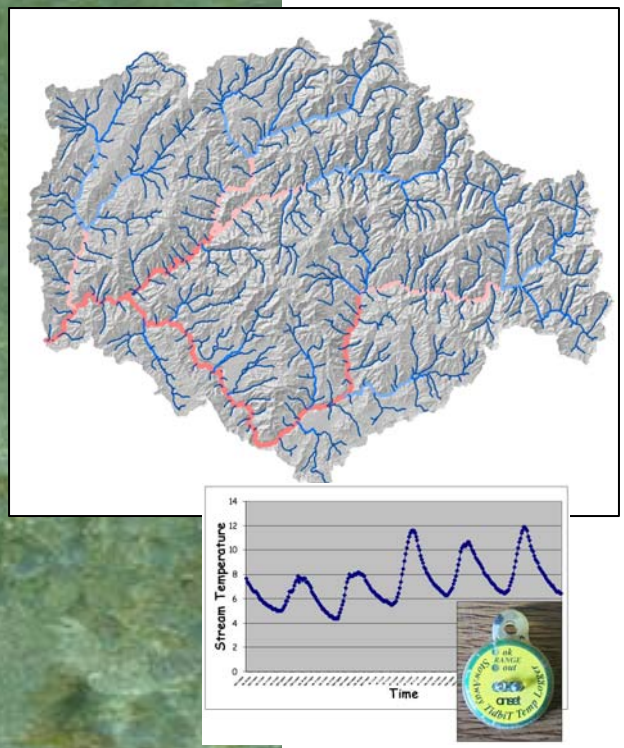
# Predicting Stream Temperatures Using a Spatial Statistical Model for Stream Networks

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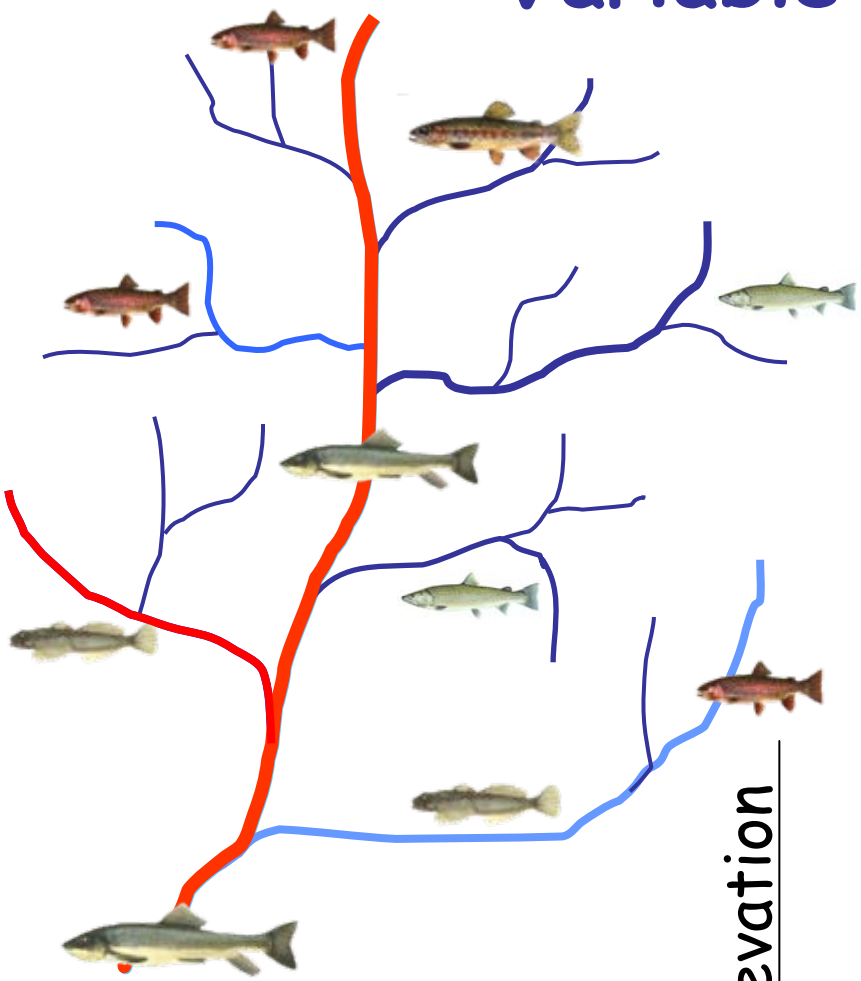
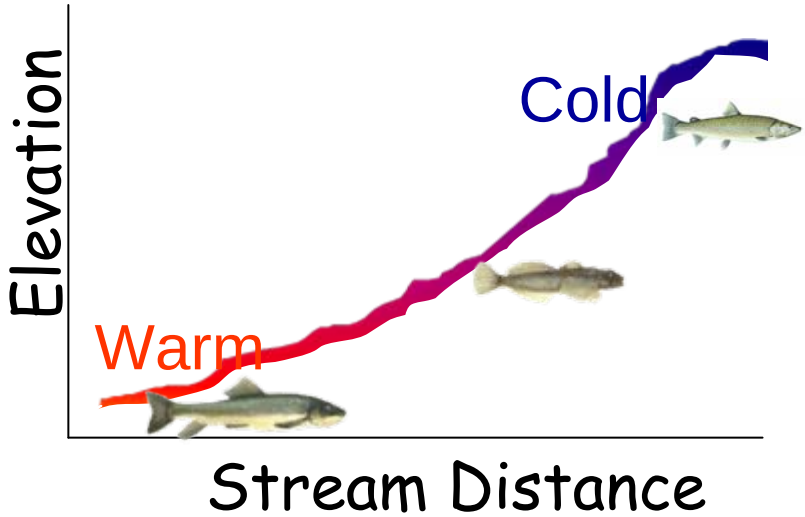
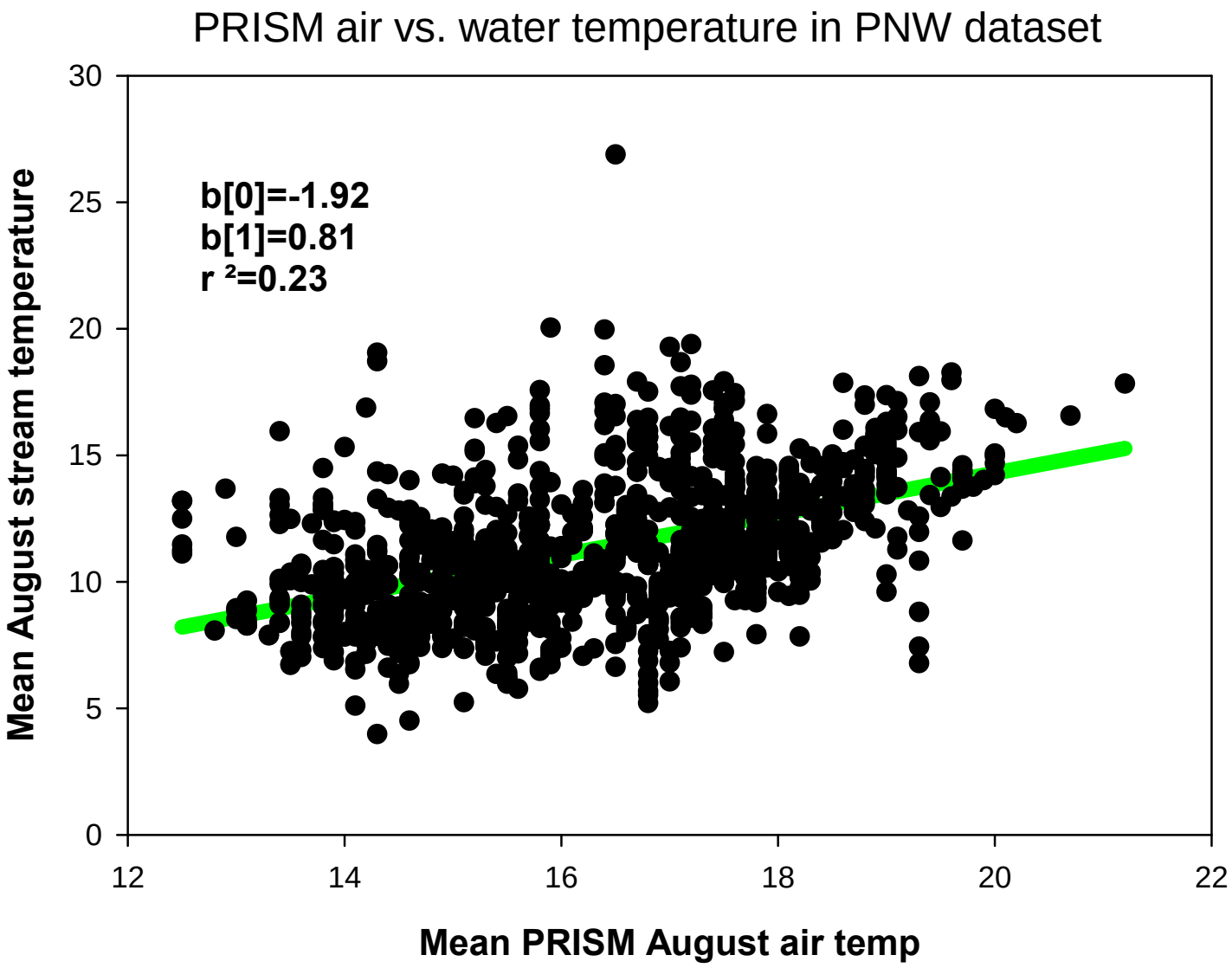
# Temperature is a "Master Variable" in Streams



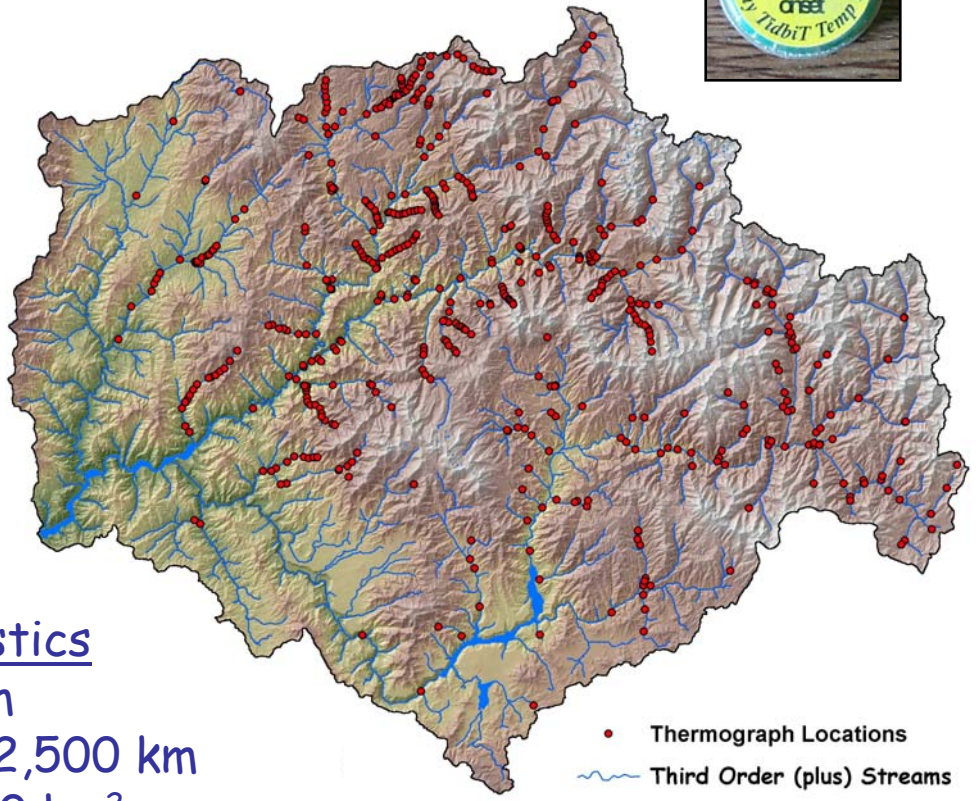


# Air temp ≠ water temp



# Boise River Watershed

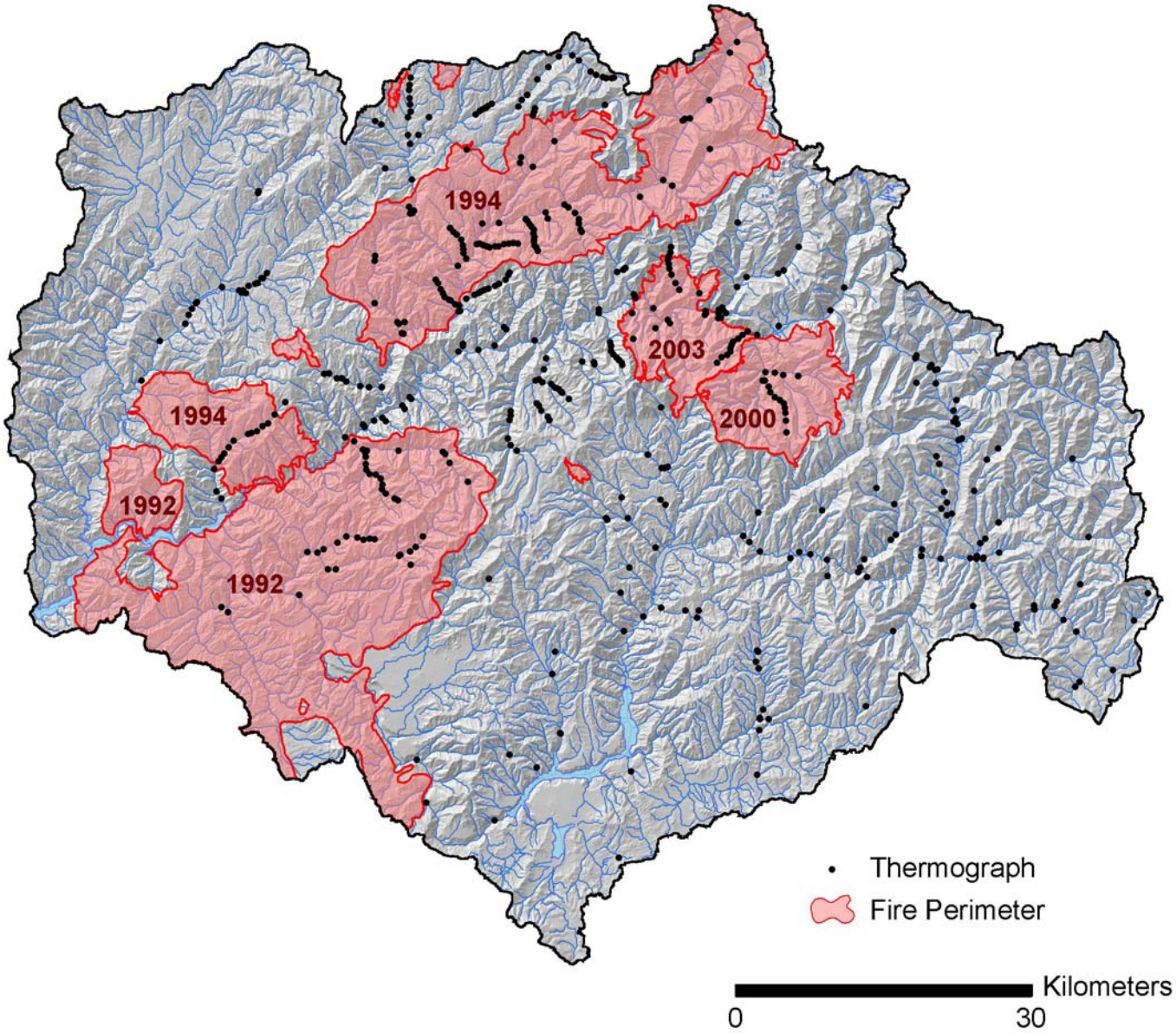
Stream Temperature Database
780 observations
518 unique locations
14 year period (1993 – 2006)

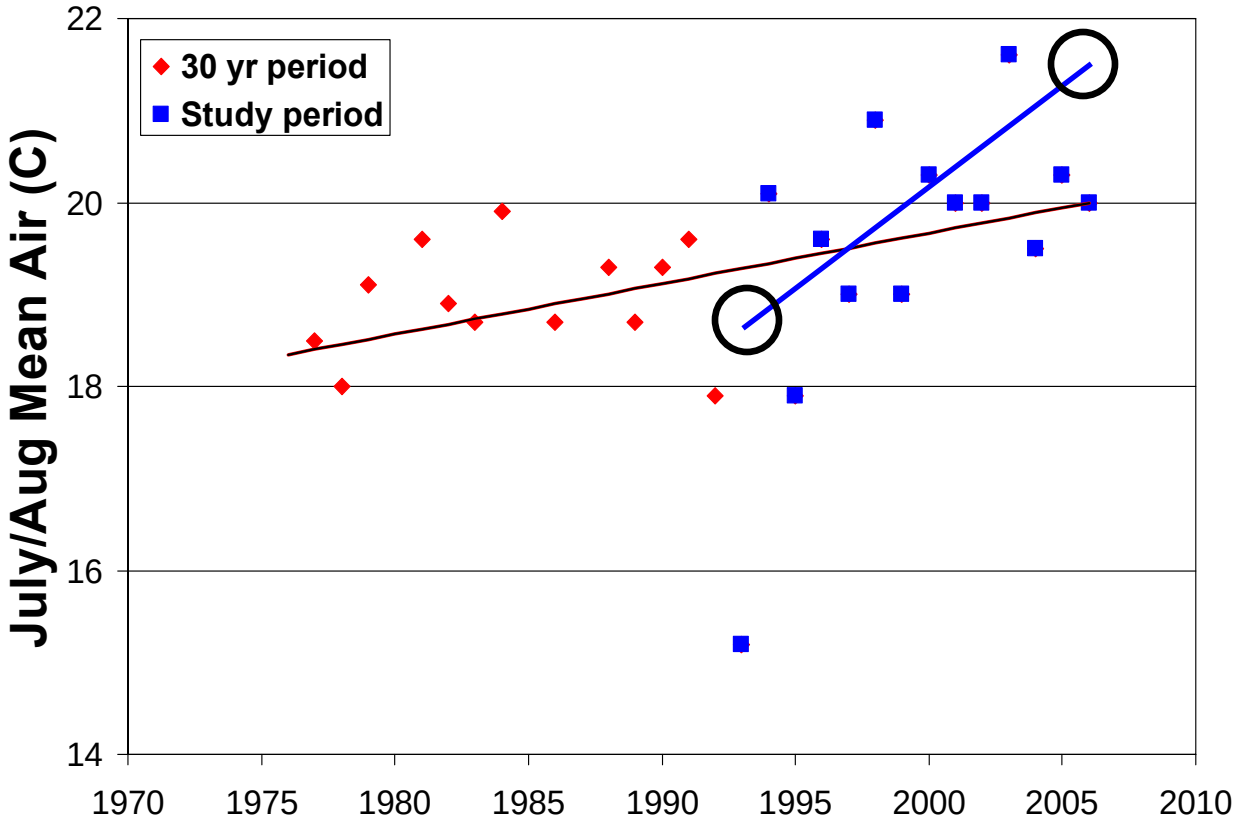

Watershed Characteristics
Ele Range 900 – 3300 m
Fish bearing streams ~2,500 km
Watershed area = 6,900 km$^2$

# Recent Fires in the Boise Basin

## 25% burned since 1992



# Air Temp Trends in the Boise

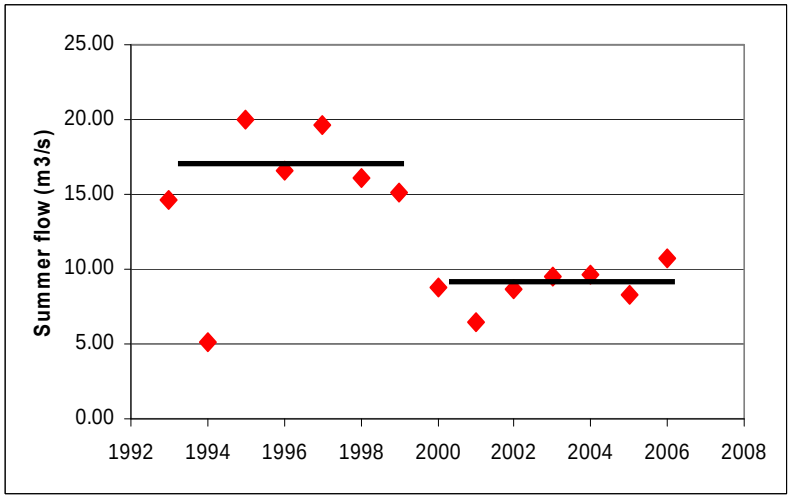



**1976 – 2006**
Summer Mean = +0.57°C
Summer MWMT = +0.70°C
Or ~ 0.2°C/decade

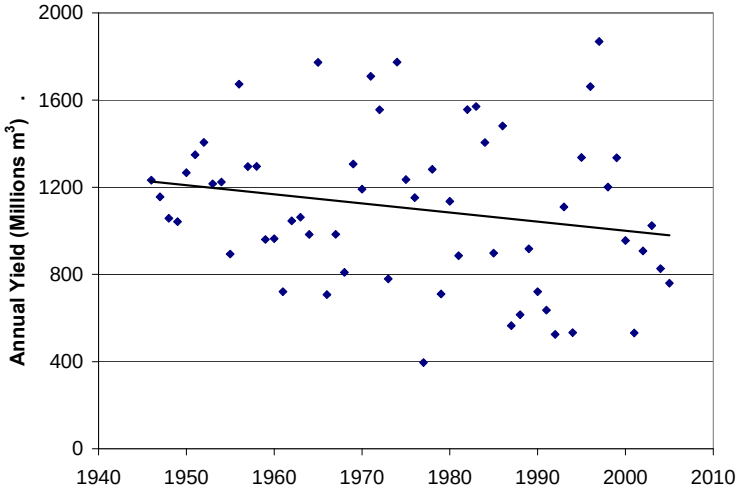
**Study period (1993-2006)**
Summer Mean = +1.3°C
Summer MWMT = +2.0°C
Or ~ 1.2°C/decade!

# Stream Flow Trends in the Boise

## Study Period




## 1946 – 2006 Water Yield



# Response Variable

Stream MWMT (highest 7-day moving average of the maximum daily temperatures)

Summer Mean (average temperature July 15 – Sept 15)

# Predictor Variables

Geomorphic attributes (DEM derived)

- -basin elevation
- -basin size
- -reach slope
- -glaciated valley extent
- -alluviated/flat valley extent

Climate attributes (3 weather & 2 flow stations)

- -annual summer discharge
- -annual air MWMT

Solar radiation (TM satellite imagery pre- & postfire)

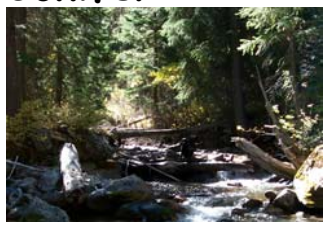
# Solar Radiation Estimates from Remote Sensing

TM satellite imagery classifies riparian vegetation pre- & postfire into (open, shrub, conifer)

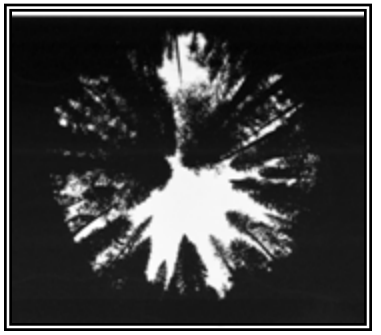
Open

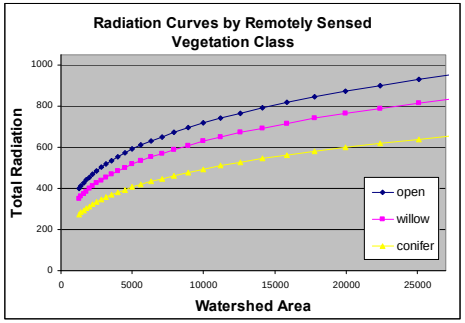
Willow

Conifer



Canopy Photography estimates site-level radiation for each class (181 sites)






Radiation curves by vegetation class

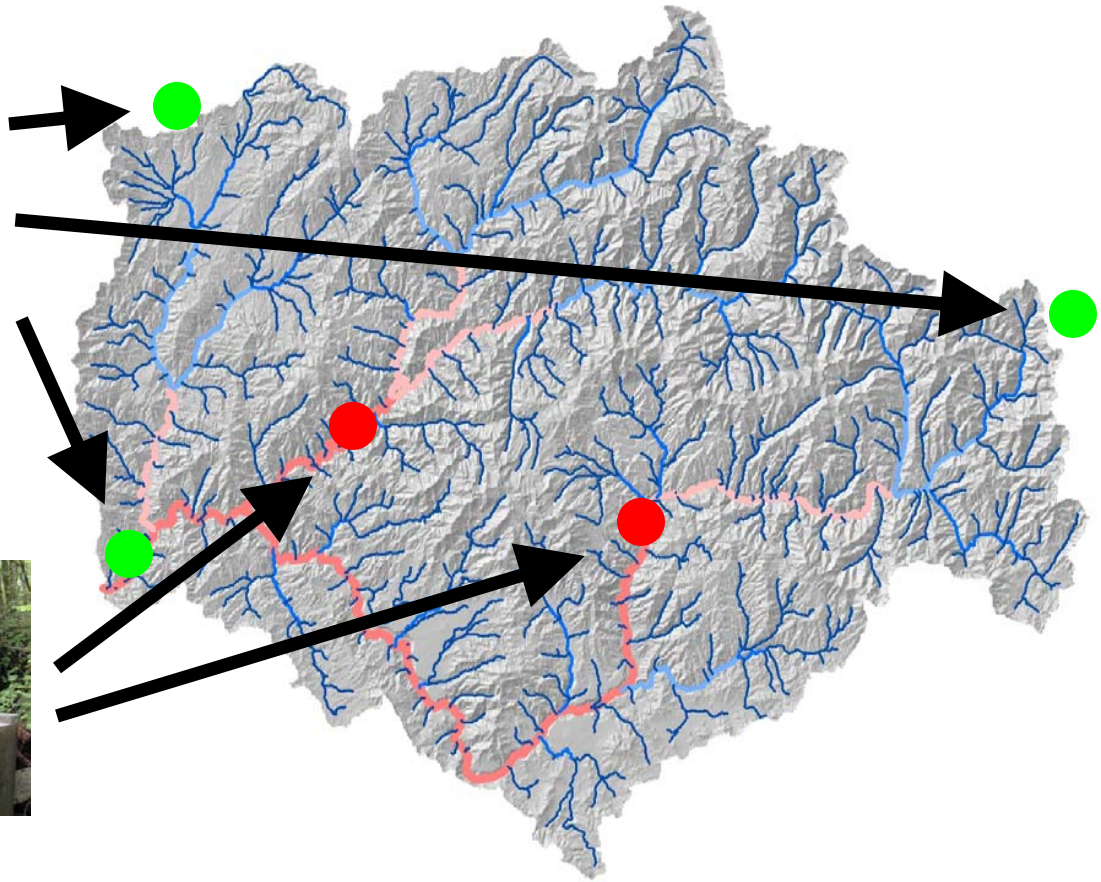
**Predicted radiation across stream network**

Luce et al., manuscript in preparation

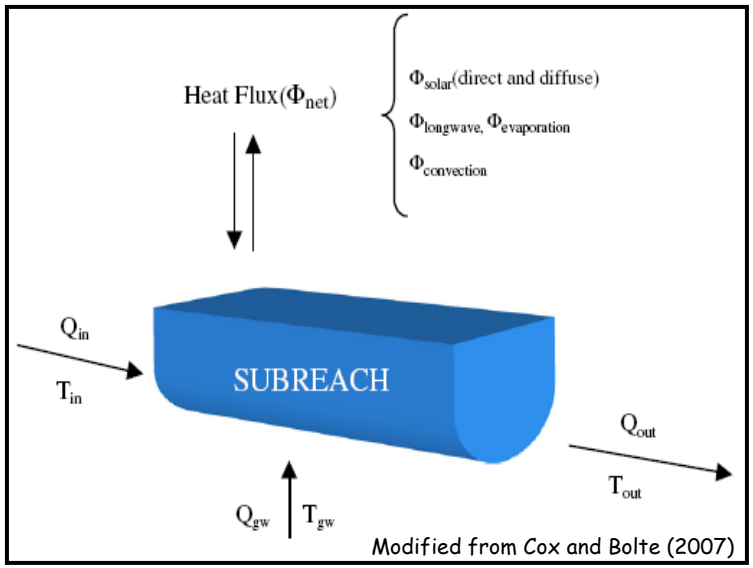
# Air Temperature & Stream Flow Effects

Air Temps

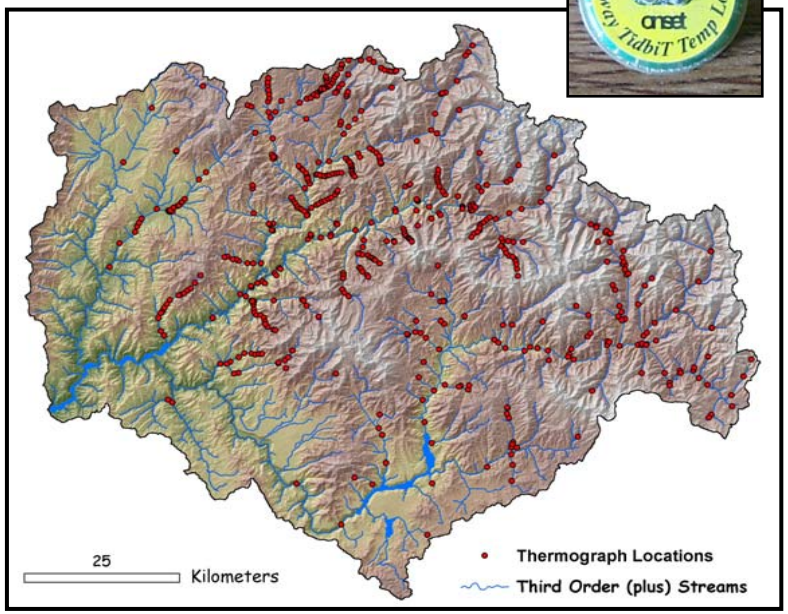
Stream flow



# Statistical vs Mechanistic Stream Temperature Models



Modified from Cox and Bolte (2007)

# Spatial Statistical Models for 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

## Functional Linkage of Water basins and Streams (FLoWS) v1 User's Guide:

ArcGIS tools for Network-based analysis of freshwater ecosystems

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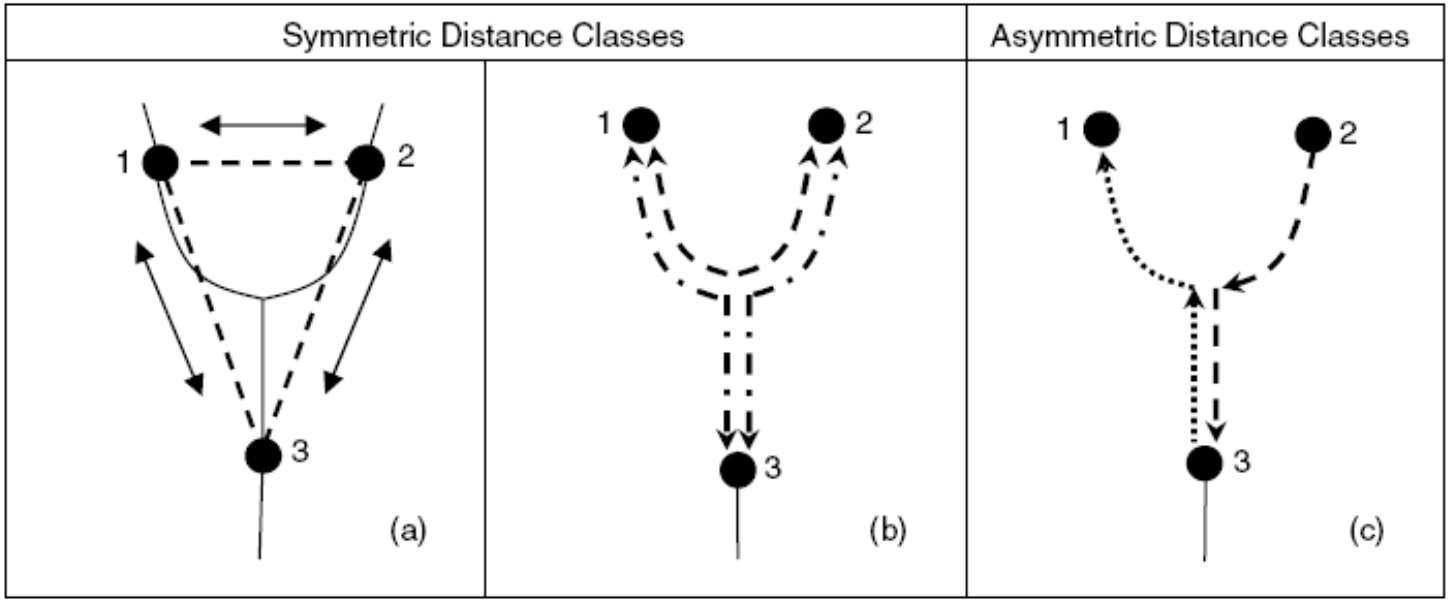
# Spatial Statistical Models for Stream Networks




**Advantages:**

- -flexible covariance structures account for different spatial autocorrelations
- -weighting by stream size
- -improved predictive ability & parameter estimates relative to OLS

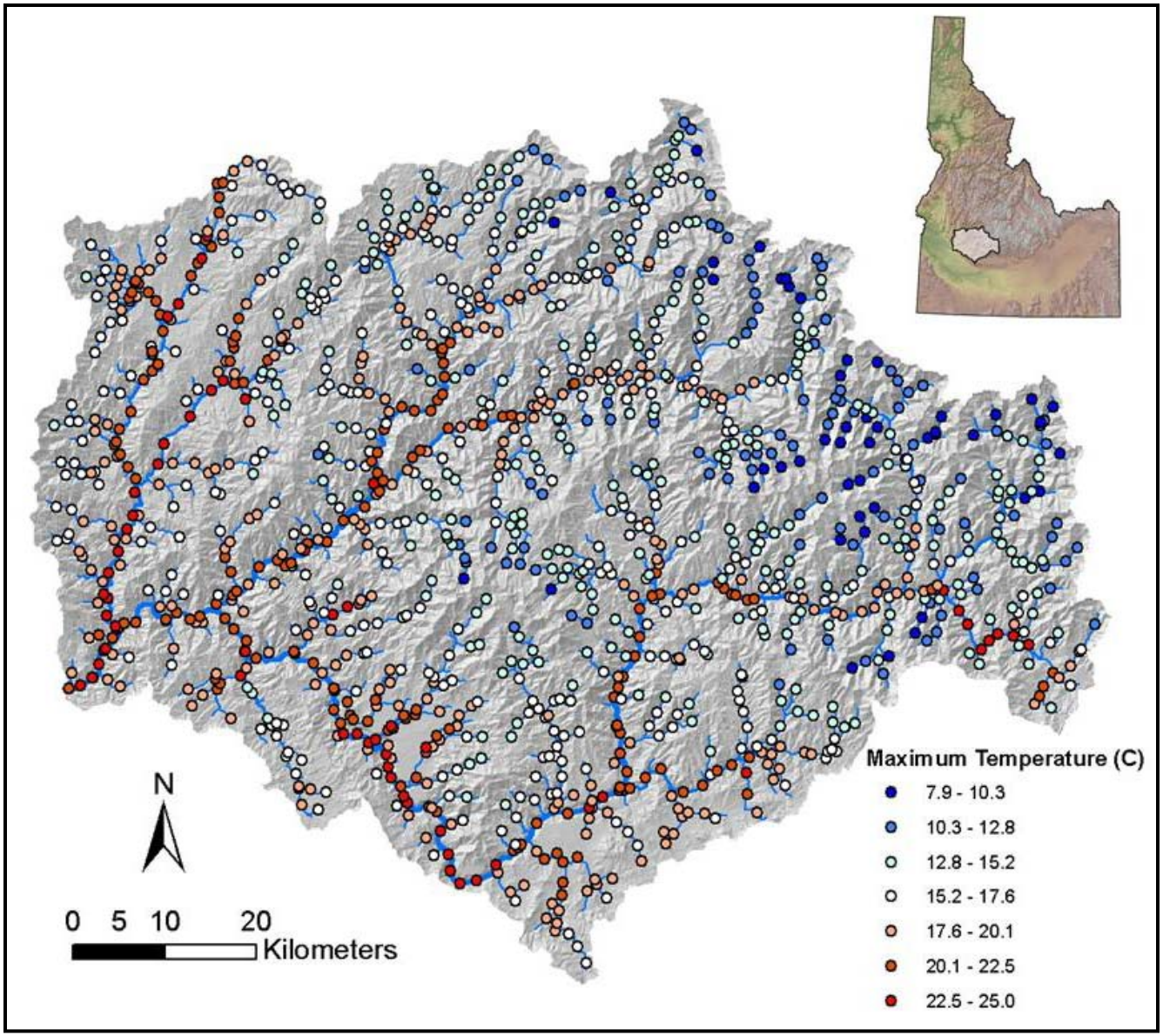
Peterson et al. 2006; Ver Hoef et al. 2006

# Comparison of Model Results

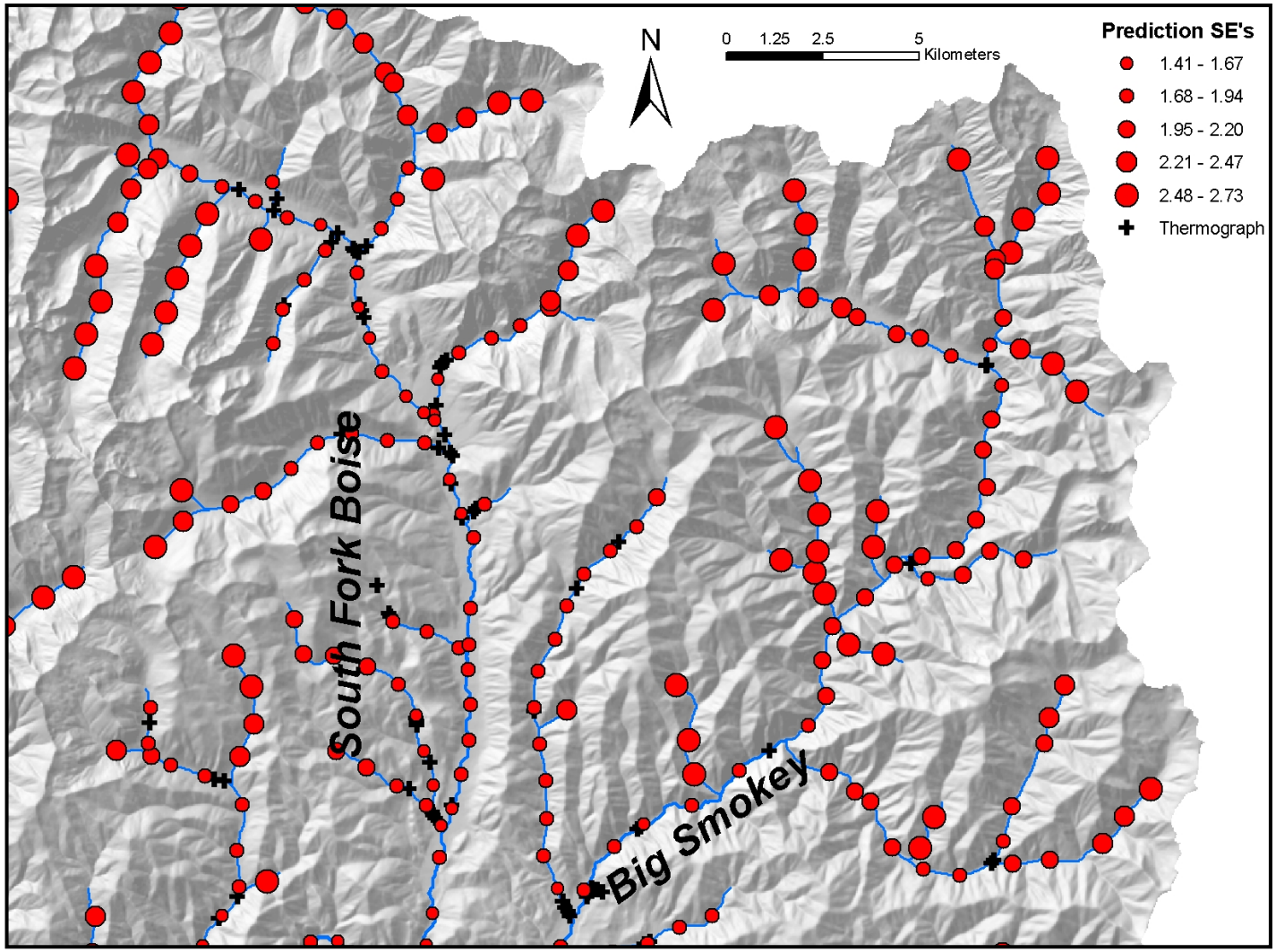
## Spatial vs. Ordinary Least Squares Estimates
## Response Variable = Maximum 7-day Max Temp

| Model Type | Model Predictors | RMSPE | ΔAICc | $R^2$ | Variance Component | |
|---|---|---|---|---|---|---|
| | | | | | Fixed Effect | Spatial Error |
| Spatial | Elevation, Radiation, Air Temp, Stream Flow | 1.54 | 0 | 0.86 | 0.63 | 0.37 |
| OLS | Elevation, Radiation, Air Temp, Stream Flow | 2.75 | 787 | 0.54 | 1.00 | -- |

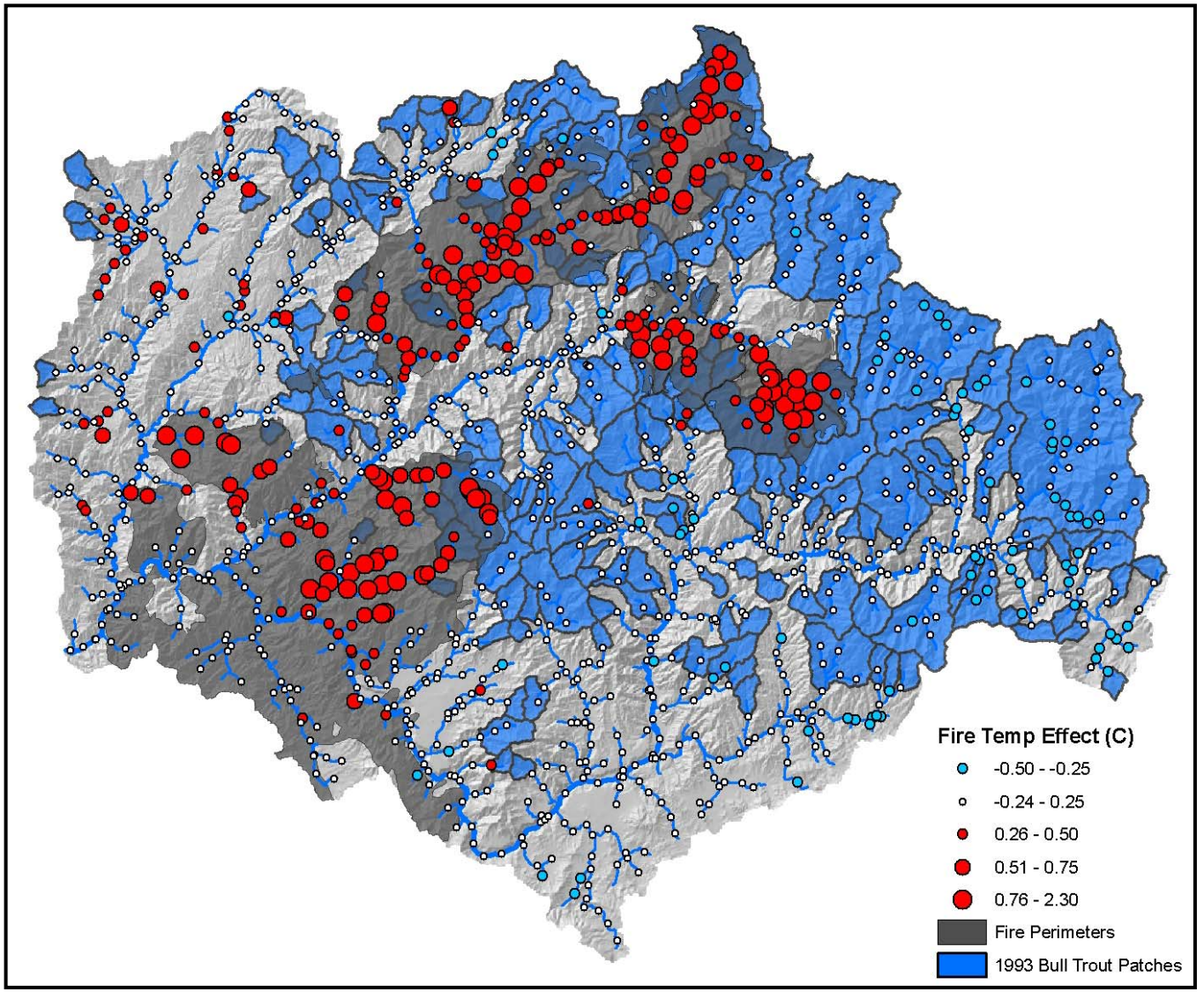
# Stream Temperature Predictions



# Temperature Prediction Precision



# Fire Effect on Stream Temperature



# Conclusions…

1) New spatial statistical models for stream networks improve predictive accuracy relative to OLS models. Response metric can be any stream attribute.

2) Integration of remote sensing & use of GIS routines to quantify predictor variables makes predictions possible for broad areas w/minimal field effort.

3) Model applications could include…
   a. Delineation of suitable habitat patches for sampling
   b. Development of efficient temperature monitoring protocols
   c. Describe/forecast habitat distributions under various climate & fire scenarios
   d. Compliance with water quality standards
   e. Block kriging to derive stream-scale population estimates from fish survey data

# US Forest Service
# Rocky Mountain Research Station

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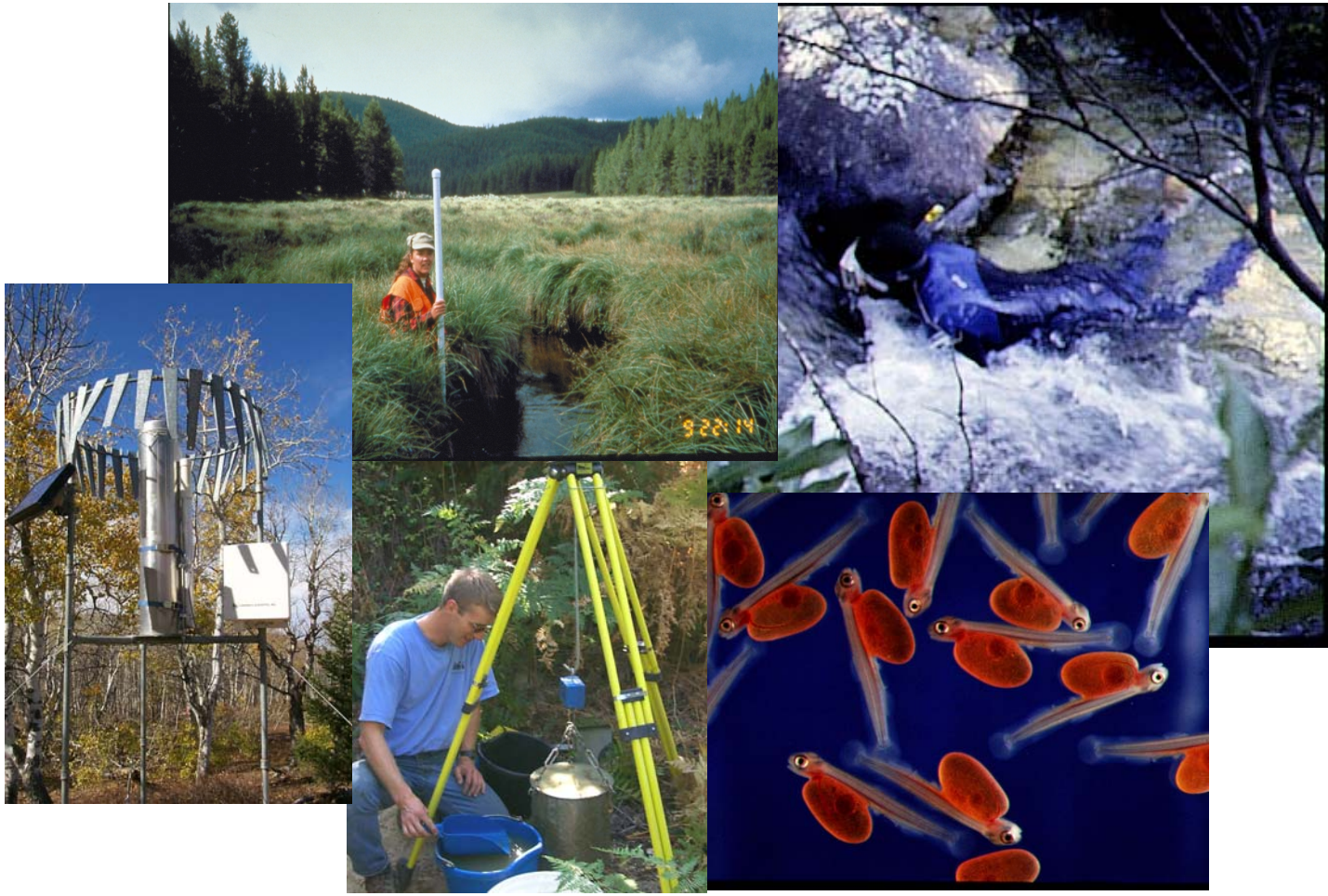

website: www.fs.fed.us/rm/boise