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

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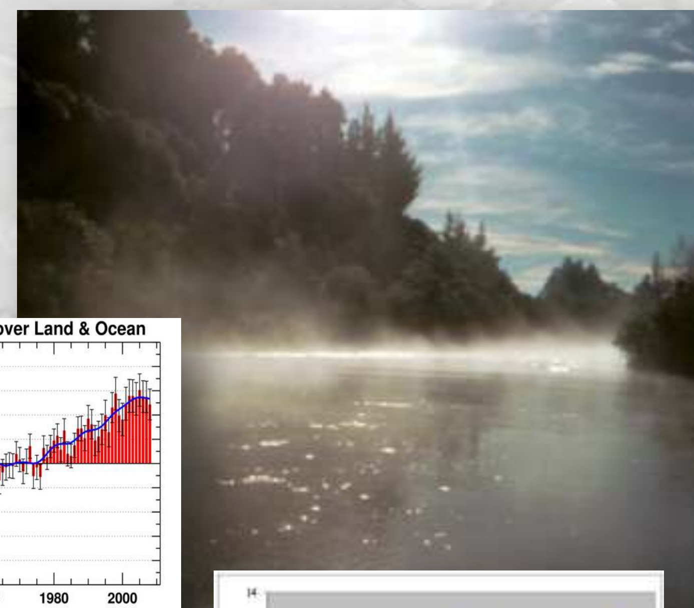
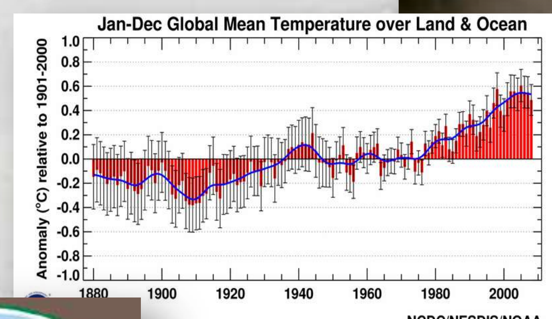
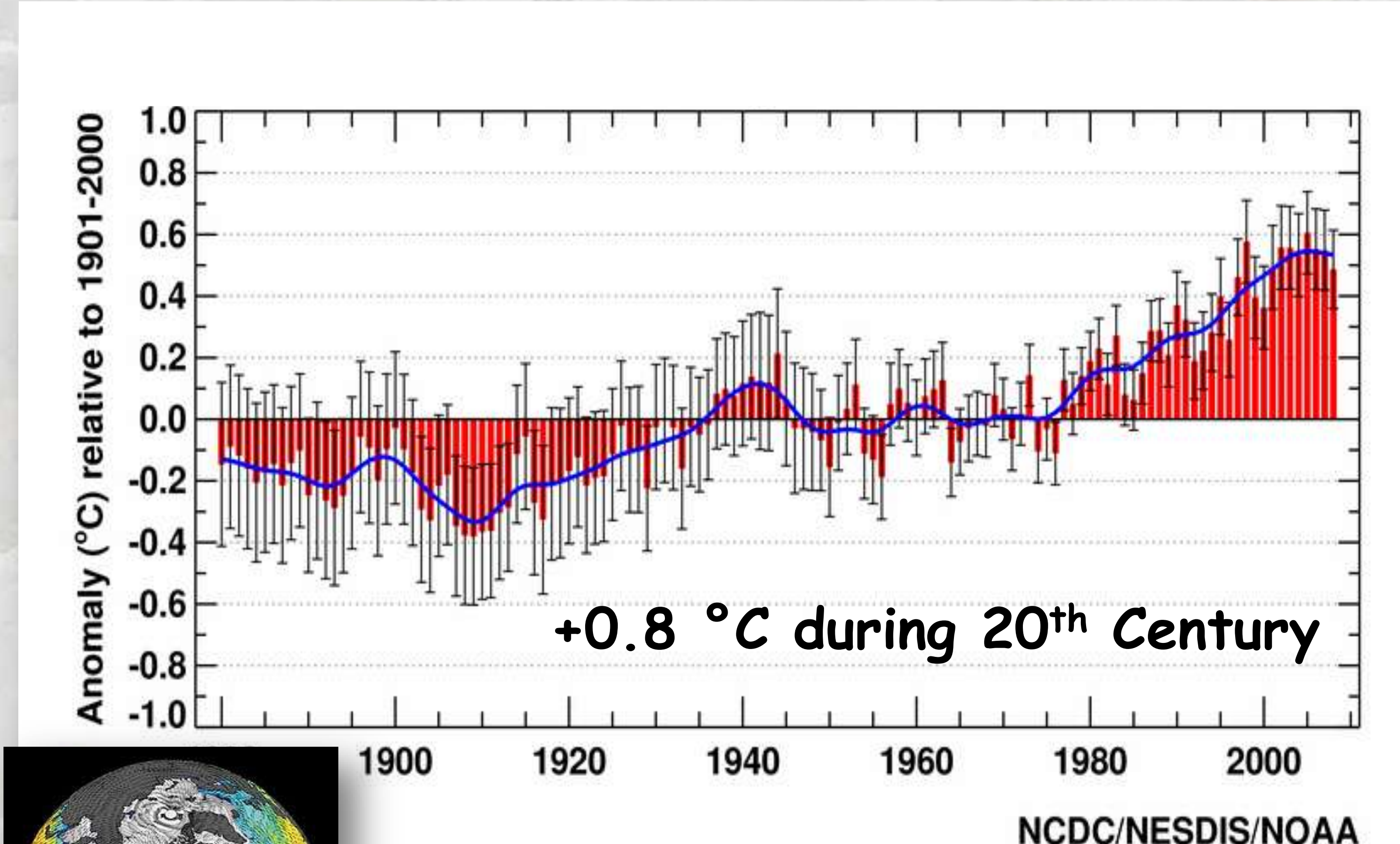
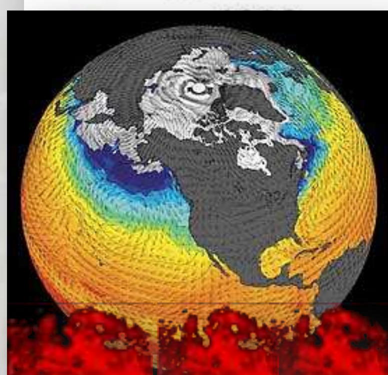
Boise, ID 83702





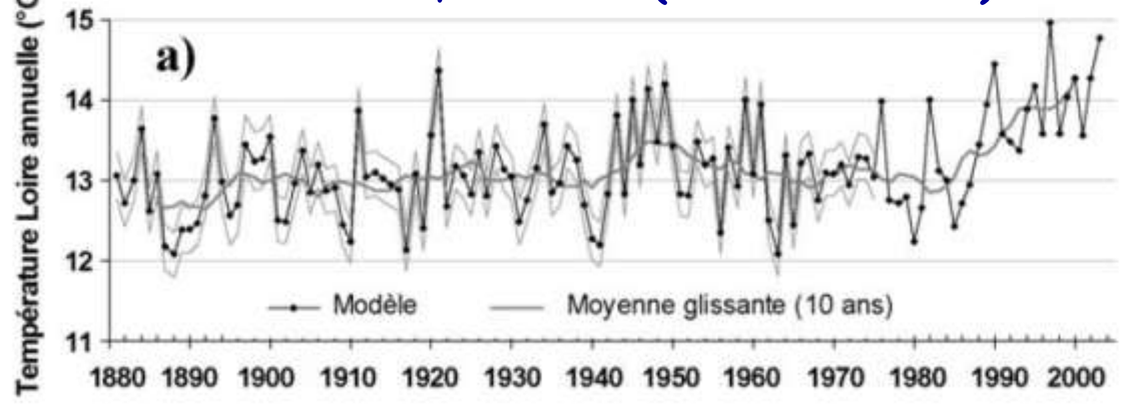
Global Trends in Air Temperatures





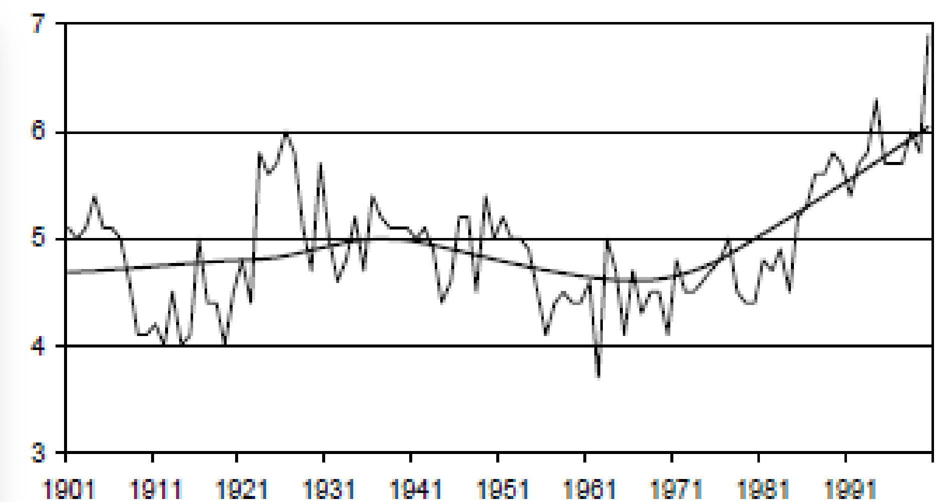
Global Trends in River Temperatures

River Loire, France (1880 – 2003)



Moatar and Gailhard 2006

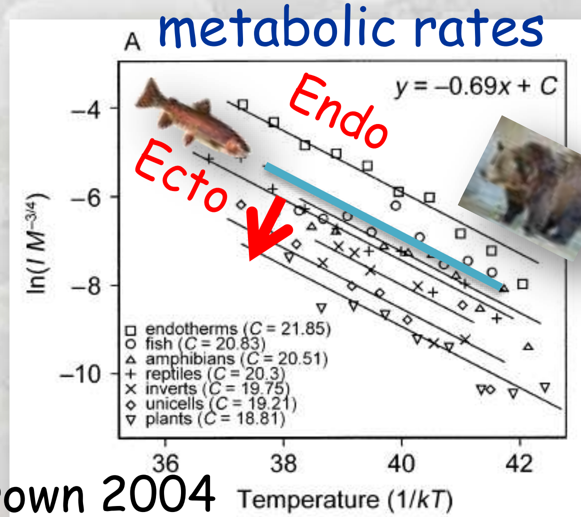
Danube River, Austria (1901 – 2000)



Webb and Nobilus 2007

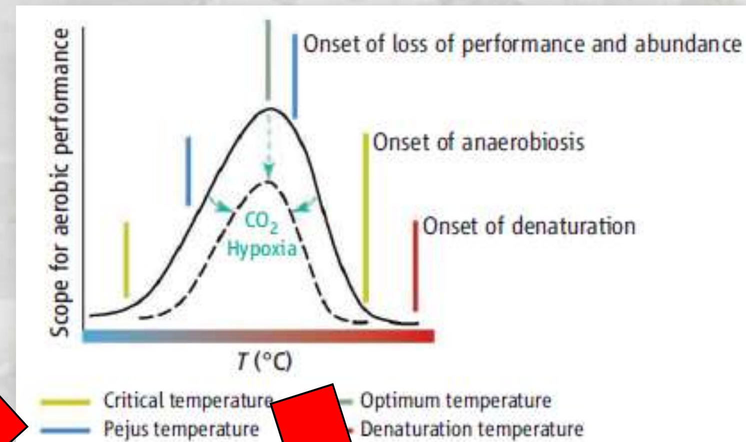
Temperature is Primary Control for Ectotherms Like Fish

Temperature & metabolic rates

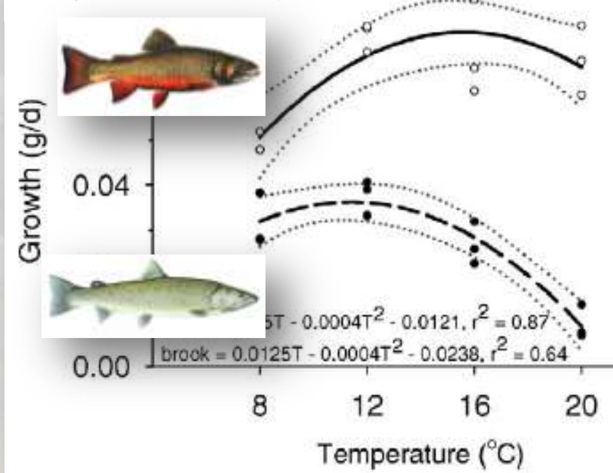


Brown 2004

Thermal Niche

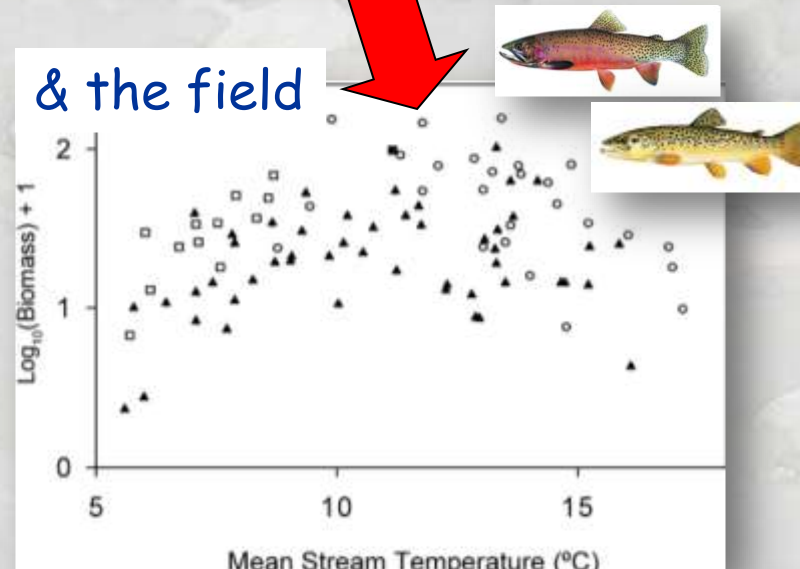


In the lab…



McMahon et al. 2007

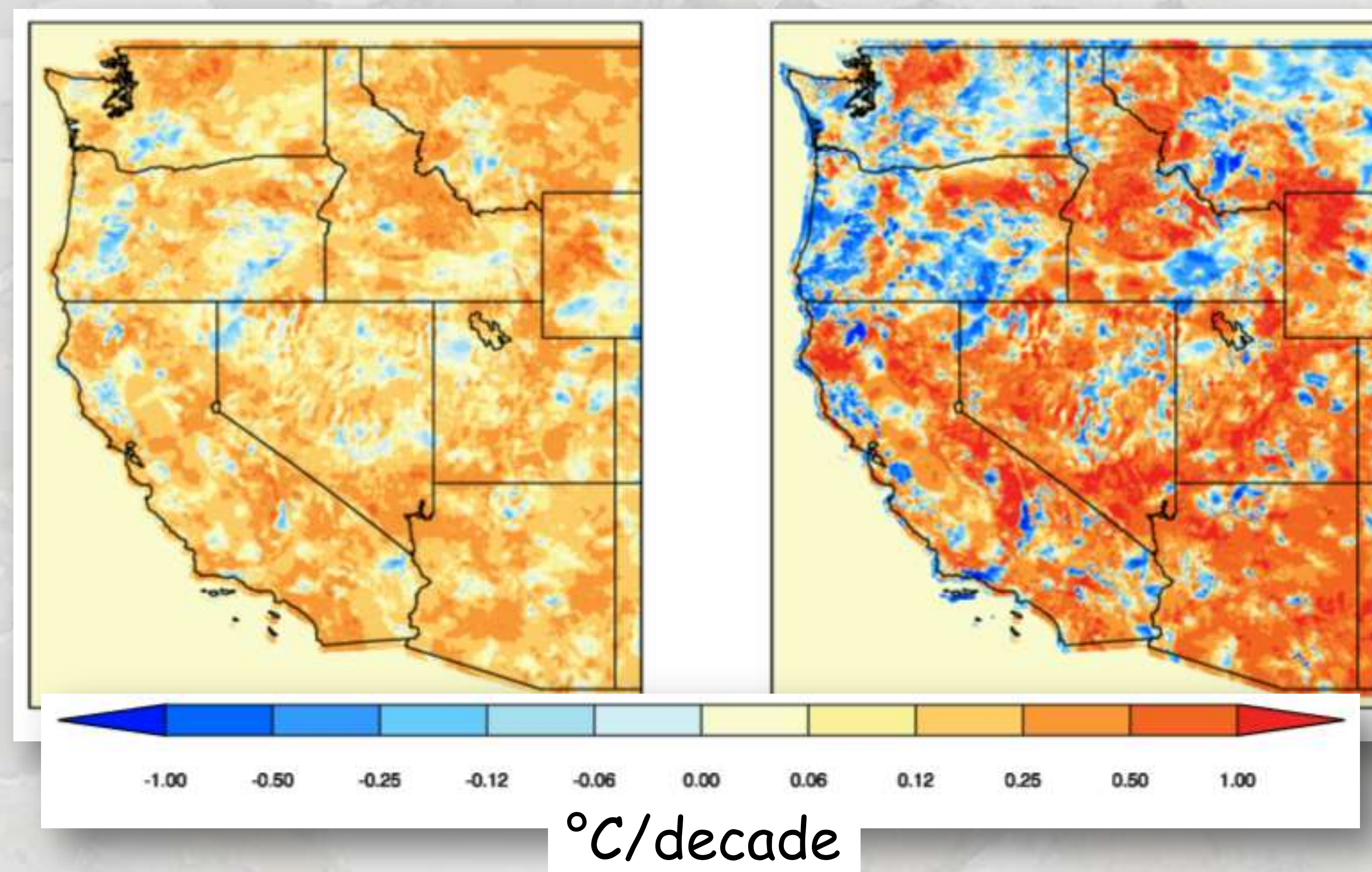
& the field



Isaak & Hubert 2004

Western U.S. Air Temperature Trends

1950 - 2009 **1987 - 2009**

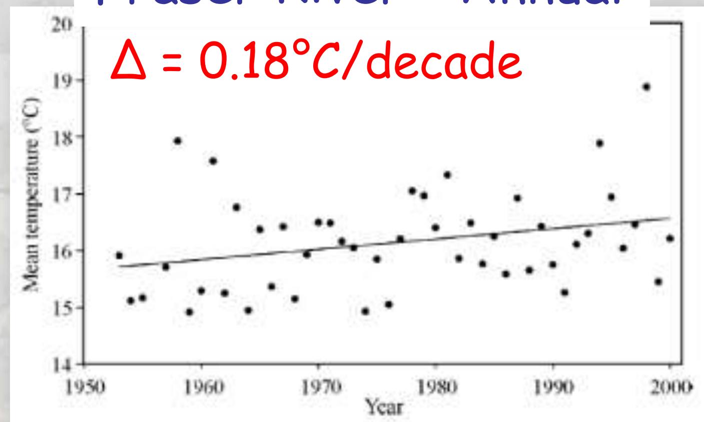


*PRISM maps interpolated from weather station data

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

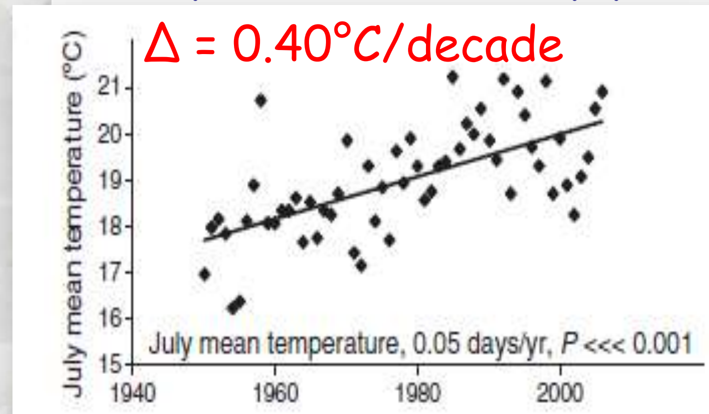
Regional Trends In Northwest Rivers

Fraser River - Annual



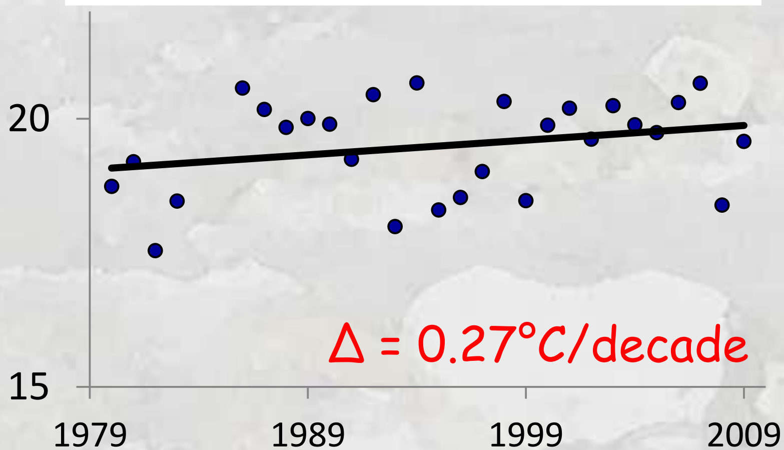
Morrison et al. 2002

Columbia River - Summer

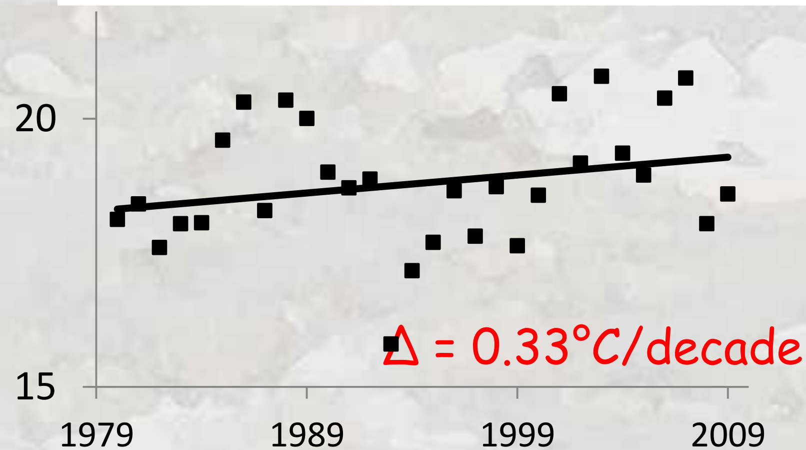


Crozier et al. 2008

Snake River, ID - Summer



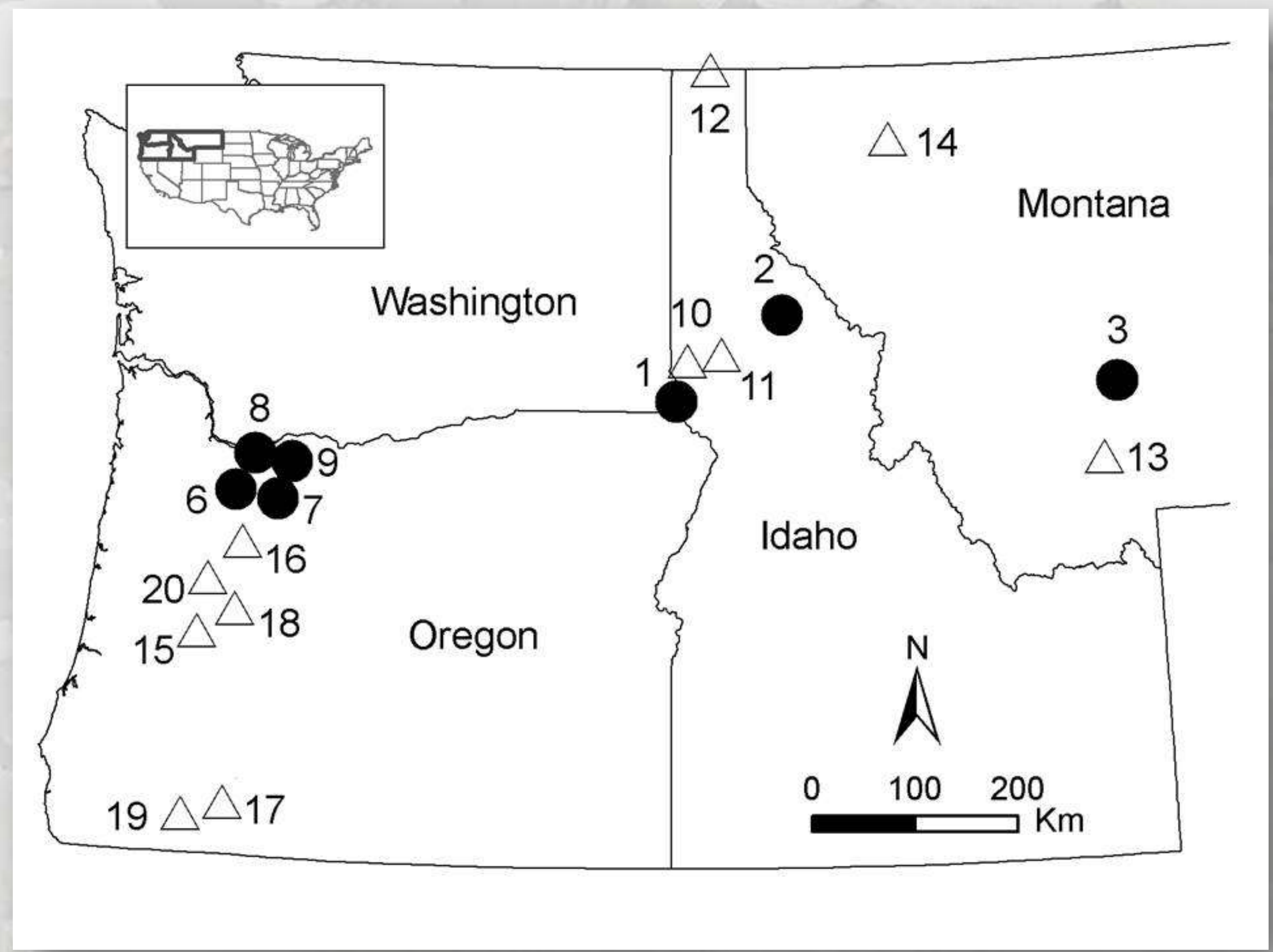
Missouri River, MT - Summer



Isaak et al. 2011. *Climatic Change*

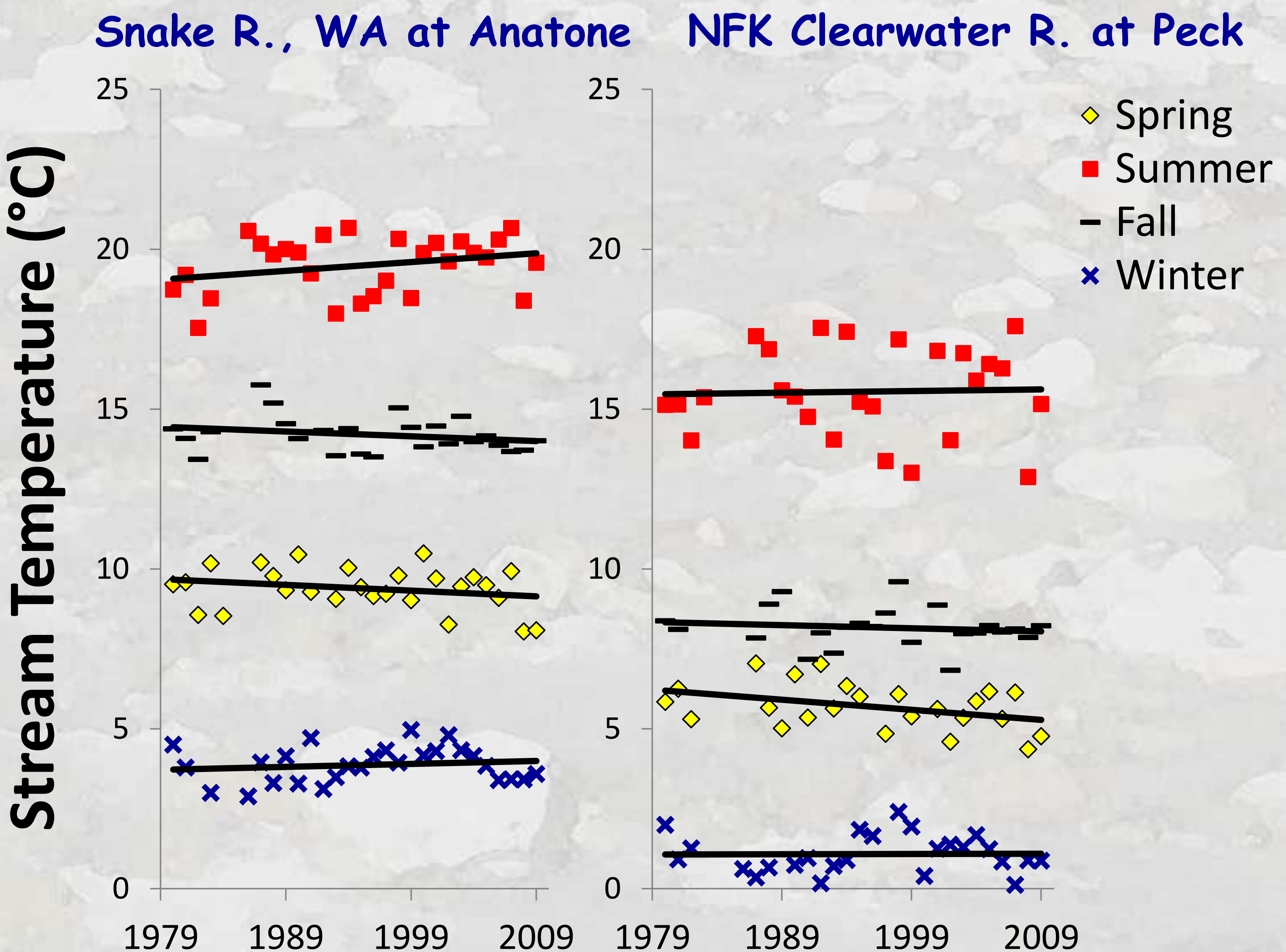
30 Year Monitoring Sites in NW U.S.

△ = regulated (11) ● = unregulated (7)

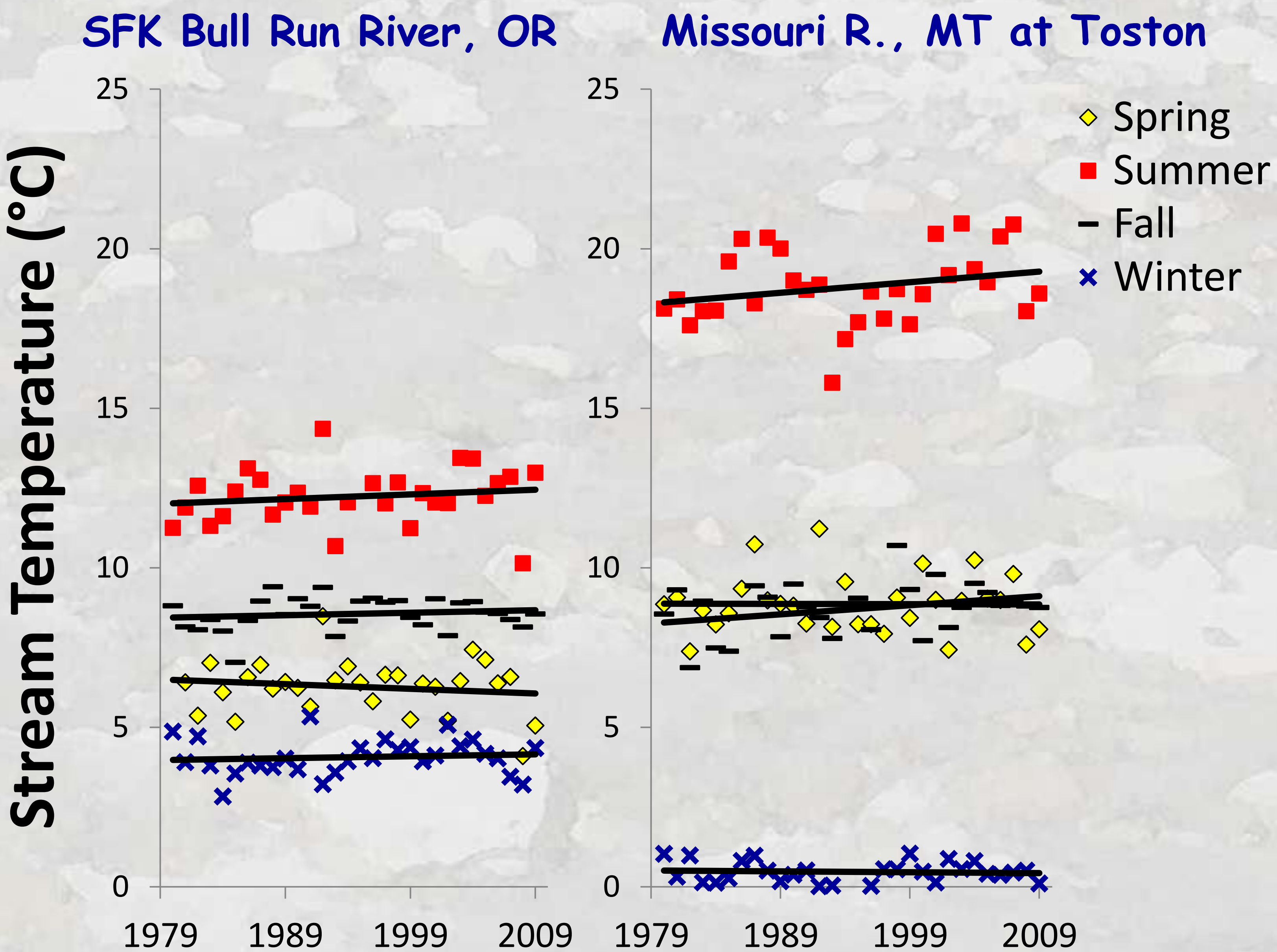


Data Source: USGS NWIS

Example 30 Year Monitoring Records



Example 30 Year Monitoring Records



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

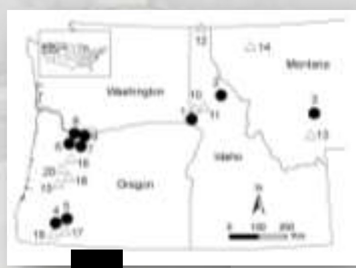
- Statistical significance of trends assessed across monitoring sites with 1-sample *t*-test

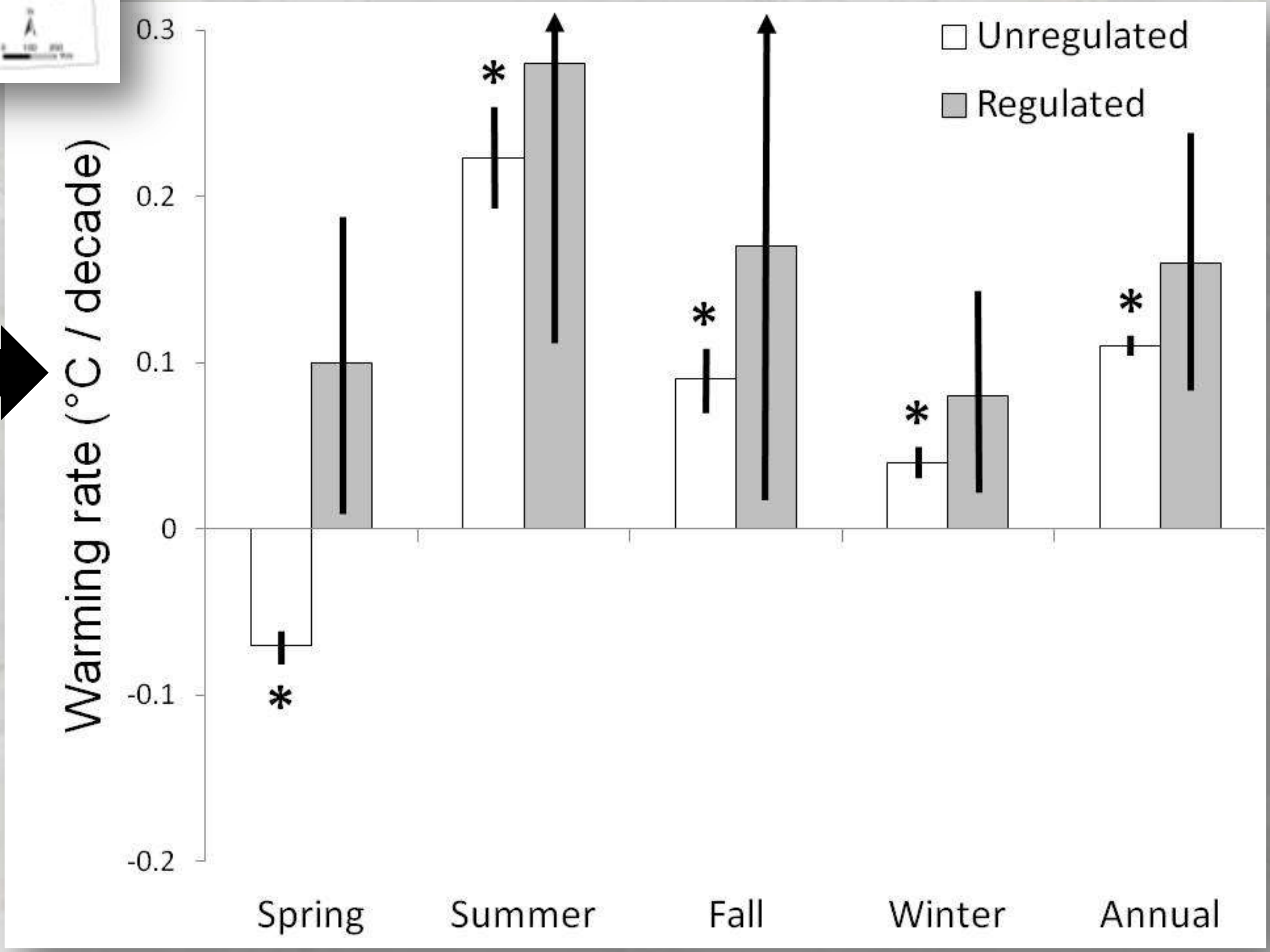
Example Multiple Regression Results

Spring period (March, April, May)

Stream site	Multiple regression equation (Air / Discharge)	R^2	RMSE (C)	Significant Interaction?
Spring period				
1. Snake River Near Anatone, WA	$y=3.43+0.588^{a}(\text{air °C})+0.00013(m^3/s)$	0.68	0.37	No
2. North Fork Clearwater River, ID	$y=1.48+0.548^{a}(\text{air °C})+0.00373(m^3/s)$	0.79	0.32	No
3. Missouri River, MT	$y=7.05+0.583^{a}(\text{air °C})+0.00499^{a}(m^3/s)$	0.85	0.35	Yes
6. South Fork Bull Run River, OR	$y=1.01+0.716^{a}(\text{air °C})+0.183^{a}(m^3/s)$	0.85	0.32	No
7. Fir Creek, OR	$y=0.0139+0.701^{a}(\text{air °C}) - 0.313(m^3/s)$	0.89	0.26	No
8. North Fork Bull Run River, OR	$y=0.768+0.710^{a}(\text{air °C}) - 0.307^{a}(m^3/s)$	0.84	0.33	No
9. Bull Run River, OR	$y=-0.276+0.810^{a}(\text{air °C}) - 0.0392(m^3/s)$	0.83	0.32	No

Seasonal Trends In Temperatures (1980-2009)

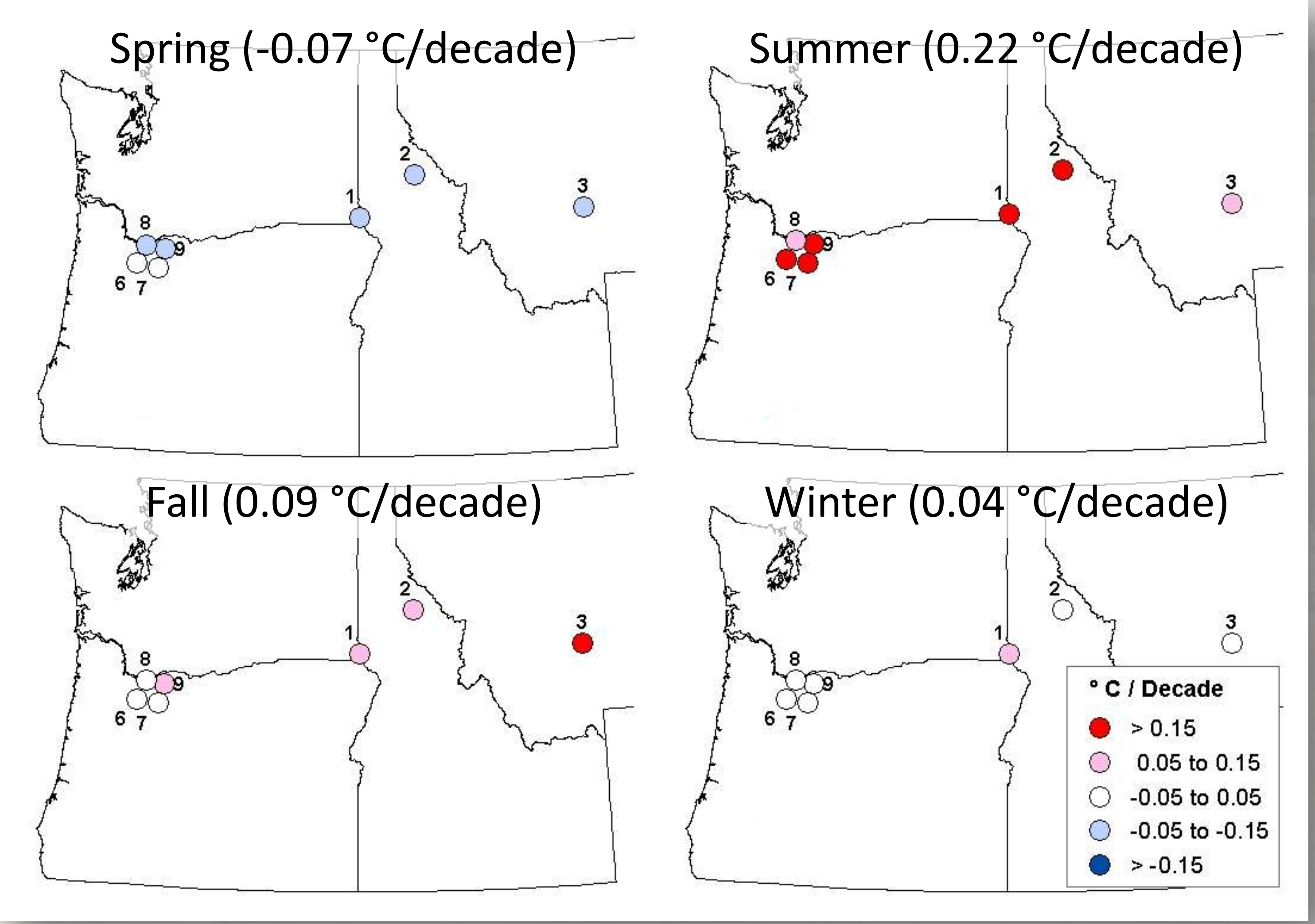




Isaak et al. 2011. *Climatic Change*

Seasonal Trends In Temperatures (1980-2009)

Unregulated sites (7)



Attribution of Stream Warming Trends

Air temp & discharge effects are additive

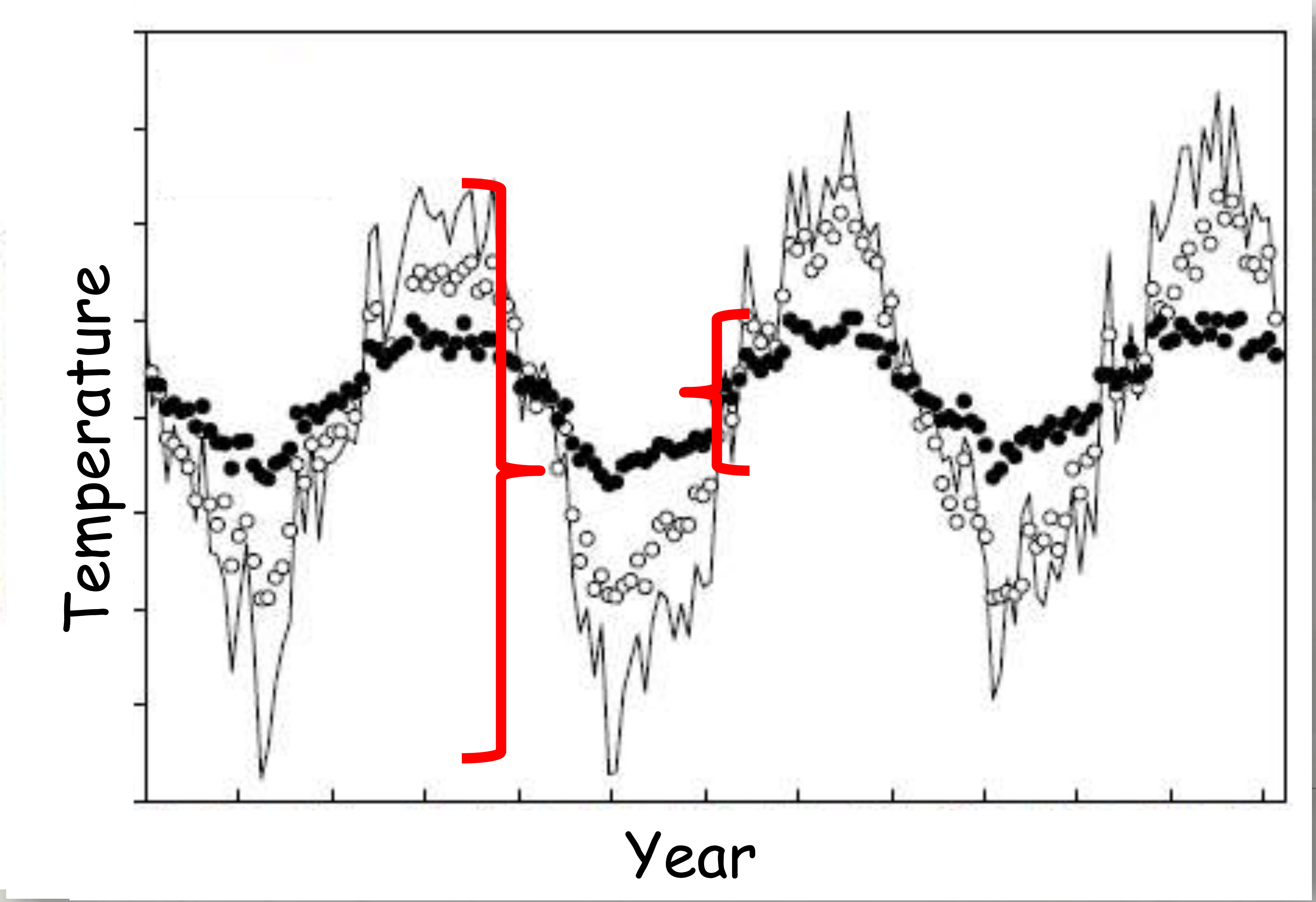
Site	Reconstructed trends		
	Total stream temperature change (°C)	Air temperature, discharge contributions (°C)[a]	Standardized b_x's (air temperature, discharge)[b]
Spring Period			
1. Snake River Near Anatone, WA	−0.325	−0.307, −0.018	0.78, −0.12
2. North Fork Clearwater River, ID	−0.346	−0.453, 0.107	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

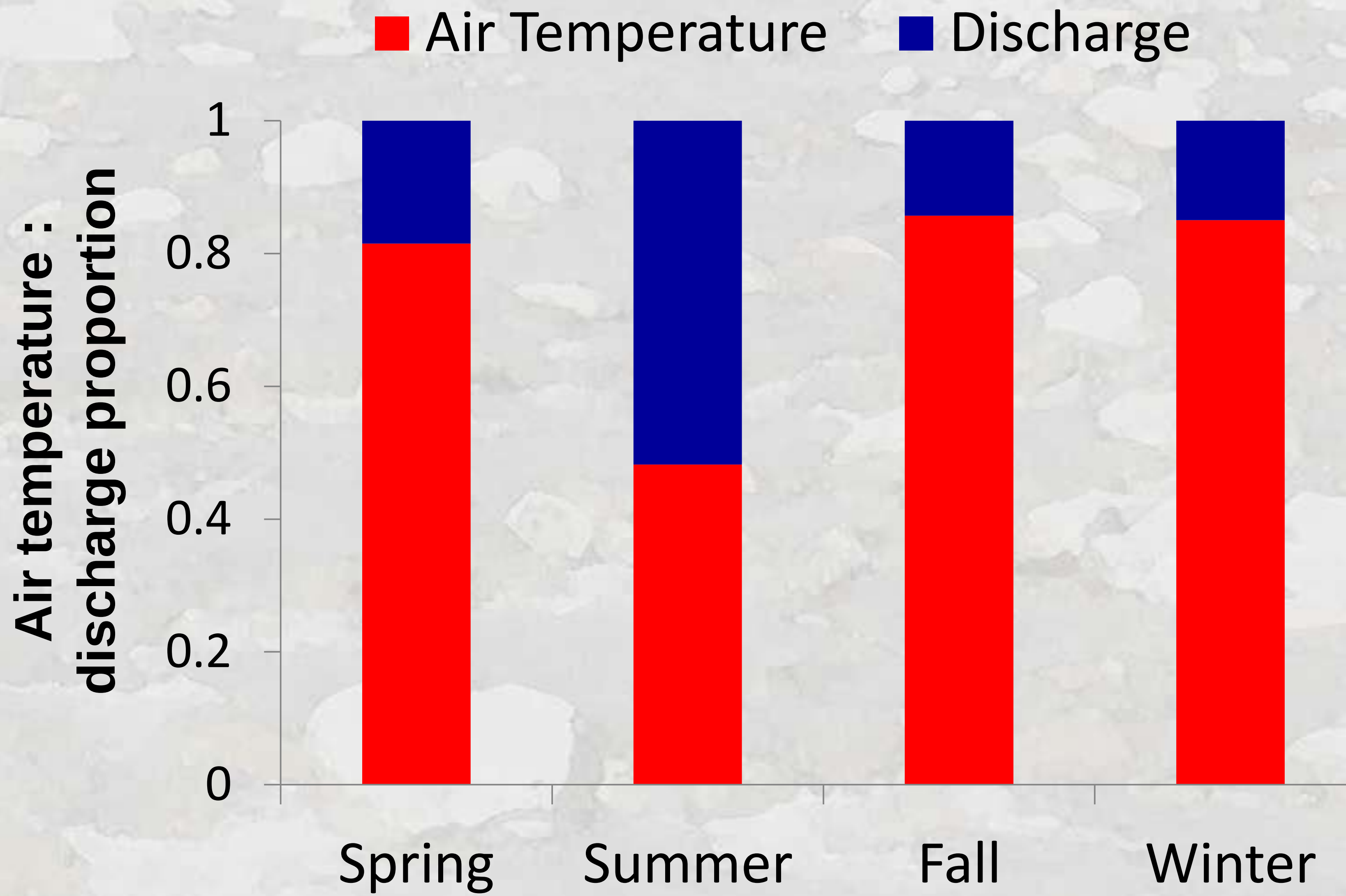
Attribution of Stream Warming Trends

Inter-annual variation ~ environmental noise



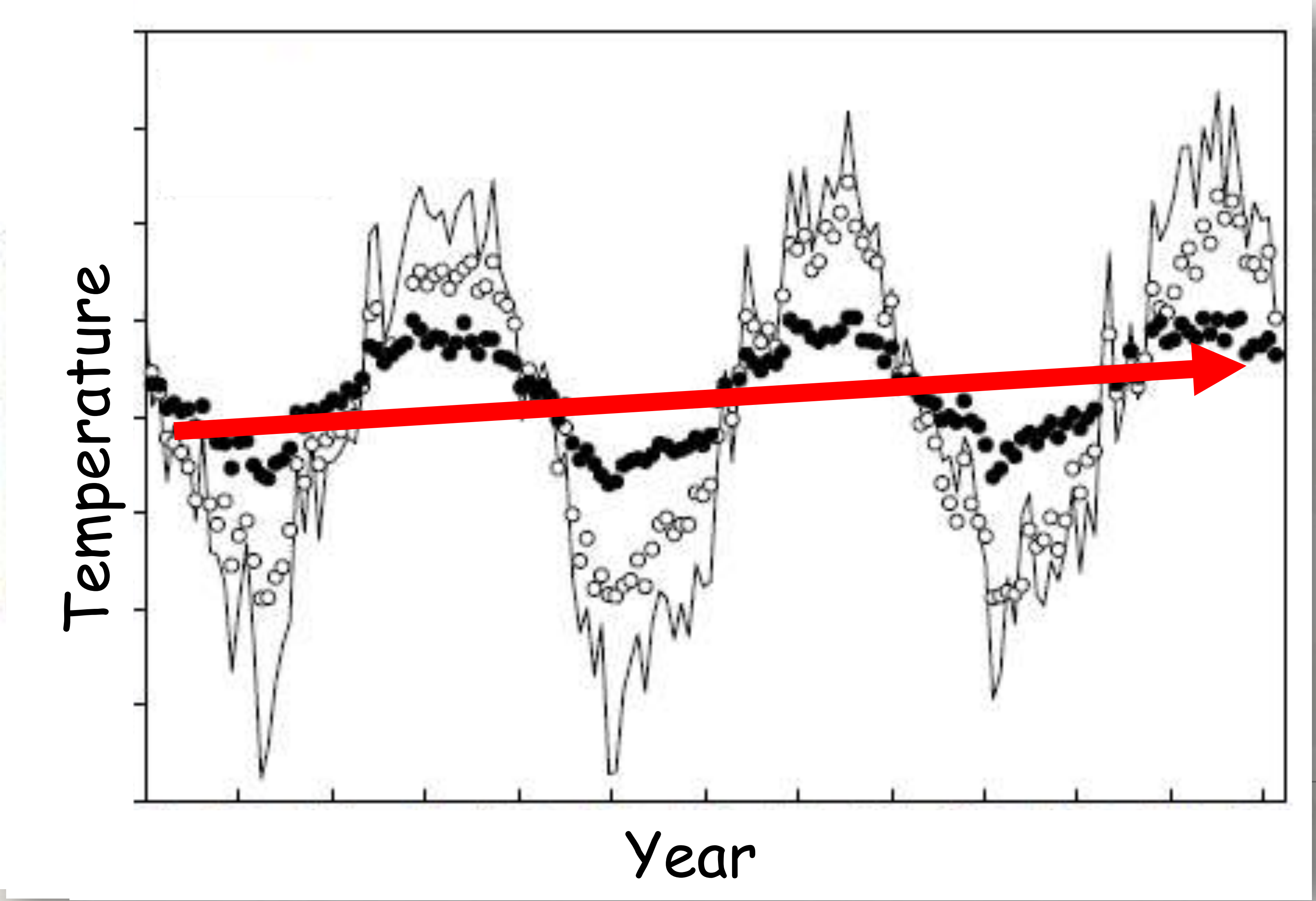
Attribution of Stream Warming Trends

Inter-annual variation ~ environmental noise



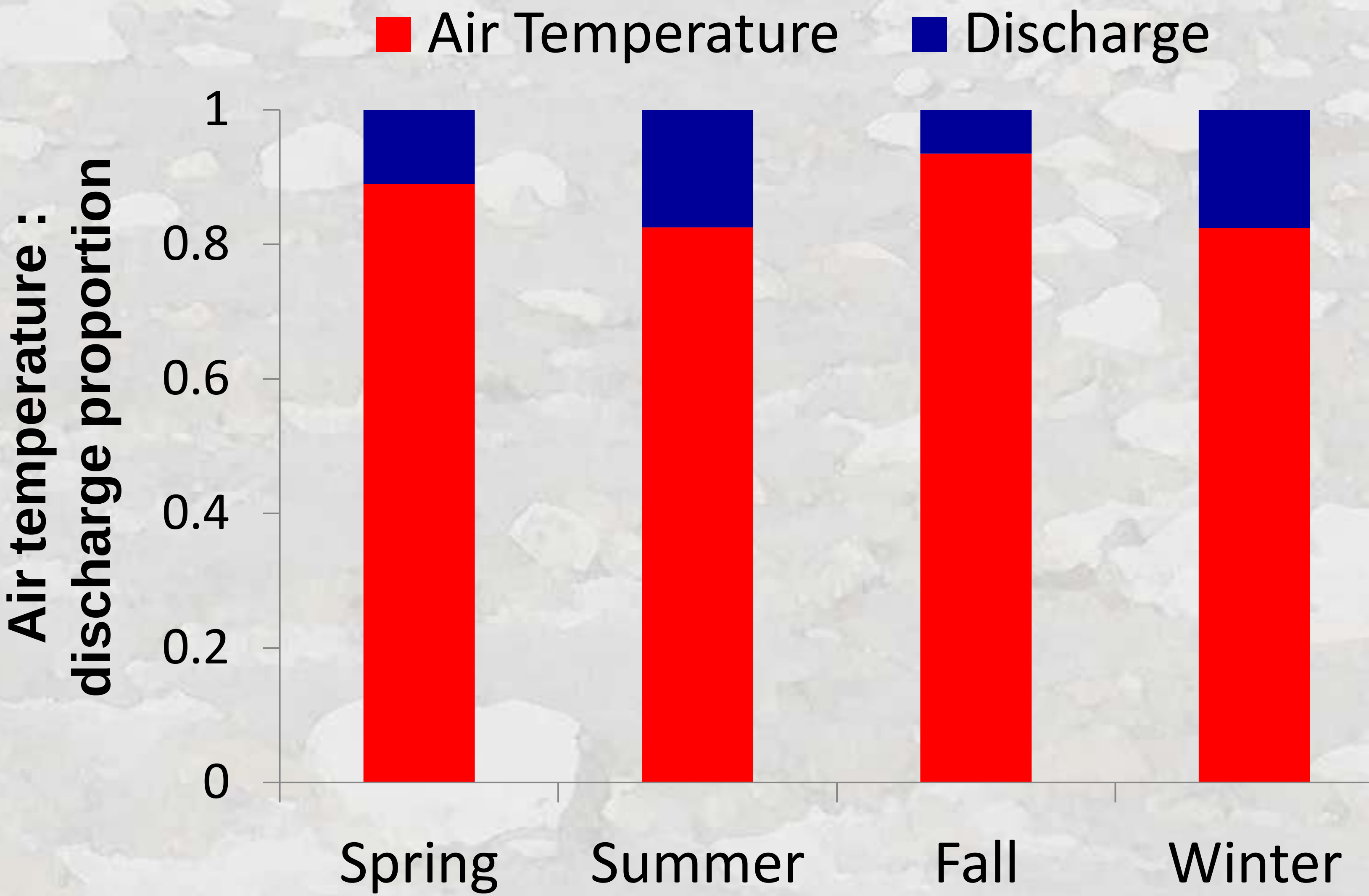
Attribution of Stream Warming Trends

Long-term trend ~ environmental signal



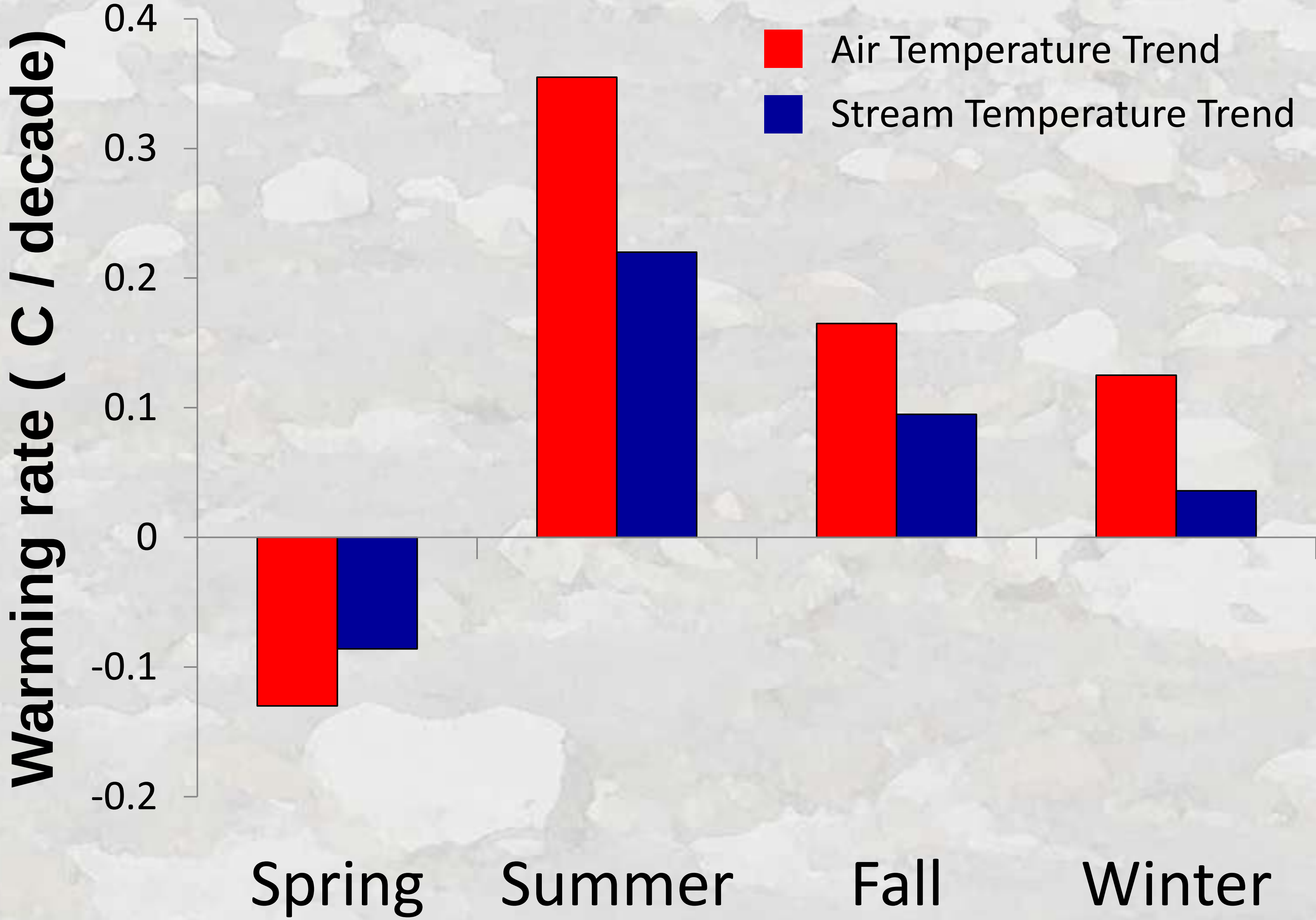
Attribution of Stream Warming Trends

Long-term trend ~ environmental signal



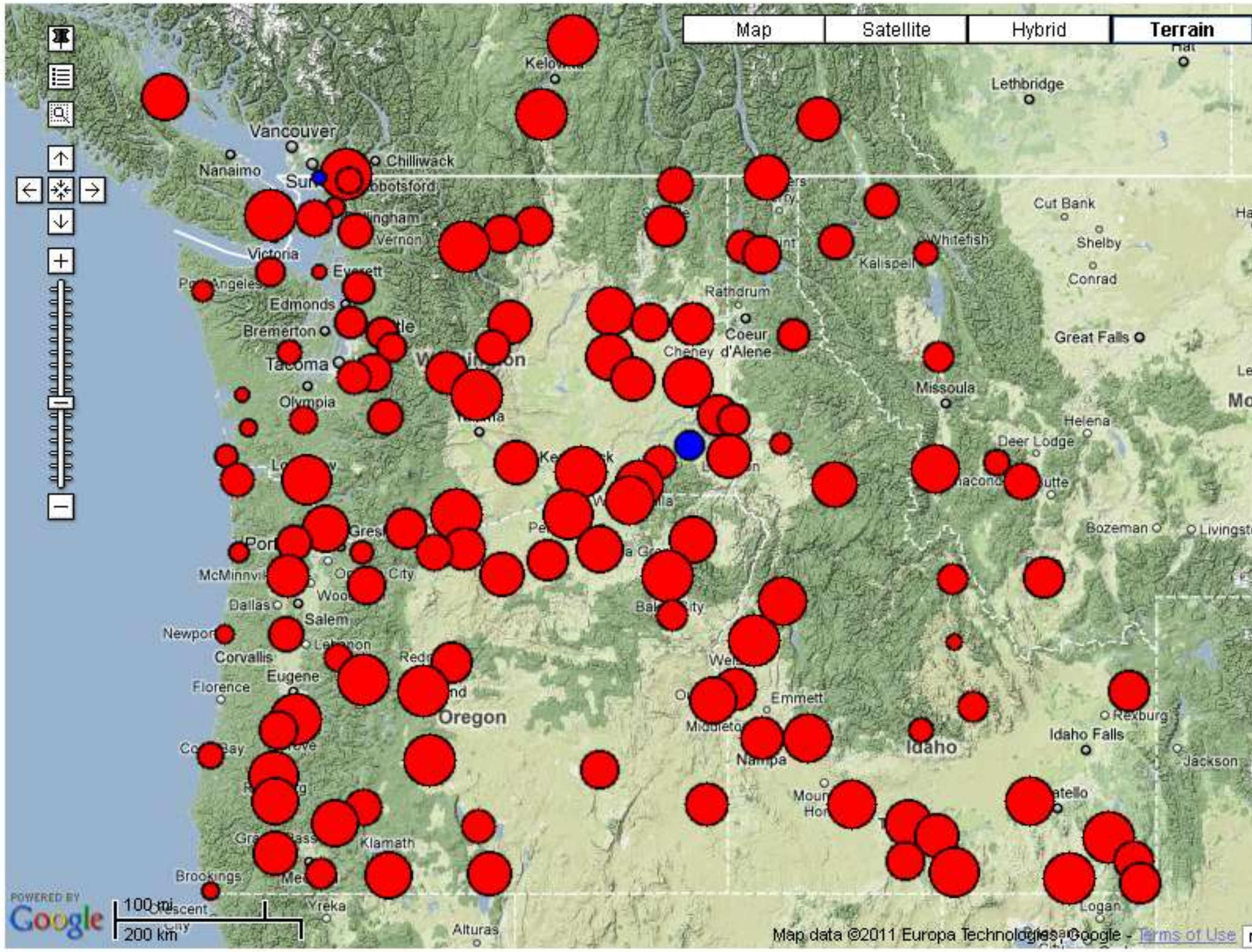
Attribution of Stream Warming Trends

Comparison to Air Temp Trends at Local Climate Stations



Similar Trends in Most Regional Streams?

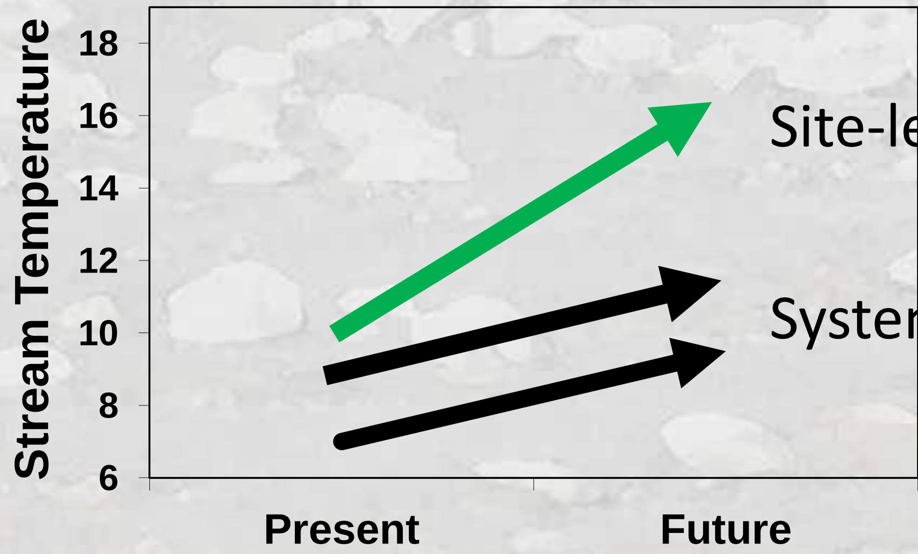
Mean Summer Air Temp Trends (1980 – 2009)



OWSC Climate Tool map

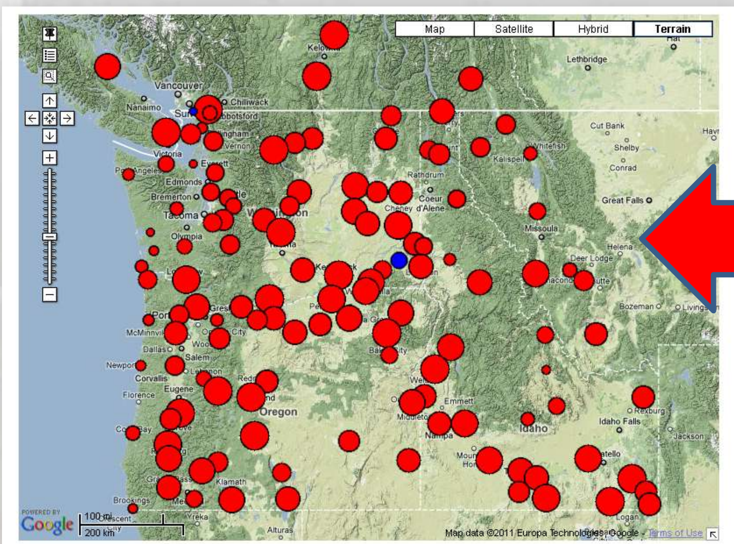
http://www.climate.washington.edu/trendanalysis/

Spatial Variation in Temperature Changes



Different Climate Forcing?

Or Different Sensitivity?

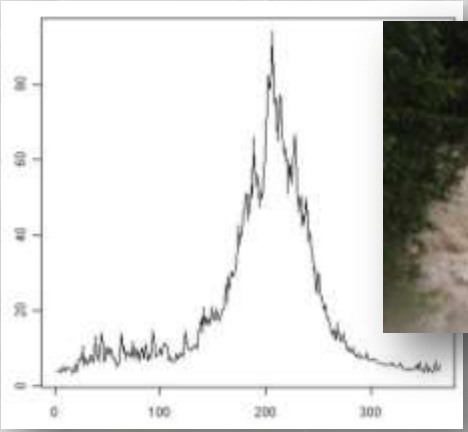


Glaciation?
Riparian type?
Groundwater?

Easy Method for Full Year Data

Underwater Epoxy Protocol

Annual Flooding Concerns



Underwater epoxy cement

<u>$100 = 5 years of data</u>

Data retrieved from underwater

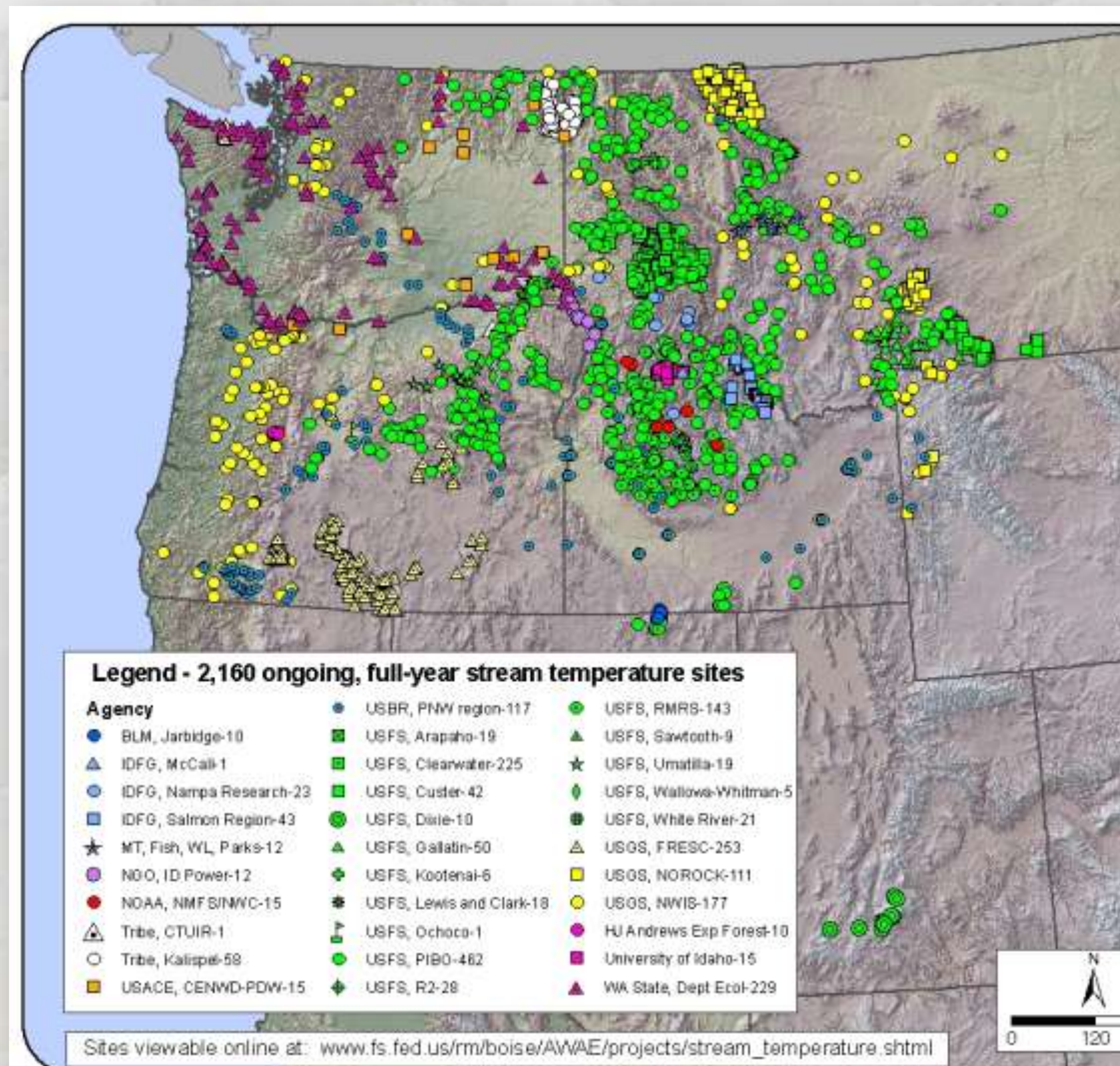
Sensors or protective housings glued to large boulders

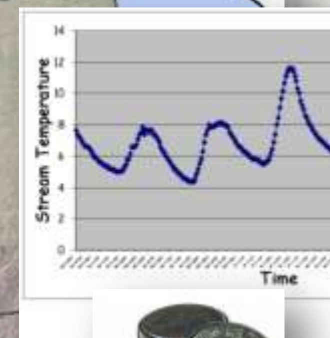
Isaak & Horan 2011. *NAJFM* 31:134-137 ➡ **Google Search "Stream Temperature Boise"**

Massive Regional Monitoring Network

2,160 current full-year monitoring sites

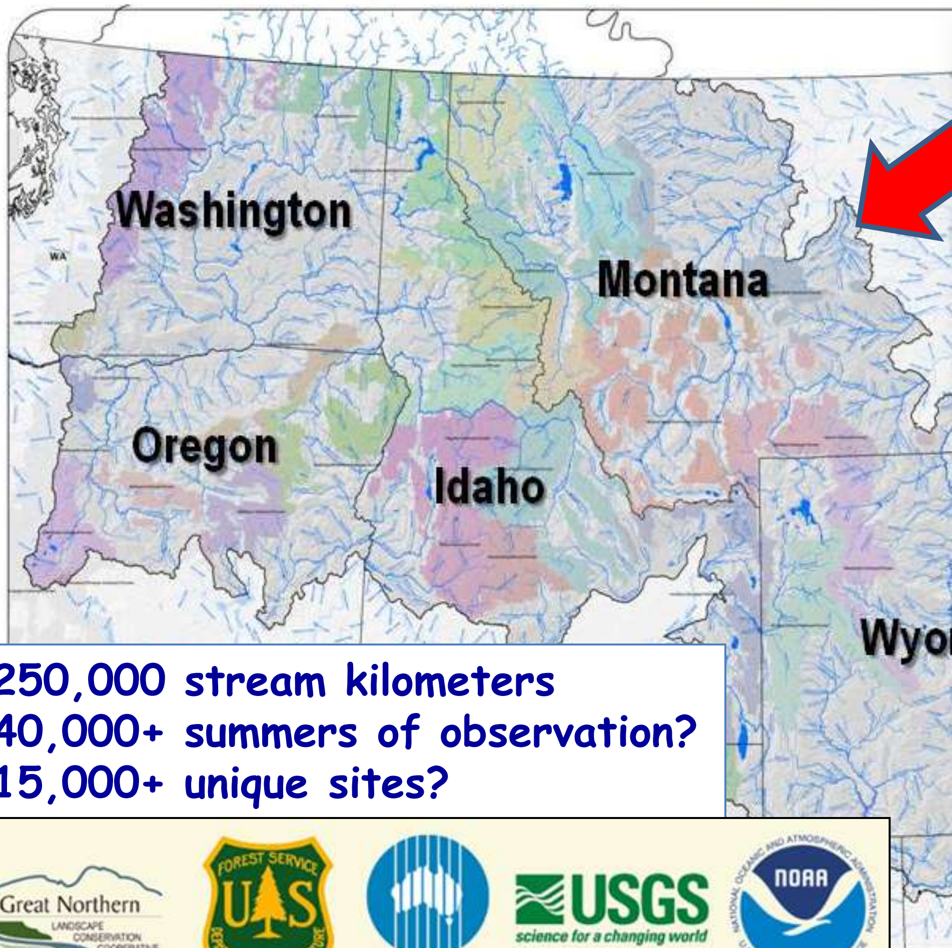
~1,000 new 2011 deployments





A Regional Stream Temperature Database & Model

Great Northern
LANDSCAPE CONSERVATION COOPERATIVE



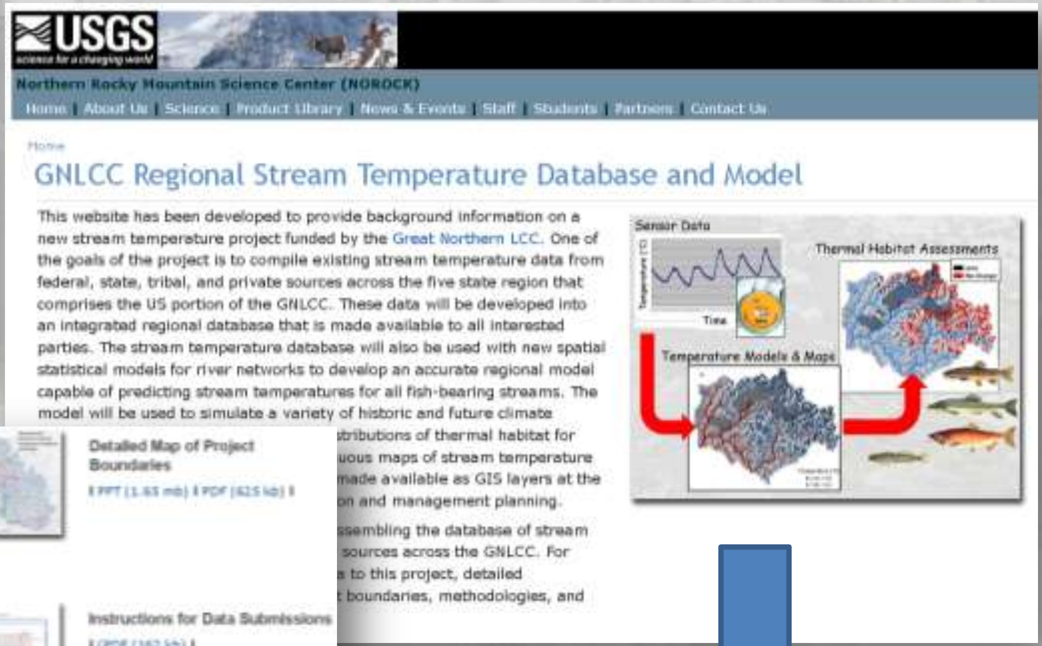
Landscape Conservation Cooperatives

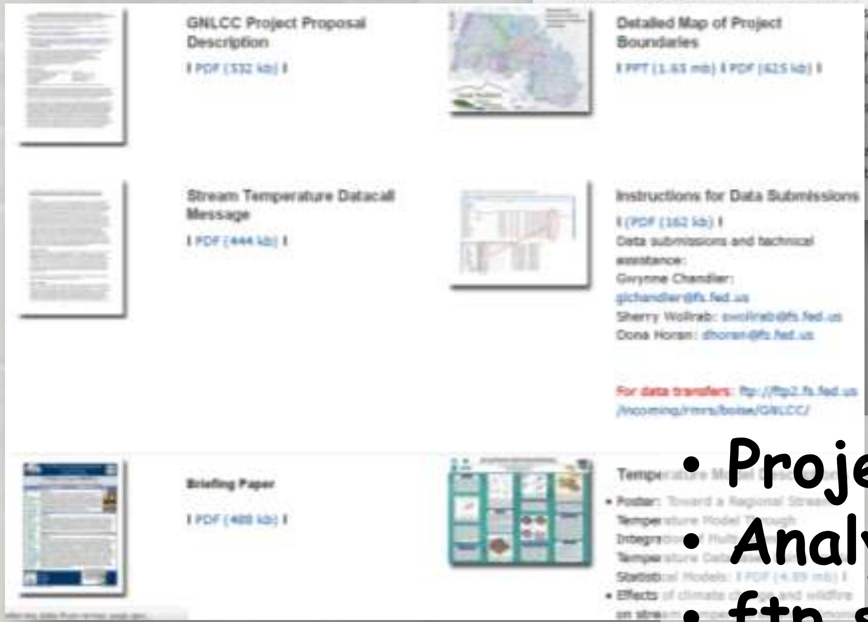
- 250,000 stream kilometers
- 40,000+ summers of observation?
- 15,000+ unique sites?

Regional Stream Temperature Datacall

Visit the Datacall Website…

Google Search "GNLCC Stream Temperature"

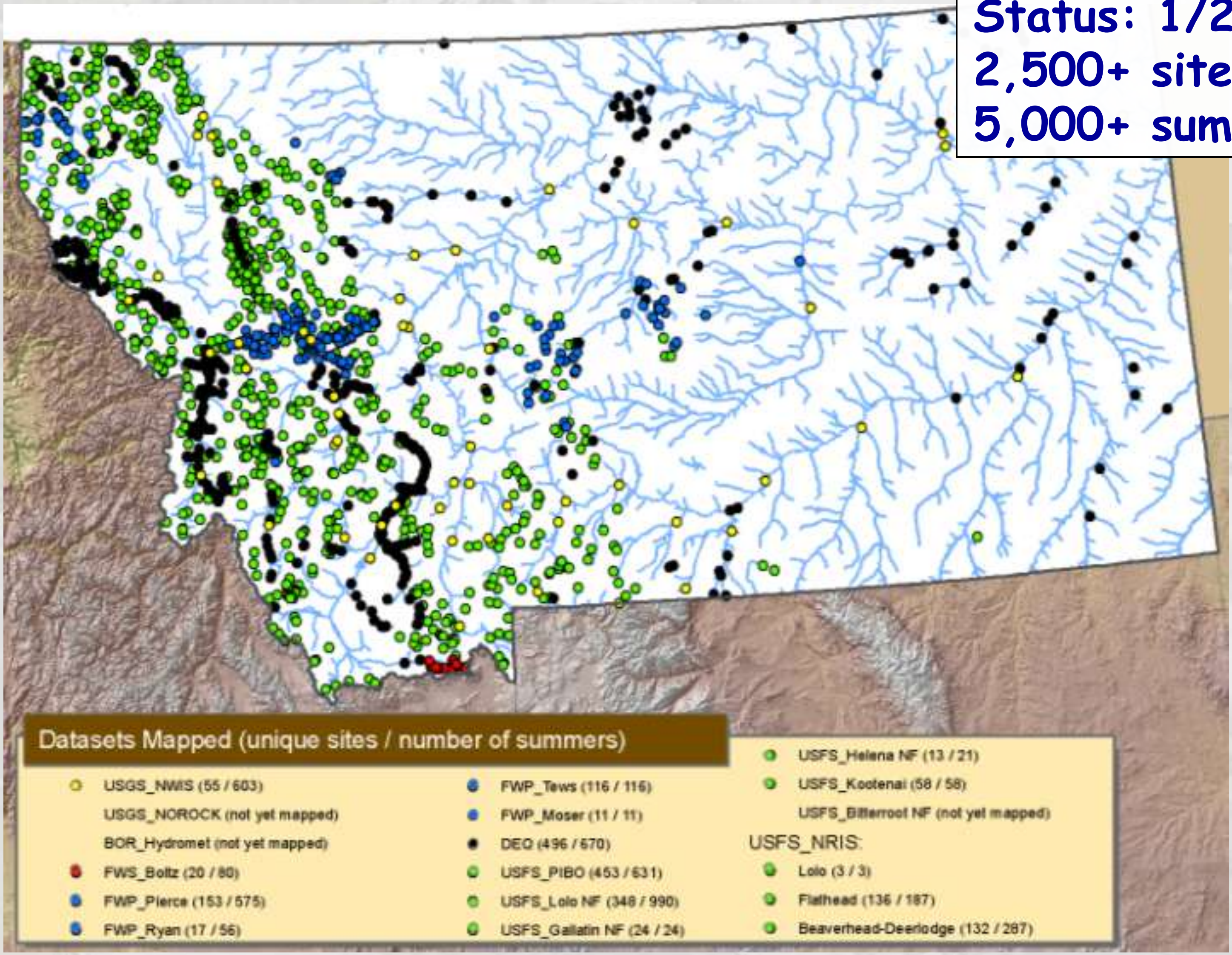




- Project description
- Analytical details
- ftp site for data transfers

NorWeS$_{tream}$T$_{emp}$ Database

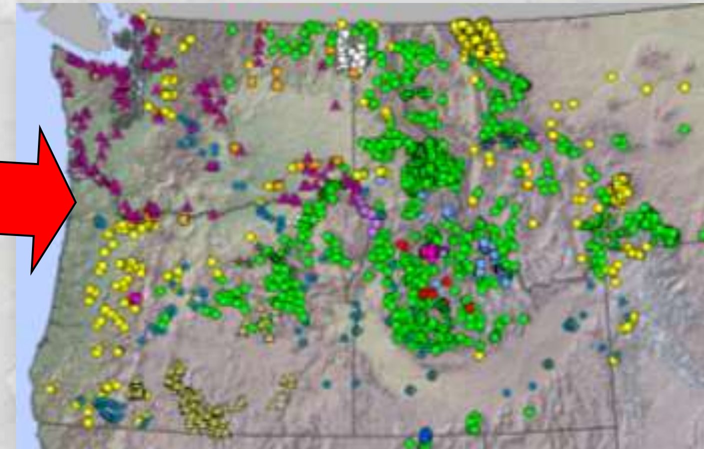
Montana Domain
Status: 1/26/12
2,500+ sites
5,000+ summers



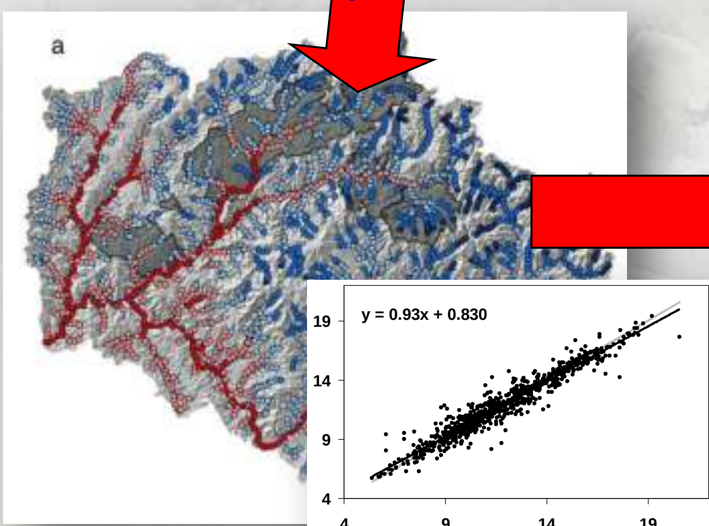
Viewable at the Datacall Website…

NorWeS$_{tream}$T$_{emp}$ Applications

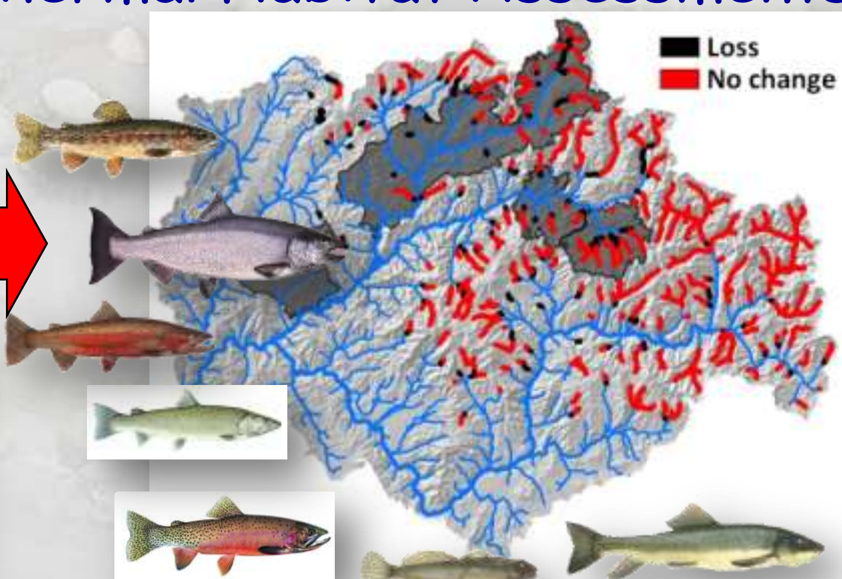
More Efficient Monitoring



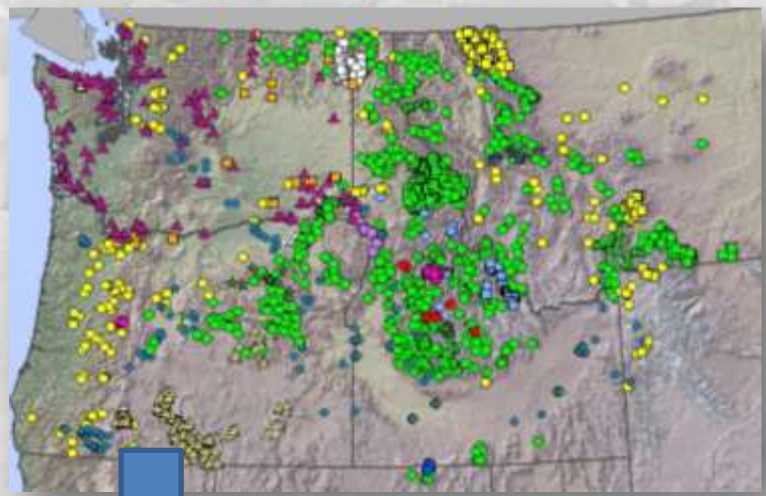
Temperature Model & Thermal Maps

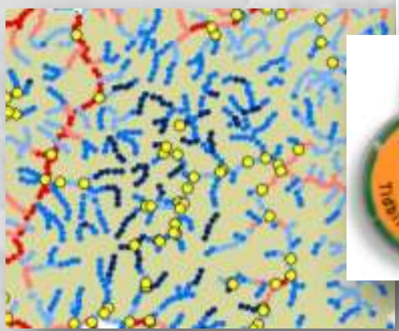


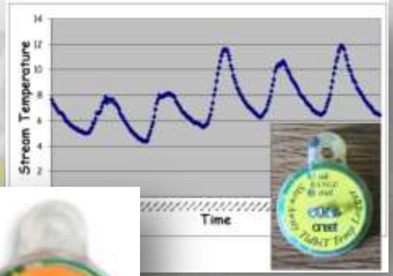
Thermal Habitat Assessments

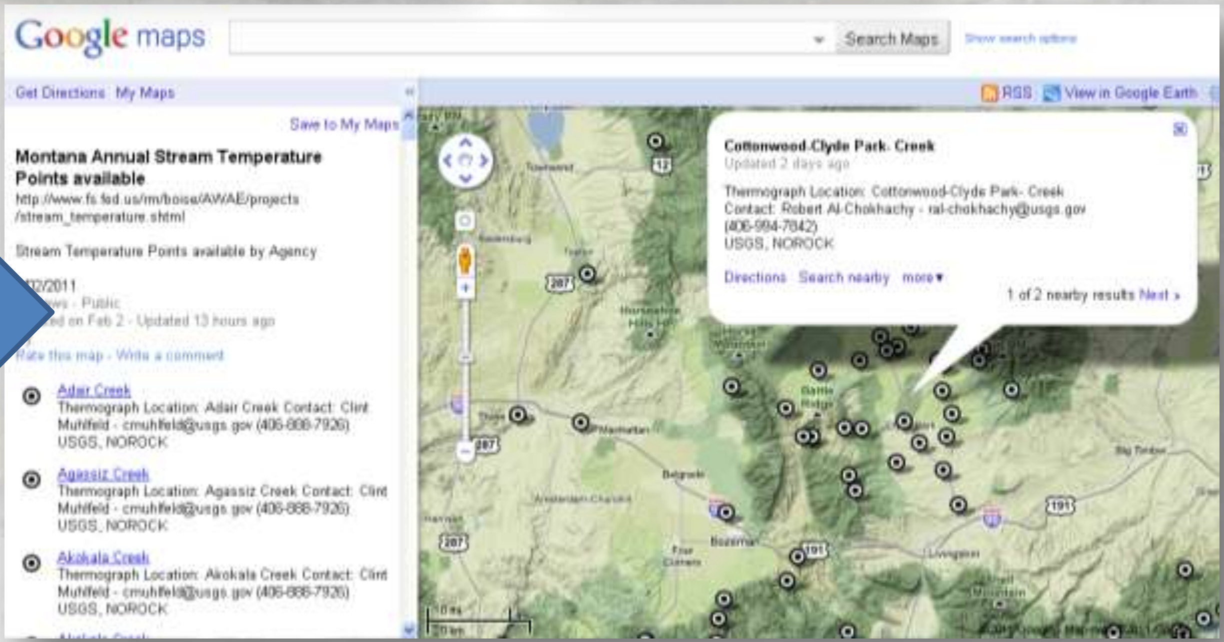


Website for Accessing Stream Temperature Data



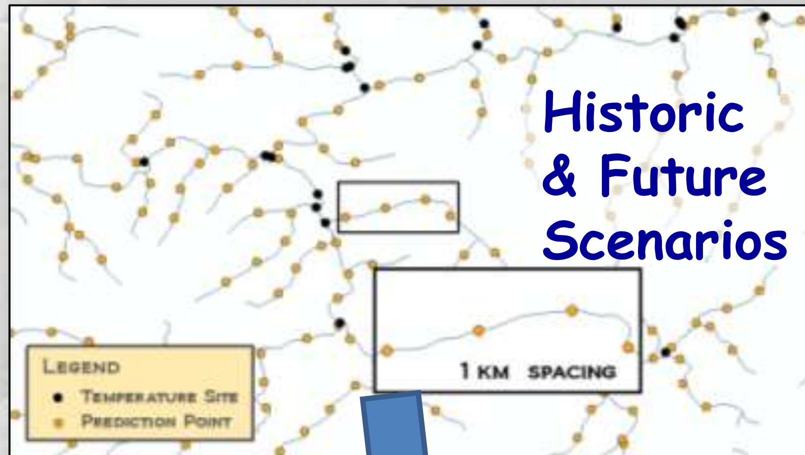






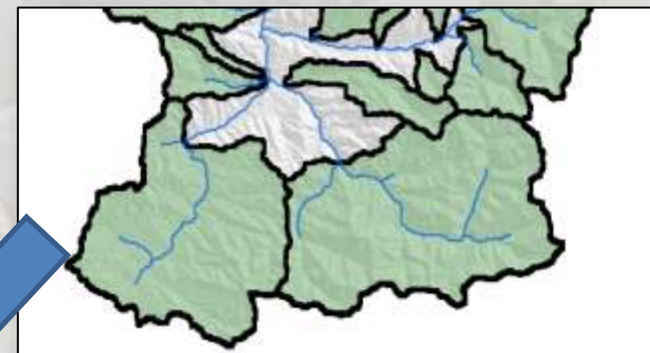
Website for Accessing Temperature Model Outputs

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



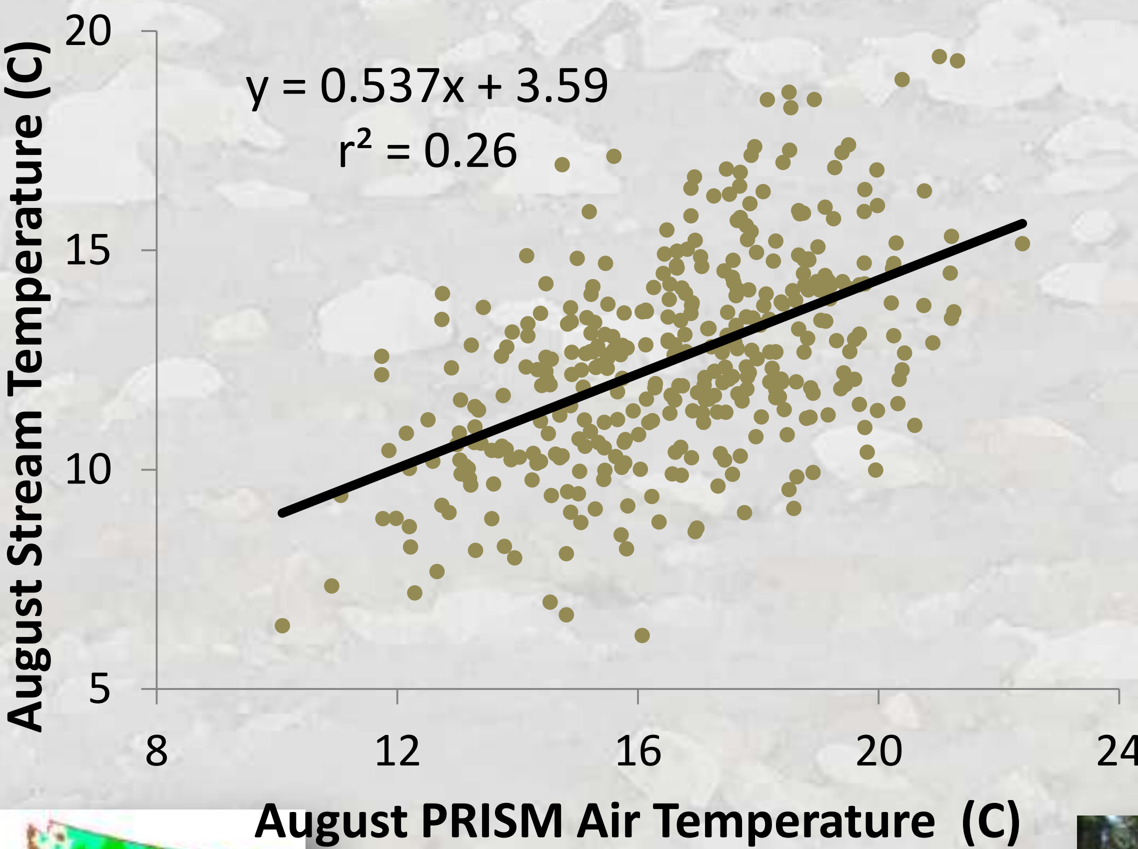
Historic & Future Scenarios

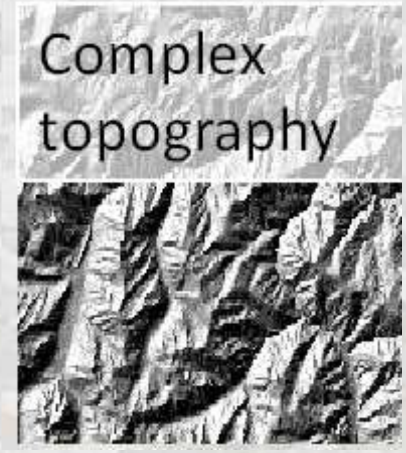
& thermally suitable habitats aggregated into "patch" polygons based on species-specific criteria

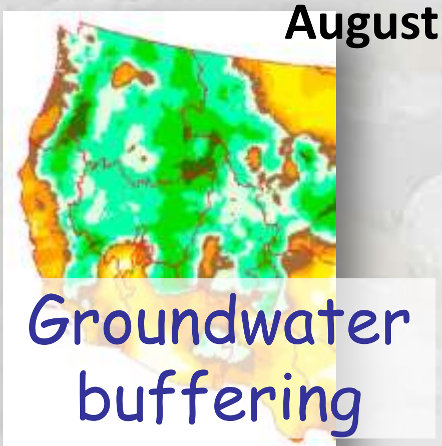


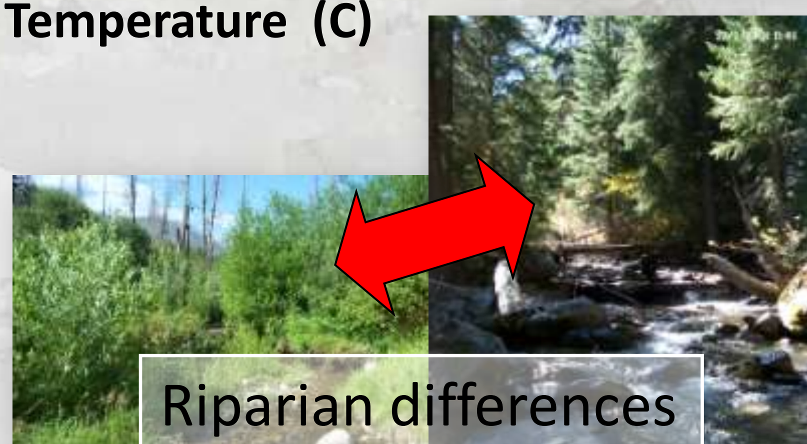
Websites for Distribution

Air Temp ≠ Stream Temp

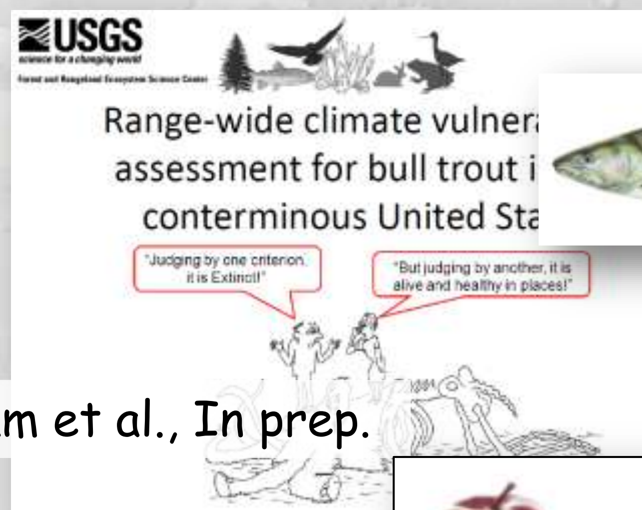




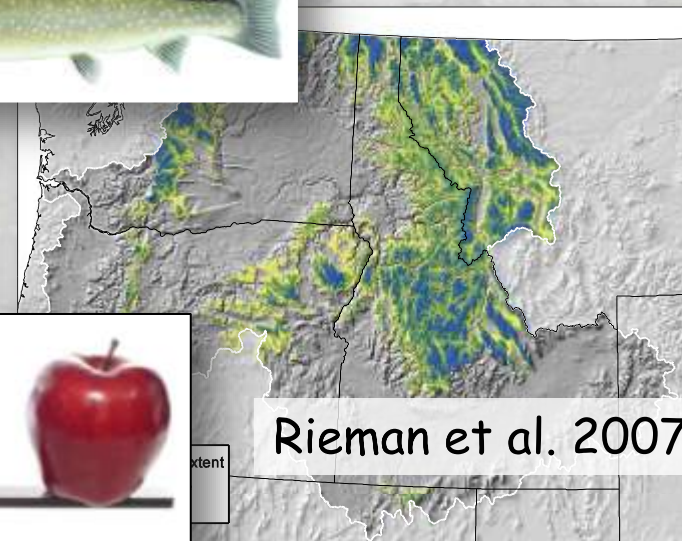


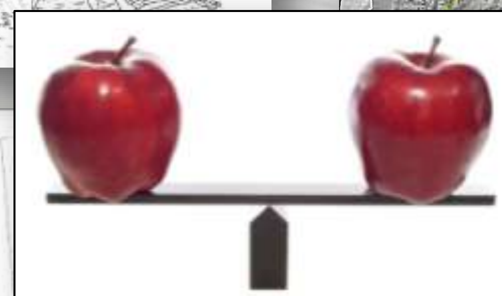


More Precise Bioclimatic Assessments

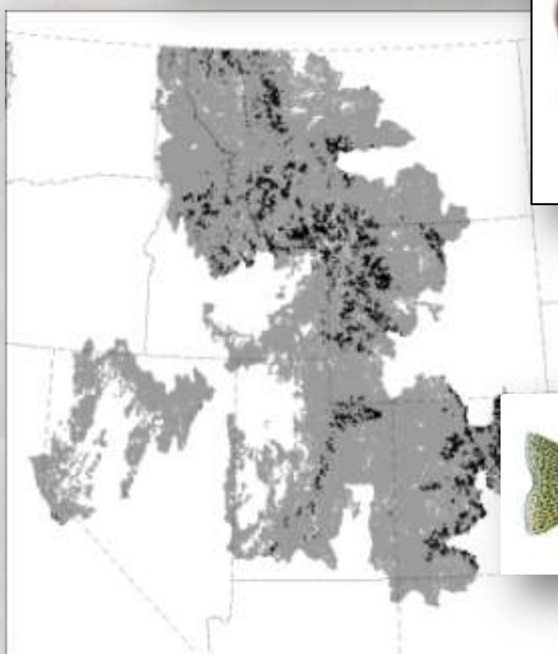


Dunham et al., In prep.

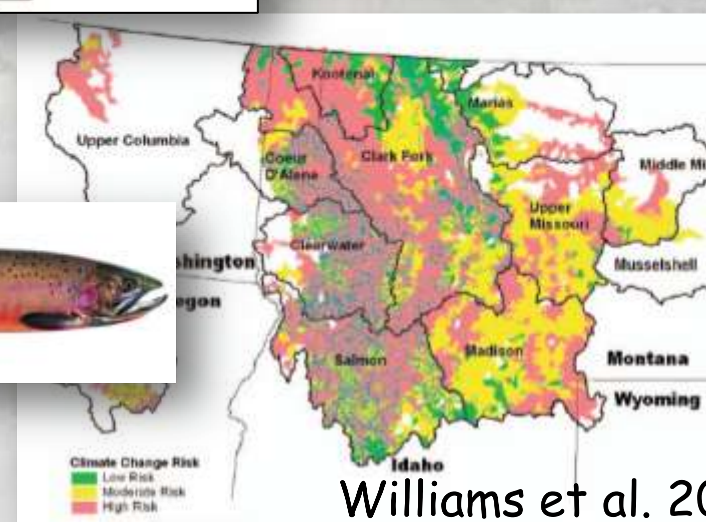




Rieman et al. 2007



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

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. Chandler[1]

[1]*U.S. Forest Service, Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory, 322 E. Front Street, Suite 401, Boise, Idaho 83702 USA*
[2]*Commonwealth 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 autocovariance 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 Ecosystem Health Monitoring Program in Southeast Queensland, Australia, an important national program aimed at monitoring water quality. We model two water chemistry variables, pH and conductivity, for sample sizes 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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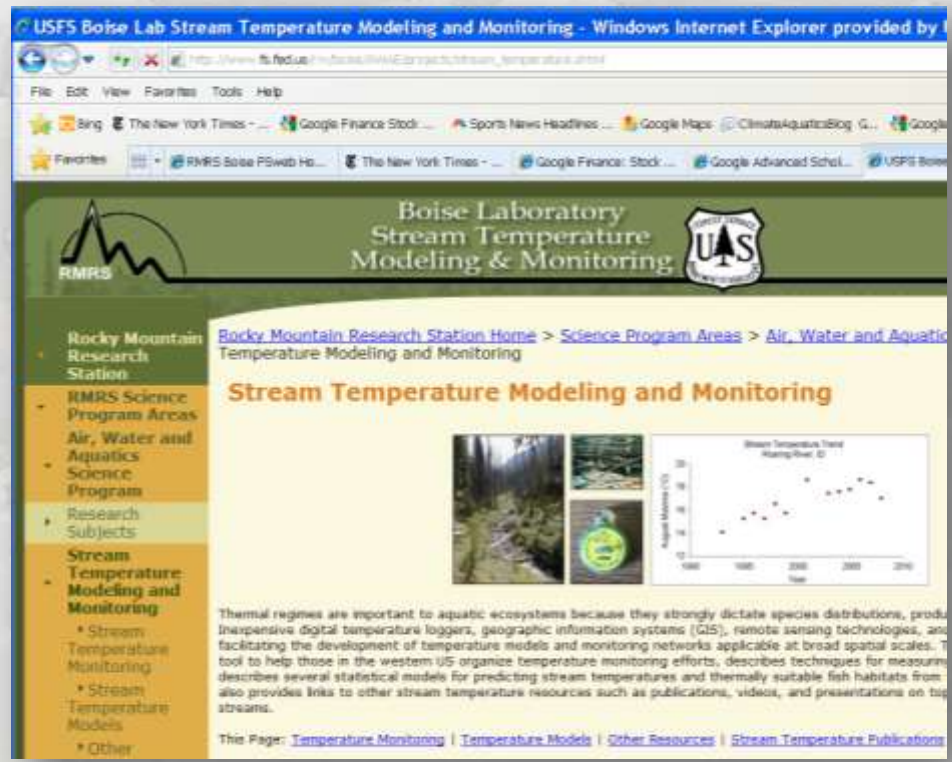
Available for Download at…

U.S. Forest Service stream temperature website

Just Google "Stream Temperature Forest Service"



- 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