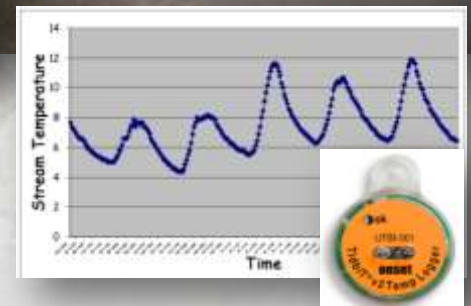
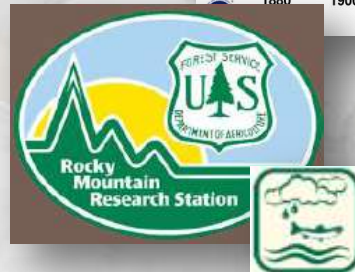
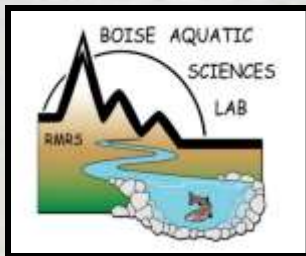
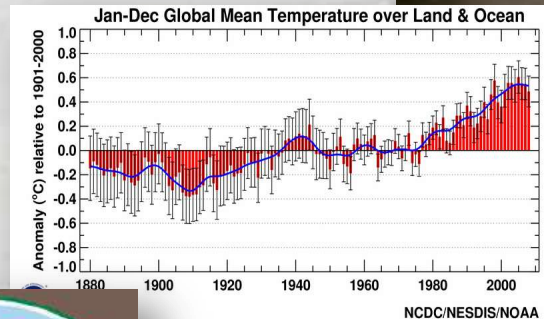
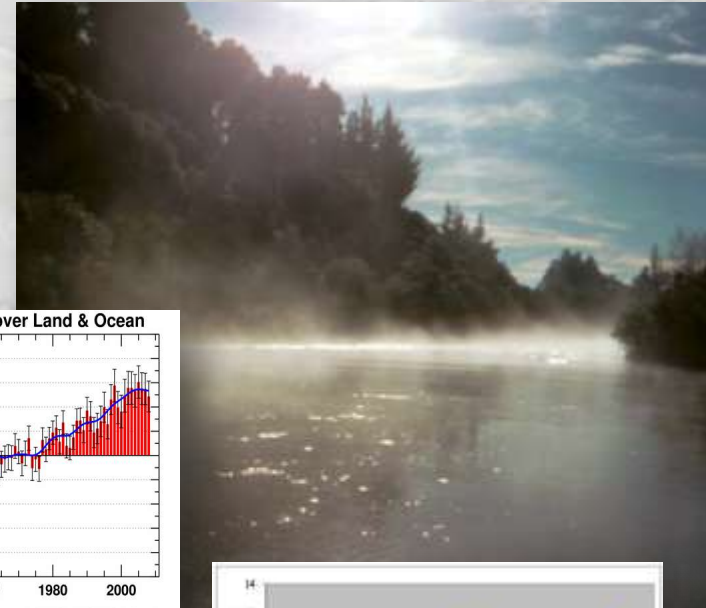
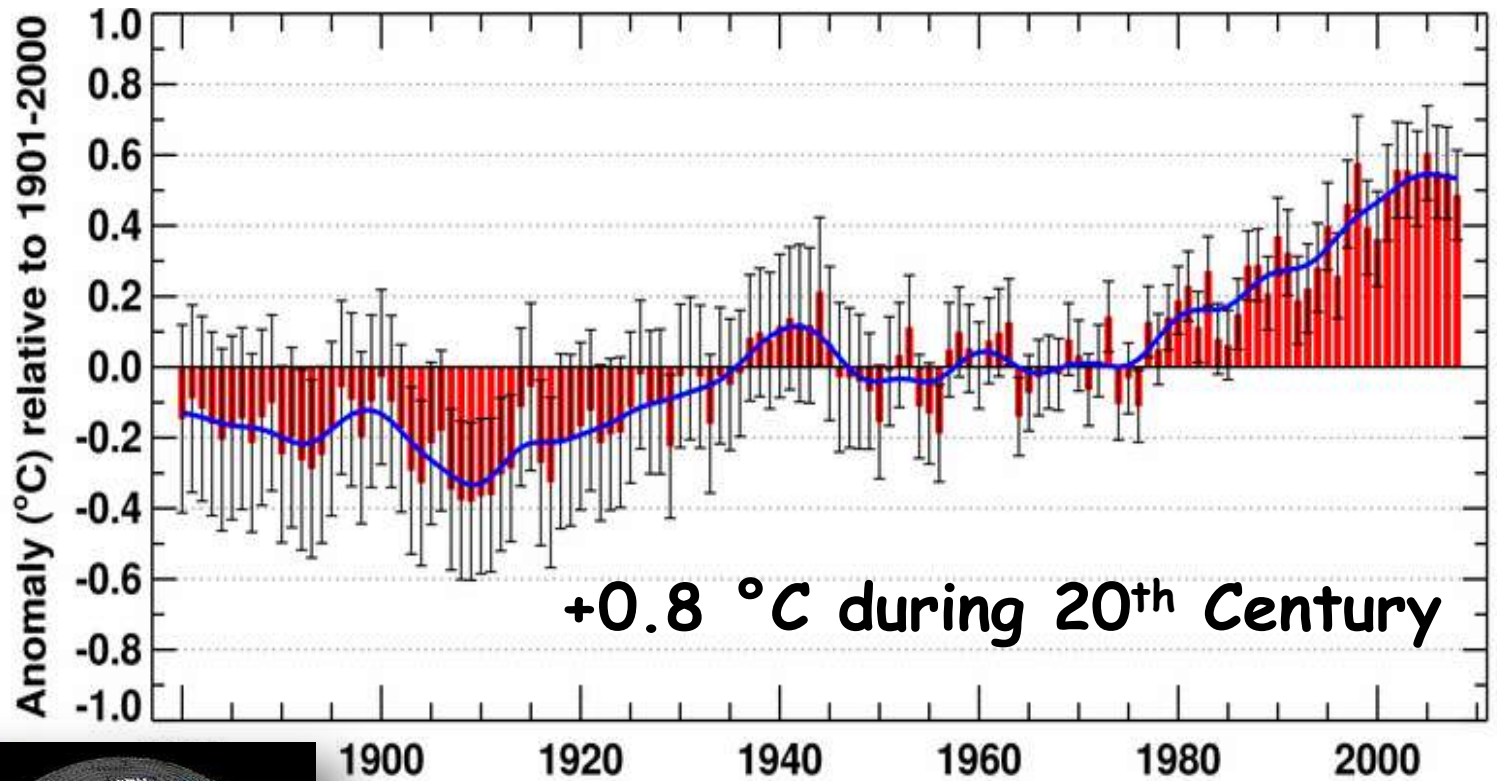


Climate Change Effects on Stream & River Temperatures across the Northwest U.S. from 1980-2009

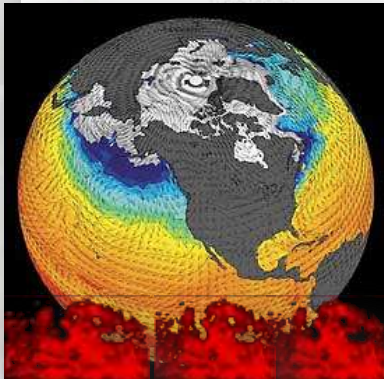
Dan Isaak, Sherry Wollrab, Dona Horan, Gwynne Chandler
US Forest Service - Air, Water & Aquatics Program
Rocky Mountain Research Station
Boise, ID 83702



Global Trends in Air Temperatures

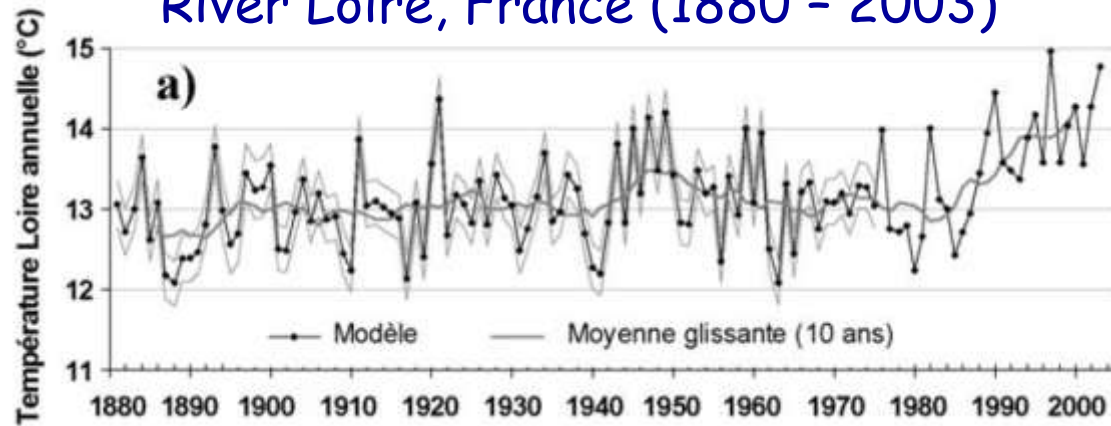


NCDC/NESDIS/NOAA



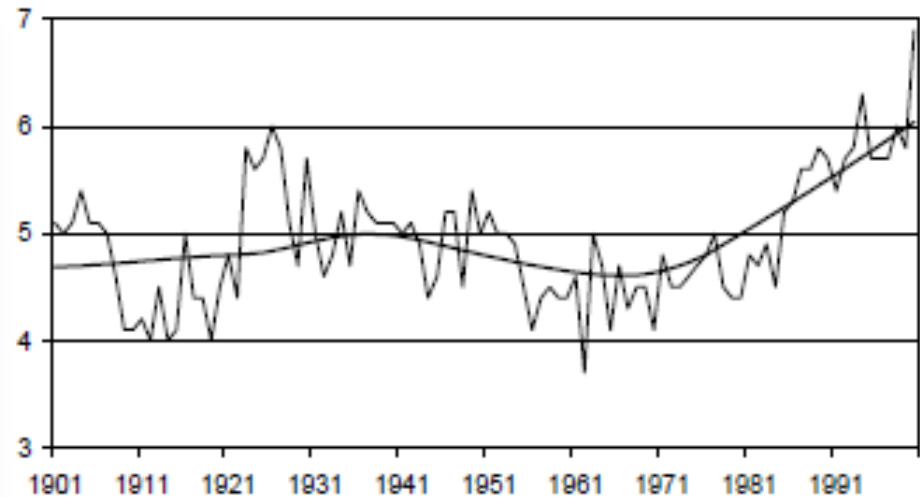
Global Trends in River Temperatures

River Loire, France (1880 - 2003)



Moatar and Gailhard 2006

Danube River, Austria (1901 - 2000)

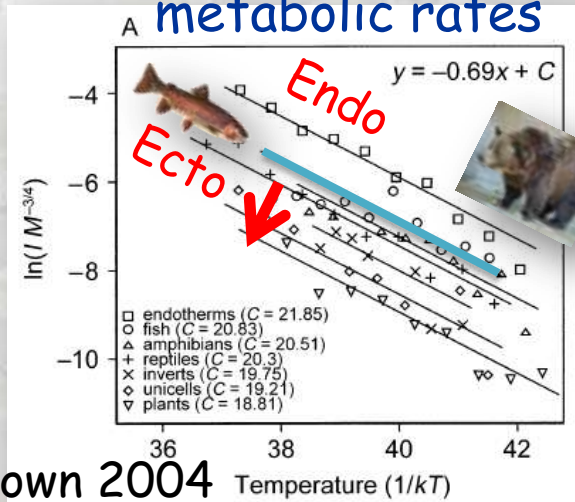


Webb and Nobilus 2007



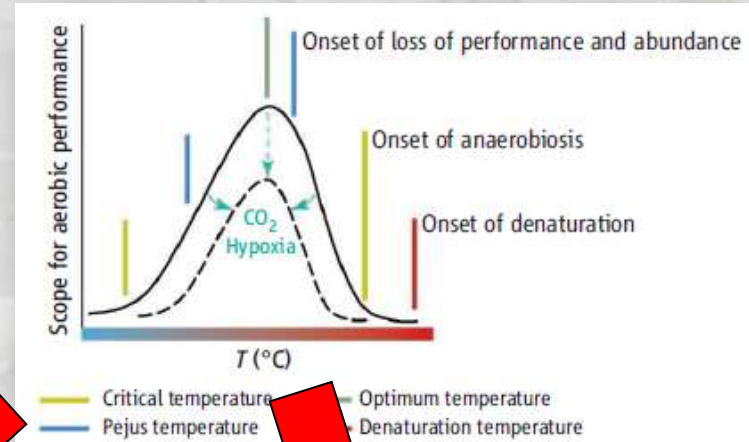
Temperature is Primary Control for Ectotherms Like Fish

Temperature & metabolic rates

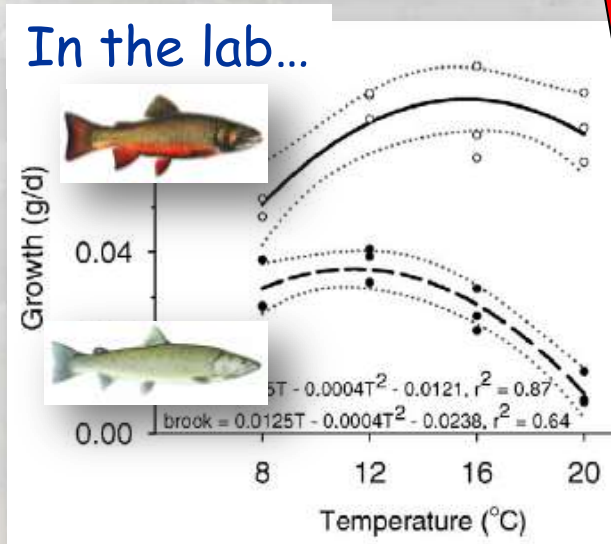


Brown 2004

Thermal Niche

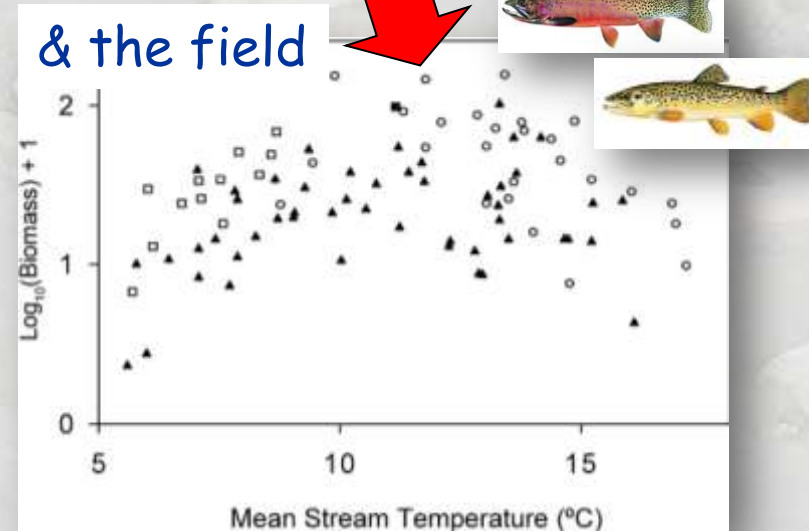


In the lab...



McMahon et al. 2007

& the field

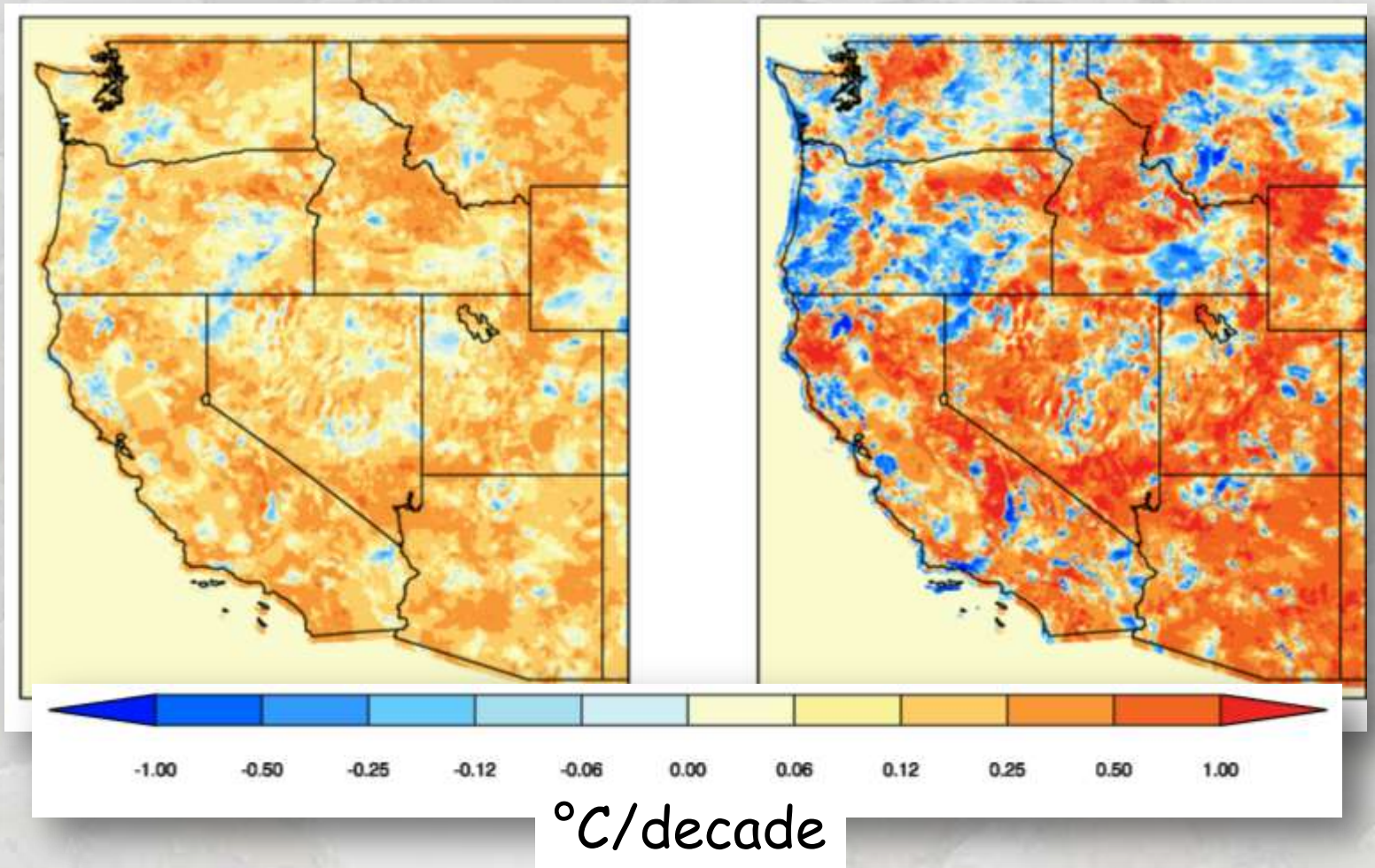


Isaak & Hubert 2004

Western U.S. Air Temperature Trends

1950 - 2009

1987 - 2009

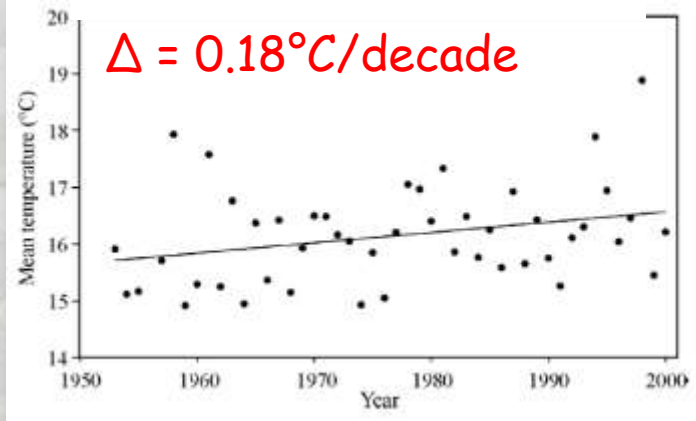


*PRISM maps interpolated from weather station data

Maps courtesy of J. Alder & S. Hostetler, OSU

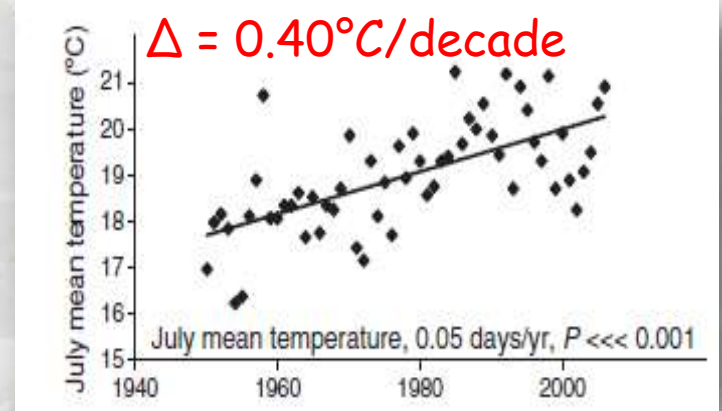
Regional Trends In Northwest Rivers

Fraser River - Annual



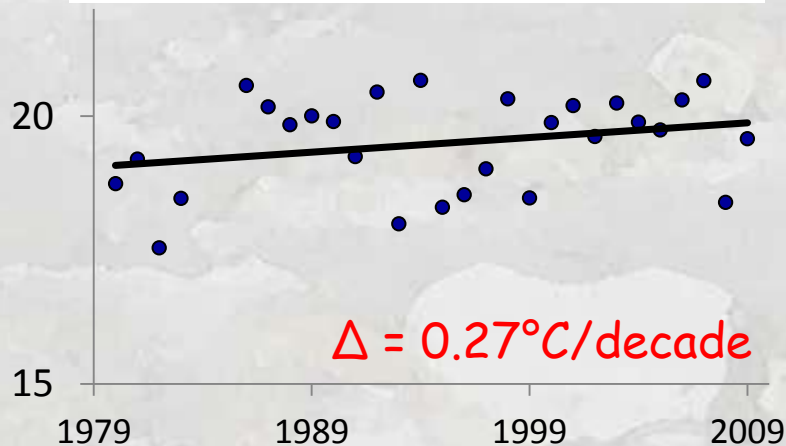
Morrison et al. 2002

Columbia River - Summer



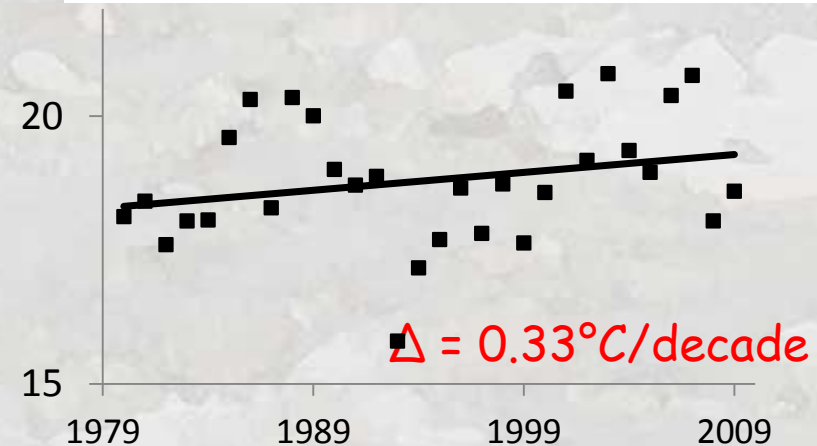
Crozier et al. 2008

Snake River, ID - Summer



Isaak et al. 2011. *Climatic Change*

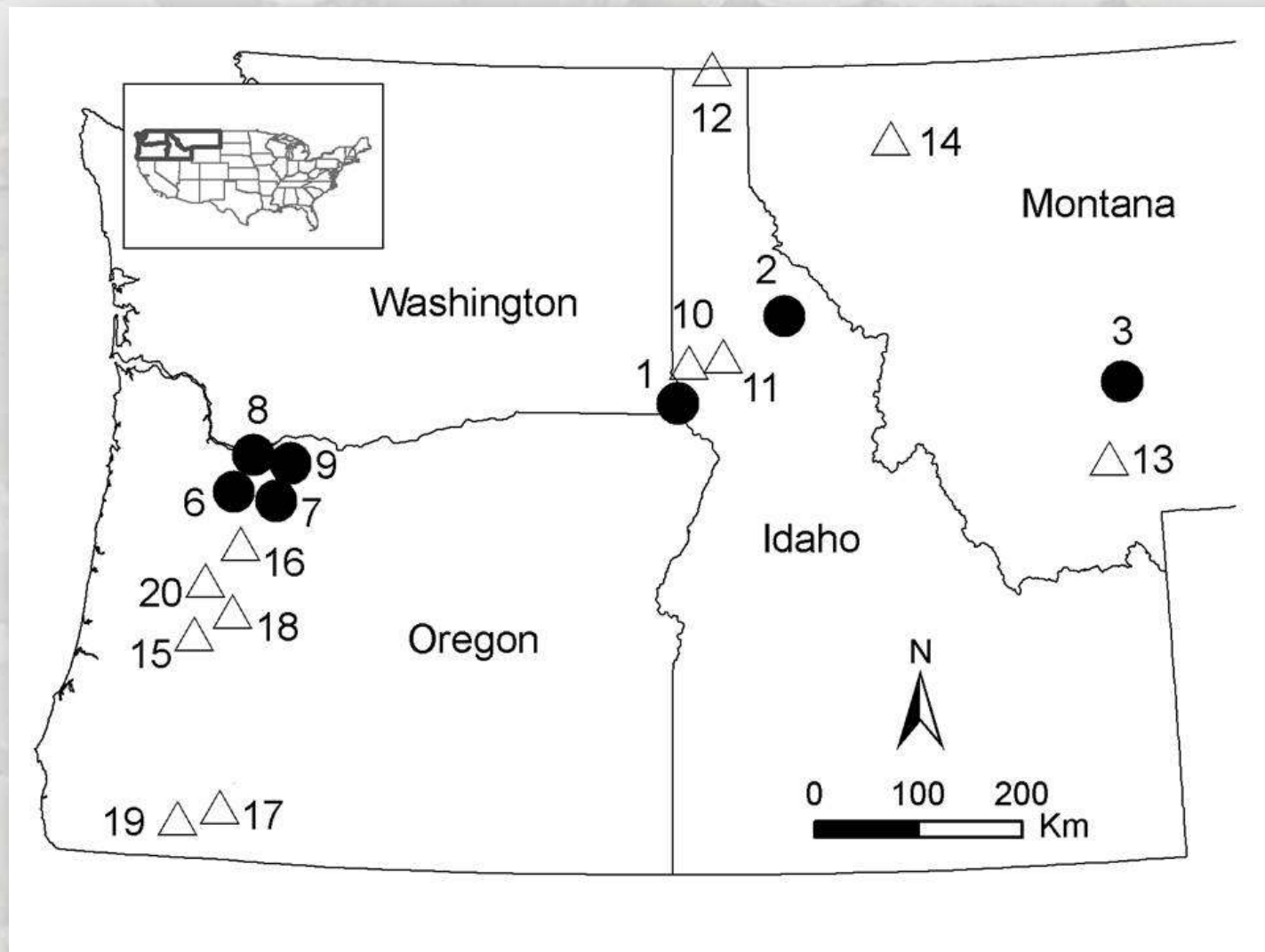
Missouri River, MT - Summer



30 Year Monitoring Sites in NW U.S.

△ = regulated (11)

● = unregulated (7)

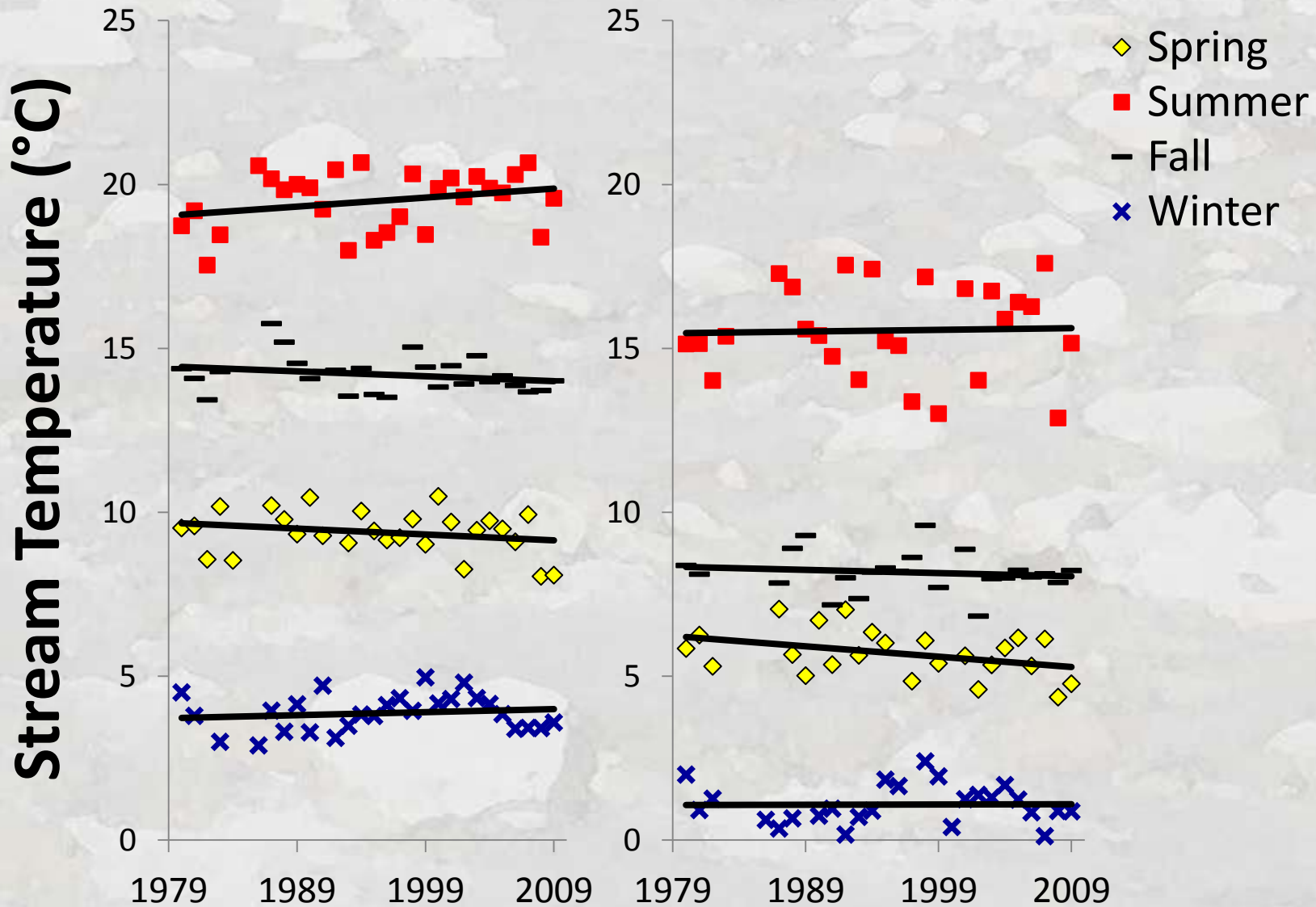


Data Source: USGS NWIS

Example 30 Year Monitoring Records

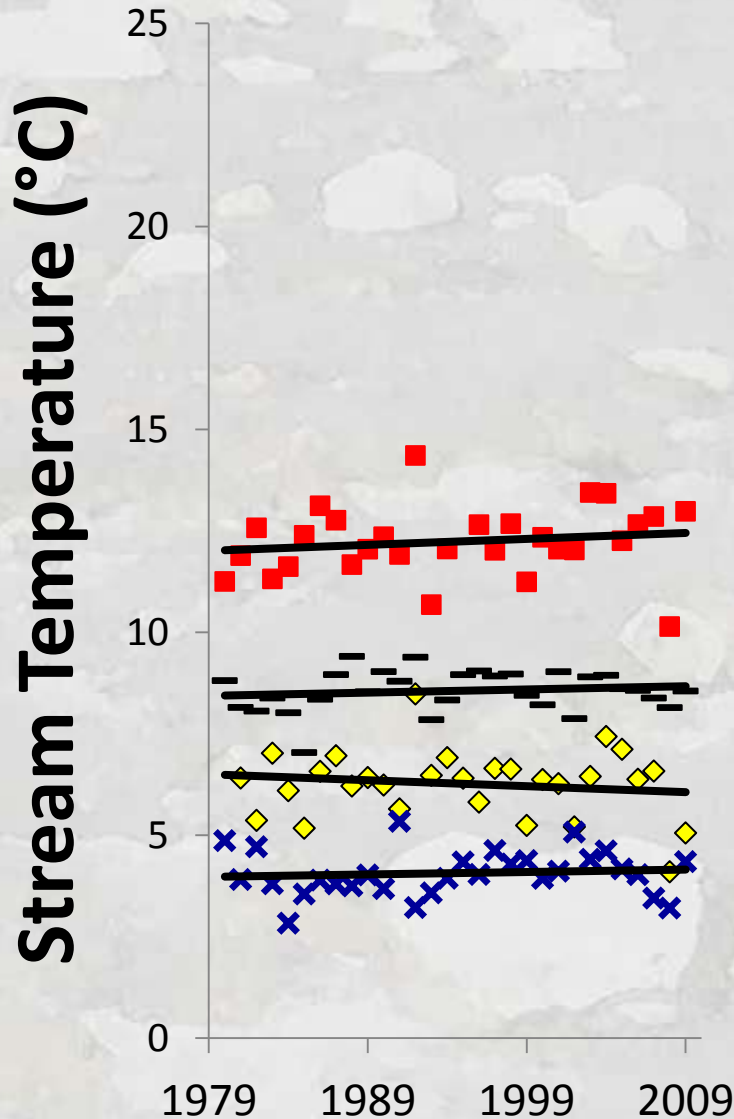
Snake R., WA at Anatone

NFK Clearwater R. at Peck

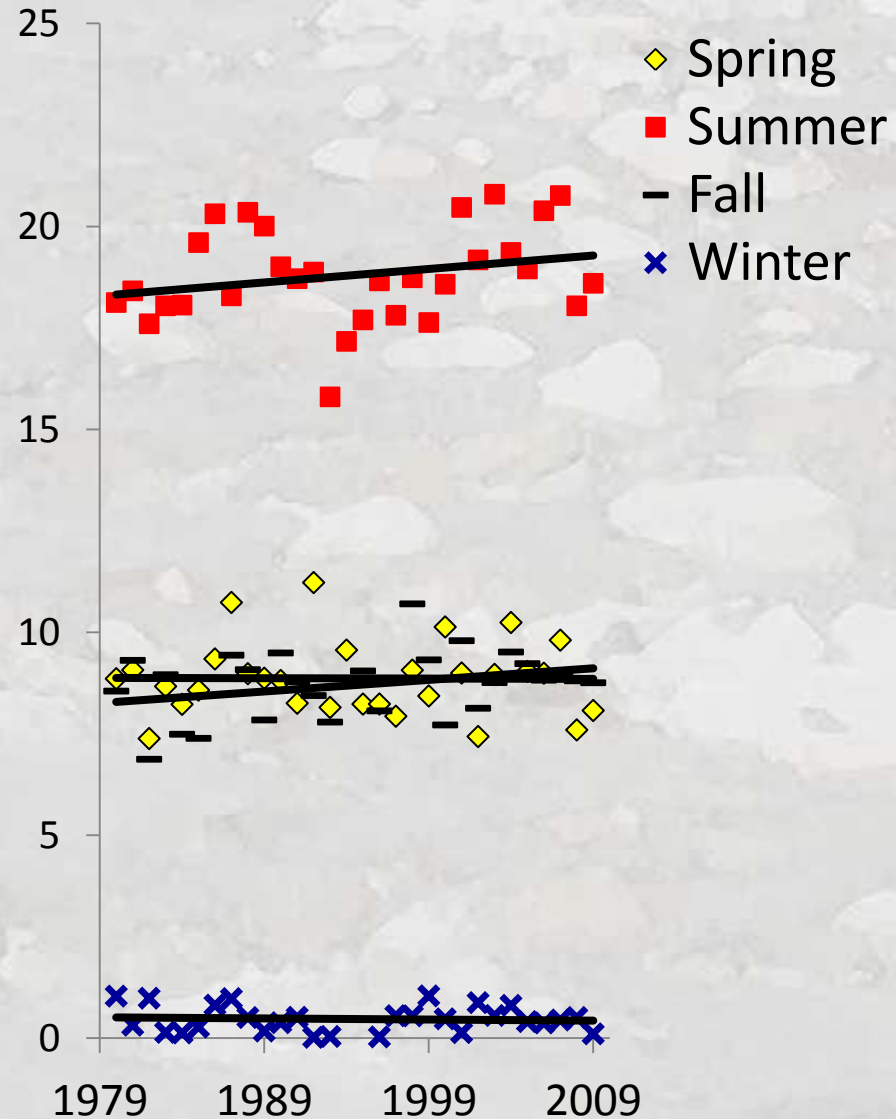


Example 30 Year Monitoring Records

SFK Bull Run River, OR



Missouri R., MT at Toston





Methods

- Multiple regression models to describe seasonal stream temperature relationships with discharge (co-located USGS gage) & air temperature (3 nearest NOAA climate stations) at each monitoring site.

$$\text{Stream temperature (Y)} = b_0 + b_1(\text{air}) - b_2(\text{discharge})$$

- Advantages:
 - 1) parameter estimates for attribution & significance testing
 - 2) predictive equations for description of stream temperature trends associated with various climate scenarios (historic or future)
 - 3) trend estimates not affected by missing stream temperature observations
- Statistical significance of trends assessed across monitoring sites with 1-sample *t*-test

Example Multiple Regression Results

Spring period (March, April, May)

| Stream site | Multiple regression equation |
|------------------------------------|---|
| Spring period | |
| 1. Snake River Near Anatone, WA | $y = 3.43 + 0.588^a(\text{air } ^\circ\text{C}) - 0.00013(\text{m}^3/\text{s})$ |
| 2. North Fork Clearwater River, ID | $y = 1.48 + 0.548^a(\text{air } ^\circ\text{C}) - 0.00373(\text{m}^3/\text{s})$ |
| 3. Missouri River, MT | $y = 7.05 + 0.583^a(\text{air } ^\circ\text{C}) - 0.00499^a(\text{m}^3/\text{s})$ |
| 6. South Fork Bull Run River, OR | $y = 1.01 + 0.716^a(\text{air } ^\circ\text{C}) - 0.183^a(\text{m}^3/\text{s})$ |
| 7. Fir Creek, OR | $y = 0.0139 + 0.701^a(\text{air } ^\circ\text{C}) - 0.313(\text{m}^3/\text{s})$ |
| 8. North Fork Bull Run River, OR | $y = 0.768 + 0.710^a(\text{air } ^\circ\text{C}) - 0.307^a(\text{m}^3/\text{s})$ |
| 9. Bull Run River, OR | $y = -0.276 + 0.810^a(\text{air } ^\circ\text{C}) - 0.0392(\text{m}^3/\text{s})$ |

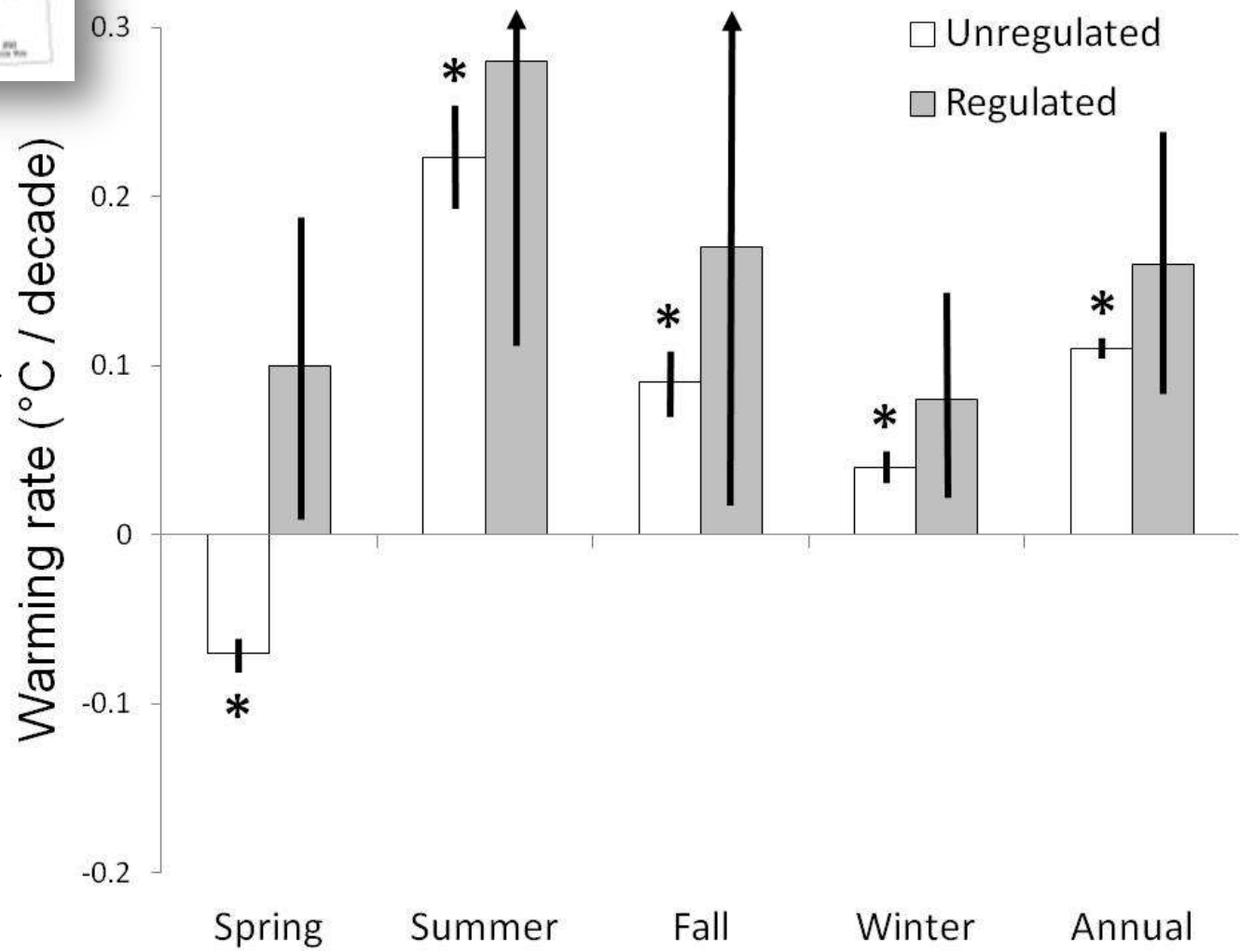
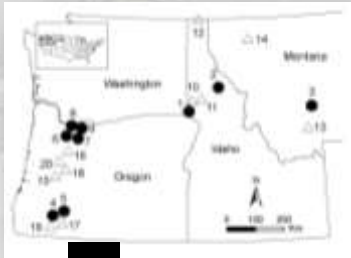
Air

Discharge

| R ² | RMSE (C) | Significant Interaction? |
|----------------|----------|--------------------------|
| 0.68 | 0.37 | No |
| 0.79 | 0.32 | No |
| 0.85 | 0.35 | Yes |
| 0.85 | 0.32 | No |
| 0.89 | 0.26 | No |
| 0.84 | 0.33 | No |
| 0.83 | 0.32 | No |

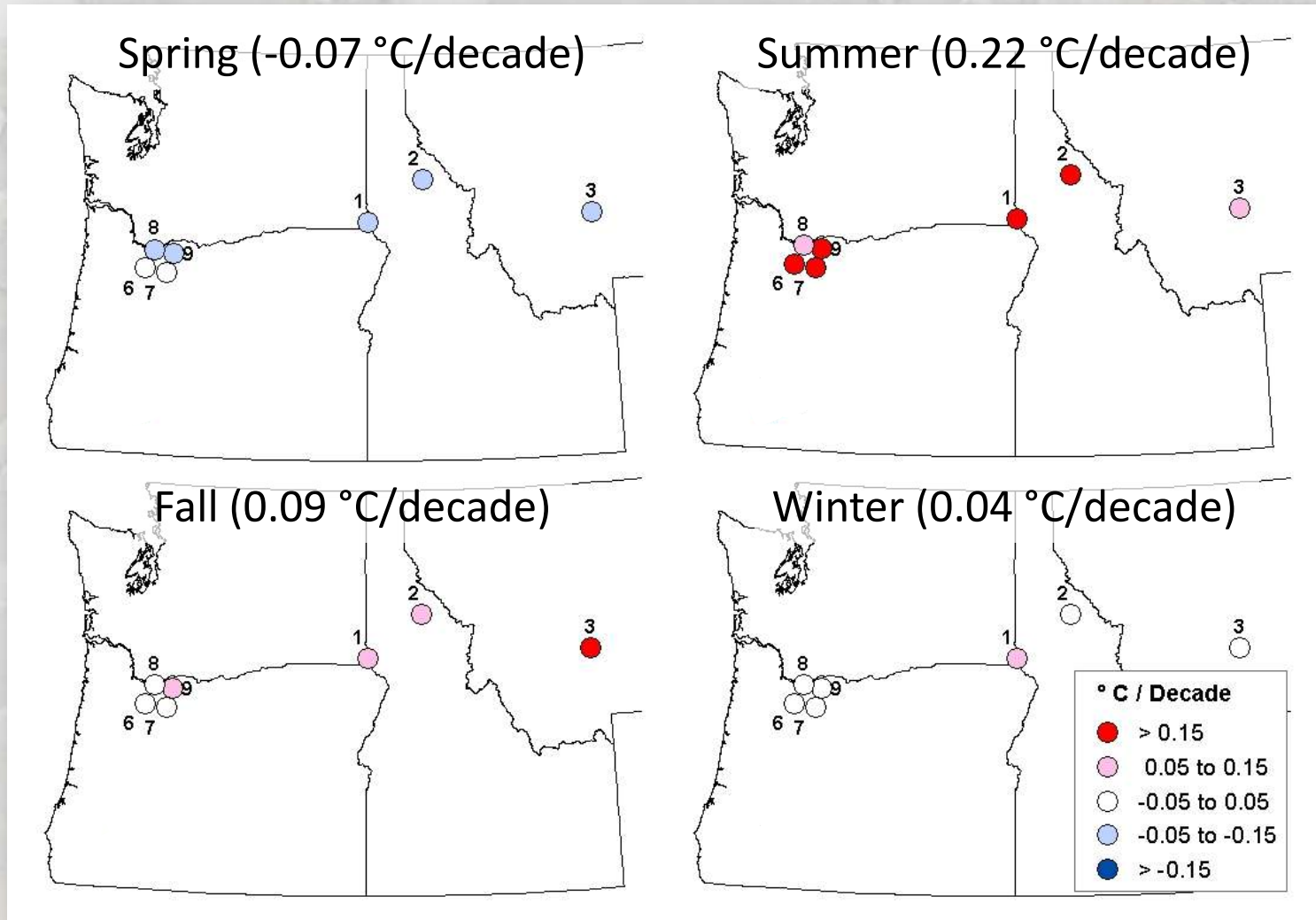


Seasonal Trends In Temperatures (1980-2009)



Seasonal Trends In Temperatures (1980-2009)

Unregulated sites (7)



Attribution of Stream Warming Trends

Air temp & discharge effects are additive

| Site | Reconstructed trends | | |
|------------------------------------|--------------------------------------|--|---|
| | Total stream temperature change (°C) | Air temperature, discharge contributions (°C) ^a | Standardized b_x 's (air temperature, discharge) ^b |
| Spring Period | | | |
| 1. Snake River Near Anatone, WA | -0.325 | -0.307, -0.018 | 0.78, -0.12 |
| 2. North Fork Clearwater River, ID | -0.346 | -0.453, 0.107 | 0.80, -0.20 |
| 3. Missouri River, MT | -0.155 | -0.198, 0.043 | 0.81, -0.25 |
| 6. South Fork Bull Run River, OR | -0.143 | -0.168, 0.024 | 0.81, -0.20 |
| 7. Fir Creek, OR | -0.147 | -0.164, 0.017 | 0.88, -0.14 |
| 8. North Fork Bull Run River, OR | -0.150 | -0.166, 0.017 | 0.80, -0.22 |
| 9. Bull Run River, OR | -0.181 | -0.189, 0.009 | 0.85, -0.17 |

Air

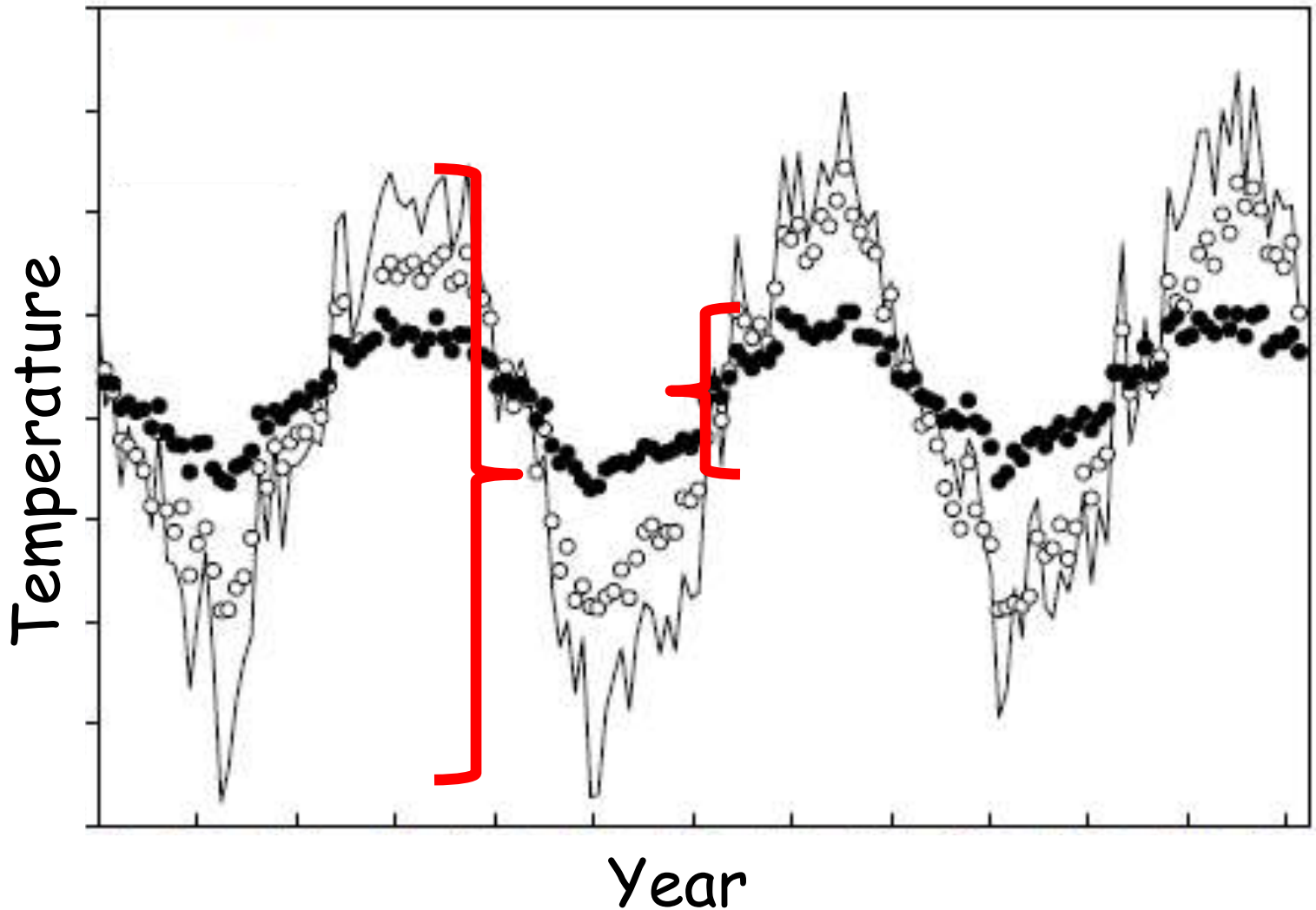


Discharge



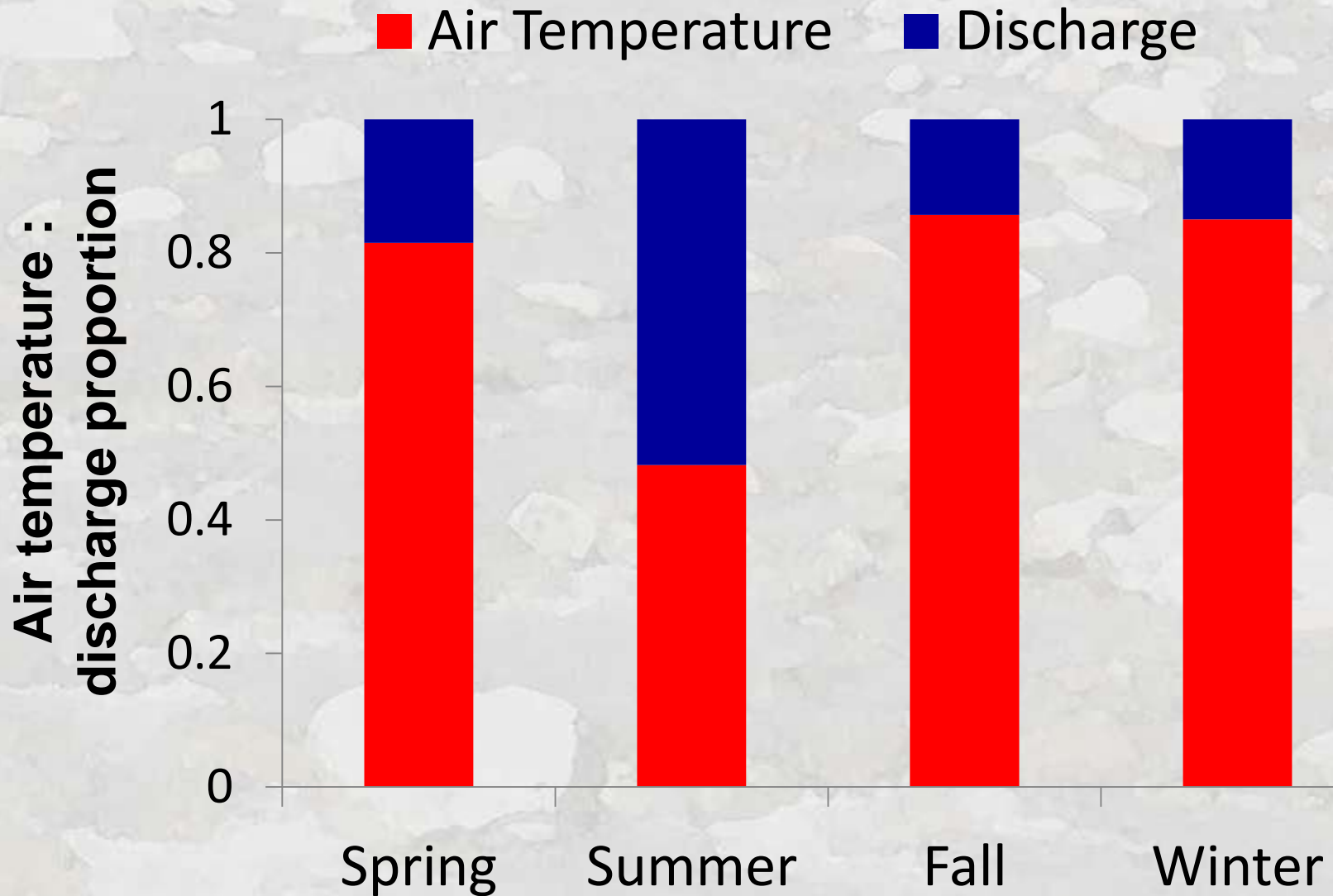
Attribution of Stream Warming Trends

Inter-annual variation \sim environmental noise



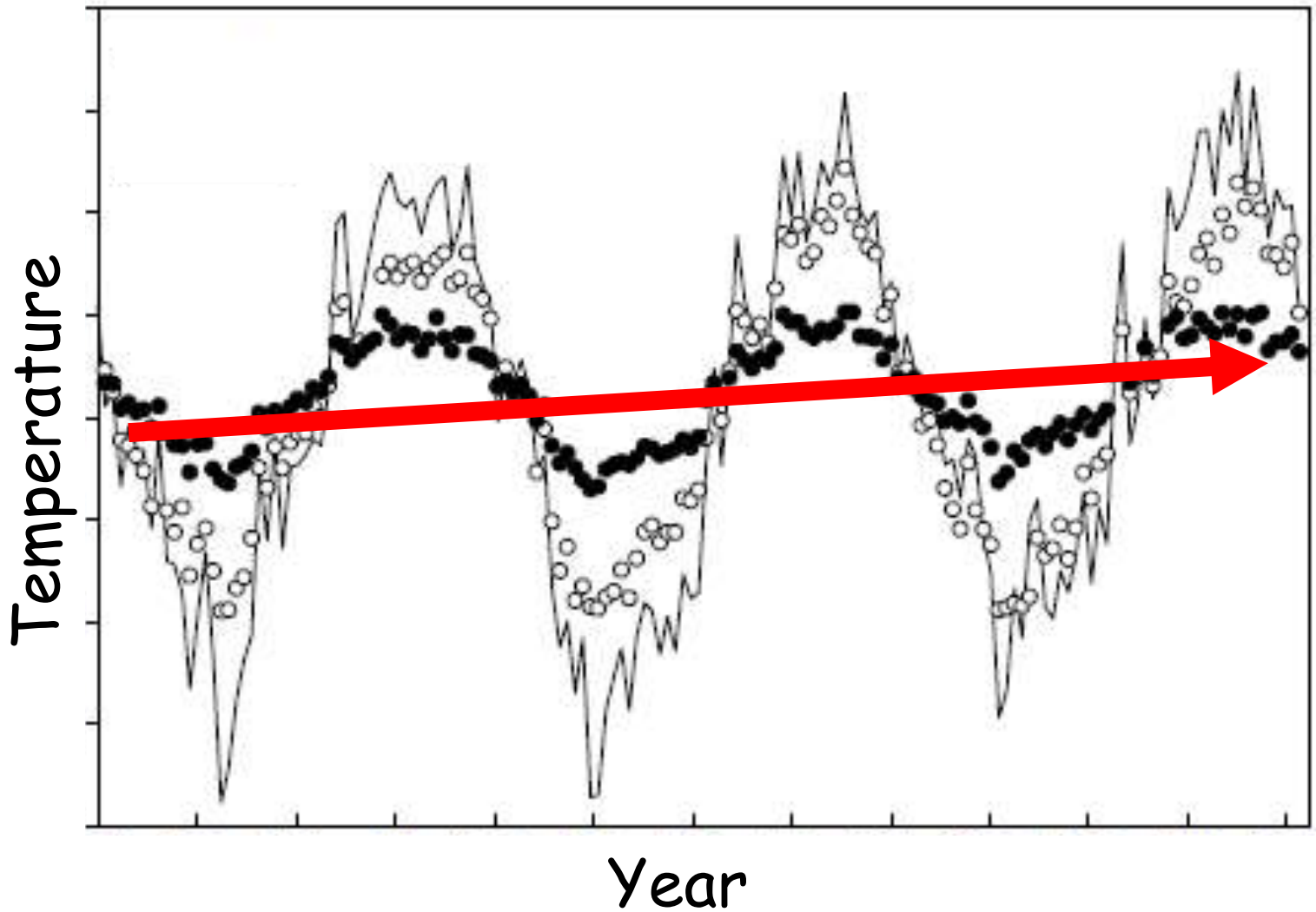
Attribution of Stream Warming Trends

Inter-annual variation \sim environmental noise



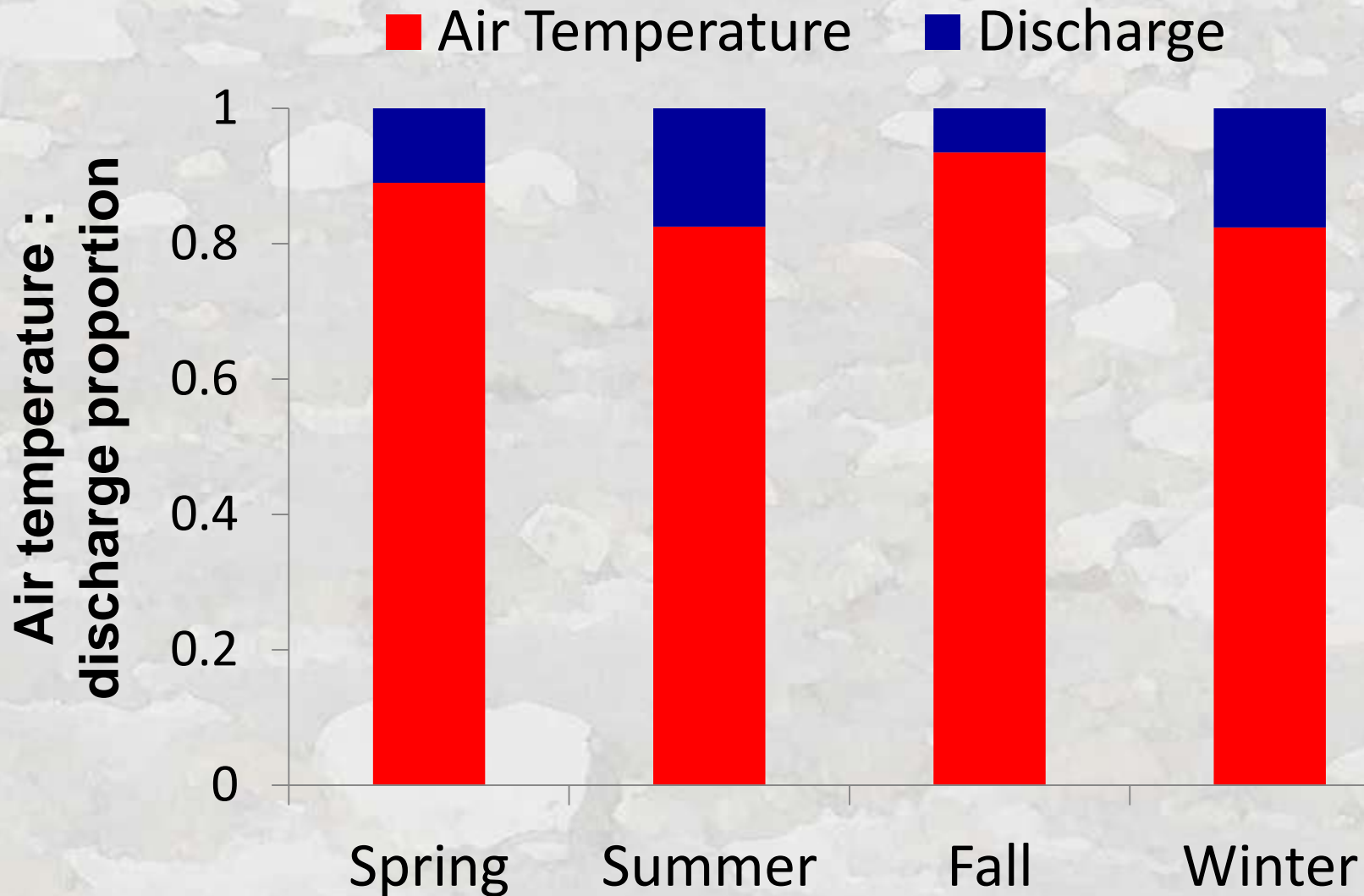
Attribution of Stream Warming Trends

Long-term trend \sim environmental signal



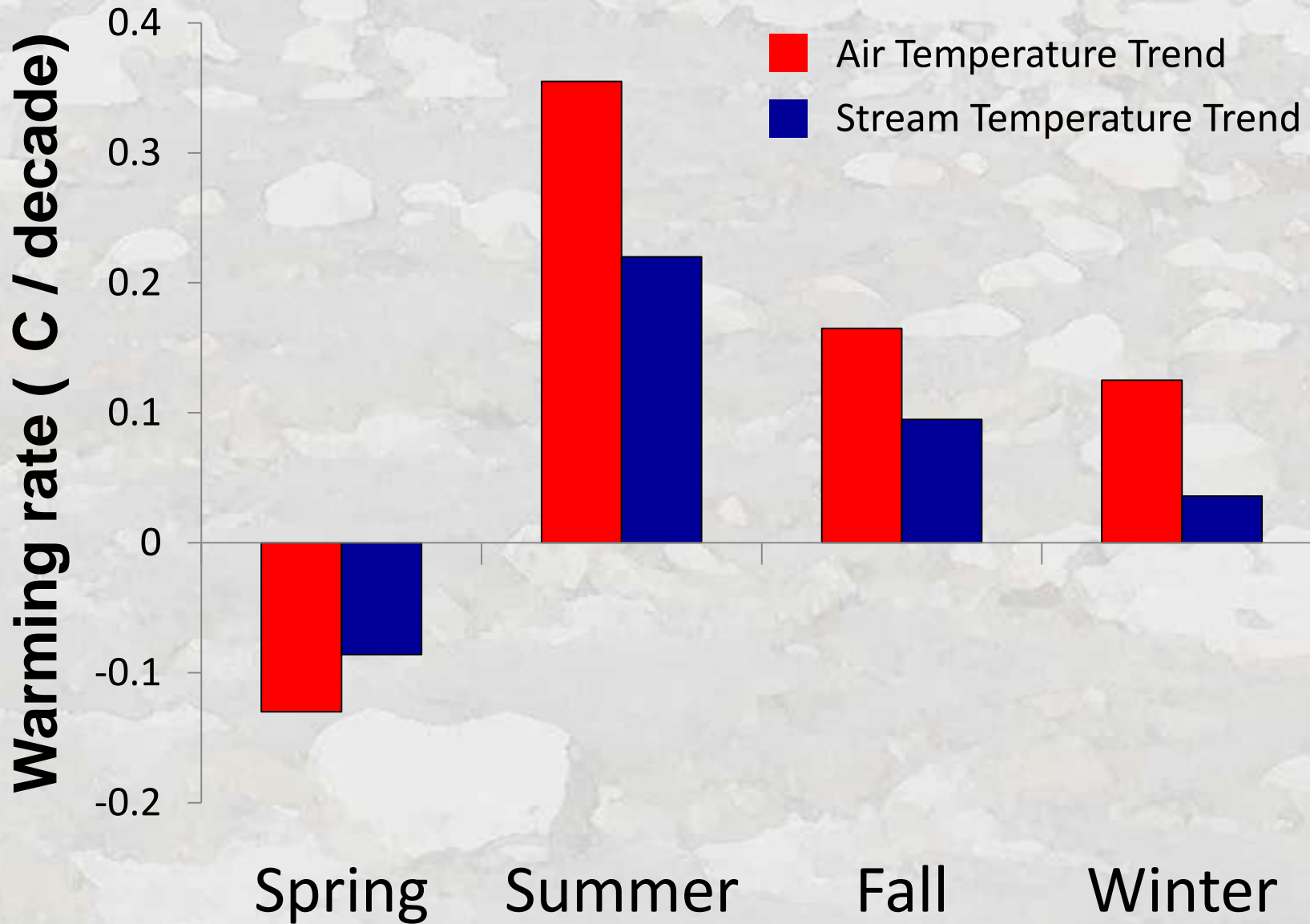
Attribution of Stream Warming Trends

Long-term trend ~ environmental signal



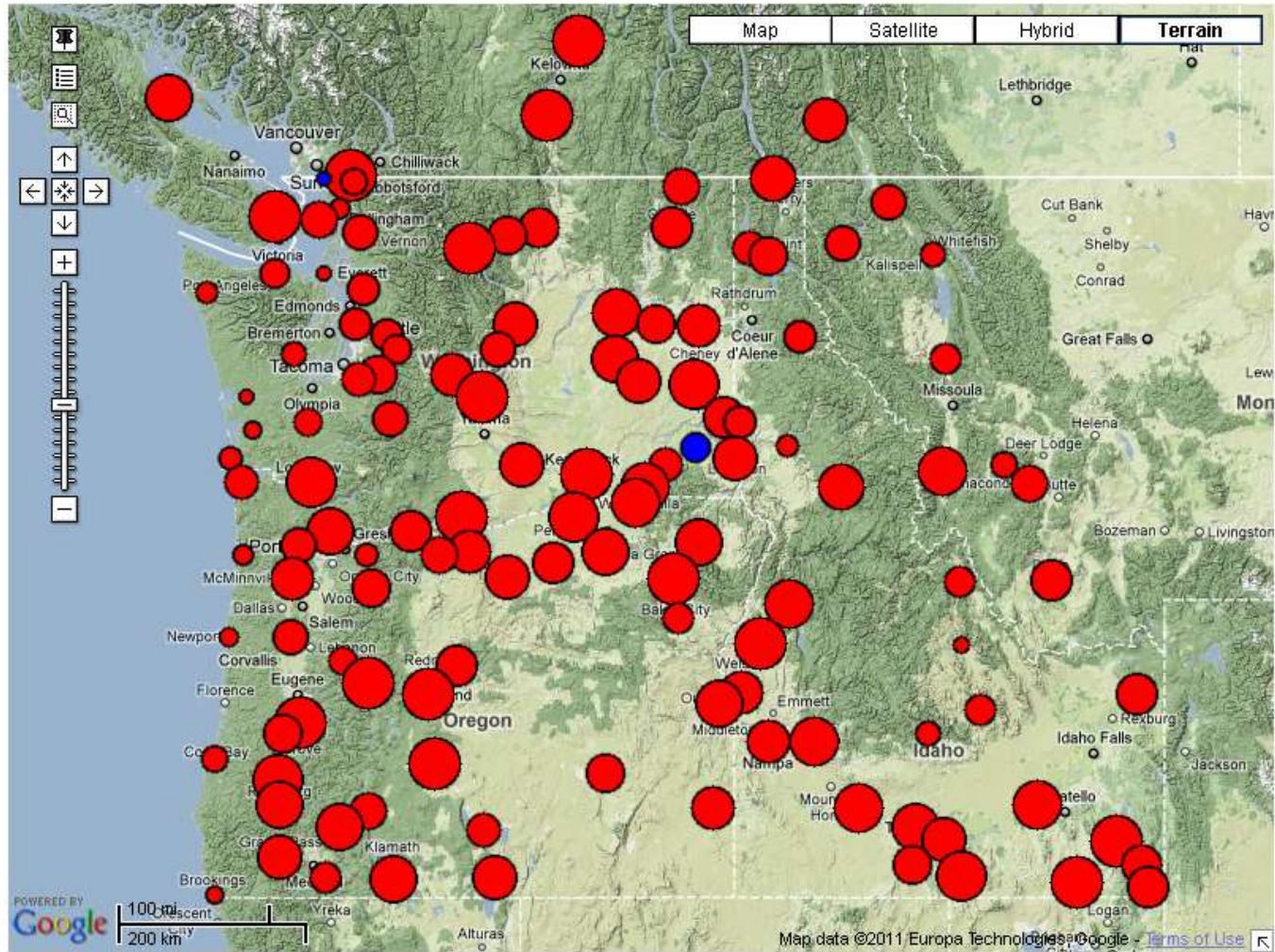
Attribution of Stream Warming Trends

Comparison to Air Temp Trends at Local Climate Stations



Similar Trends in Most Regional Streams?

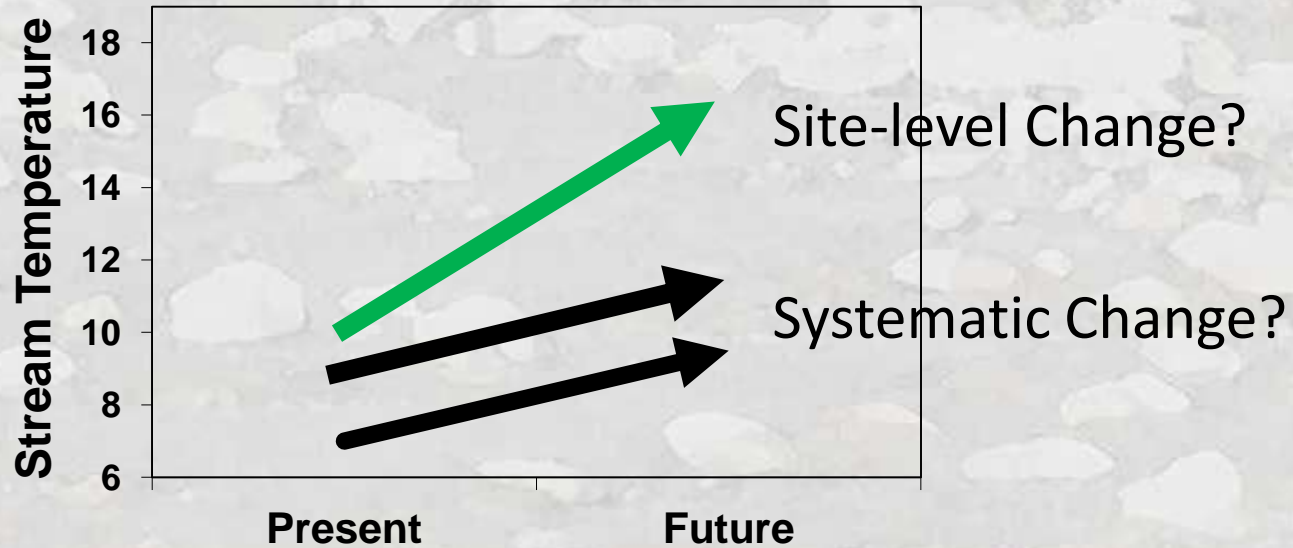
Mean **Summer** Air Temp Trends (1980 - 2009)



OWSC Climate Tool map

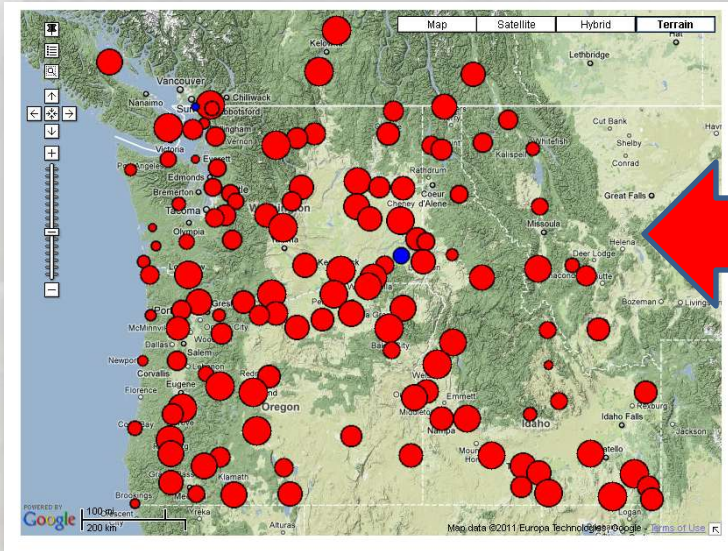
<http://www.climate.washington.edu/trendanalysis/>

Spatial Variation in Temperature Changes



Different Climate Forcing?

Or Different Sensitivity?

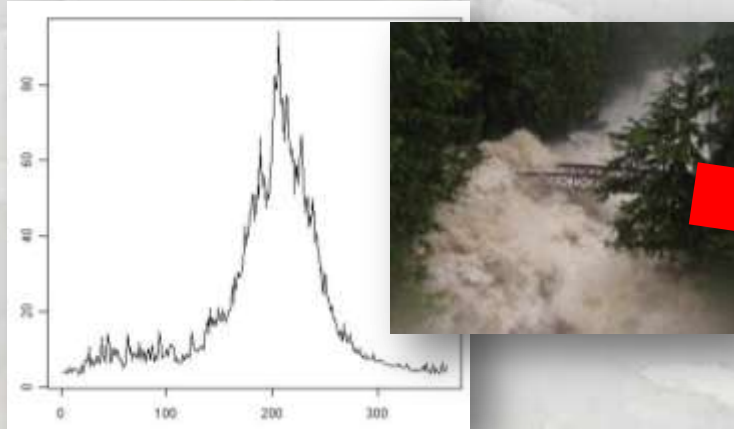


Glaciation?
Riparian type?
Groundwater?

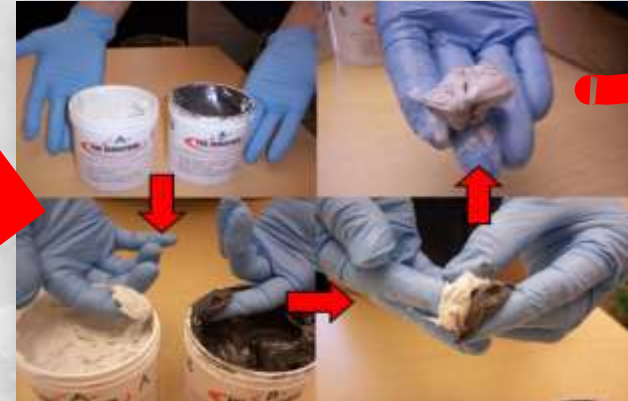
Easy Method for Full Year Data

Underwater Epoxy Protocol

Annual Flooding Concerns



Underwater epoxy cement



\$100 = 5 years of data

Data retrieved
from underwater



Sensors or protective housings
glued to large boulders



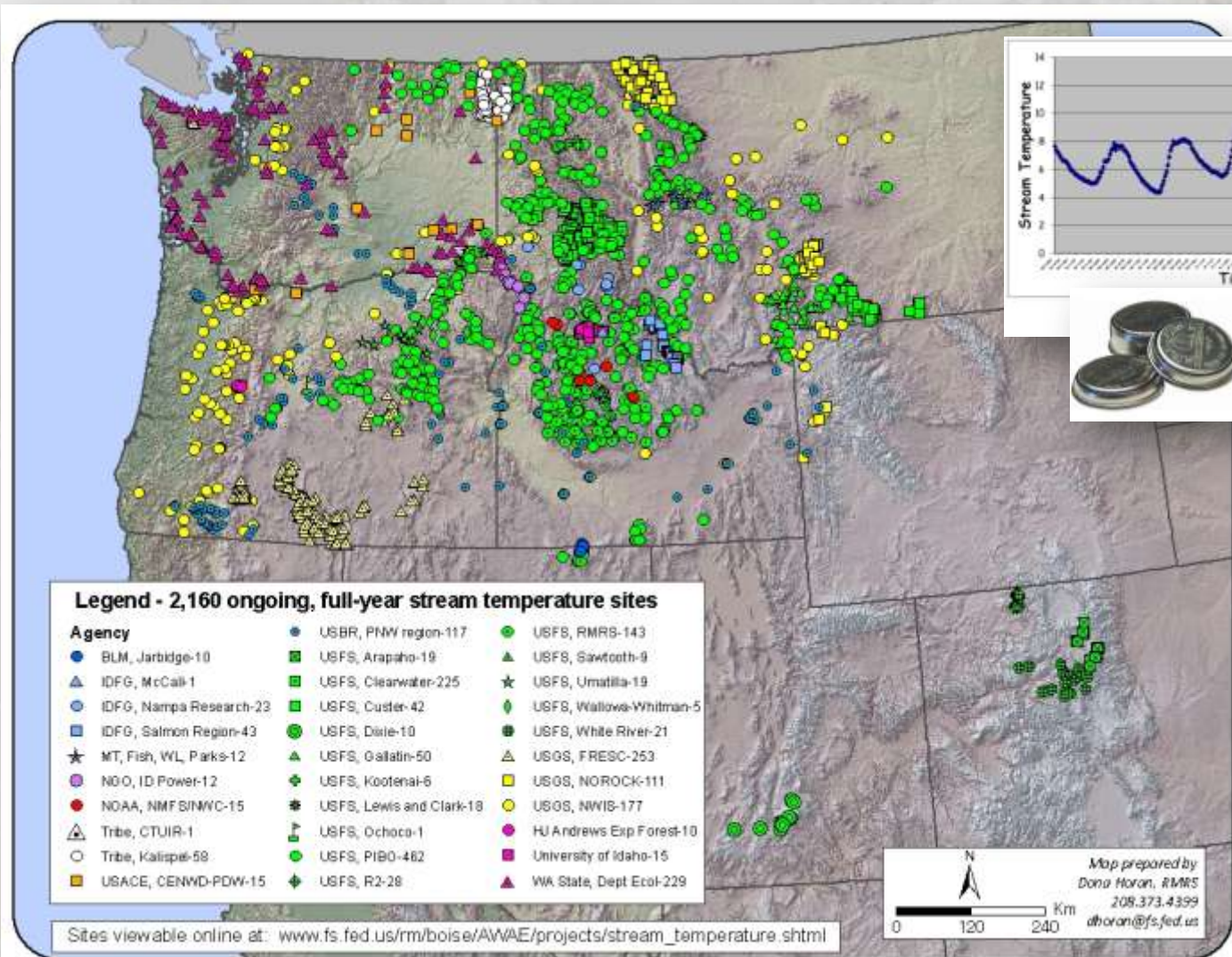
Isaak & Horan 2011. *NAJFM* 31:134-137

Google Search "Stream
Temperature Boise"


Massive Regional Monitoring Network

2,160 current full-year monitoring sites

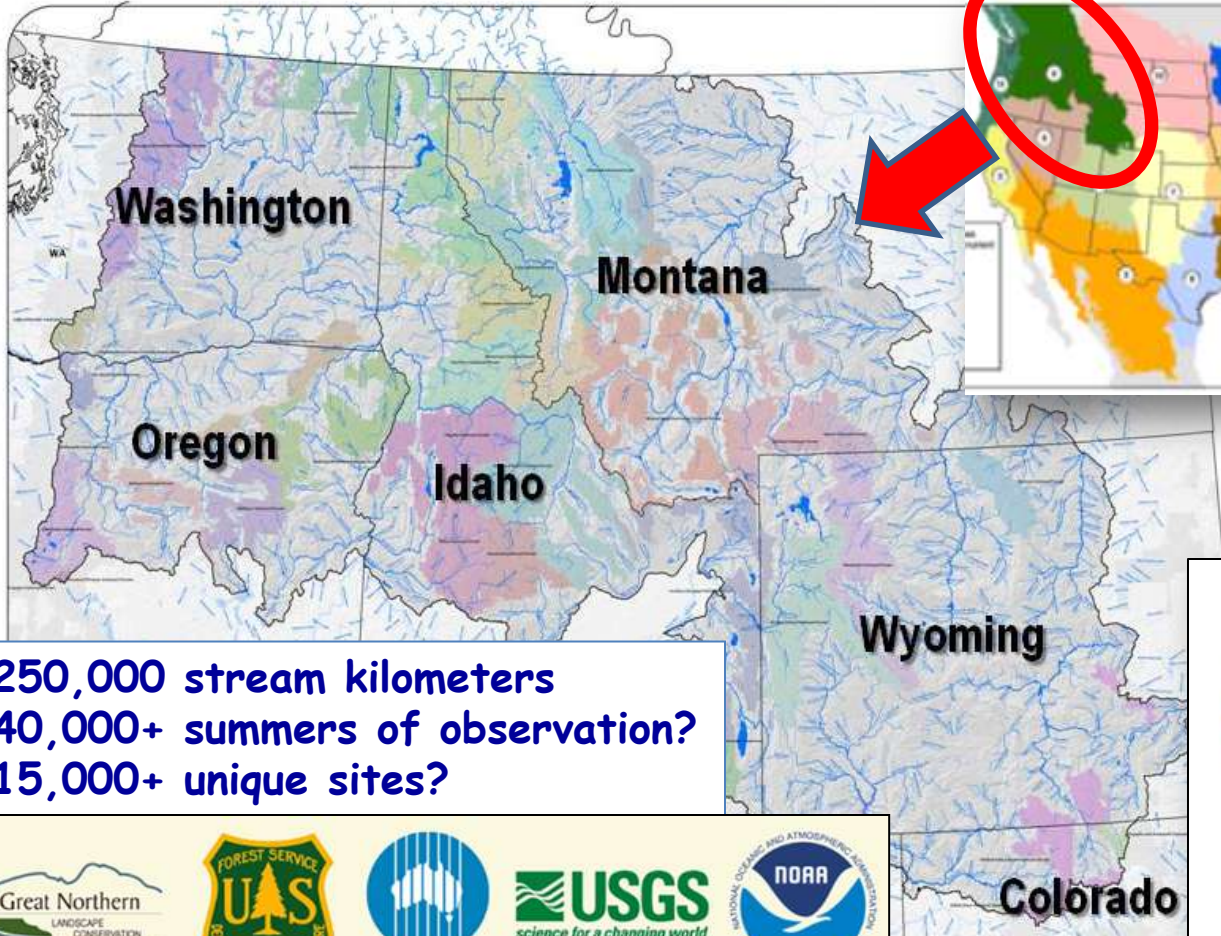
~1,000 new 2011 deployments



A Regional Stream Temperature Database & Model




Great Northern
LANDSCAPE CONSERVATION COOPERATIVE



Washington
Oregon
Idaho
Montana
Wyoming
Colorado

- 250,000 stream kilometers
- 40,000+ summers of observation?
- 15,000+ unique sites?

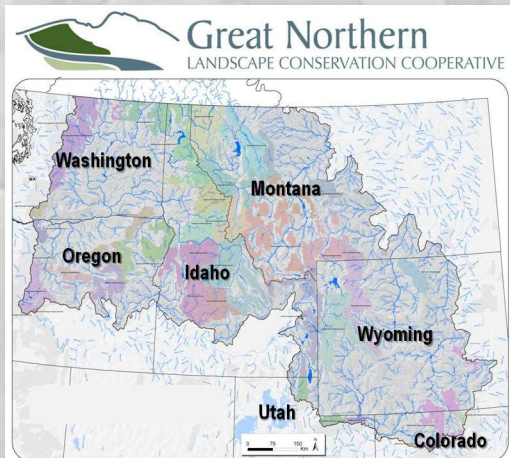


Landscape
Conservation
Cooperatives



Regional Stream Temperature Datacall

Visit the Datacall Website...



Google Search "GNLCC Stream Temperature"

USGS
science for a changing world

Northern Rocky Mountain Science Center (NOROCK)

Home | About Us | Science | Product Library | News & Events | Staff | Students | Partners | Contact Us

Home

GNLCC Regional Stream Temperature Database and Model

This website has been developed to provide background information on a new stream temperature project funded by the Great Northern LCC. One of the goals of the project is to compile existing stream temperature data from federal, state, tribal, and private sources across the five state region that comprises the US portion of the GNLCC. These data will be developed into an integrated regional database that is made available to all interested parties. The stream temperature database will also be used with new spatial statistical models for river networks to develop an accurate regional model capable of predicting stream temperatures for all fish-bearing streams. The model will be used to simulate a variety of historic and future climate

Sensor Data
Temperature vs. Time

Thermal Habitat Assessments
Map of stream temperature distribution

Temperature Models & Maps
Map of stream temperature distribution

distributions of thermal habitat for various maps of stream temperature made available as GIS layers at the on and management planning.

assembling the database of stream sources across the GNLCC. For e to this project, detailed s boundaries, methodologies, and

GNLCC Project Proposal Description
PDF (532 kb)

Stream Temperature Datacall Message
PDF (444 kb)

Detailed Map of Project Boundaries
EPT (1.55 mb) | PDF (625 kb)

Instructions for Data Submissions
PDF (162 kb)
Data submissions and technical assistance:
Gwynne Chandler: gichandler@fs.fed.us
Sherry Wolrab: swolrab@fs.fed.us
Donna Horan: dhoran@fs.fed.us

For data transfers: <ftp://ftp2.fs.fed.us/incoming/irms/boxes/GNLCC/>

Briefing Paper
PDF (488 kb)

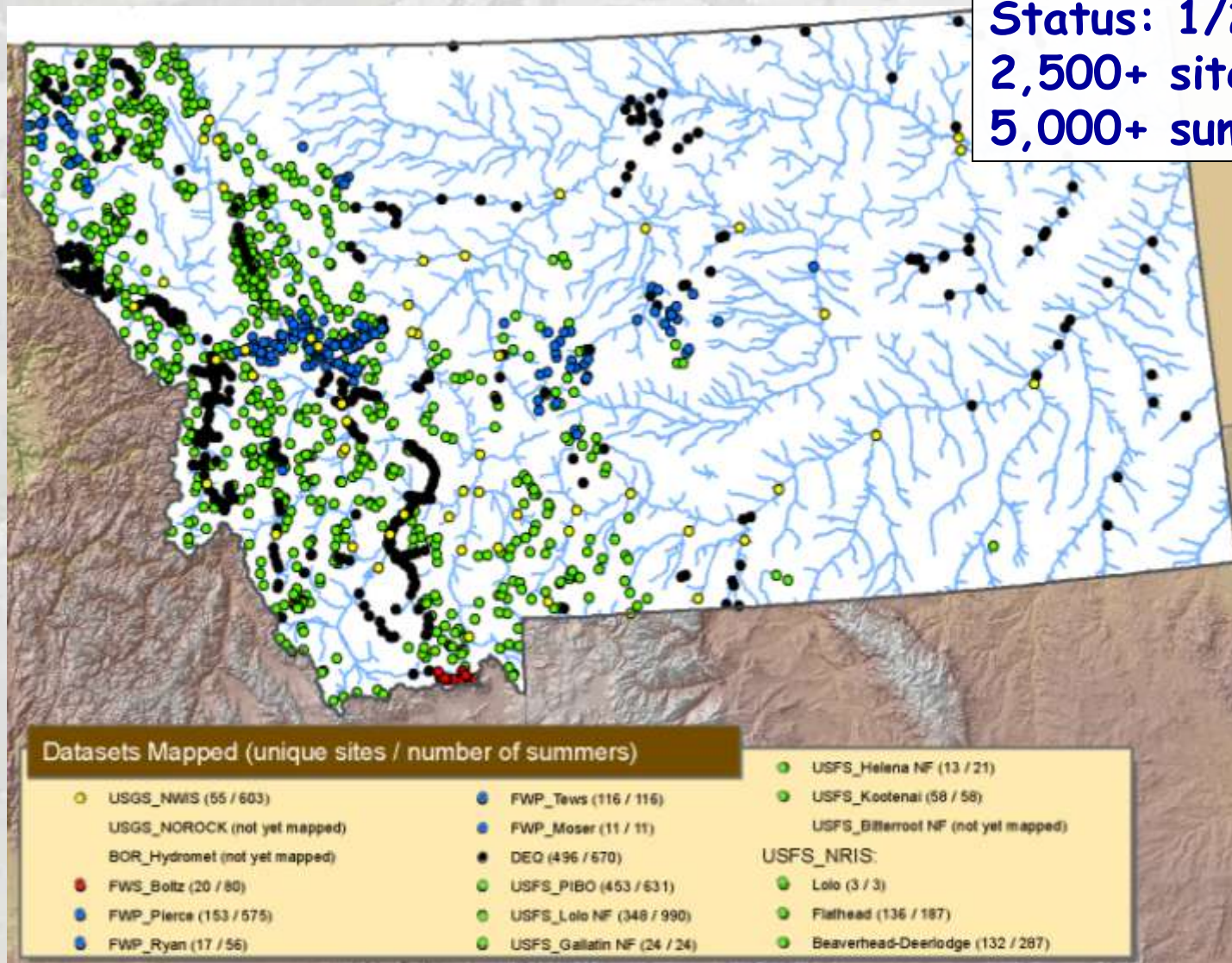
Temperature Model with Integrative Hub
Statistical Models: PDF (4.89 mb)

• Effects of climate change and wildfire on stream temperature

- Project description
- Analytical details
- ftp site for data transfers

NorWeS_{tream}Temp Database

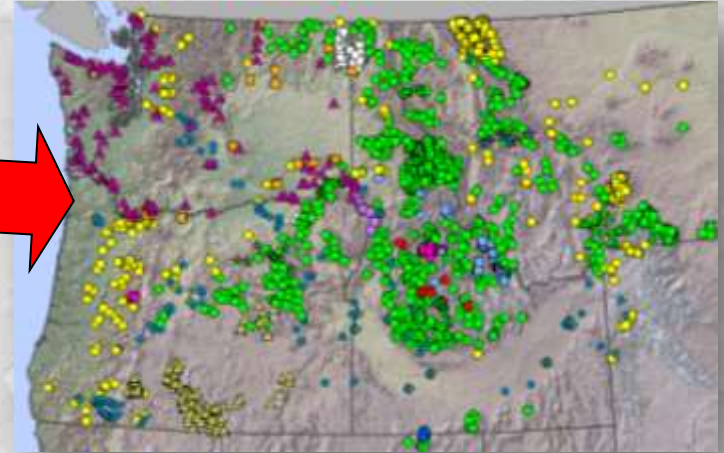
Montana Domain
Status: 1/26/12
2,500+ sites
5,000+ summers



Viewable at the Datacall Website...

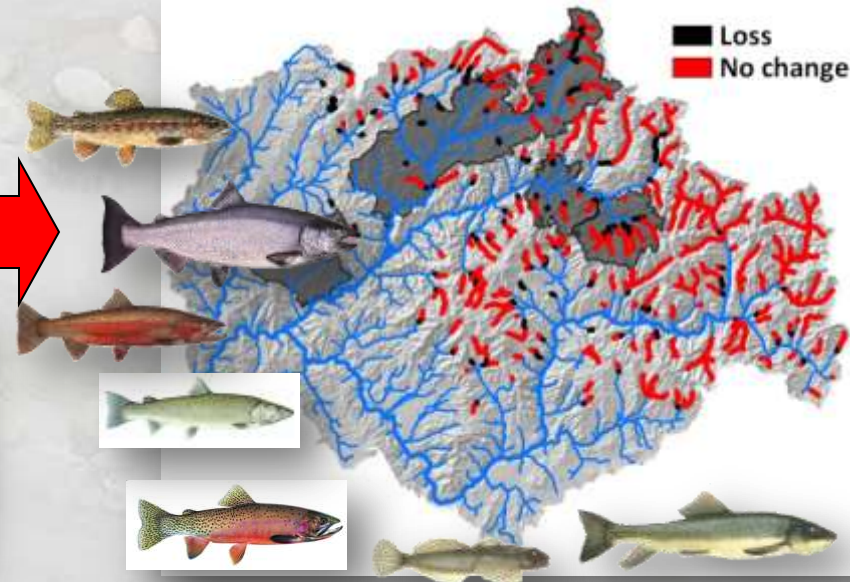
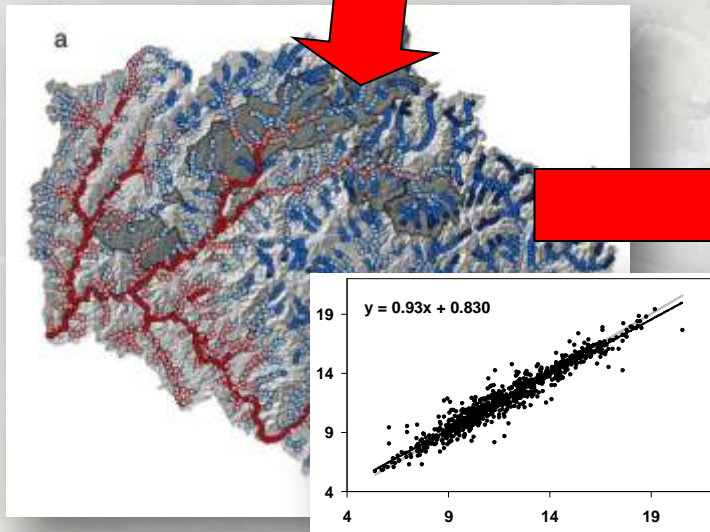
NorWeS_{stream}Temp Applications

More Efficient Monitoring

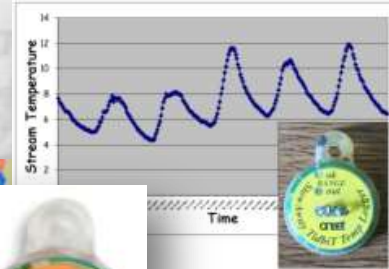
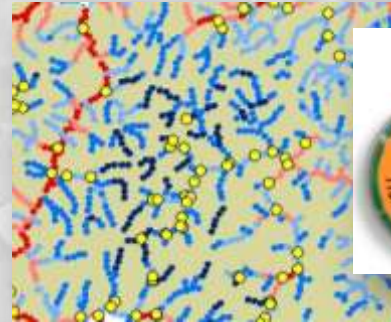
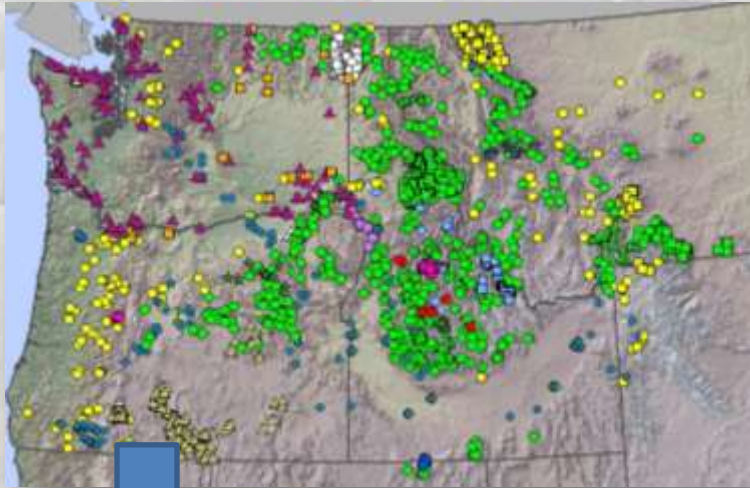


Temperature Model & Thermal Maps

Thermal Habitat Assessments



Website for Accessing Stream Temperature Data



A screenshot of a Google Maps interface. The search bar contains 'Montana Annual Stream Temperature Points available'. The left sidebar shows a list of stream temperature points available by agency, including Adair Creek, Agassiz Creek, and Akokals Creek. The main map area shows a detailed view of the Cottonwood-Clyde Park-Creek area, with a pop-up window providing details for the 'Cottonwood-Clyde Park-Creek' location, including the thermograph location, contact information for Robert Al-Chokhachy, and the agency (USGS, NOROCK).

Montana Annual Stream Temperature Points available
http://www.fs.fed.us/m/boise/AWAE/projects/stream_temperature.shtml

Stream Temperature Points available by Agency

Adair Creek
Thermograph Location: Adair Creek Contact: Clint Muhfeld - cmuhfeld@usgs.gov (406-888-7926)
USGS, NOROCK

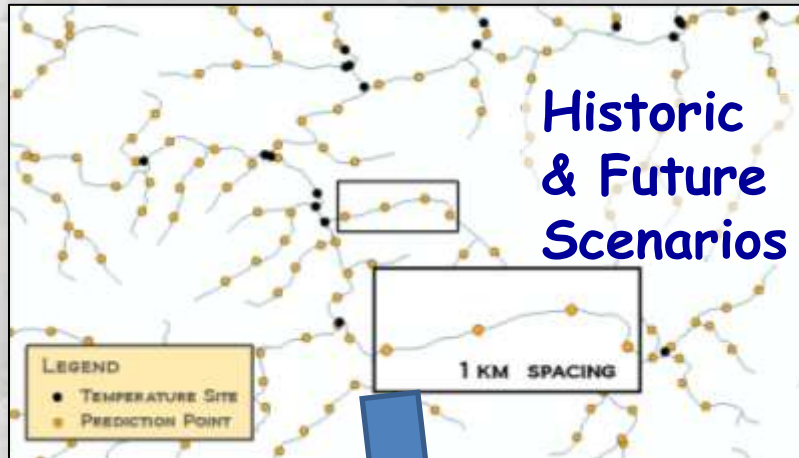
Agassiz Creek
Thermograph Location: Agassiz Creek Contact: Clint Muhfeld - cmuhfeld@usgs.gov (406-888-7926)
USGS, NOROCK

Akokals Creek
Thermograph Location: Akokals Creek Contact: Clint Muhfeld - cmuhfeld@usgs.gov (406-888-7926)
USGS, NOROCK

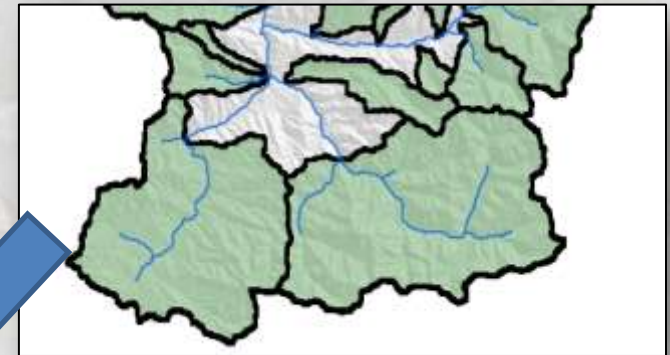
Cottonwood-Clyde Park-Creek
Updated 2 days ago
Thermograph Location: Cottonwood-Clyde Park-Creek
Contact: Robert Al-Chokhachy - ral-chokhachy@usgs.gov (406-994-7842)
USGS, NOROCK
Directions Search nearby more

Website for Accessing Temperature Model Outputs

GIS files of temperature predictions at 1 km resolution on all fish-bearing streams...

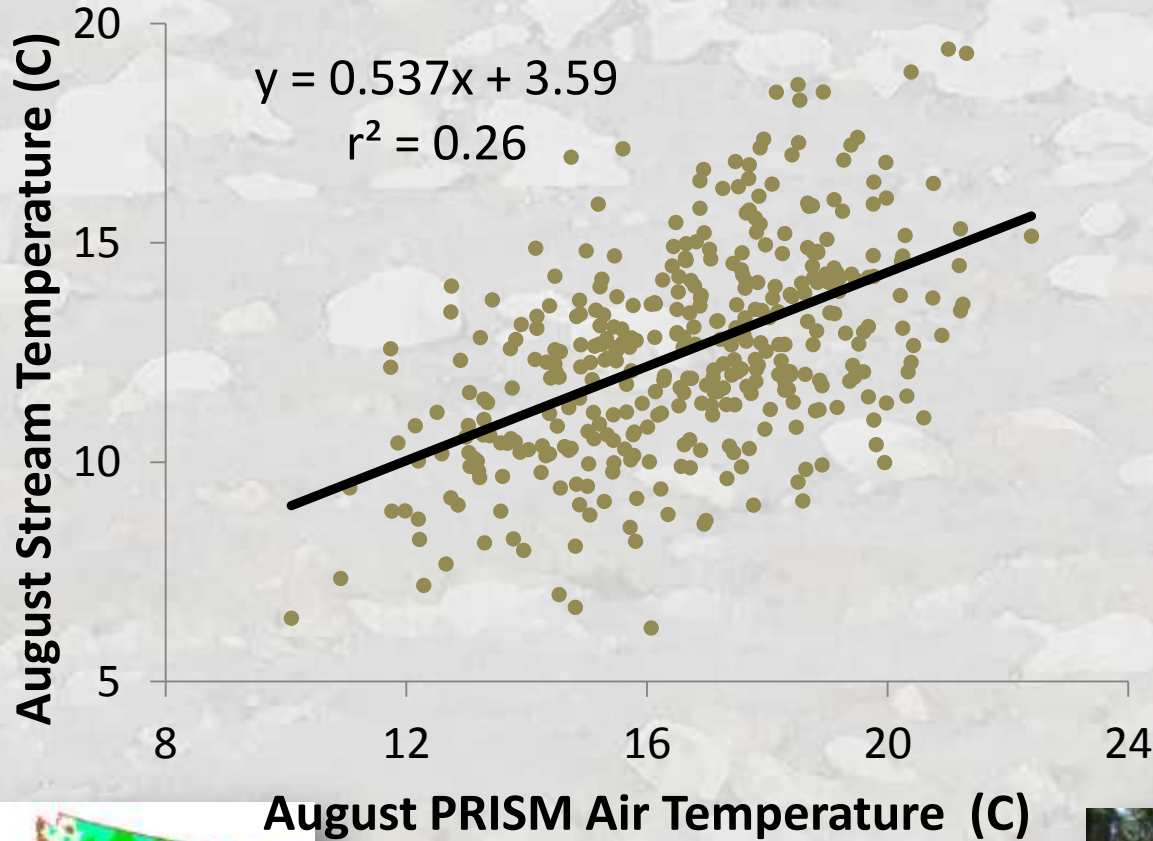


& thermally suitable habitats aggregated into "patch" polygons based on species-specific criteria



Websites for Distribution

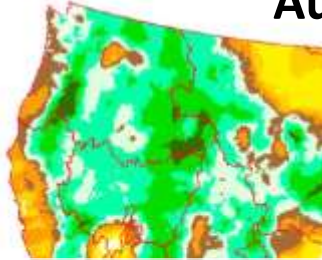
Air Temp \neq Stream Temp



Complex topography



Glaciation



Groundwater buffering



Riparian differences

More Precise Bioclimatic Assessments



USGS
United States Geological Survey
Science for a changing world
Forest and Rangeland Ecosystem Science Center

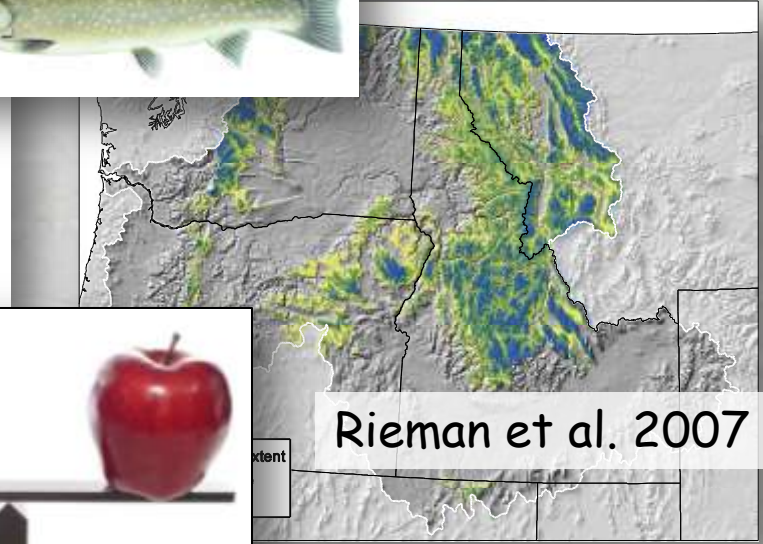
Range-wide climate vulnerability assessment for bull trout in the conterminous United States

"Judging by one criterion, it is Extinct!"

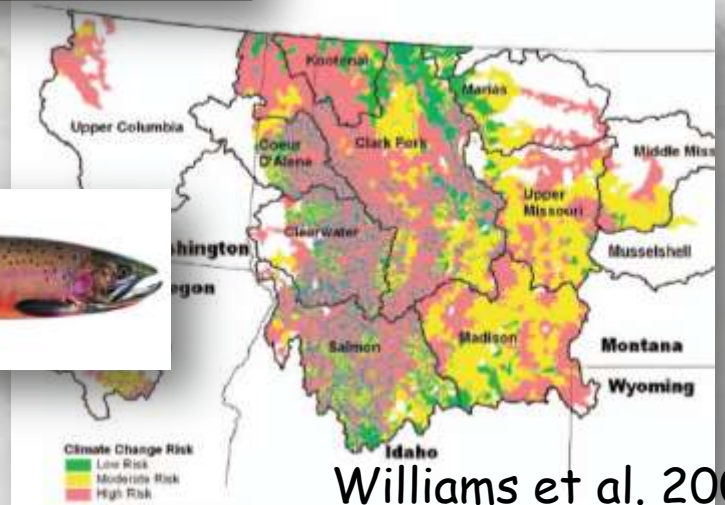
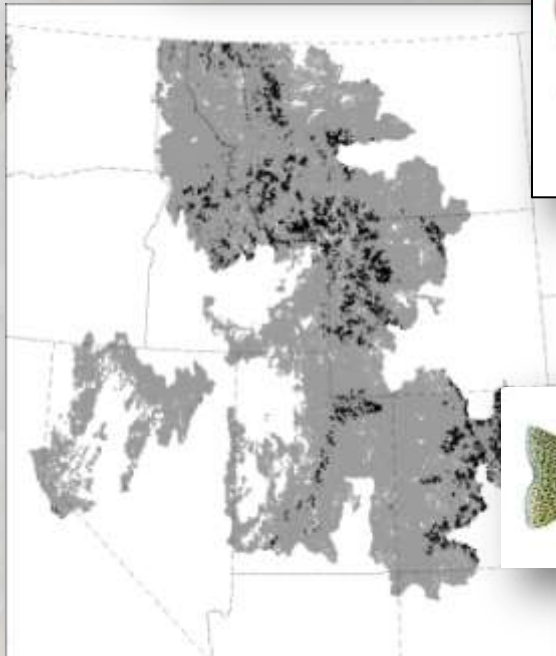
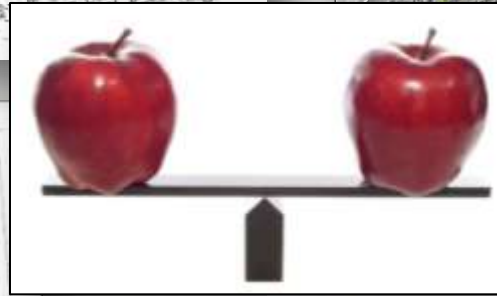
"But judging by another, it is alive and healthy in places!"



Dunham et al., In prep.



Rieman et al. 2007



Wenger et al. 2011. *PNAS*.

Williams et al. 2009

Relevant Publications...

Regional Trend Description...

Climate change effects on stream and river temperatures across the northwest U.S. from 1980–2009 and implications for salmonid fishes

D. J. Isaak, S. Wollrab, D. Horan & G. Chandler

Climatic Change
An Interdisciplinary, International Journal Devoted to the Description, Causes and Implications of Climatic Change

ISSN 0165-0009

Climatic Change
DOI 10.1007/s10584-011-0326-z



Regional Modeling Approach...

Ecological Applications, 20(5), 2010, pp. 1350–1371
© 2010 by the Ecological Society of America

Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network

DANIEL J. ISAAK,^{1,3} CHARLES H. LUCE,¹ BRUCE E. RIEMAN,¹ DAVID E. NAGEL,¹ ERIN E. PETERSON,² DONA L. HORAN,¹ SHARON PARKES,¹ AND GWYNNE L. CHANDLER¹

¹U.S. Forest Service, Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory, 322 E. Front Street, Suite 401, Boise, Idaho 83702 USA

²Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Mathematical and Information Sciences, Indooroopilly, Queensland, Australia

A Moving Average Approach for Spatial Statistical Models of Stream Networks

Jay M. VER HOEF and Erin E. PETERSON

In this article we use moving averages to develop new classes of models in a flexible modeling framework for stream networks. Streams and rivers are among our most important resources, yet models with autocorrelated errors for spatially continuous stream networks have been described only recently. We develop models based on stream distance rather than on Euclidean distance. Spatial autocorrelation models developed for Euclidean distance may not be valid when using stream distance. We begin by describing a stream topology. We then use moving averages to build several classes of valid models for streams. Various models are derived depending on whether the moving average has a "tail-up" stream, a "tail-down" stream, or a "two-tail" construction. These models also can account for the volume and direction of flowing water. The data for this article come from the Ecosystems Health Monitoring Program in Southeast Queensland, Australia, an important national program aimed at assessing water quality. We model two water chemistry variables, pH and conductivity, for sample sites close to 100. We estimate fixed effects and make spatial predictions. One interesting aspect of stream networks is the possible dichotomy of autocorrelation between flow-connected and flow-unconnected locations. For this reason, it is important to have a flexible modeling framework, which we achieve on the example data using a variance component approach.

KEY WORDS: Euclidean distance; Geostatistics; Kernel convolution; Spatial autocorrelation; Spatial linear model.

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Stream Temperature Modeling and Monitoring

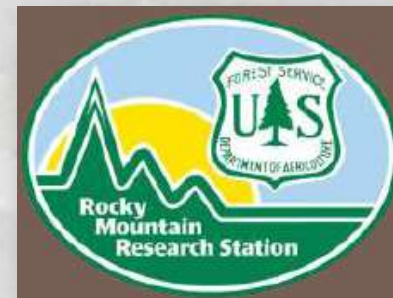


Thermal regimes are important to aquatic ecosystems because they strongly dictate species distributions, productivity, and the development of temperature models and monitoring networks applicable at broad spatial scales. This tool to help those in the western US organize temperature monitoring efforts, describes techniques for measuring stream temperature, describes several statistical models for predicting stream temperatures and thermally suitable fish habitats from stream temperature data, and also provides links to other stream temperature resources such as publications, videos, and presentations on the topic.

This Page: [Temperature Monitoring](#) | [Temperature Models](#) | [Other Resources](#) | [Stream Temperature Publications](#)

- Stream temperature publications & protocols
- Processing macro for temperature data
- GoogleMap Temperature Webtool
- Temperature model descriptions & outputs

A video demonstration of the epoxy protocol is also available on the temperature website.



The End

