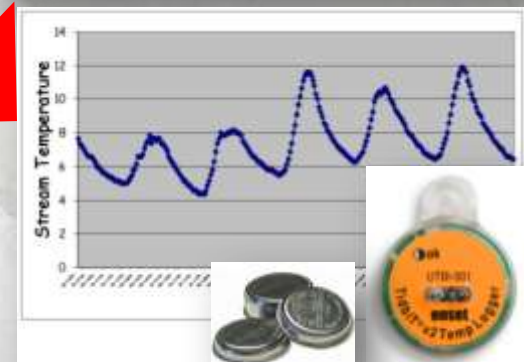
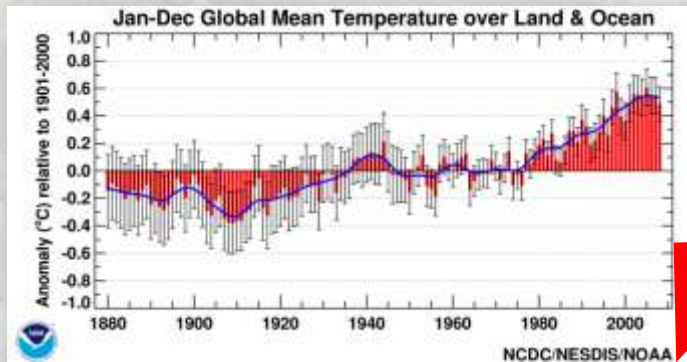
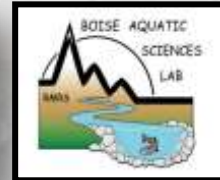


Recent Research Toward Understanding Spatial, Temporal, and Climatic Variation in Stream Temperatures Across the Northwest US

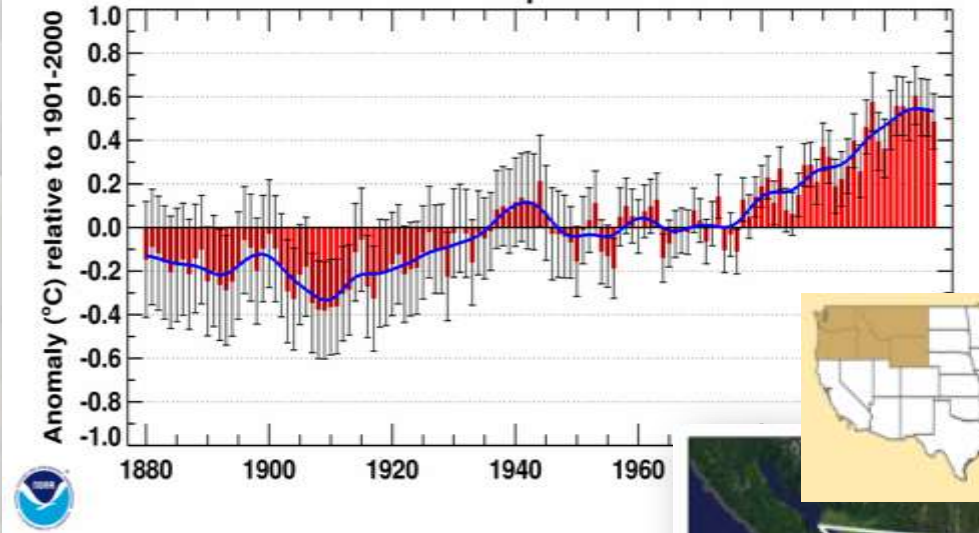
Dan Isaak, Charlie Luce, Brett Roper, Zack Holden, Dona Horan, Gwynne Chandler, Sherry Wollrab

U.S. Forest Service

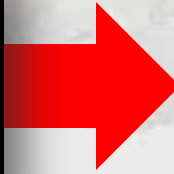
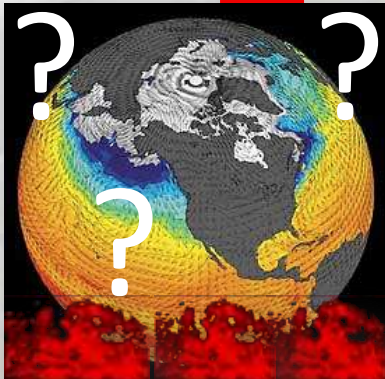
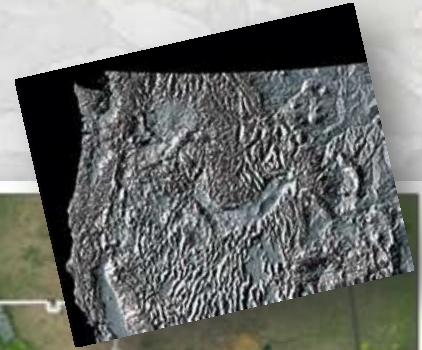


Global Trends in Air Temperatures

+0.6 °C during 20th Century

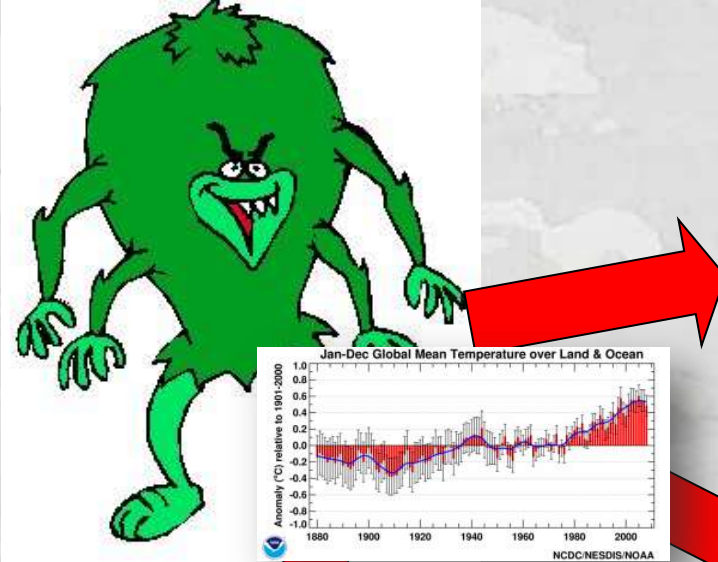


- >50% public lands
- Wildland settings
- Mountainous terrain



Valuable Resources & Potential Conflicts...

Climate Boogeyman



Recreational Fisheries

Low Flows Prompt Fishing Closure On Upper Beaverhead River And Reduced Limits On Clark Canyon Reservoir

Wednesday, September 29, 2004
Fishing

High Water
Temperature In Grande
Ronde Kills 239 Adult
Spring Chinook
Columbia Basin Bulletin,
August 14, 2009 (PST)



Land Use & Water Development



ESA Listed Species



Urbanization + Reservoirs + Climate Change = Warming Rivers & Streams

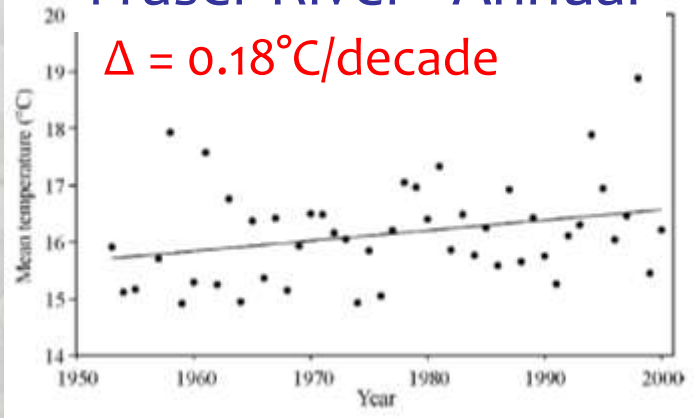
Rising stream and river temperatures in the United States

Sujay S Kaushal^{1*}, Gene E Likens², Norbert A Jaworski³, Michael L Pace^{2†}, Ashley M Sides¹, David Seekell⁴, Kenneth T Belt⁵, David H Secor¹, and Rebecca L Wingate¹

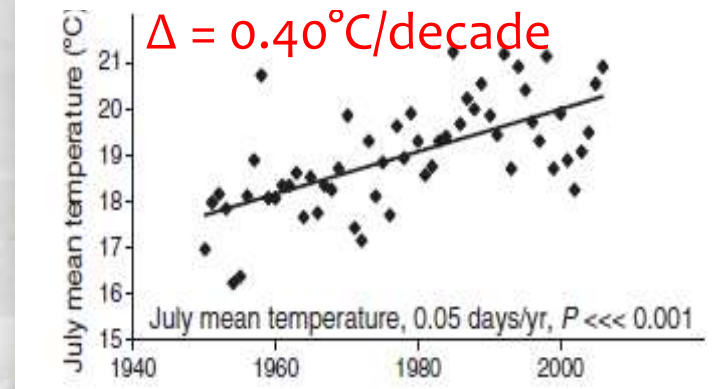


Regional Trends In Northwest Rivers

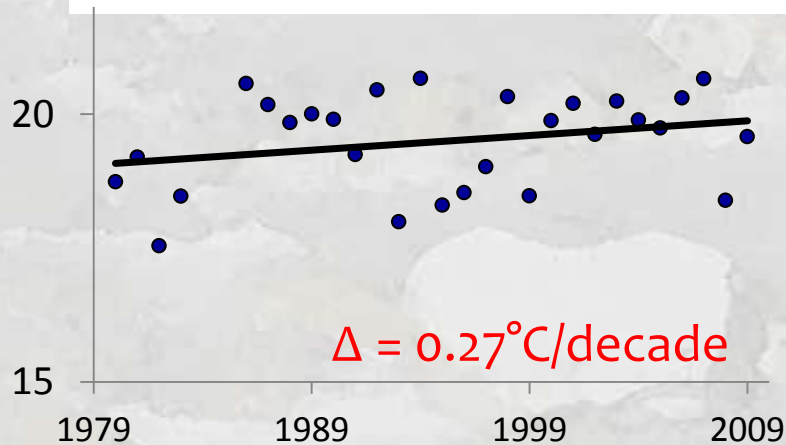
Fraser River - Annual



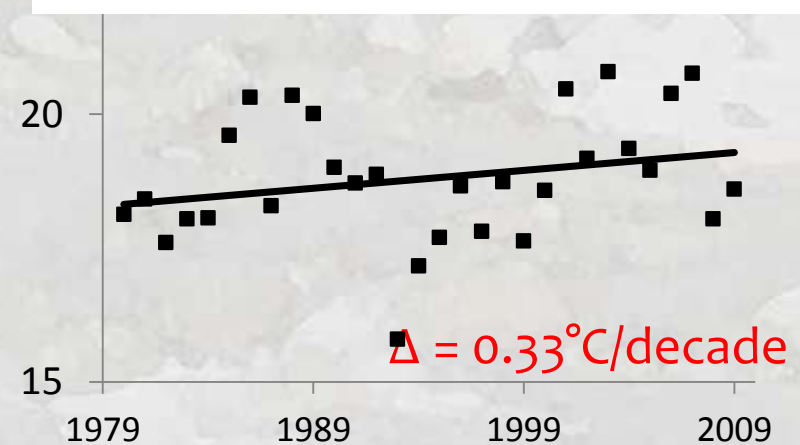
Columbia River - Summer



Snake River, ID - Summer

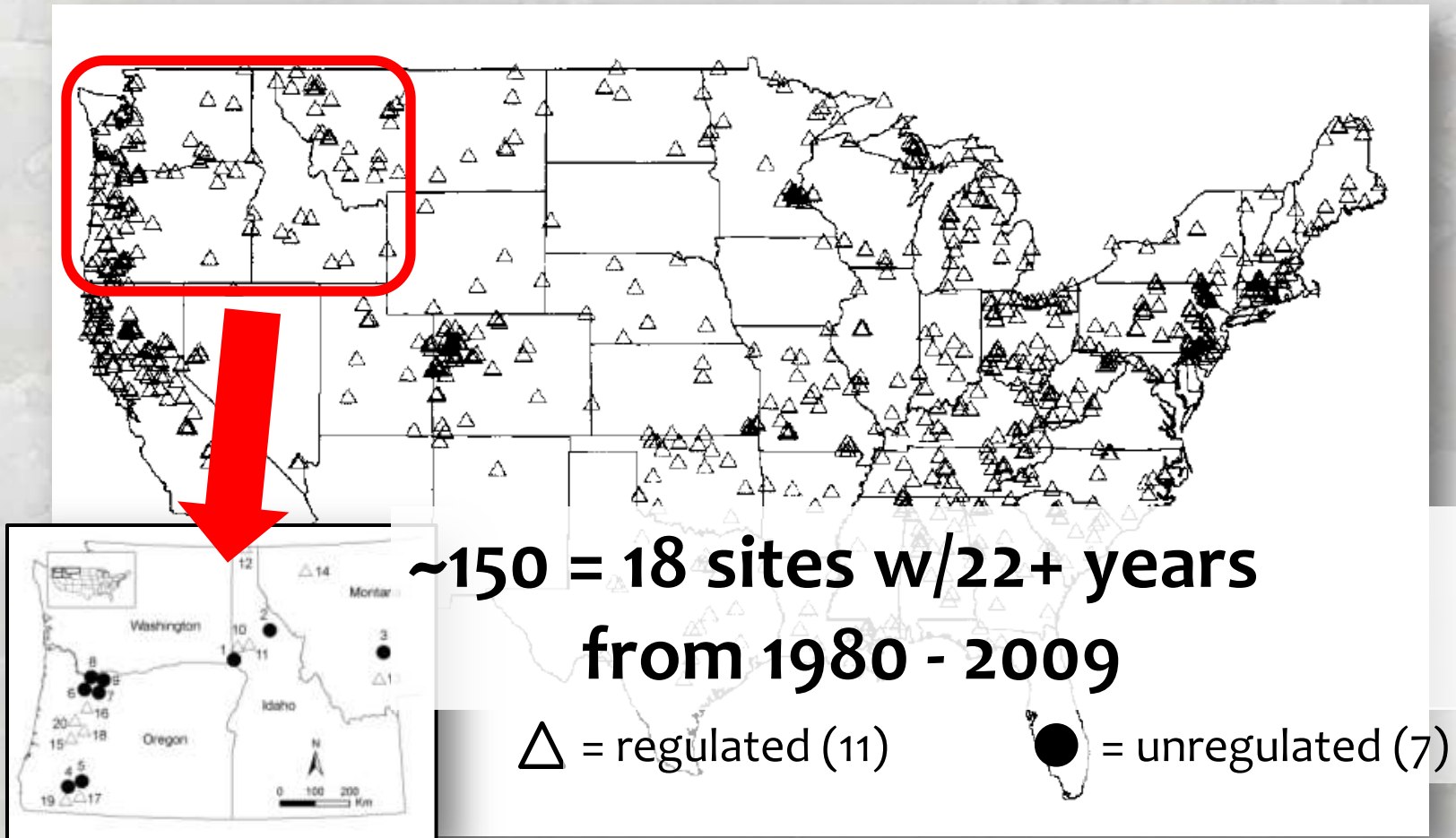


Missouri River, MT - Summer



Are There “Pristine” Sites with Long-term Data to Serve as Climate Sentinels?

764 USGS gages have some temperature data



USGS NWIS Database (<http://waterdata.usgs.gov/nwis>)



Regression Models for Trend Reconstruction

Air temp & discharge as predictors of interannual change

Model control for:

- PDO/ENSO cycles
- Missing data
- Inconsistent start/stop dates & monitoring periods

Good Accuracy

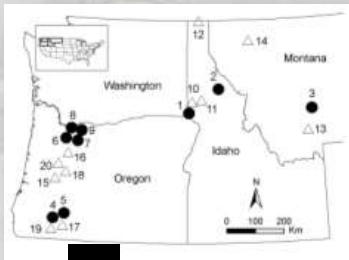
R ²	RMSE (C)	Significant Interaction?
0.68	0.37	No
0.79	0.32	No
0.85	0.35	Yes
0.85	0.32	No
0.89	0.26	No
0.84	0.33	No
0.83	0.32	No

Rare

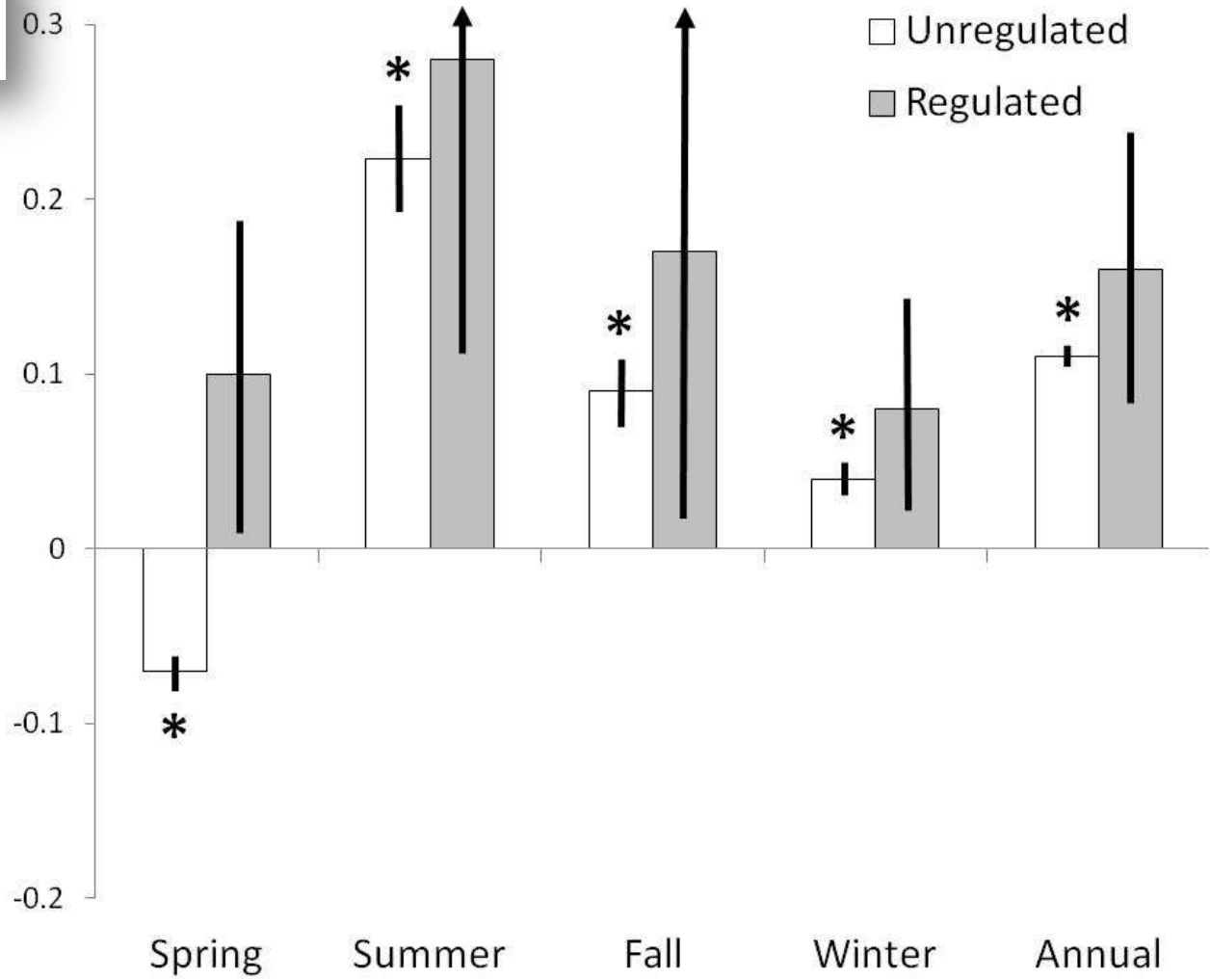
Stream site	Multiple regression equation
Spring period	
1. Snake River Near Anatone, WA	$y = 3.43 + 0.588^a(\text{air } ^\circ\text{C}) - 0.00013(\text{m}^3/\text{s})$
2. North Fork Clearwater River, ID	$y = 1.48 + 0.548^a(\text{air } ^\circ\text{C}) - 0.00373(\text{m}^3/\text{s})$
3. Missouri River, 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	$y = -0.276 + 0.810^a(\text{air } ^\circ\text{C}) - 0.0392(\text{m}^3/\text{s})$



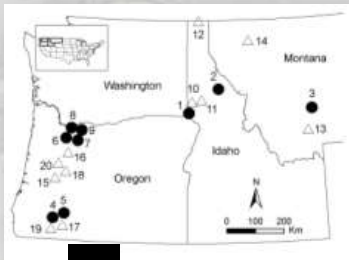
Seasonal Trends In Northwest Stream Temperatures (1980-2009)



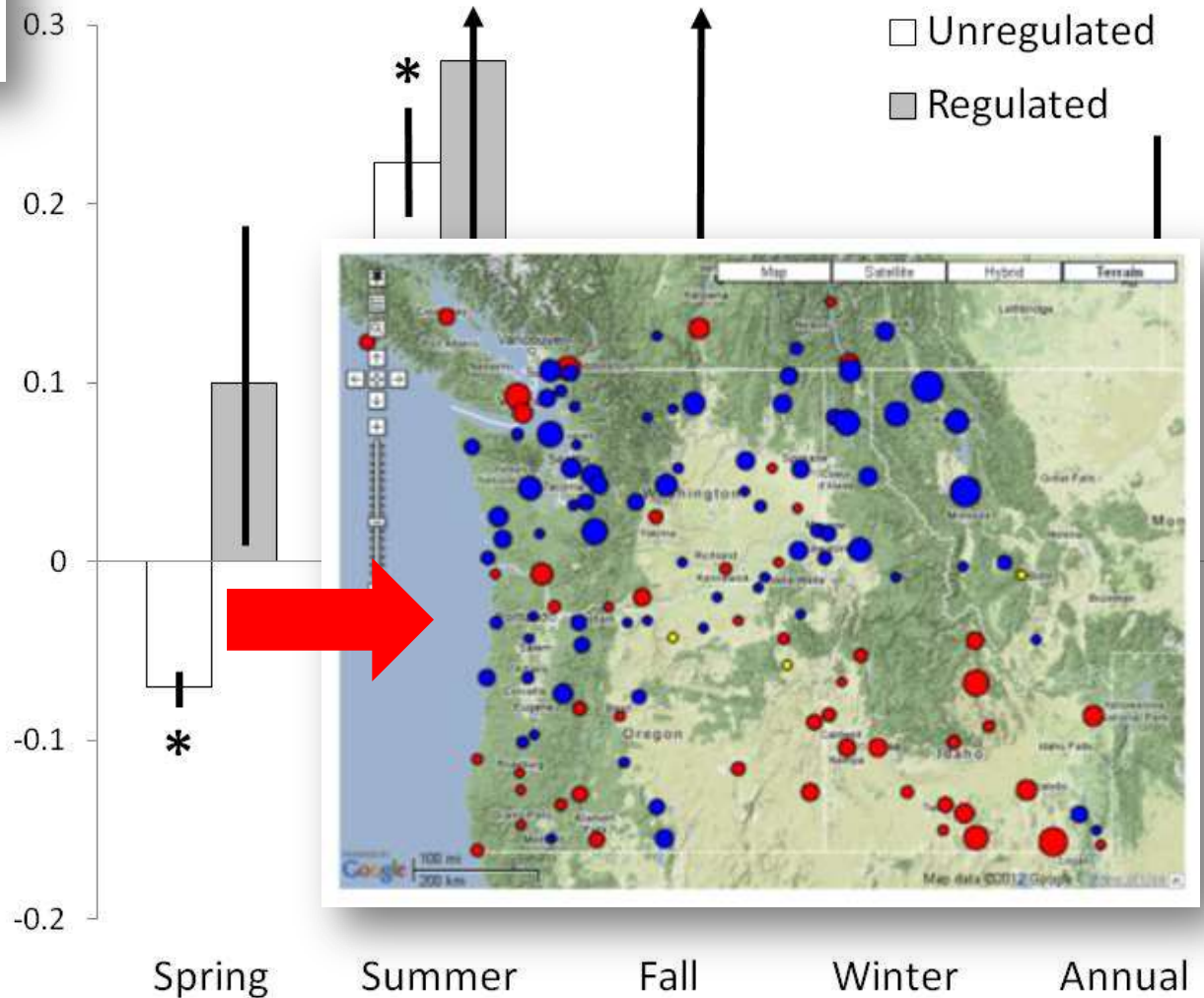
Warming rate ($^{\circ}\text{C} / \text{decade}$)



Seasonal Trends In Northwest Stream Temperatures (1980-2009)

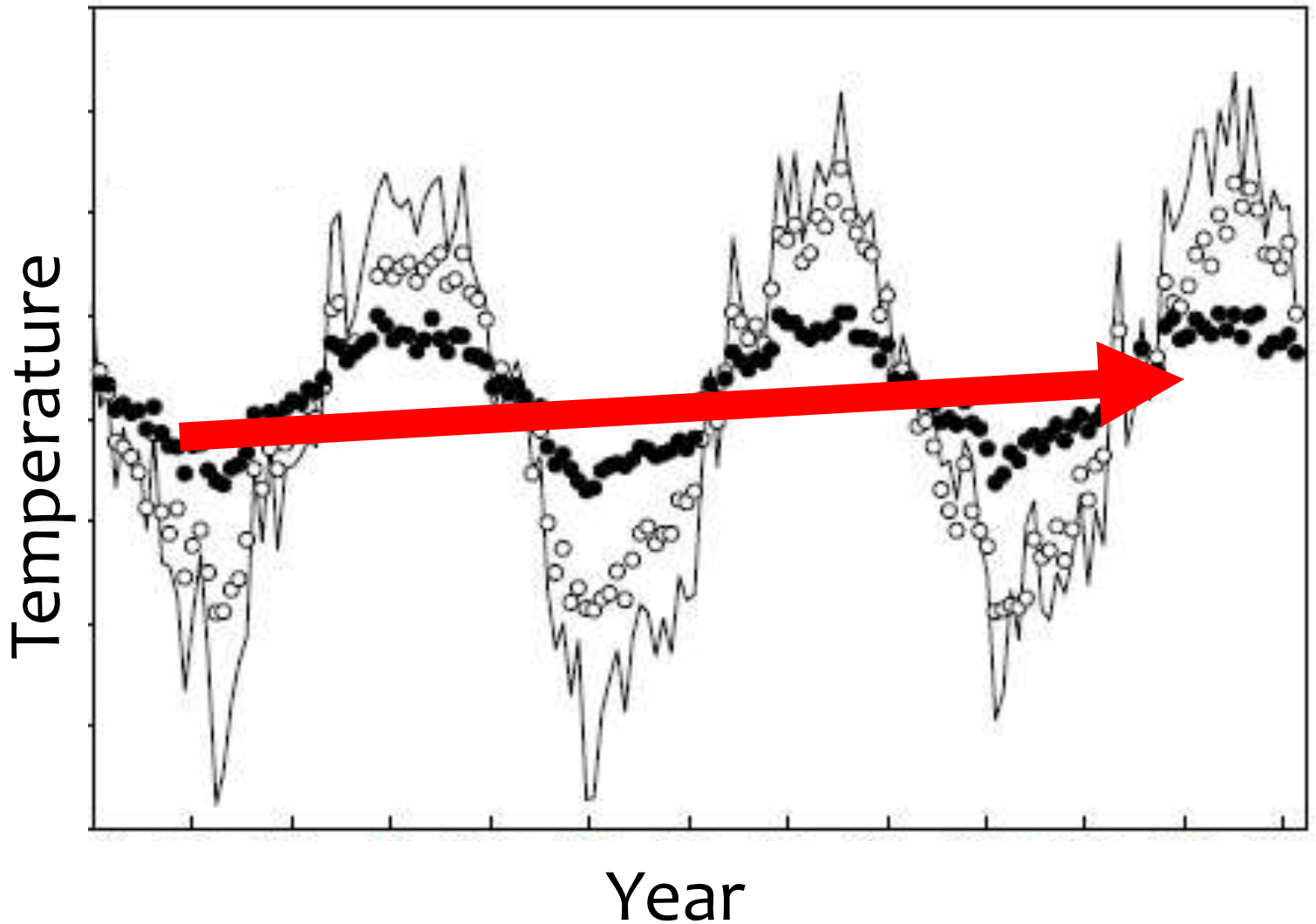


Warming rate ($^{\circ}\text{C} / \text{decade}$)



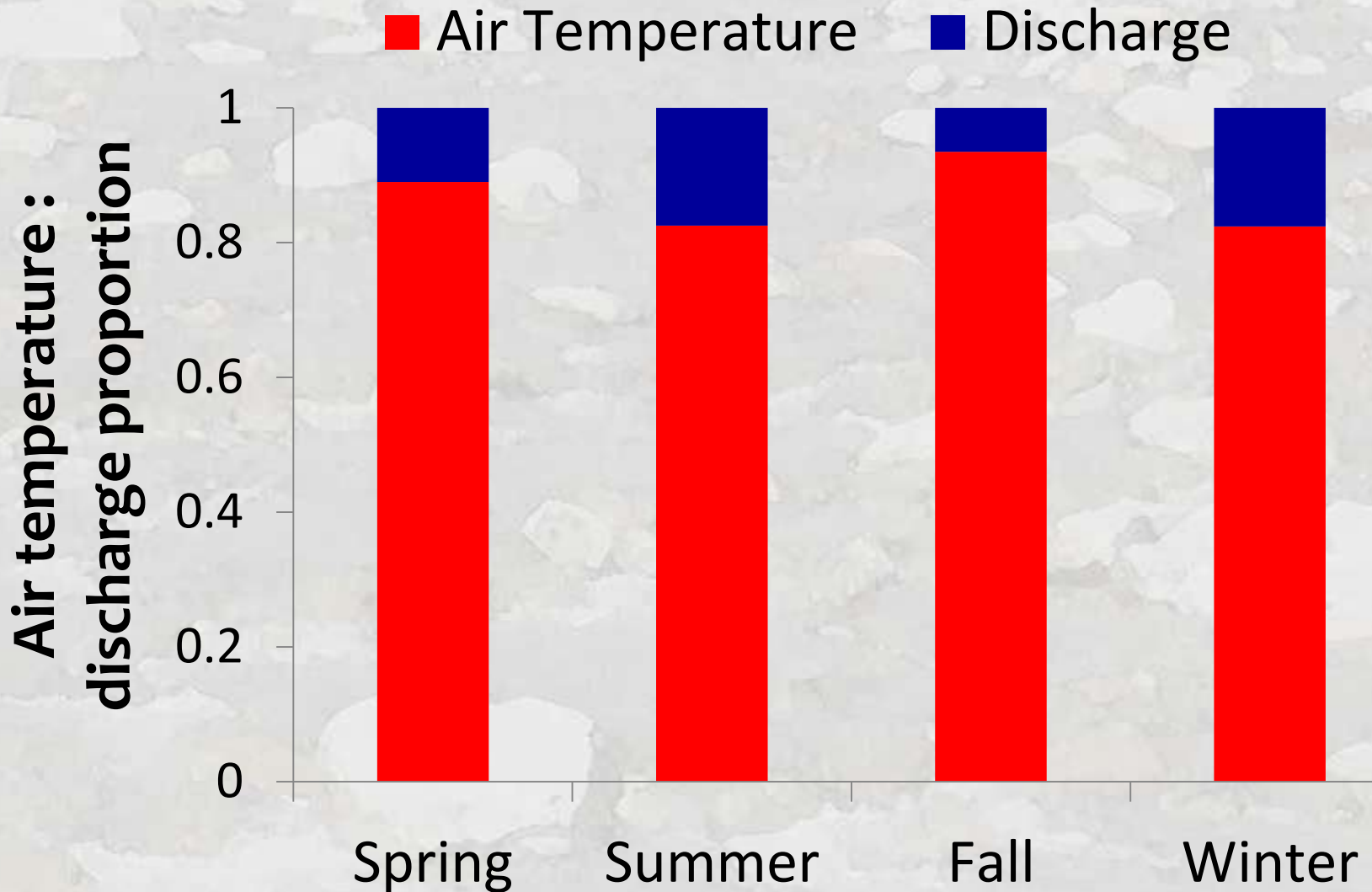
Attribution of Stream Warming Trends

Long-term trend ~ environmental signal



Attribution of Stream Warming Trends

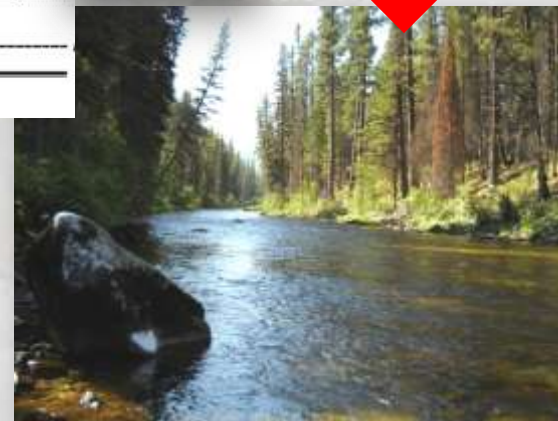
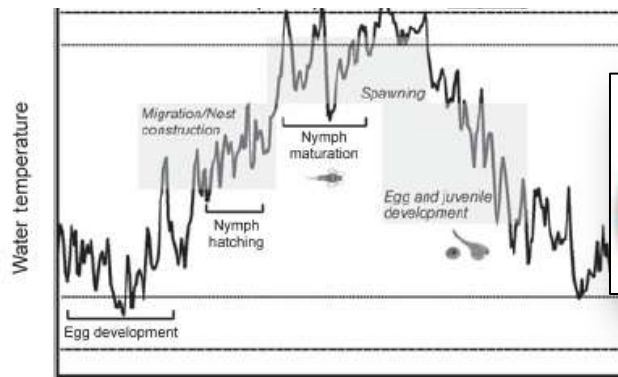
Long-term trend ~ environmental signal



Unregulated Rivers as Significant Monitoring GAP



Annual Temperature Cycle



Time



Easy Method for Full Year Monitoring Underwater Epoxy Protocol

Annual Flooding
Concerns



Underwater epoxy



\$130 = 5 years of data

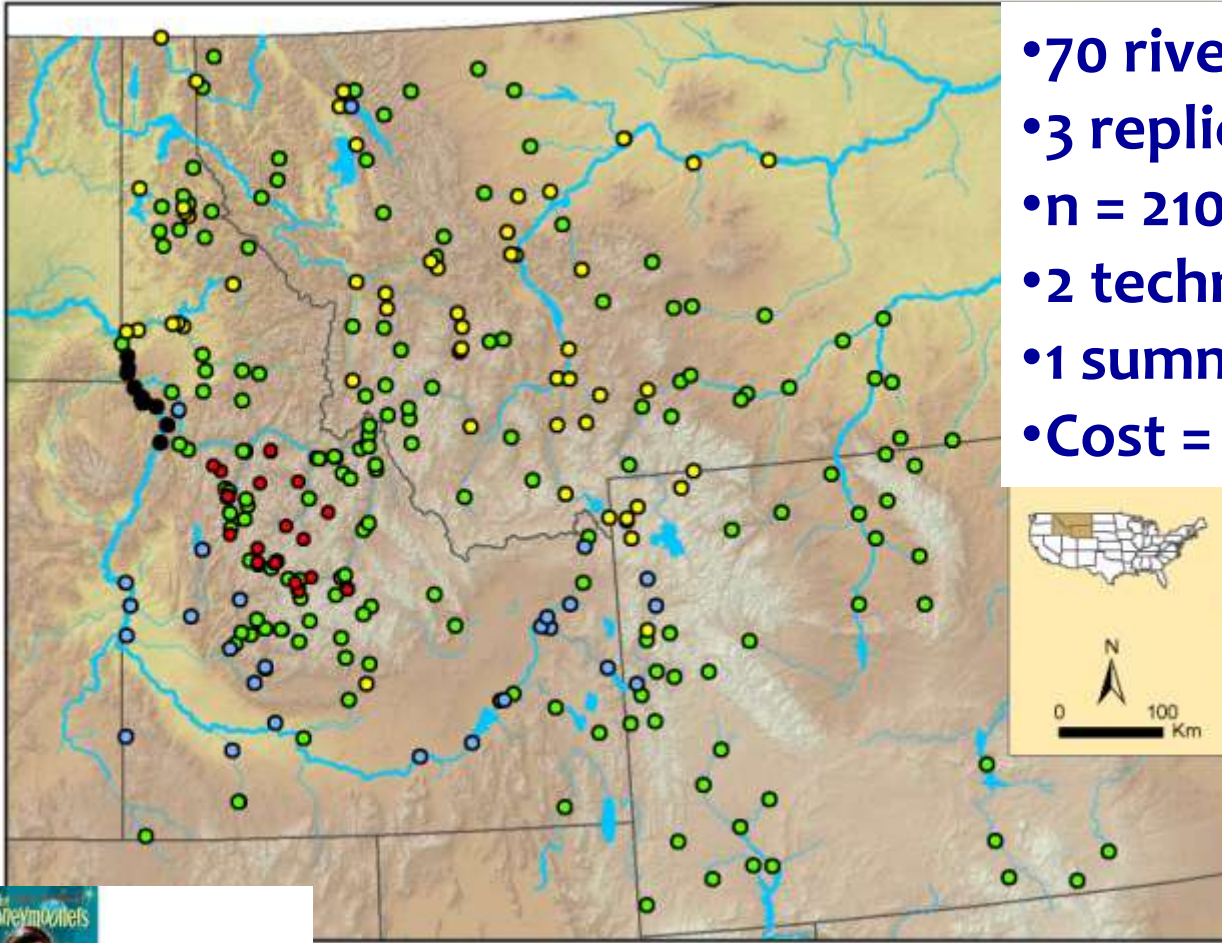
Data retrieved
from underwater



Sensors or PVC housings
glued to large boulders



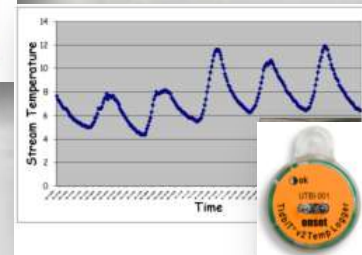
NoRRTN: Northern Rockies River Temperature Network



- 70 rivers;
- 3 replicates/river;
- n = 210 sites;
- 2 technicians;
- 1 summer of work;
- Cost = \$50,000;

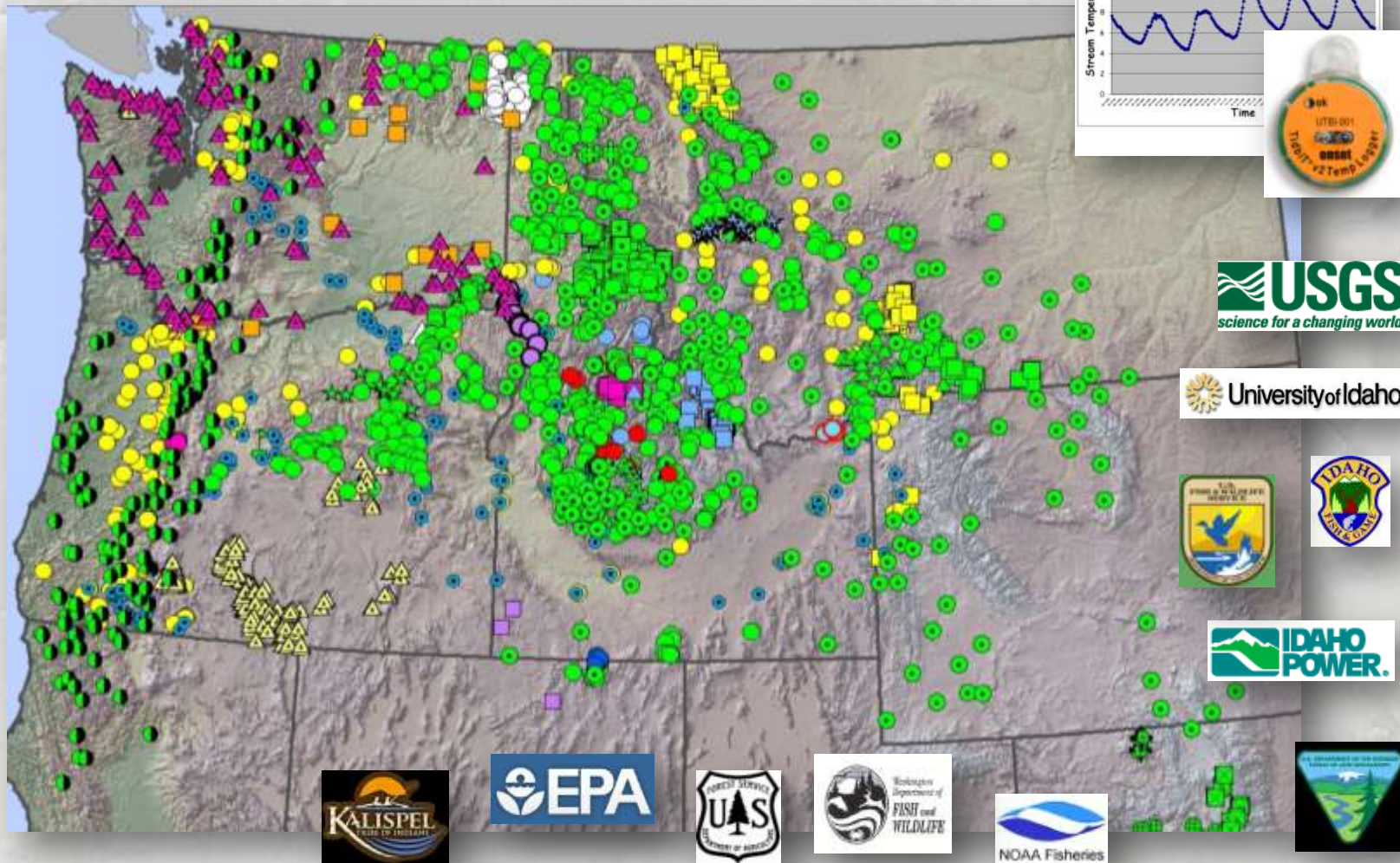


← Also Norton



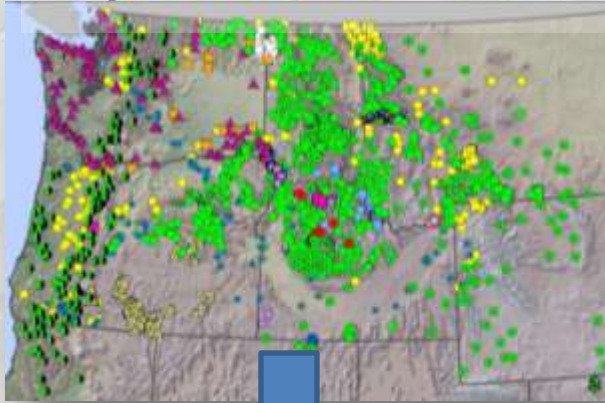
Full Year Stream Temperature Monitoring Becoming Popular...

2,761 Current full-year monitoring sites
~500 New deployments last year



A GoogleMap Tool for Dynamic Queries of Temperature Monitoring Sites

Regional Sensor Network



Site Information

- Stream name
- Data steward contact information
- Agency
- Site Initiation Date



Query Individual Sites

Montana Annual Stream Temperature Points available
www.fs.fed.us/rm/boise/AWAE/projects/temperature.shtml
Stream Temperature Points available by Agency
2002/2011
62 views - Public
Created on Feb 3 - Updated 13 hours ago
By
Rate this map - Write a comment

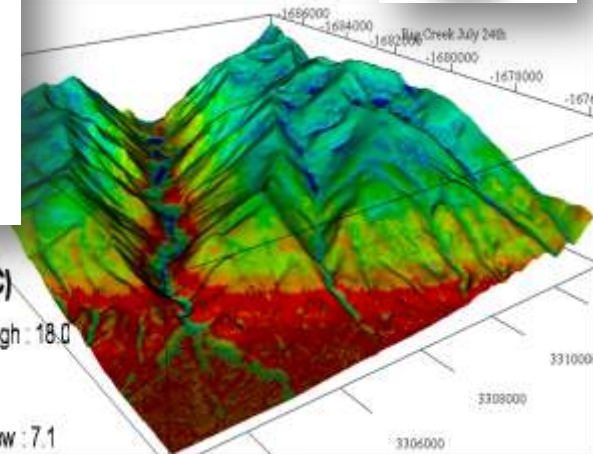
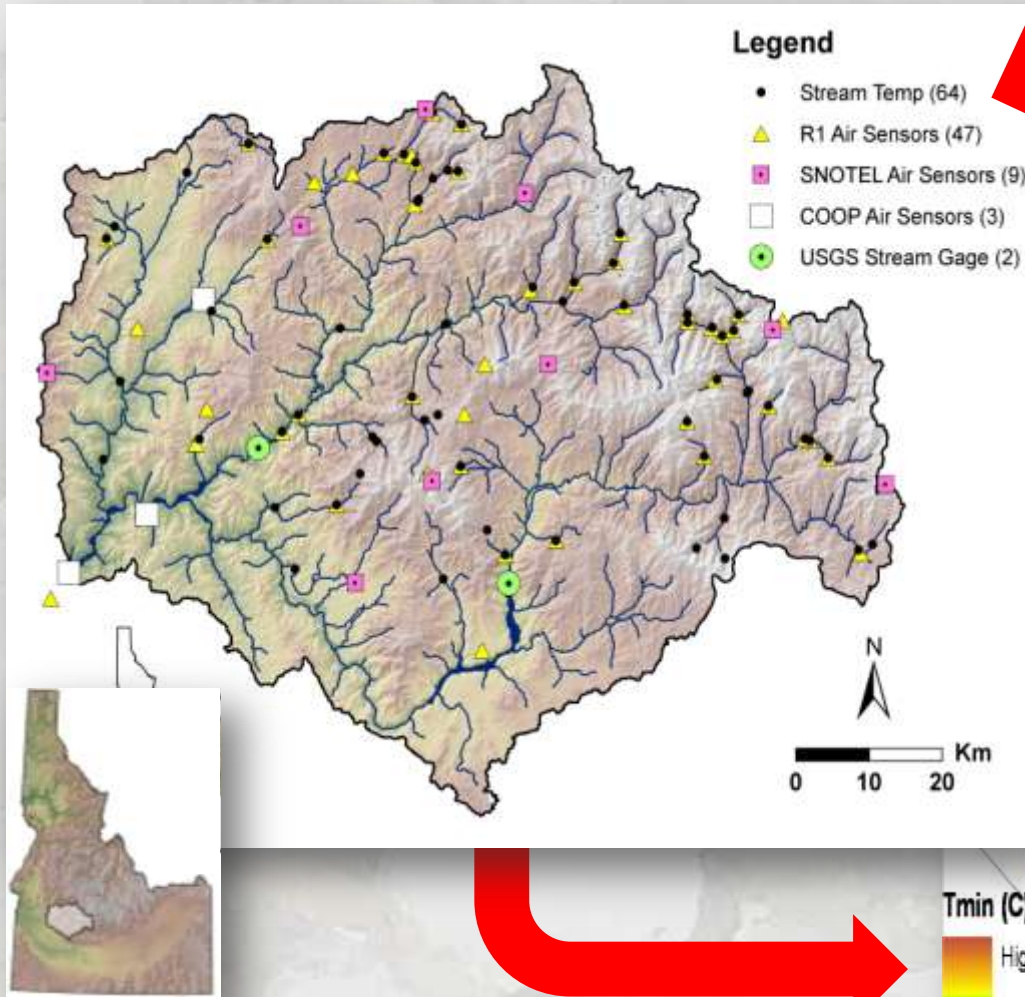
- **Adair Creek**
Thermograph Location: Adair Creek Contact: Clint Muhfeld - cmuhfeld@usgs.gov (406-866-7926)
USGS, NOROCK
- **Agassiz Creek**
Thermograph Location: Agassiz Creek Contact: Clint Muhfeld - cmuhfeld@usgs.gov (406-866-7926)
USGS, NOROCK
- **Akokala Creek**
Thermograph Location: Akokala Creek Contact: Clint Muhfeld - cmuhfeld@usgs.gov (406-866-7926)
USGS, NOROCK

Cottonwood-Clyde Park Creek
Updated 2 days ago
Thermograph Location: Cottonwood-Clyde Park- Creek
Contact: Robert Al-Chokhachy - ral-chokhachy@usgs.gov (406-864-7842)
USGS, NOROCK
Directions Search nearby more
1 of 2 nearby results Next >

Continental Monitoring Network Emerging

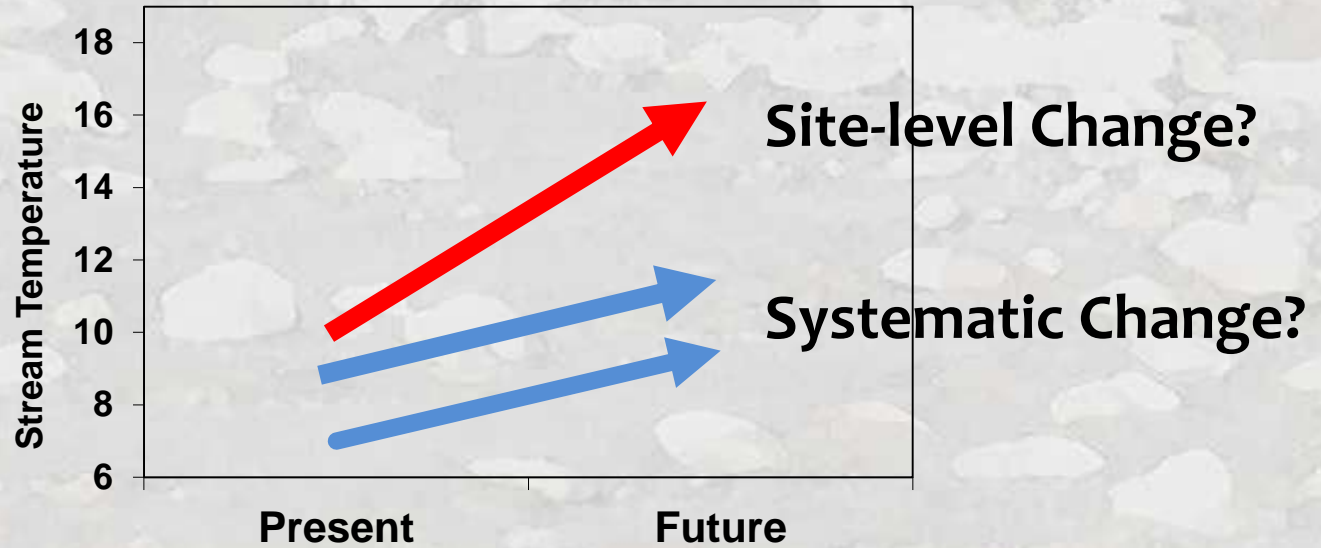


Dense Air & Stream Sensor Arrays for Microclimate Models



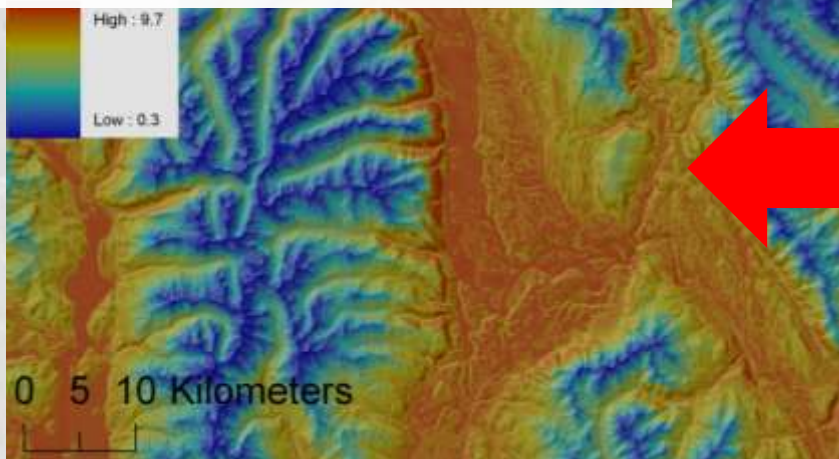
Zack Holden, USFS, Region 1

Spatial Variation in Temperature Changes



Different Climate Forcing?

Or Different Sensitivity?



Glacial Valley Buffering?

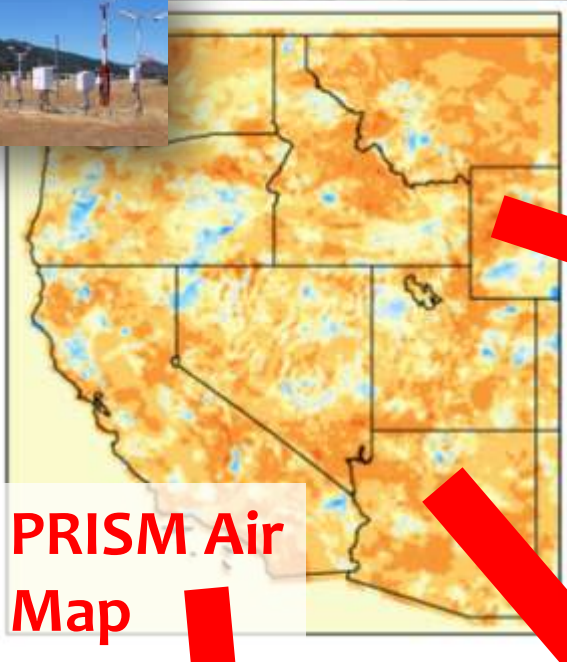


Regional BioClimatic Assessments

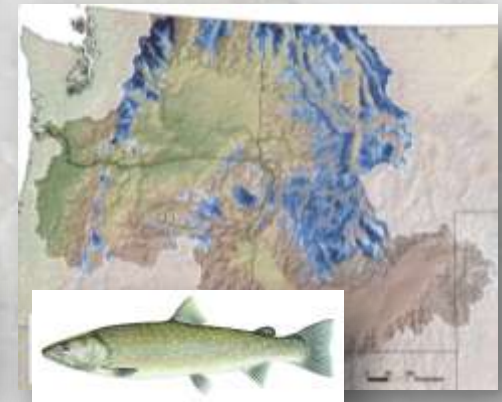
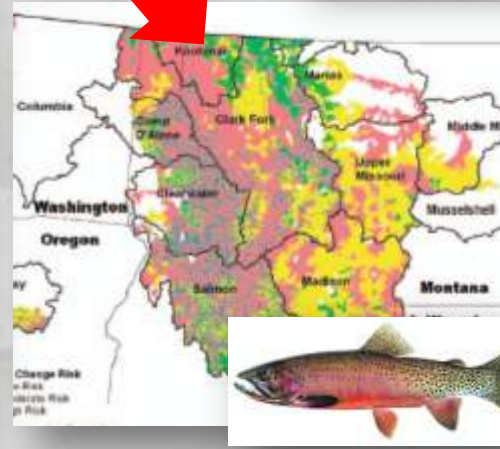
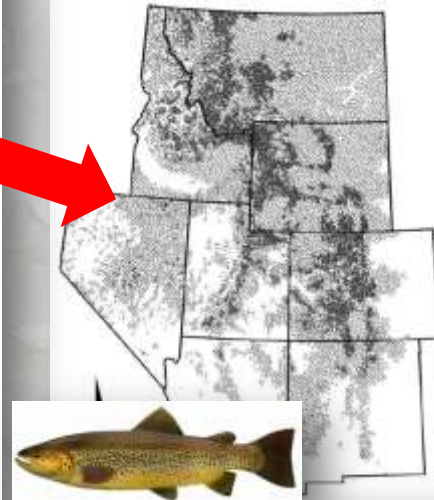
No stream temperature component

Air Temperatures...

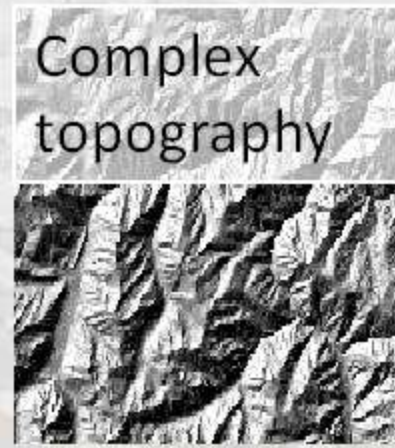
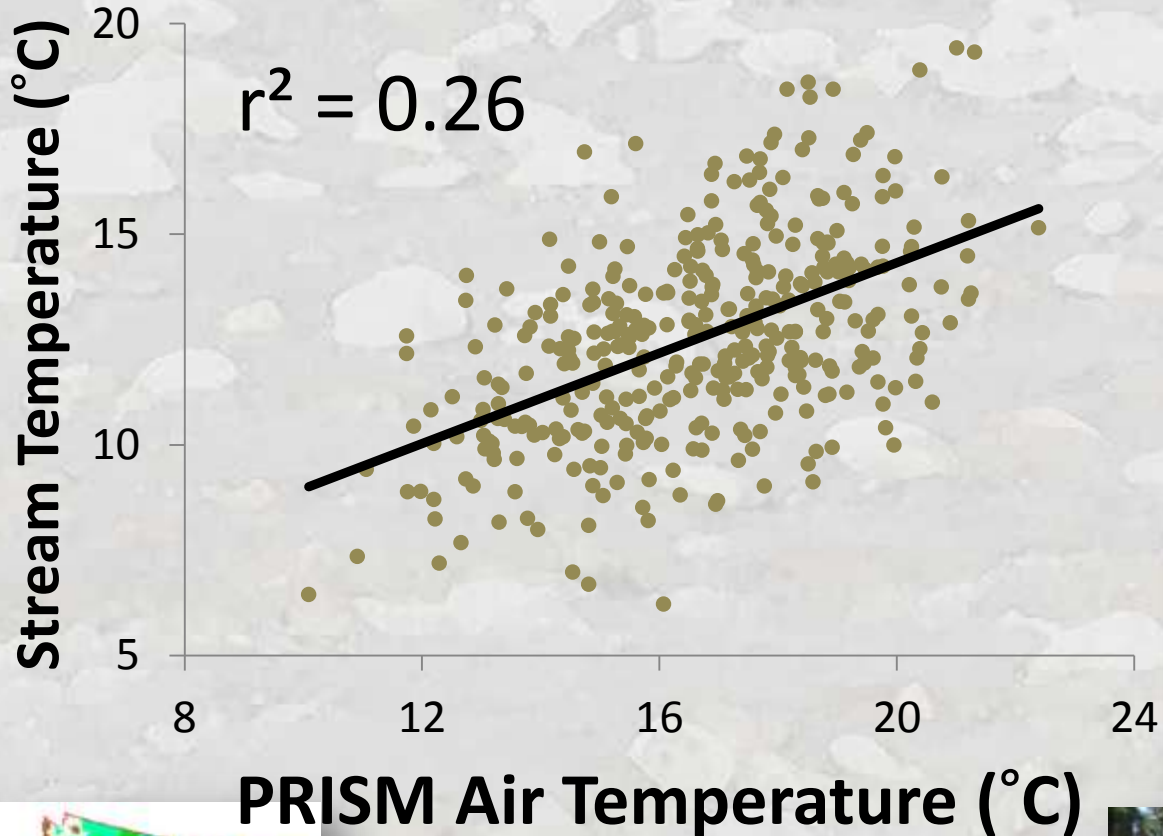
- Meisner 1988, 1990
- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.



PRISM Air Map



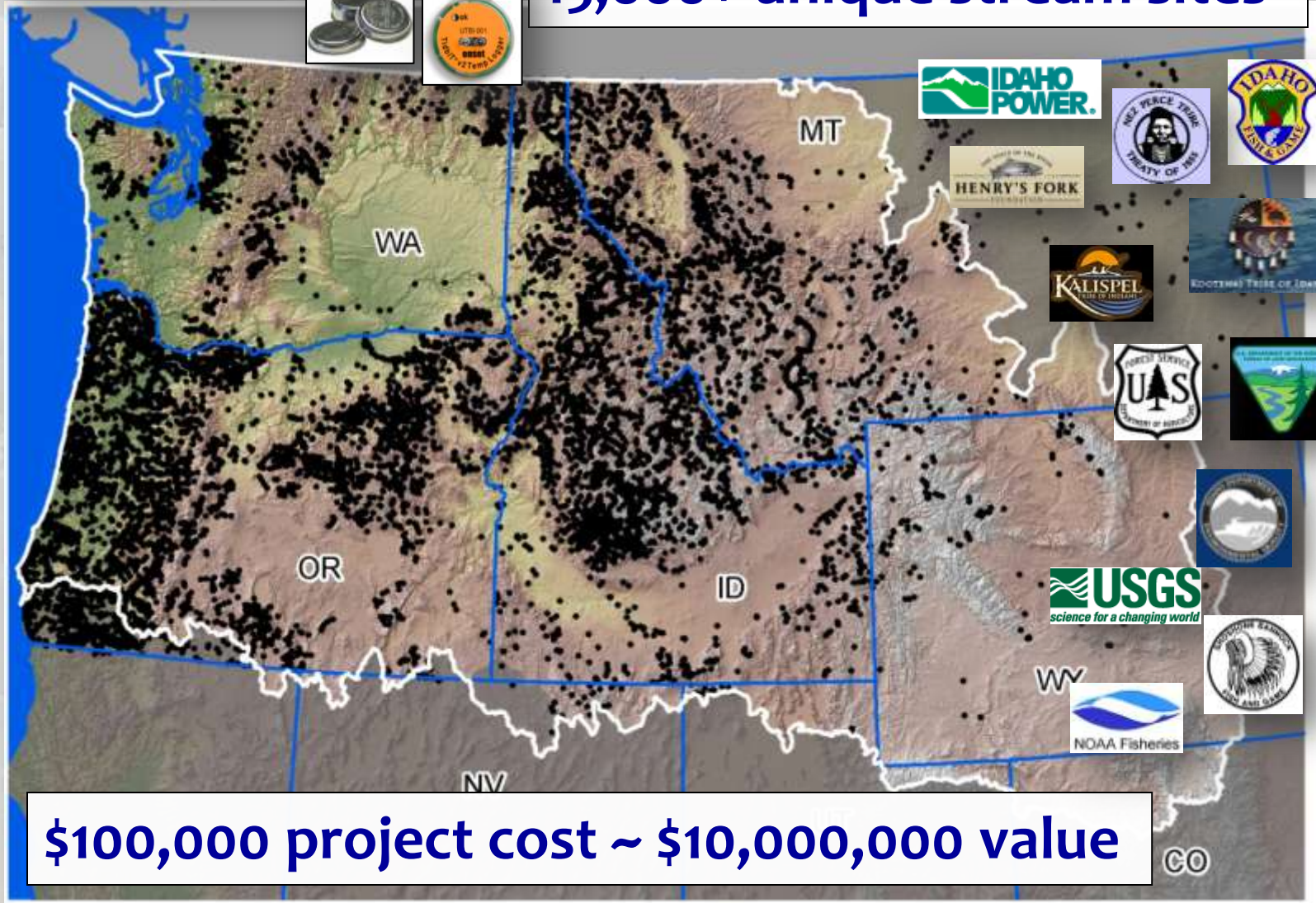
Spatial Air Pattern \neq Stream Temp



NorWeST

Stream Temp

45,000,000+ hourly records
45,000+ summers measured
15,000+ unique stream sites

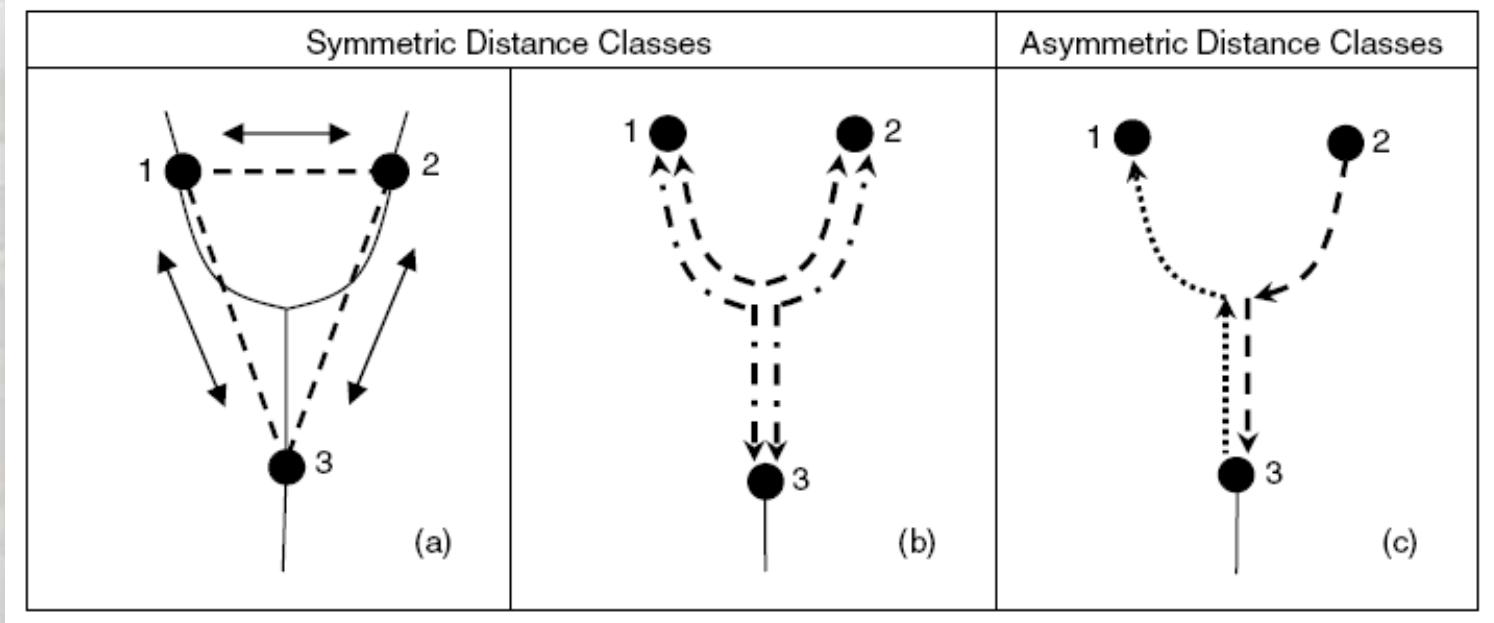


\$100,000 project cost ~ \$10,000,000 value



Spatial Statistical Stream Models

Valid means of estimation on networks



Advantages:

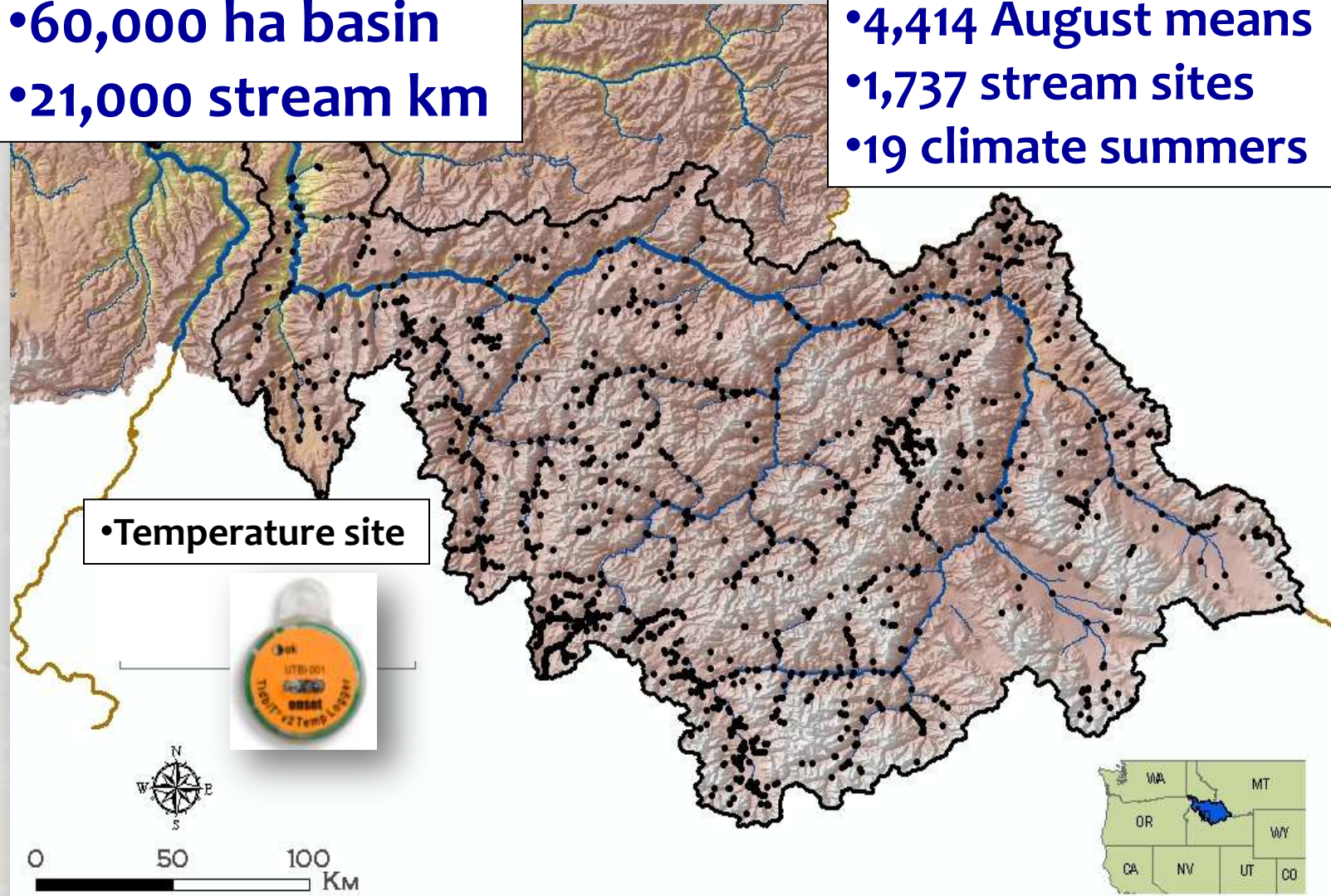
- Flexible & valid covariance structures that accommodate network topology & autocorrelation
- Much improved predictive ability & parameter estimates relative to non spatial models

Example: Salmon River Basin

Data extracted from NorWeST

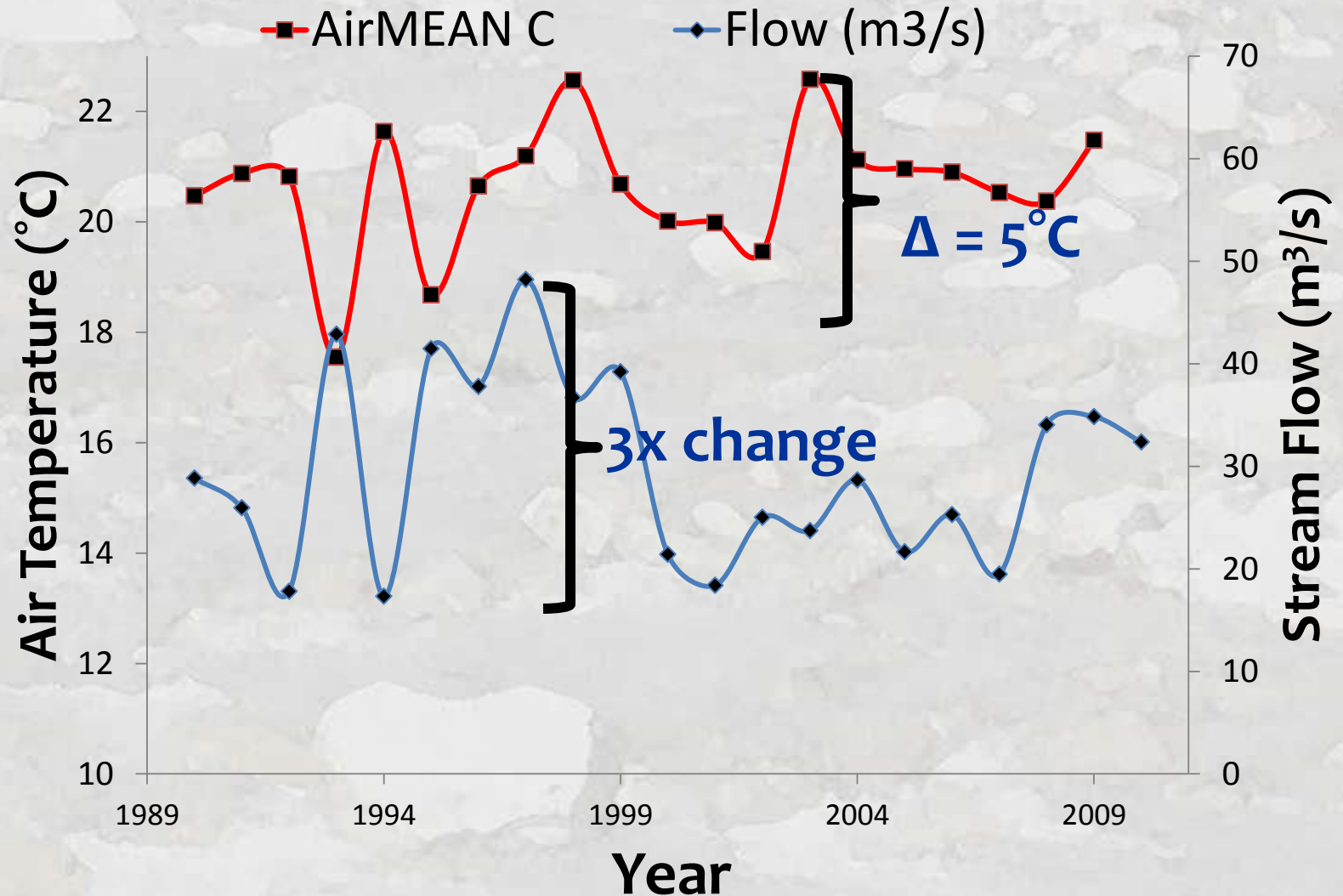
- 60,000 ha basin
- 21,000 stream km

- 4,414 August means
- 1,737 stream sites
- 19 climate summers



Climatic Variability in Historical Record

Extreme years include mid 21st-Century “averages”



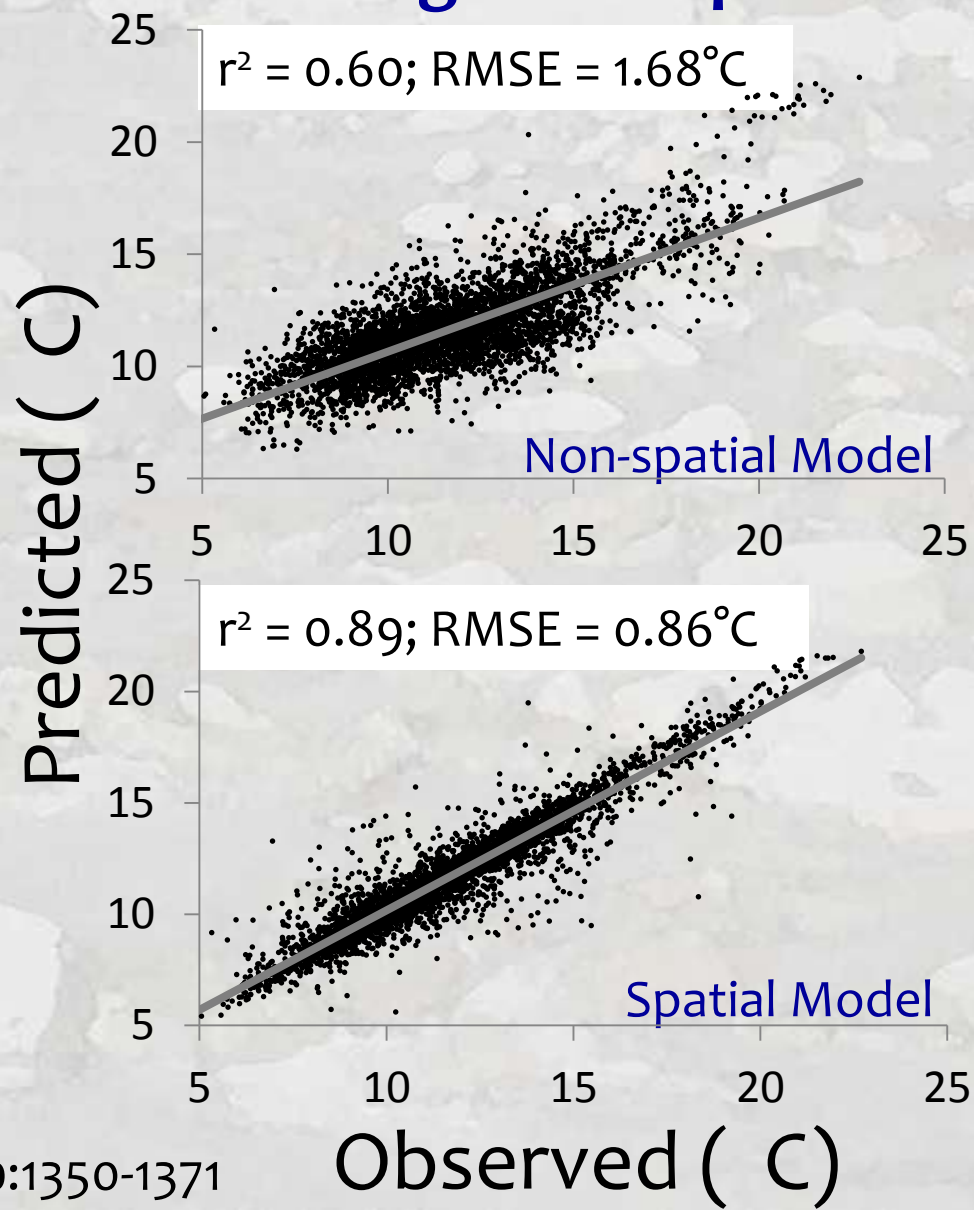
Salmon River Temperature Model

n = 4,414

Covariate Predictors

1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Glaciers upstream (%)
8. Baseflow Index
9. Watershed size (km²)
10. Discharge (m³/s)
11. Air Temperature (°C)

Mean August Temperature



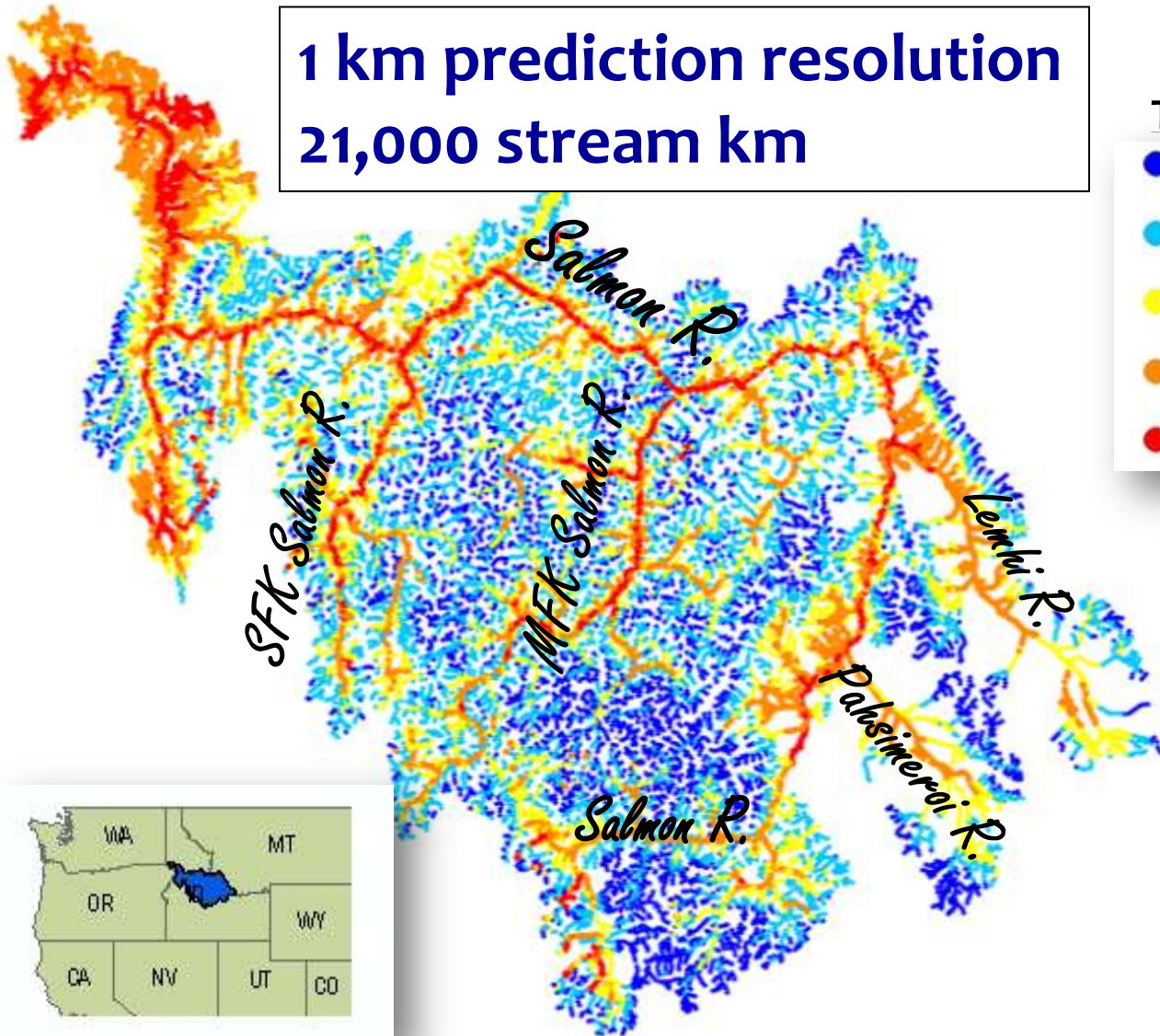
Salmon River Temperature Map

2002-2011 mean August stream temperatures

1 km prediction resolution
21,000 stream km

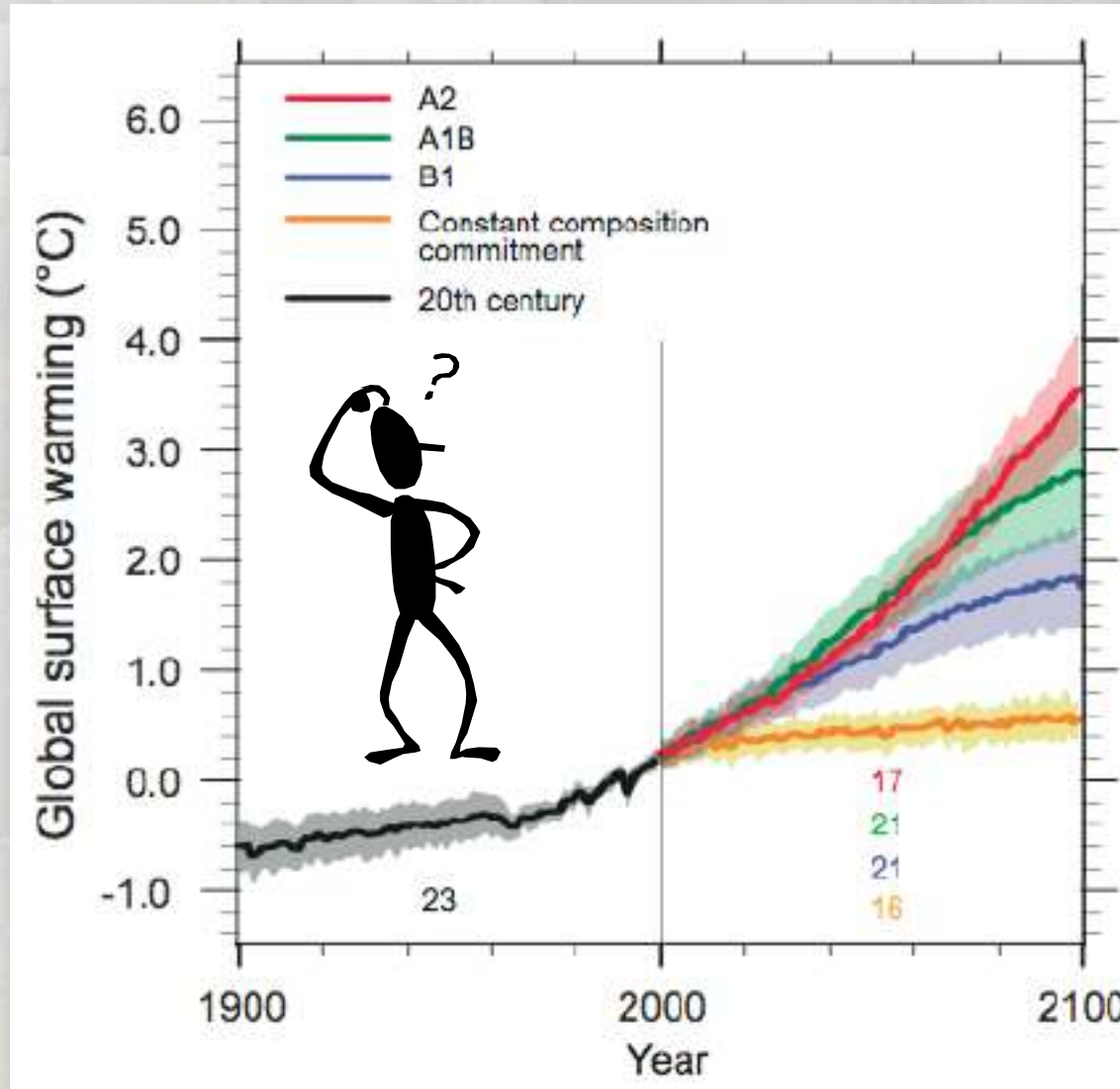
Temperature

- 3.0 - 8.0
- 8.1 - 10.0
- 10.1 - 12.0
- 12.1 - 15.0
- 15.1 - 27.0



Climate Scenario Maps

Many possibilities once model exists...



Adjust air temp
& discharge
values to
represent
scenarios

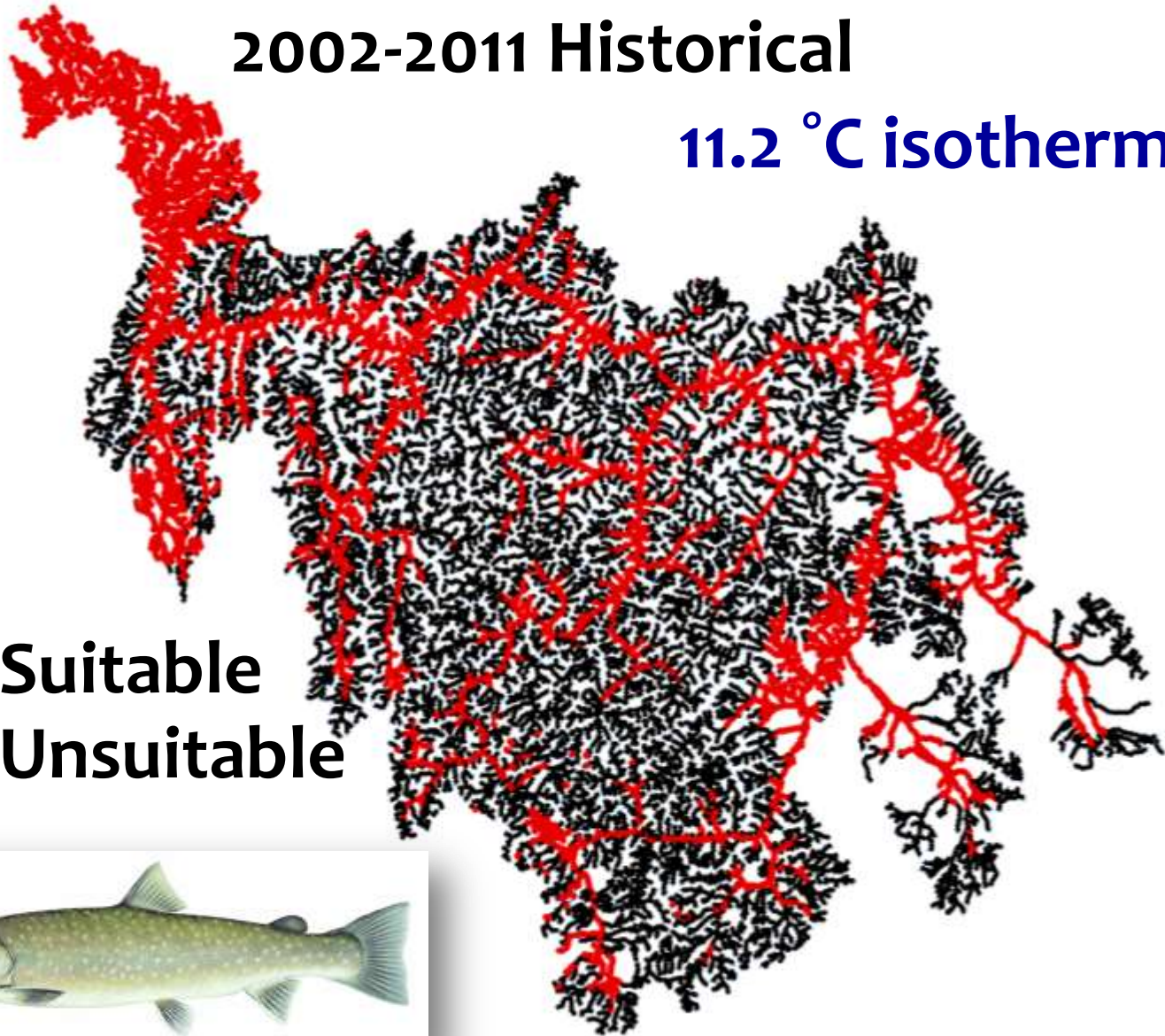


Salmon River Bull Trout Habitats

2002-2011 Historical

11.2 °C isotherm

■ Suitable
■ Unsuitable

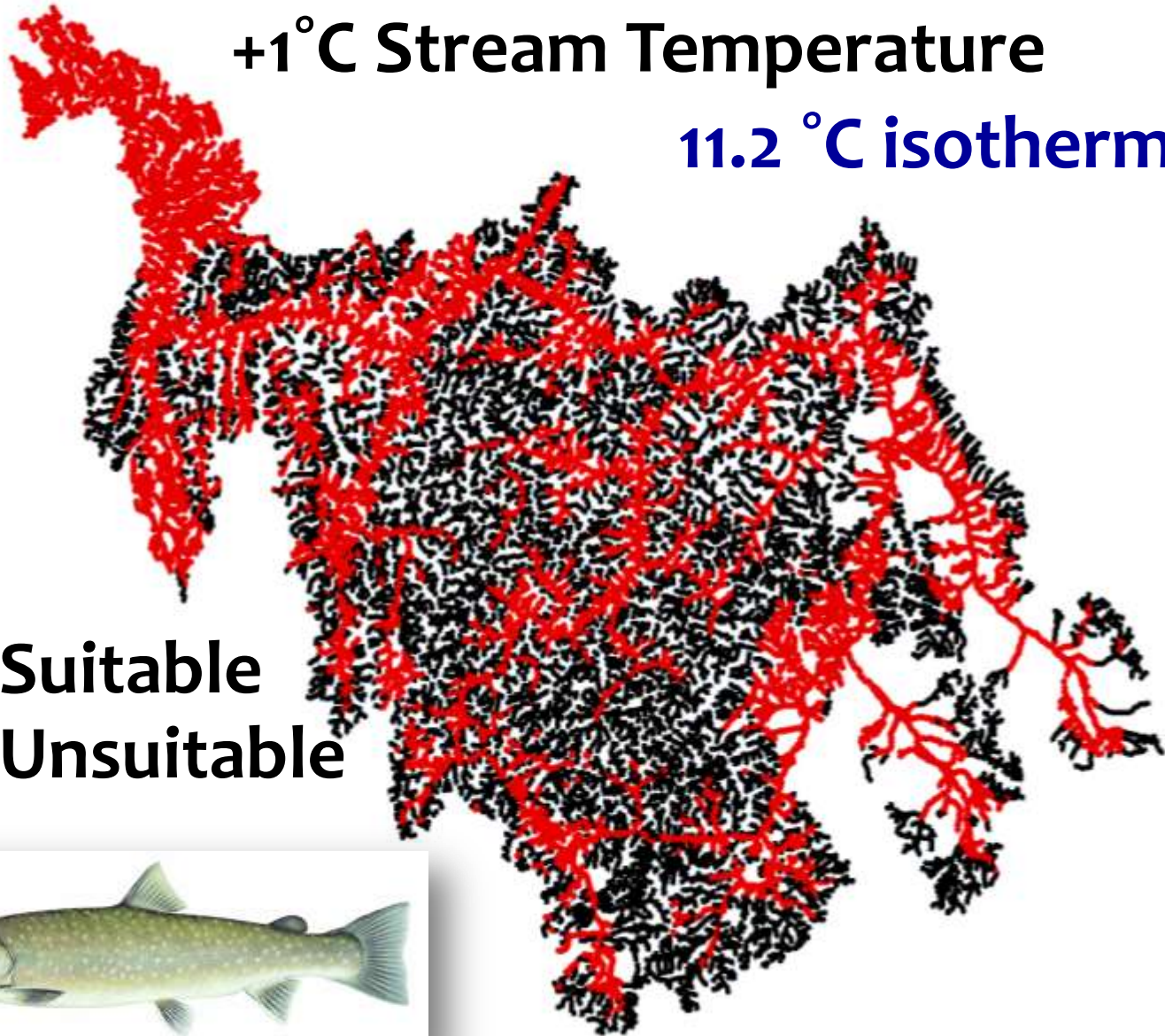


Salmon River Bull Trout Habitats

+1°C Stream Temperature

11.2 °C isotherm

■ Suitable
■ Unsuitable

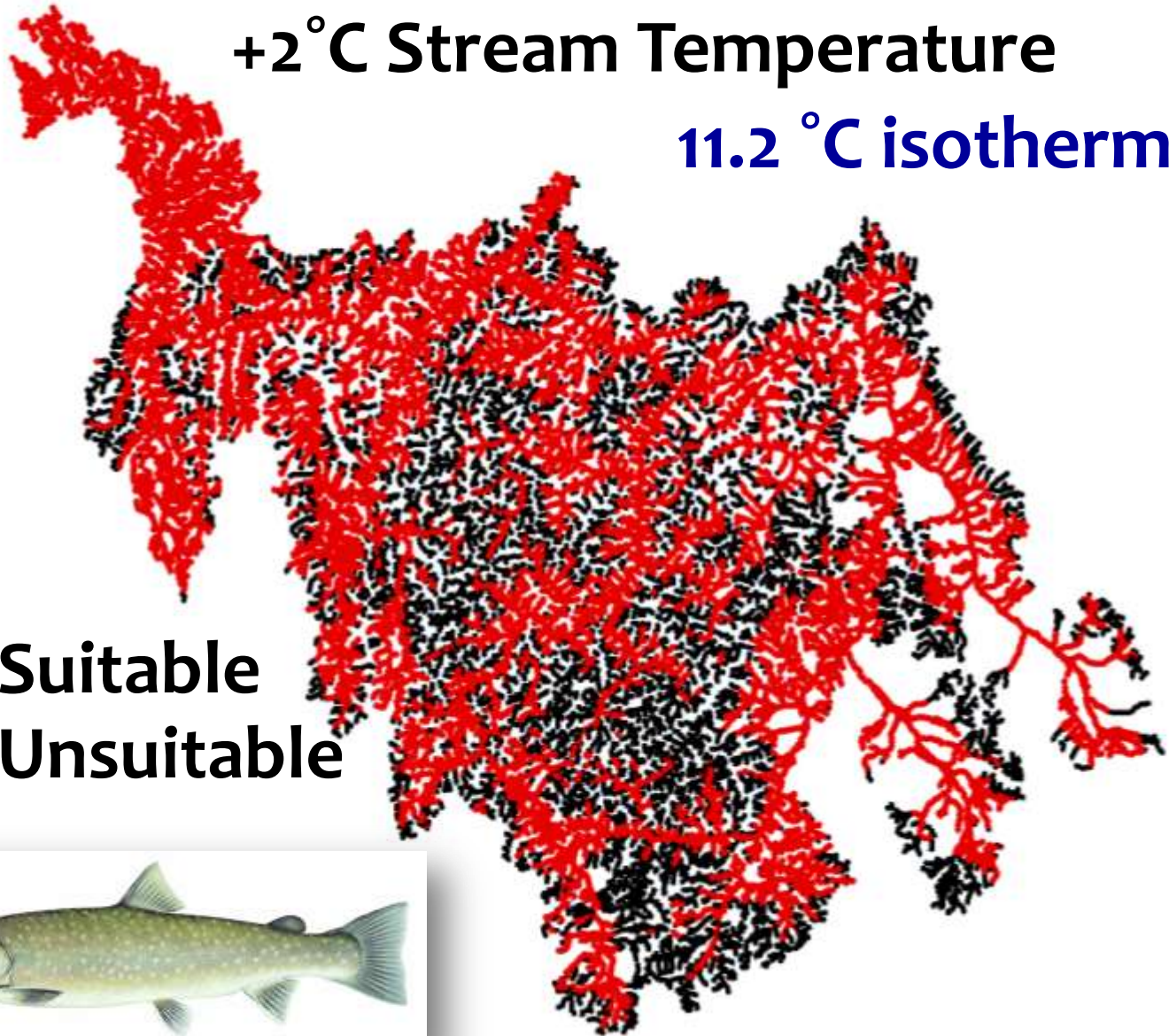


Salmon River Bull Trout Habitats

+2°C Stream Temperature

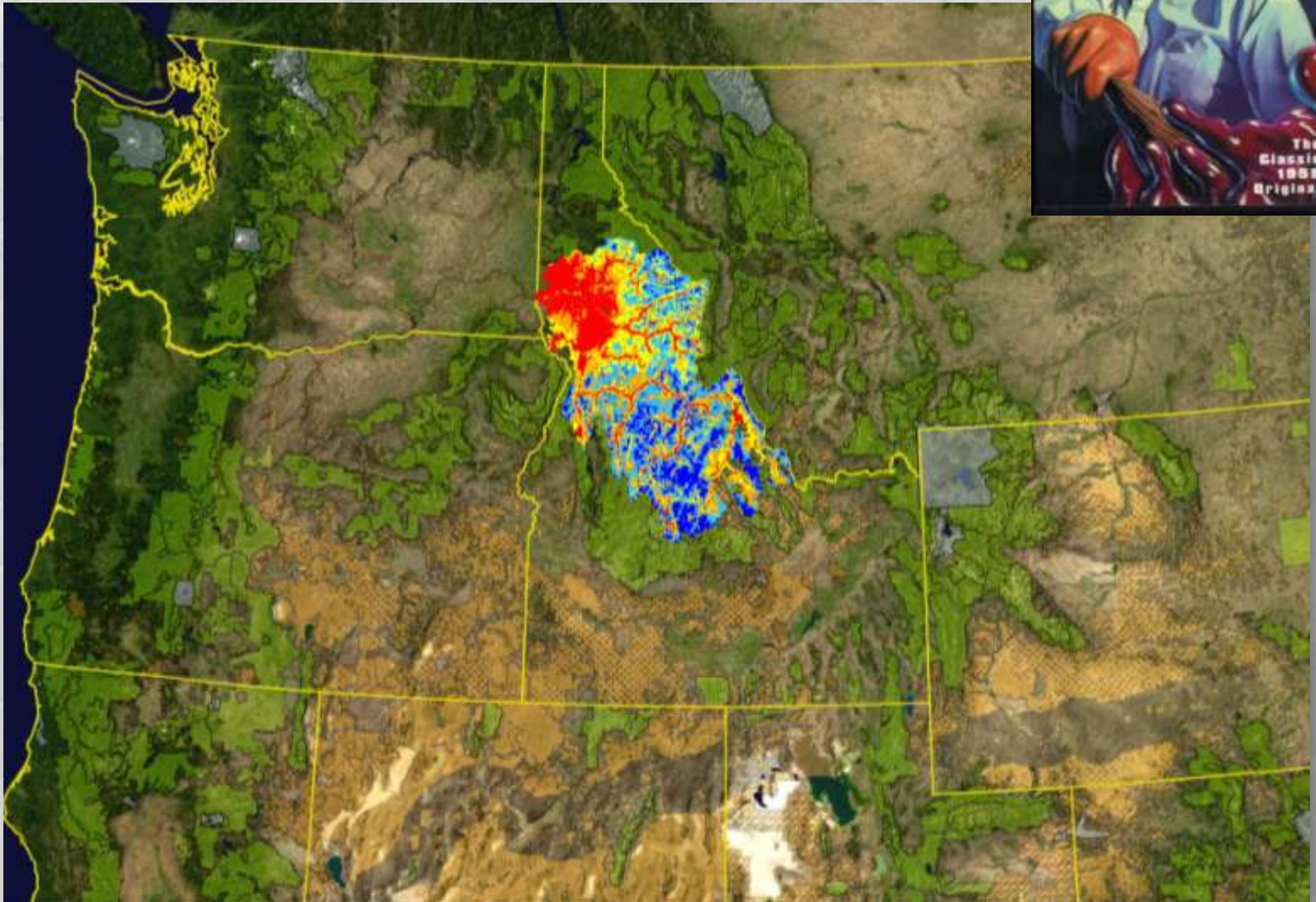
11.2 °C isotherm

■ Suitable
■ Unsuitable



NorWeST Blob Growing...

8,888 summers of data swallowed so far...



Supporting Research...

Stream Temperature 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 Organization (CSIRO), Division of Mathematical and Information Sciences, Indooroopilly, Queensland, Australia

Regional Stream Temperature Trends...

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, G. Chandler

Climatic Change

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

Co-Editors: MICHAEL OPPENHEIMER
GARY VORBE



Epoxy field test and validation work ...

An Evaluation of Underwater Epoxies to Permanently Install Temperature Sensors in Mountain Streams

Daniel J. Isaak* and Dona L. Horan

U.S. Forest Service, Rocky Mountain Research Station, B
322 East Front Street, Suite 401, Boise, Idaho 83702, US



A Simple Method Using Underwater Epoxy to Permanently Install Temperature Sensors in Mountain Streams

(Version 3.12; updated 2/02/2012)

Dan Isaak (disaak@fs.fed.us), Dona Horan (dhoran@fs.fed.us),
and Sherry Wollrab (sherrywollrab@fs.fed.us)

Epoxy “How-to” protocol...

Resources – Stream Temperature Website

Google “Forest Service Stream Temperature”

Boise Laboratory
Stream Temperature
Modeling

Rocky Mountain Research Station Home > Science Program Areas > Air, Water and Aquatics > Boise Laboratory Stream Temperature Modeling

Stream Temperature Modeling

modeling Introduction

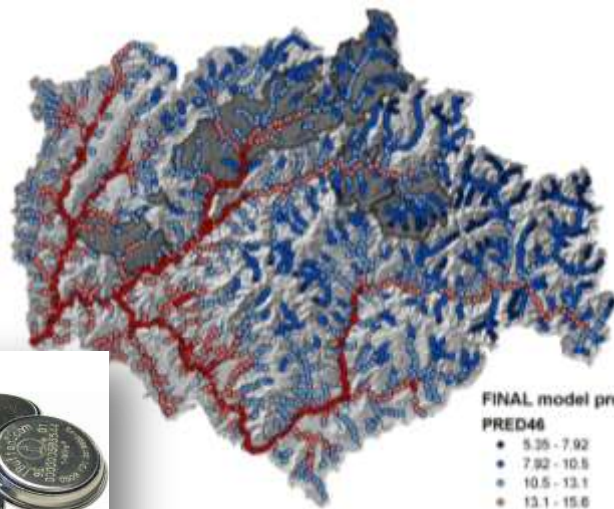
Thermal regimes are important to aquatic ecosystems because they strongly dictate species distributions, productivity, and abundance. Inexpensive digital temperature log

- Stream temperature publications & project descriptions & recent talks

- Protocols for temperature data collection & demonstration videos

- Processing macro for temperature data

- Dynamic GoogleMap showing current temperature monitoring sites



The End

