. 2011. A Hierarchical Spatial Framework and Database for the National River Fish Habitat Condition Assessment. *Fisheries* **36**:436-449.

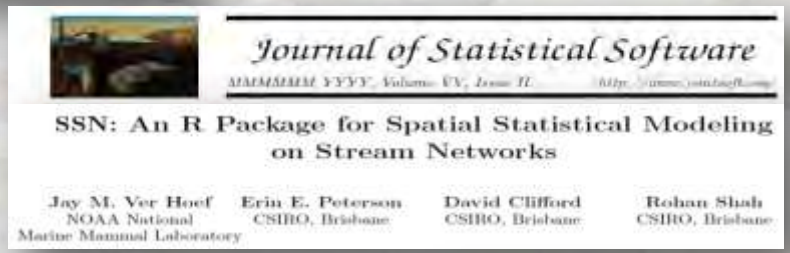
Step 3. Stream Statistical Analysis

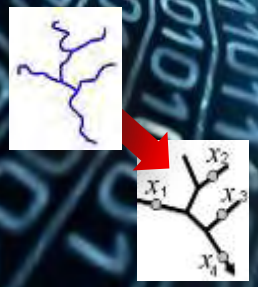
SSN/STARS Website – Free Software



Spatial Stream Networks (SSN) Package for R

- **Software**
- **Example Datasets**
- **Documentation**

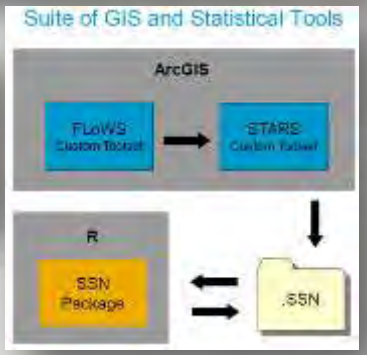




A Moving Average Approach for Spatial Statistical Models of Stream Networks

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



Stream Statistics User Community is Rapidly Developing

>11,000 Visits to SSN/STARS website in first year

>300 software downloads

Locations of visits to SSN/STARS website in last month

2nd Annual Training Workshop in Boise

May 15 – 17, prior to Joint Aquatic Sciences meeting in Portland

2nd Annual: Spatial Statistical Network Models Workshop

Co-sponsored by NOAA, CSIRO, USFS, IDAFS

WORKSHOP OVERVIEW

- Provide an overview of spatial statistical modeling on stream networks, including a discussion of when they are, or are not, useful
- Share two sets of free user-friendly tools:
  - STARS ArcGIS toolset
  - SSN package for R Statistical Software
- Demonstrate the GIS tools and the steps necessary to calculate the spatial information needed to fit a spatial statistical model in R
- Demonstrate the statistical tools and their functionality, using an existing stream temperature dataset:
  - spatial regression and prediction for continuous, presence/absence, and count data;
  - block kriging and prediction;
  - uncertainty estimation;
  - simulation; and
  - visualization techniques for spatio-temporal stream data

FREE SOFTWARE PACKAGES

STARS ArcGIS toolset
SSN package for R statistical software
http://www.fs.fed.us/rm/boise/AWAE/projects/SpatialStreamNetworks.shtml

AGENDA

Day 1: Overview of spatial statistical network models: theory, software, and applications (webinar & attendees)

Days 2 & 3: Work 1-on-1 with instructors to apply the spatial models to your datasets (attendees only)

COST	$300 (attendees) $60 (webinar viewers)
DATE	May 15 - 17
TIME	8:30 - 5:00
LOCATION	Idaho Water Center ½ mi from Grove Hotel 322 E Front Street Boise, Idaho

THE LATEST SCIENCE

Exciting new research questions have recently emerged in aquatic ecology; questions that are related to biological, ecological, and physical processes at multiple scales. Sparsely sampled locations make it difficult to recognize multi-scale patterns, and it is prohibitively costly to collect a continuous sample throughout space. Spatial statistical methods use spatial data efficiently, and can be used to investigate spatial

TO REGISTER, Go Here:
http://www.idahowfo.org/
or email Dan Isaak
(disaak@fs.fed.us)

Attendance limited to 15 participants
Webinar viewers are unlimited!

SCIENCE CONTACTS

Dr. Jay M. Ver Hoef
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Alaska Fisheries Science Center
jay.verhoef@noaa.gov

Dr. Erin E. Peterson
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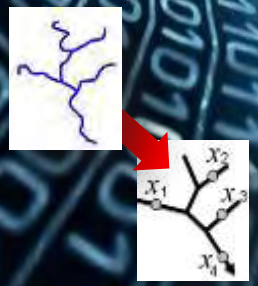
Dr. Daniel J. Isaak
US Forest Service
Rocky Mountain Research Station
disaak@fs.fed.us



Idaho Water Center

3 day workshop

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

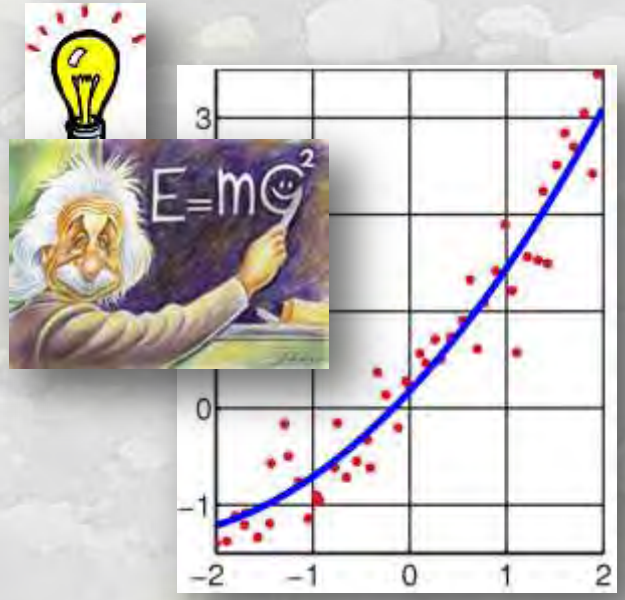
2nd/3rd days: work 1-on-1 with Jay/Erin to model your data

Attendees (15 people); 1st day webinar viewers (unlimited)

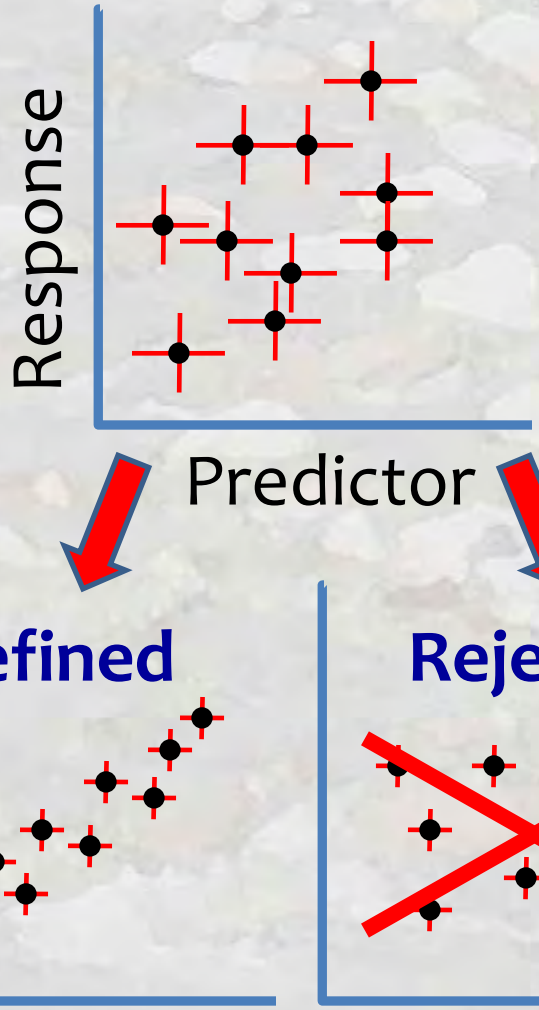
If Interested, contact Dan Isaak (disaak@fs.fed.us) or go to the SSN/STARS website for registration details

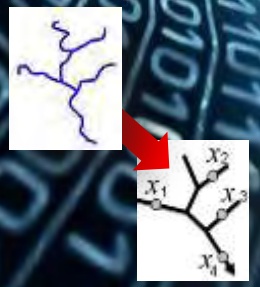
Better Understanding & Prediction for Streams & Rivers

New relationships described



Old relationships tested





NFHP & Stream Internet Are Strongly Synergistic

NATIONAL FISH HABITAT PARTNERSHIP

7 Annual conservation targets

6 National conservation strategies

4 FHP strategic priorities

3 FHP performance evaluation

2 FHP organizational development
- Governance
- Diversity
- Leveraging

5 Habitat assessment
- National
- Regional

Science

1 Community of support
- Board
- FHPs

Partnership

8 Performance-based allocation (FWS)

9 Project prioritization criteria

FHP priority projects

10 Effectiveness measurement

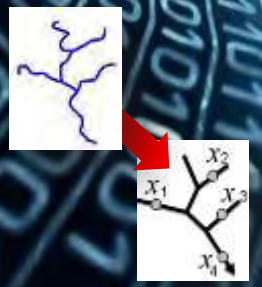
11 Project tracking

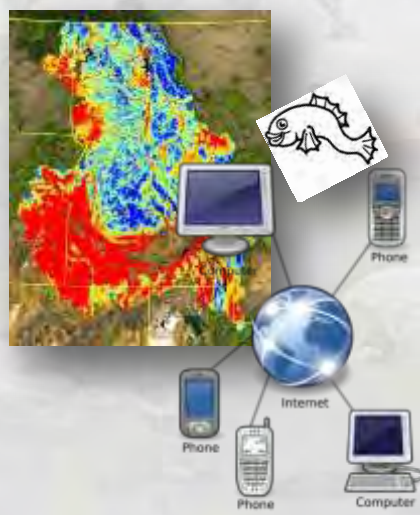
12 Waters to Watch

13

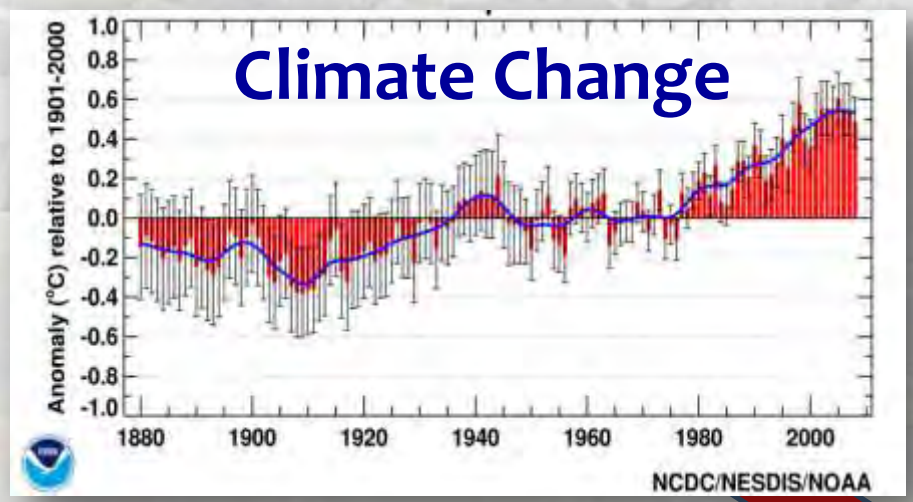
14 Measurable conservation results

Conservation





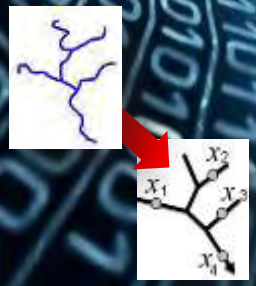
More Pressure, Fewer Resources



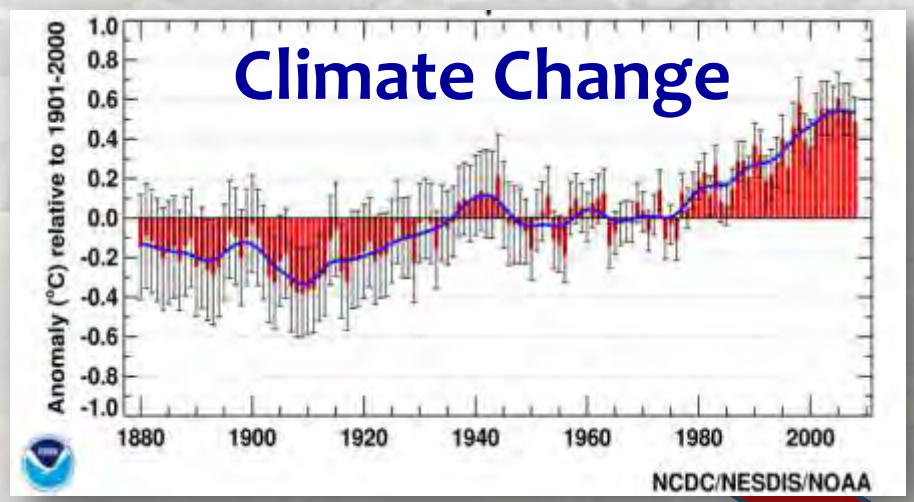
Urbanization & Population Growth

Shrinking Budgets

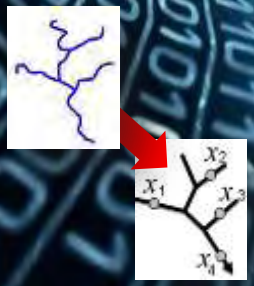
Need to do more with less



More With Less, but What If…
It was Much More?



Shrinking Budgets



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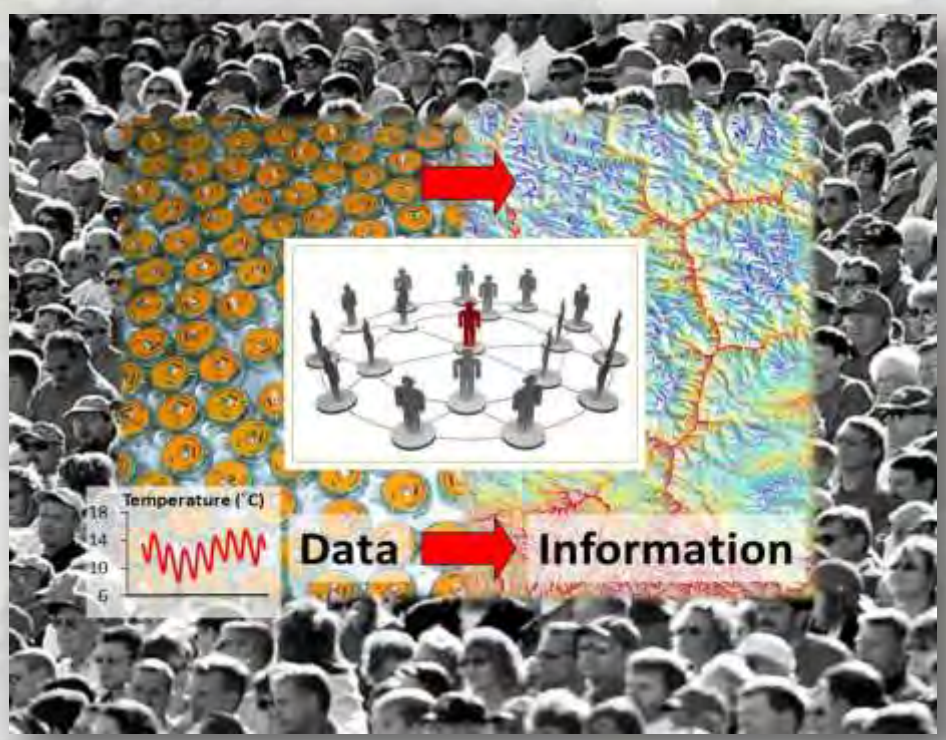
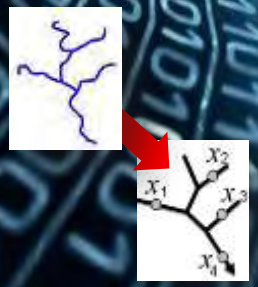
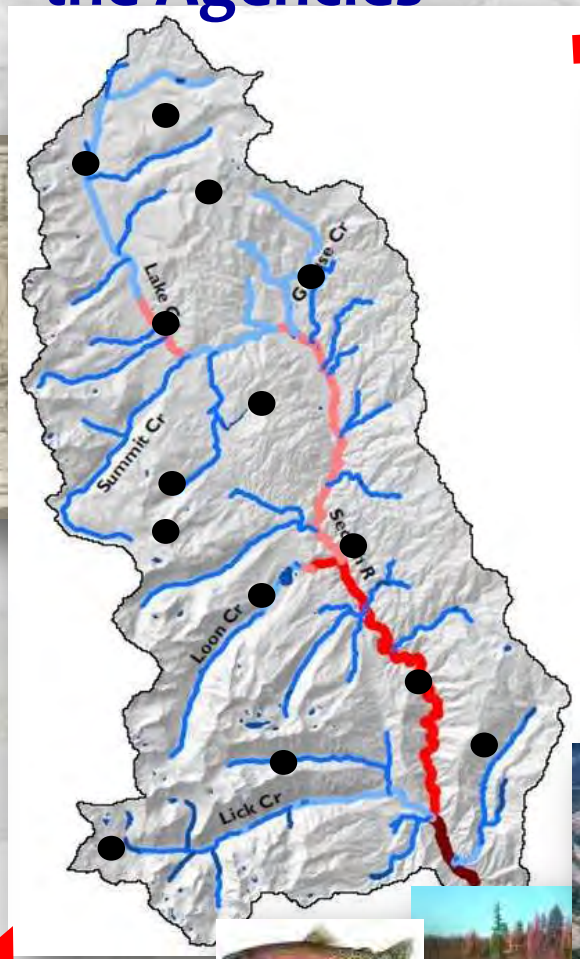
stream



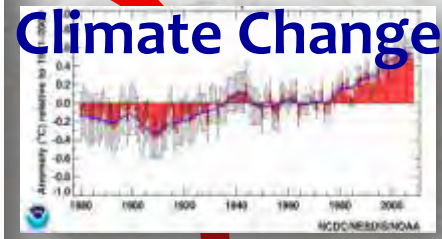


Connect the Dots to Map the Future

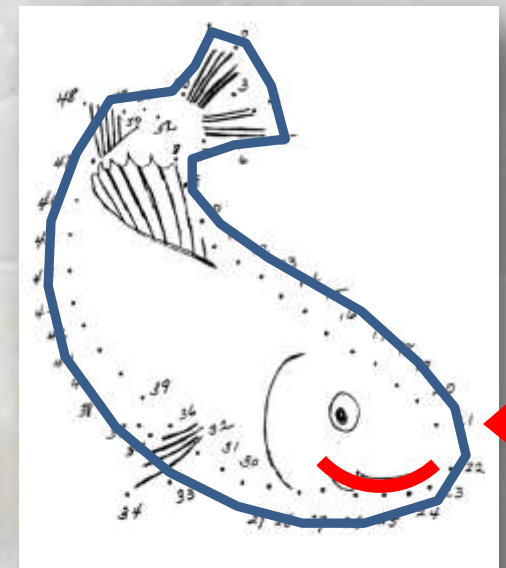
& the People & the Agencies

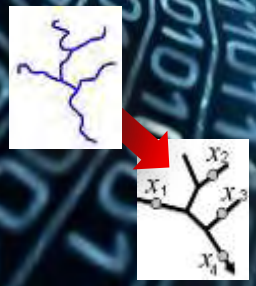


Climate Change



Urbanization & Population Growth





Land & Species Management