Stream Temperature and Thermal Networks

A GIS and Remote Sensing Approach to Assess Aquatic Habitat

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FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

Boise Lab Disciplines

Fisheries

Watershed

Physical Environment as a Template

Physical

Biology

Physical Environment Affects Stream Temperature

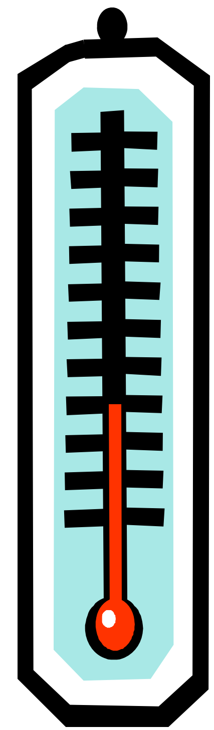
- Air temperature
- Elevation
- Shade
- Stream width

Temperature affects biology

Species of Concern

Threatened Bull Trout

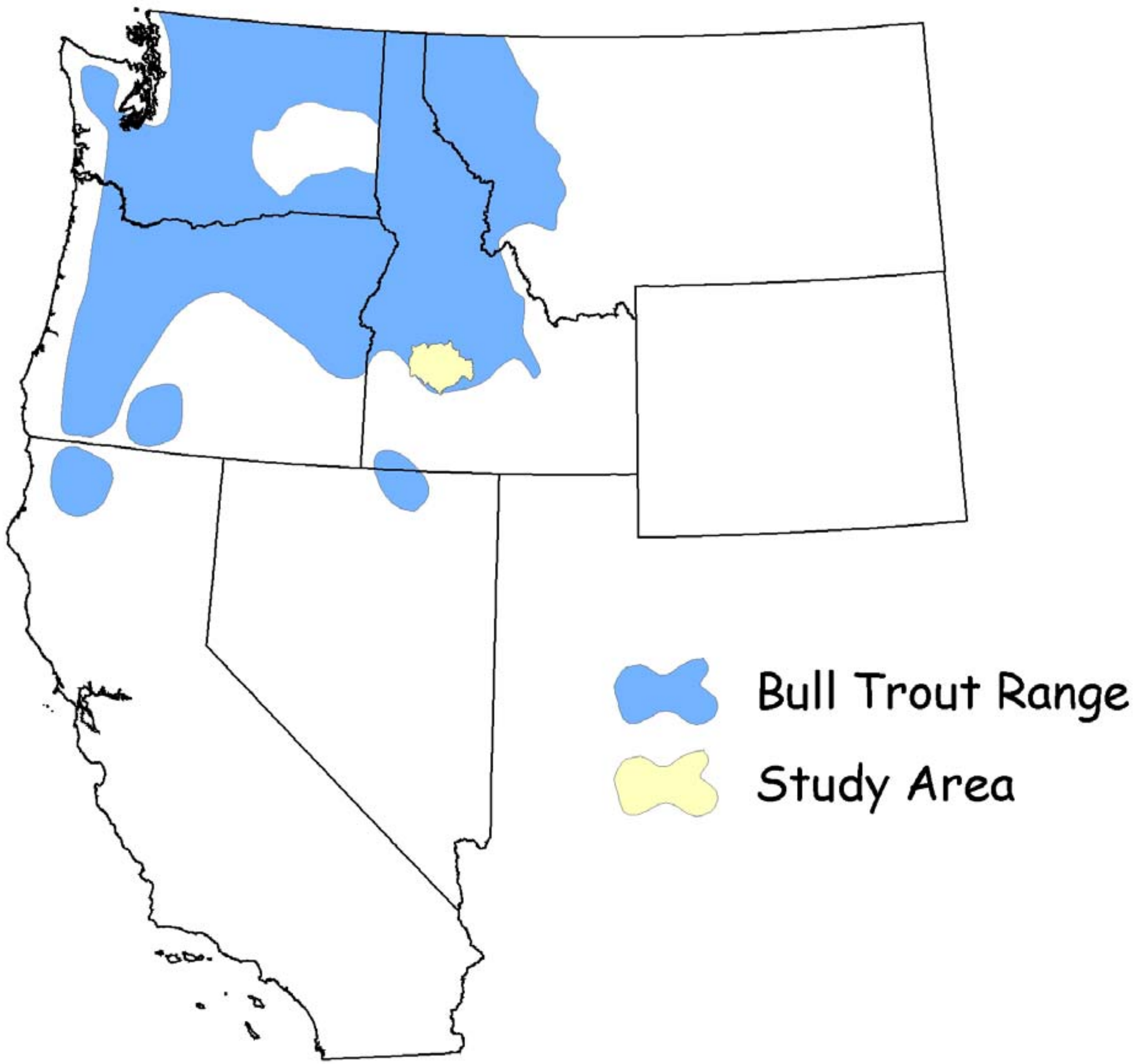
20 ° C



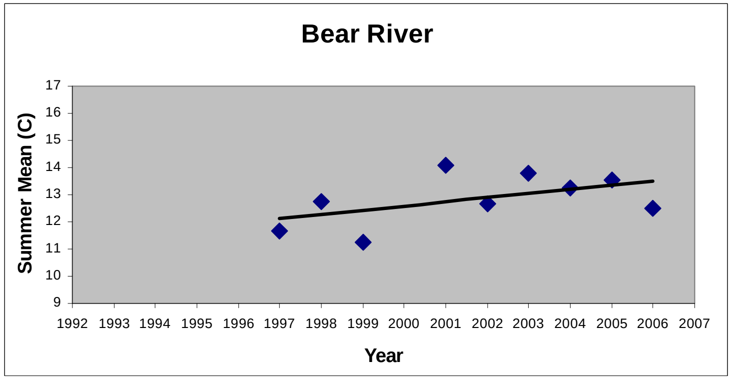
68 ° F

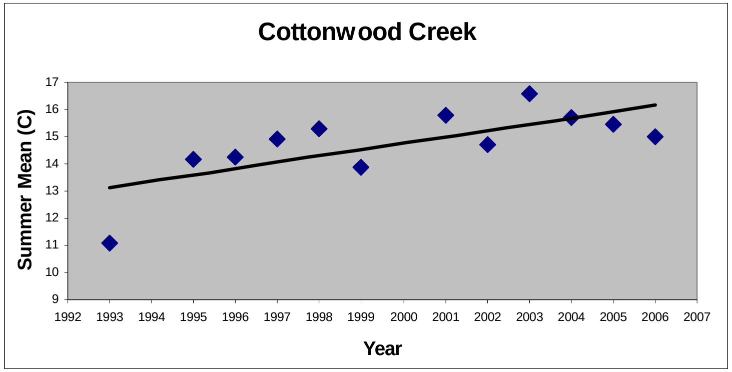
Danger

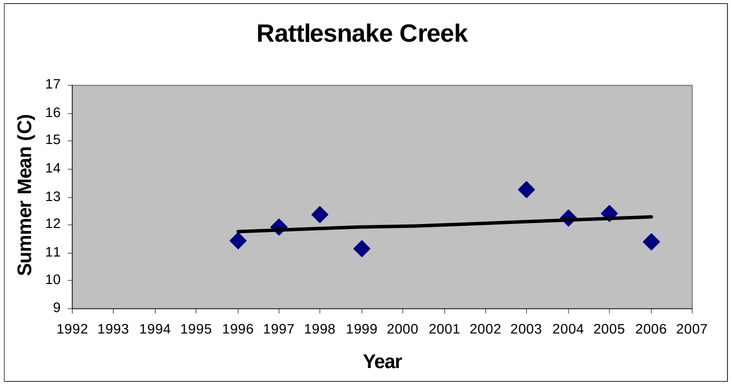
U.S. Bull Trout Range

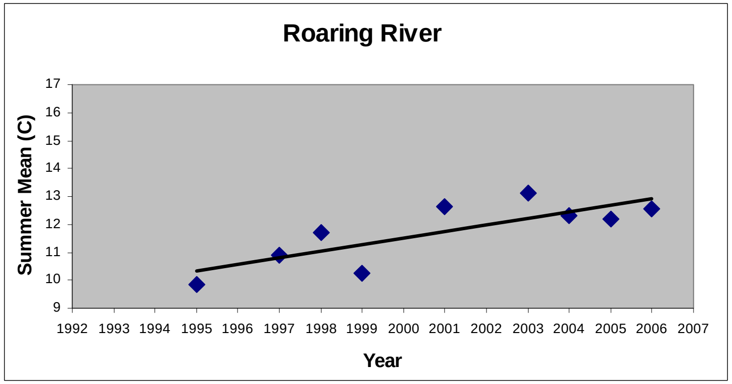


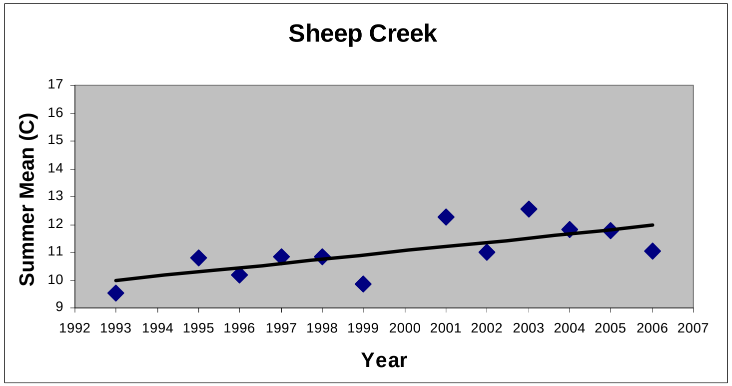
Boise Basin Summer Stream Temperature Trends (1993 – 2006)



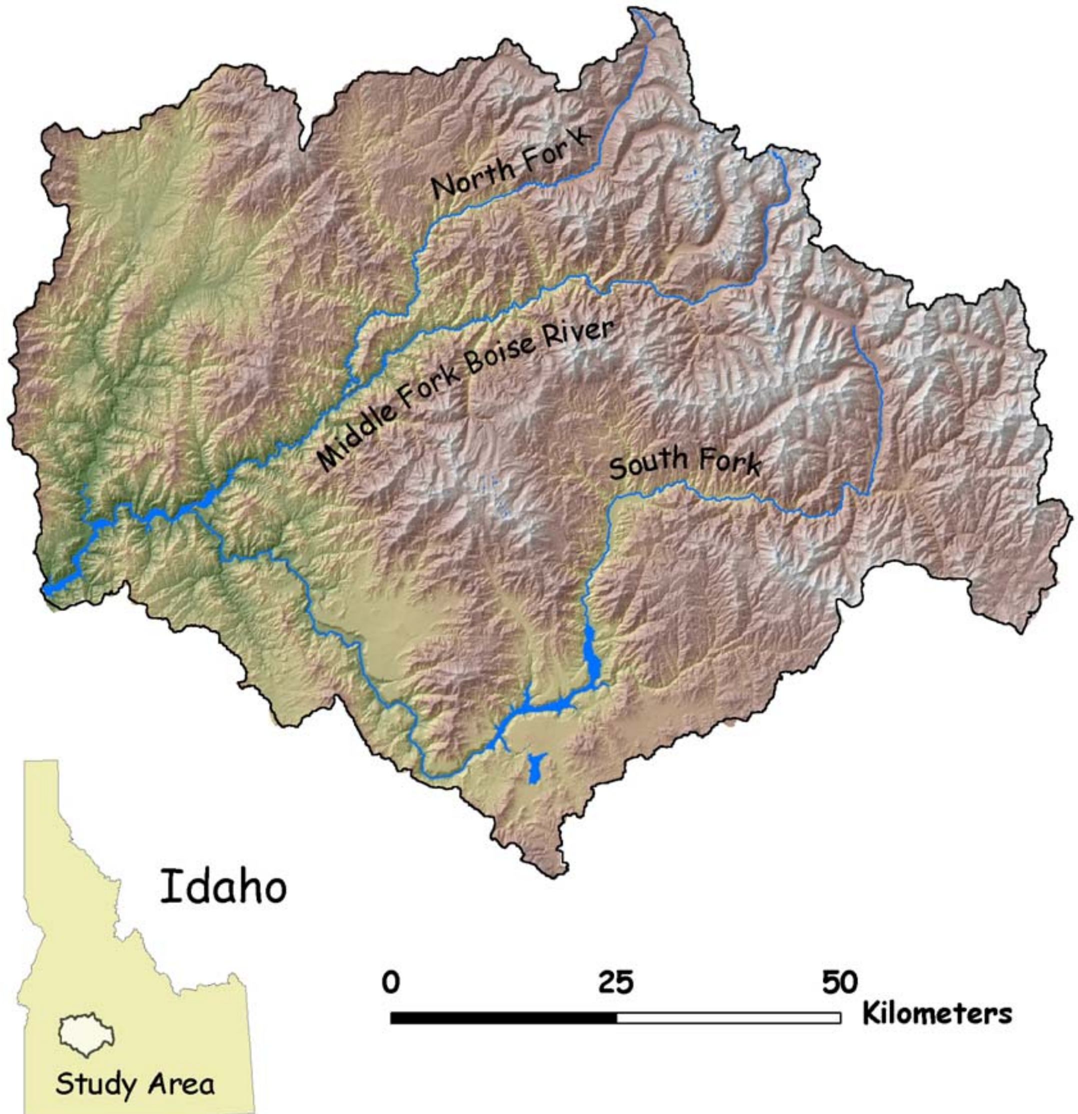






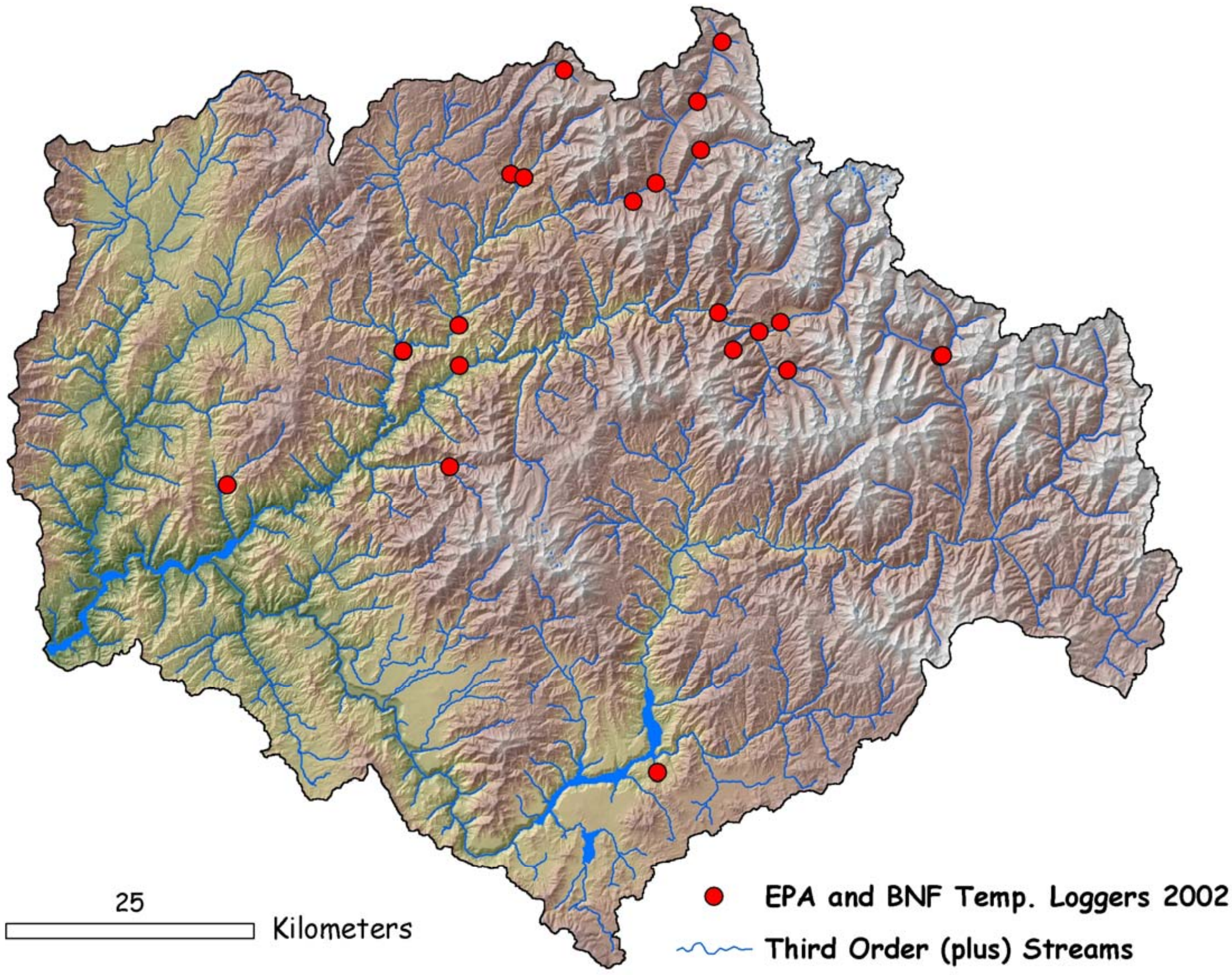


Project Study Area

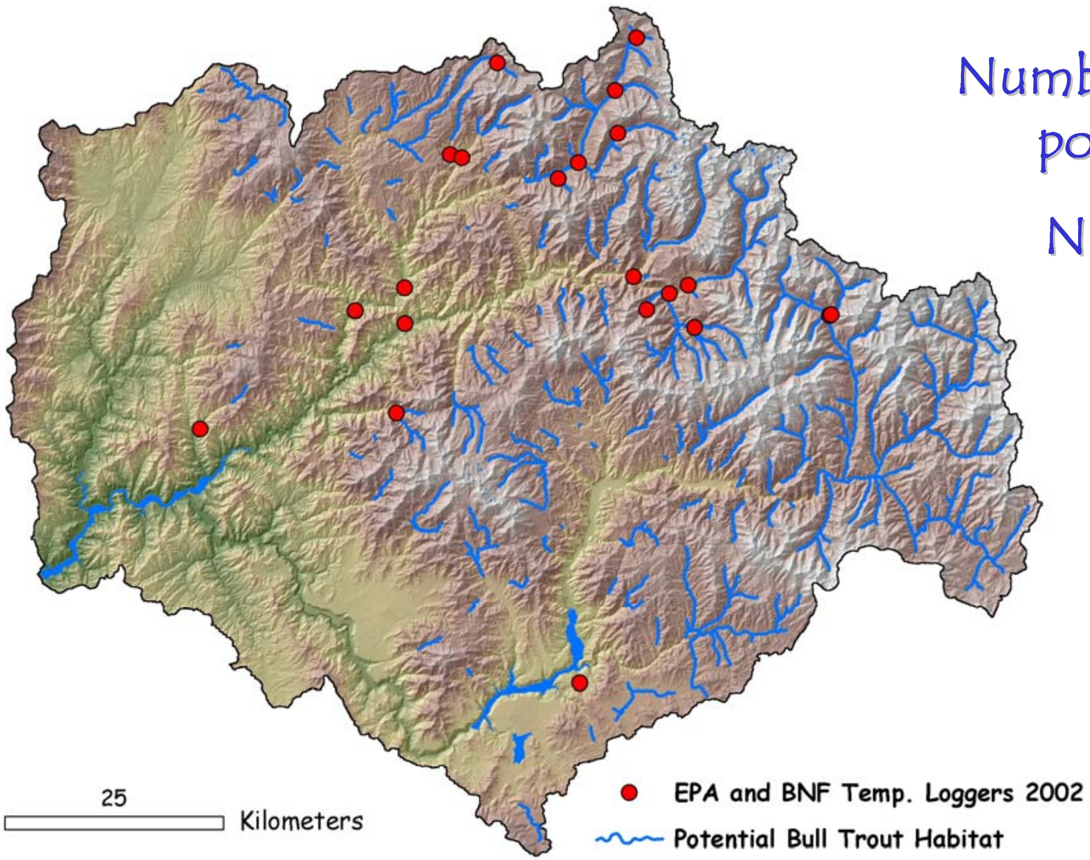


Basin Diversity

Typical Temperature Network



Potential Bull Trout Network



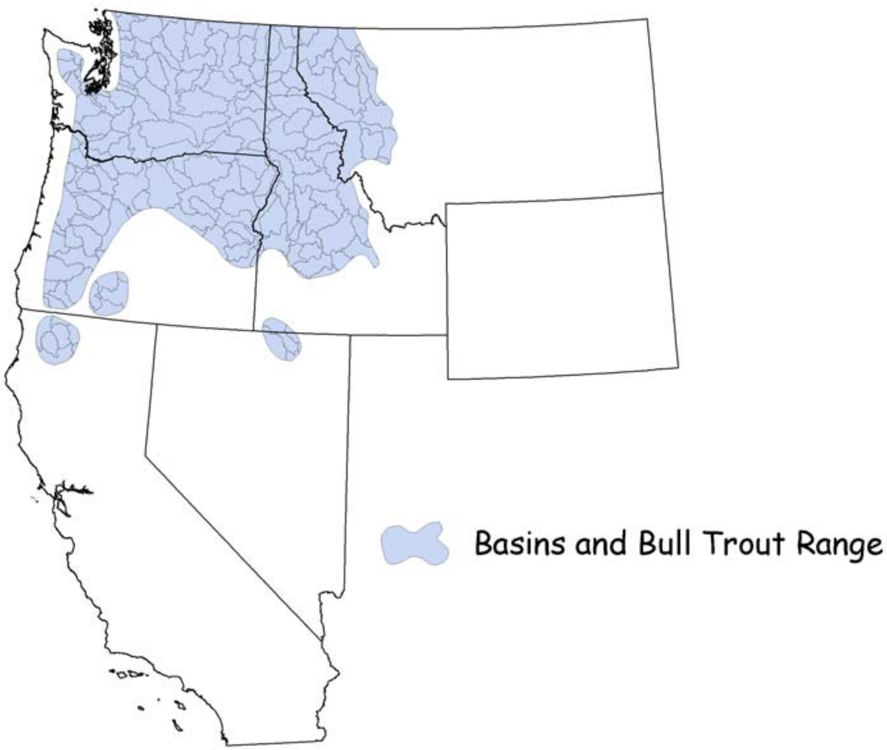
Typical Scenario

Number of stream reaches in potential range: 1500

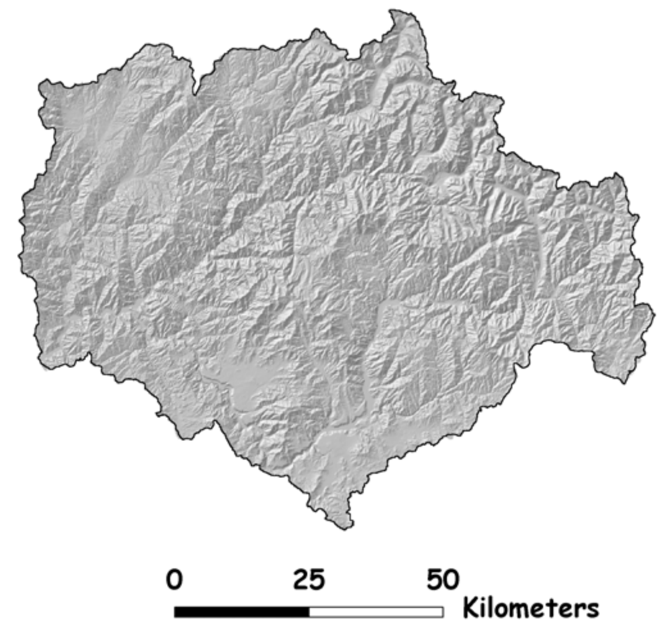
Number with known temperature: 11

Challenge:

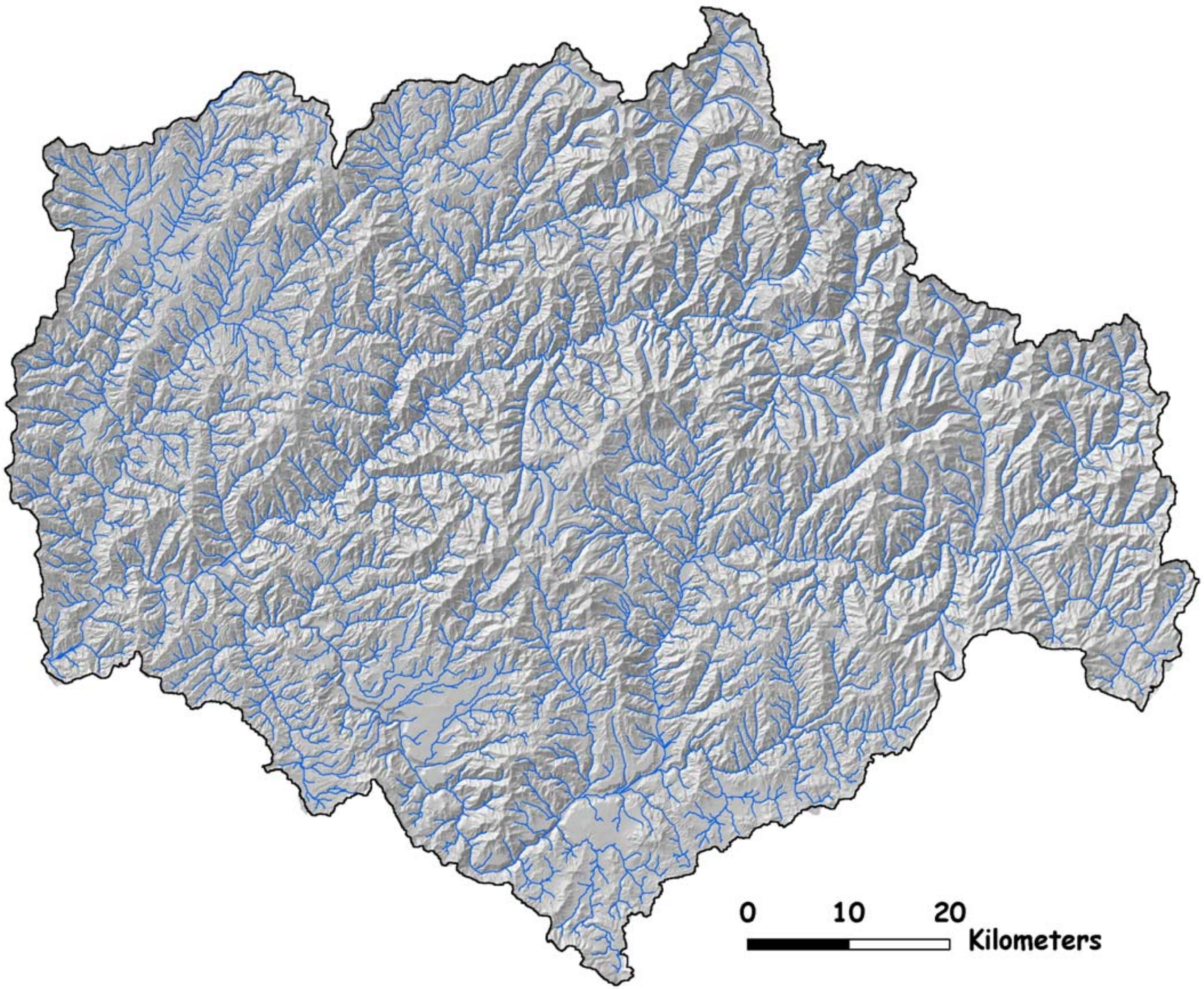
Estimate stream temperature at the drainage basin scale…..



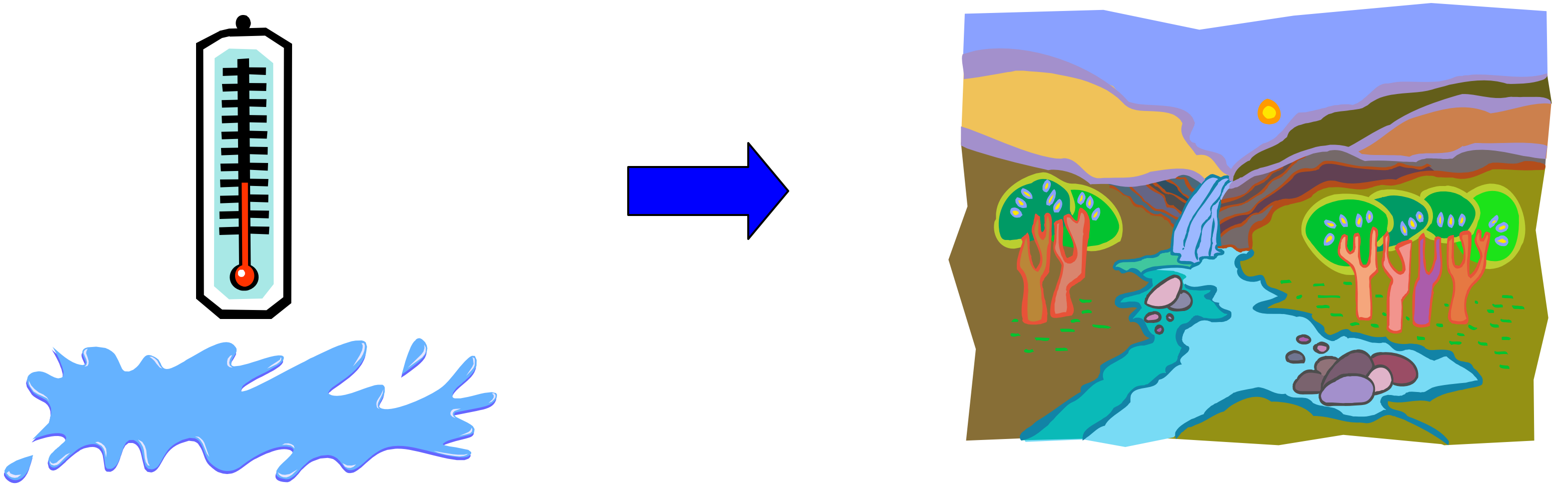
Approximate scale



….for all stream reaches in the basin



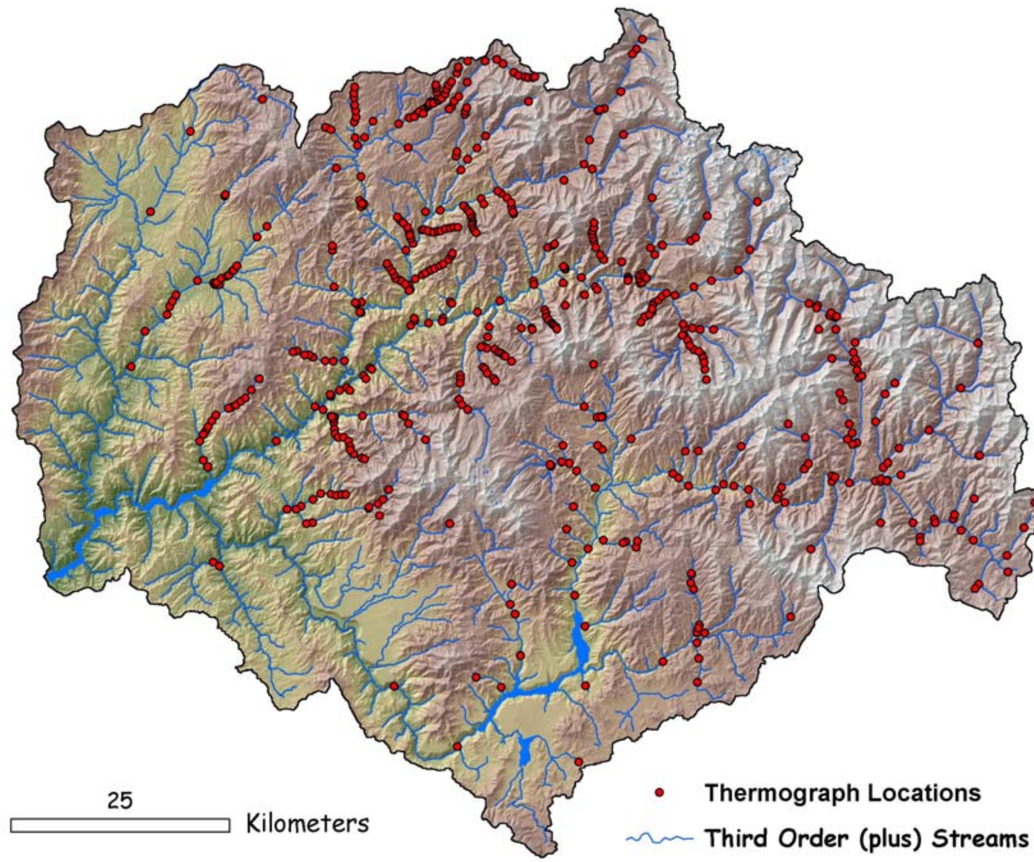
Goal: Relate stream temperature to physical landscape variables



Stream Temperature
Thermographs and Locations

Thermographs

780 observations
518 unique locations
14 year period
~ 40 per year



Determine the Physical Variables that Matter

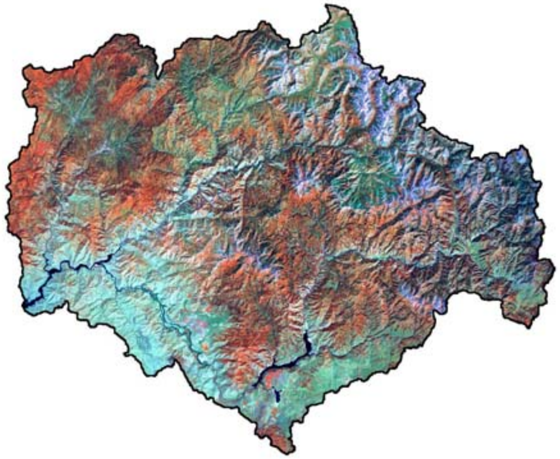
We looked at:

- Basin elevation
- Radiation (shade)
- Air temperature
- Stream flow
- Contributing area (stream size)
- Glacial valley
- Stream gradient
- Valley bottom
- Drainage density
- Lakes

Physical Variables

Elevation

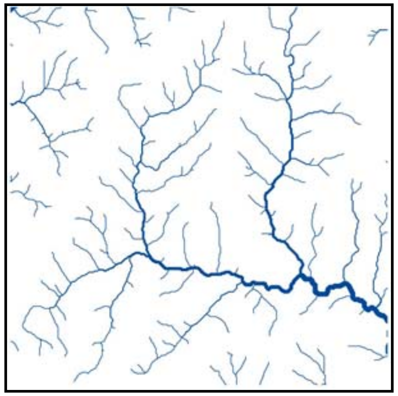
Air temperature



Solar radiation (shade)

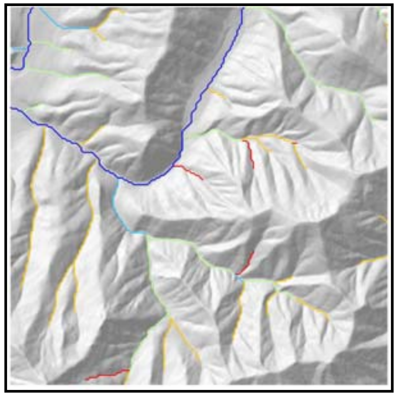
Stream flow

Physical Variables Continued



Stream size

Glaciated valley



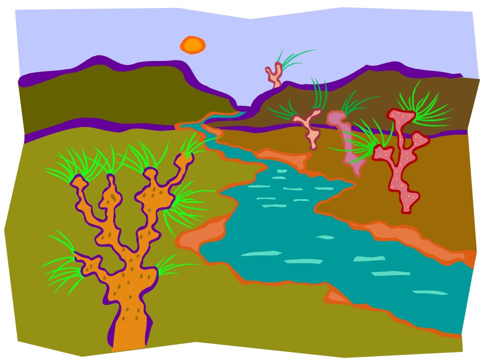
Stream gradient

Flat valley

Detour - Radiation

Estimating Radiation (Shade)

Objective: Estimate incident solar radiation at the stream surface, for the entire basin



The amount of radiation hitting the stream surface is mostly dependent on riparian vegetation

Thematic Mapper satellite imagery can be used to map riparian vegetation and thus, radiation

Estimating Radiation (Shade)

We need to know how much solar radiation gets through each vegetation type

Trees

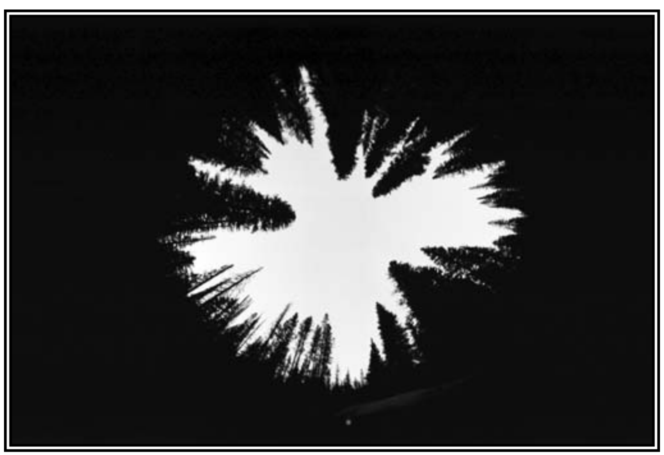
Shrubs

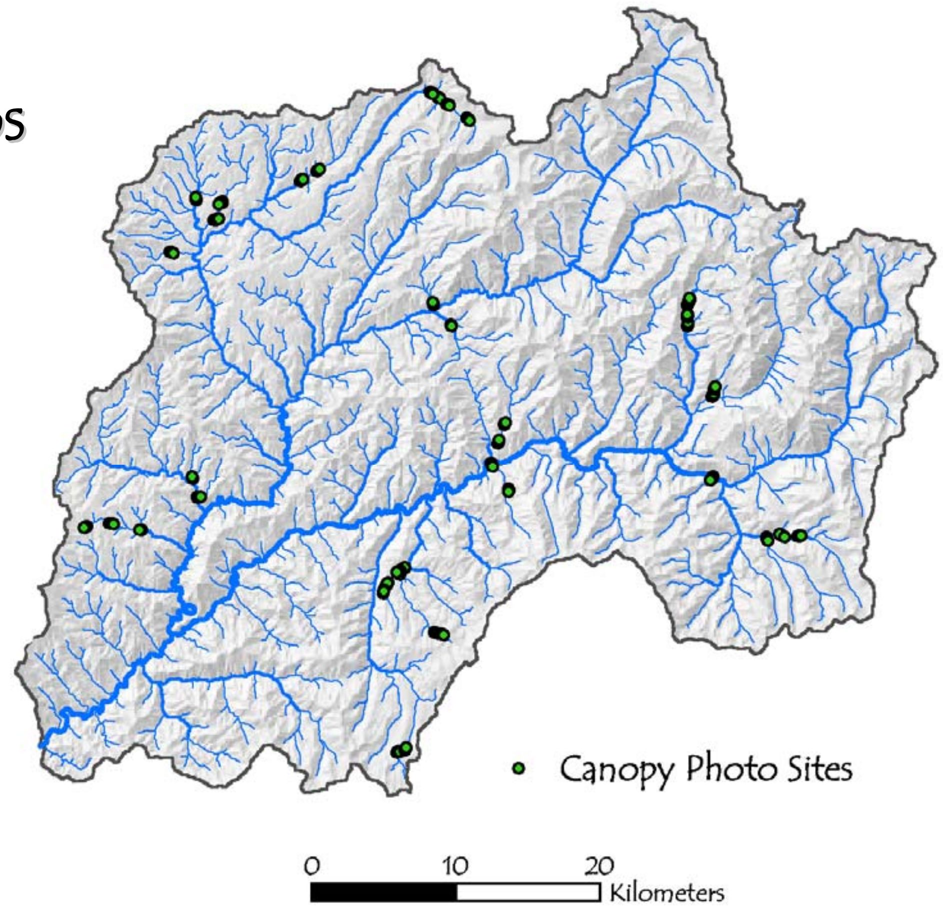
Open/grass

Estimate Radiation for Each Vegetation Type

Canopy Photography

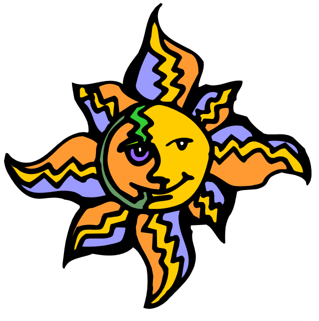
- Collected 181 canopy photos
- Differential GPS





Hemispherical Canopy Photography

- Sites distributed among different vegetation types and stream sizes
- Processed photos using Hemiview software
- Total June radiation, direct and diffuse
- Radiation values range from 118 – 1038 MJ/m^{2}yr
- Collected horizontal photos

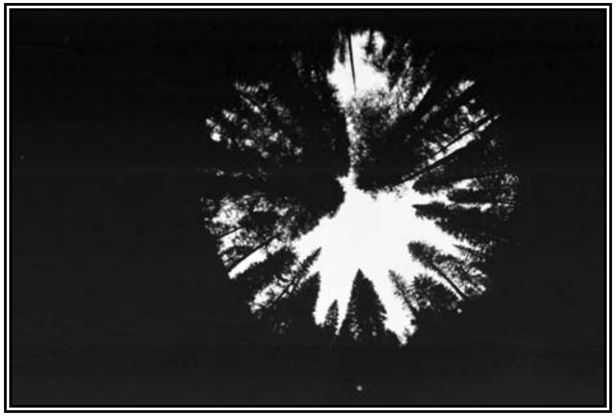


Canopy Photography and Horizontals

Radiation
(MJ/m²yr)

1038

118



Cover Classes

Open

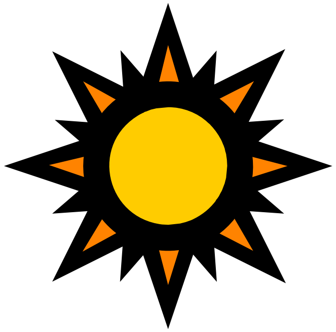
Shrub

Conifer

Radiation

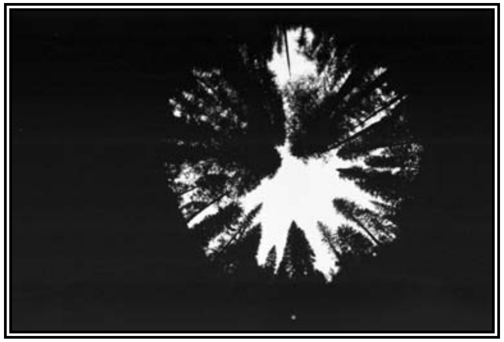
Mean Radiation Per Cover Class

Cover Class	Radiation (MJ/m^2yr)
Open/Grass	786
Broadleaf Shrub	687
Conifer	476



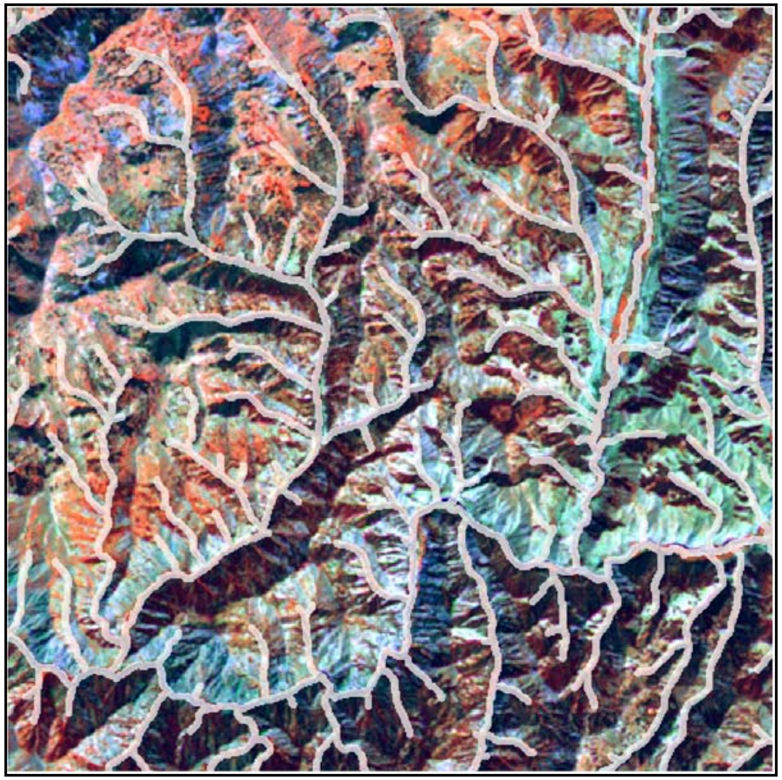
Open

Shrub

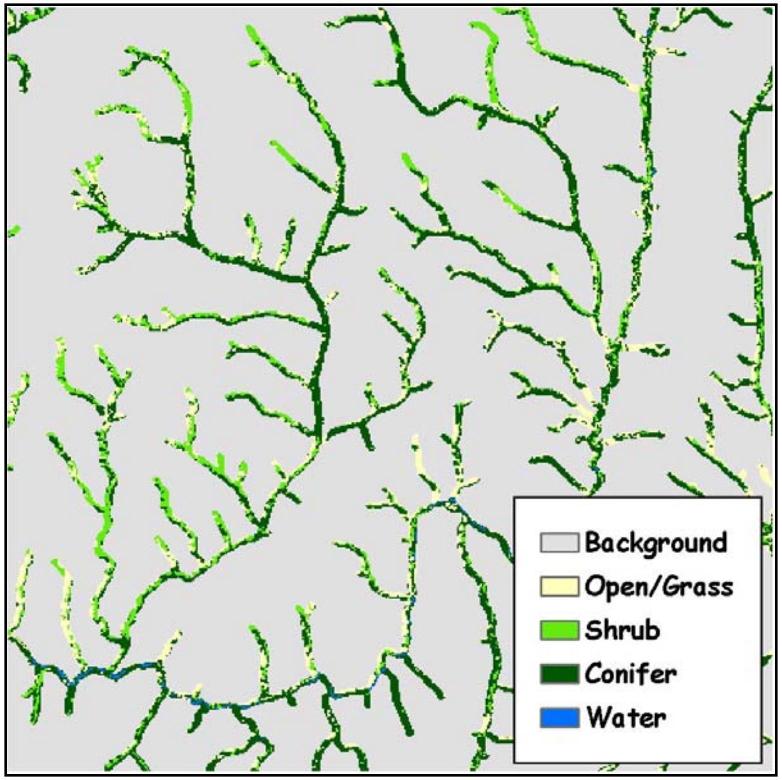


Conifer

Imagery to Vegetation

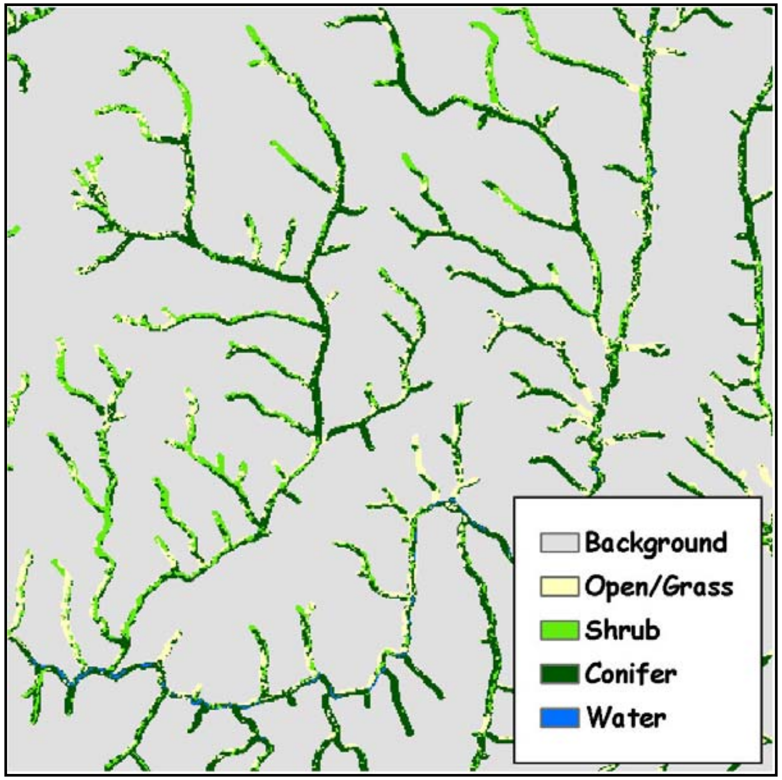


Imagery

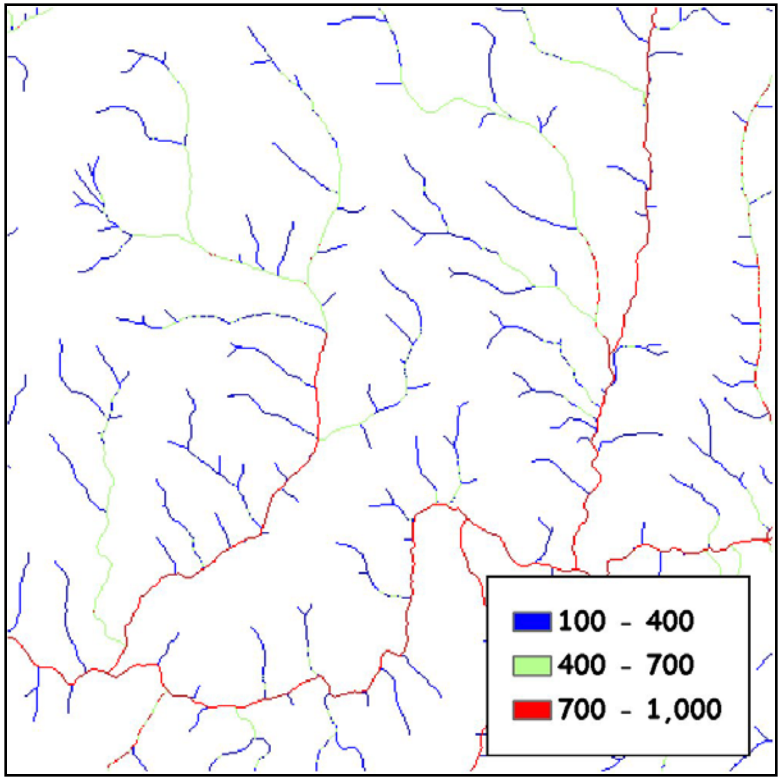


Vegetation

Vegetation to Radiation



Vegetation

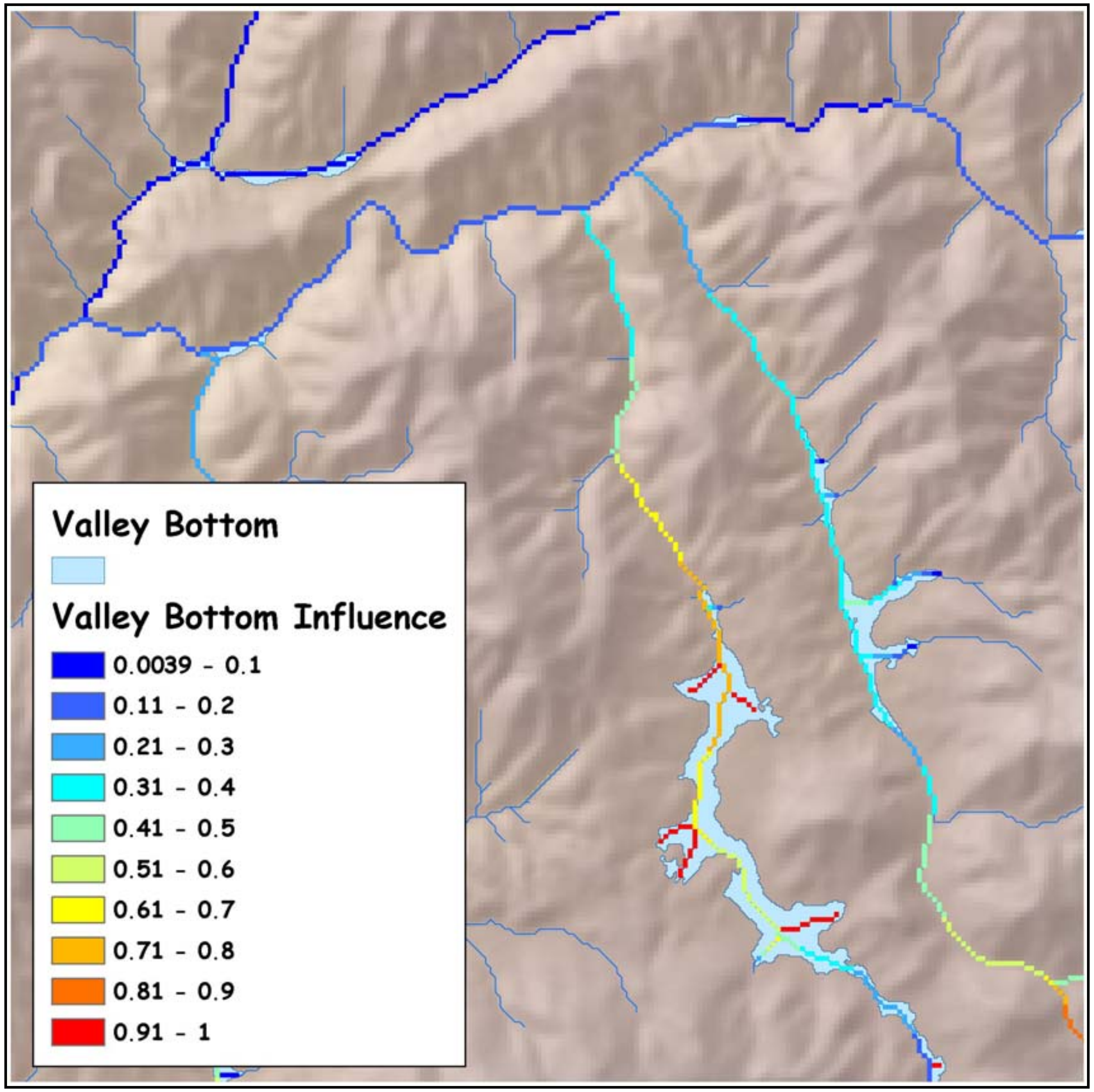


Radiation*

*Radiation adjusted for stream width

End of Detour

Accumulate Physical Variables



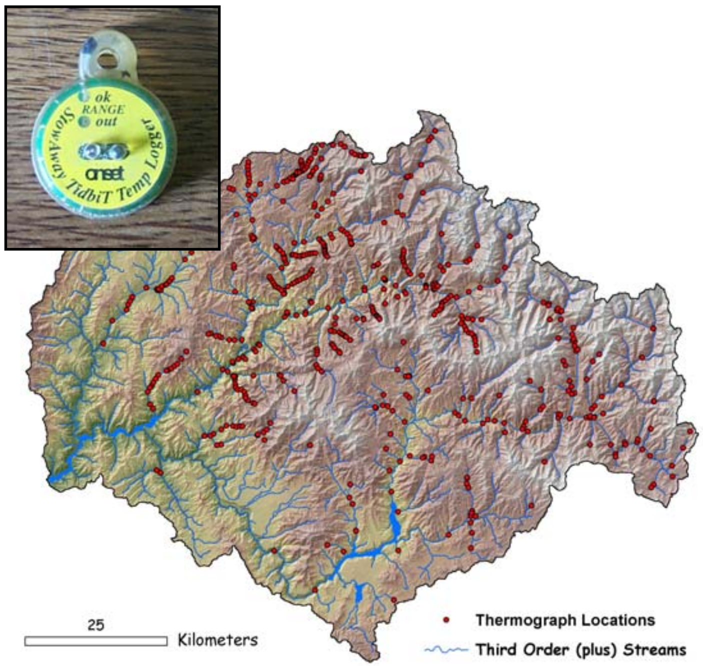
Each variable is accumulated along the stream channel

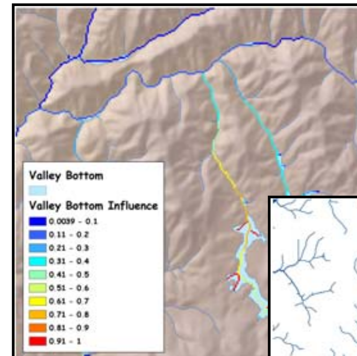
A distance decay function is used

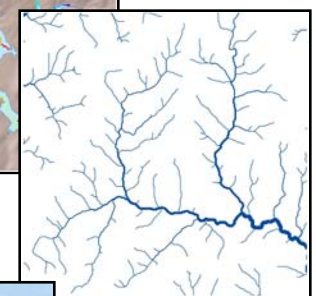
Decay tested between 1 km – 16 km

Average upstream influence is computed for each variable

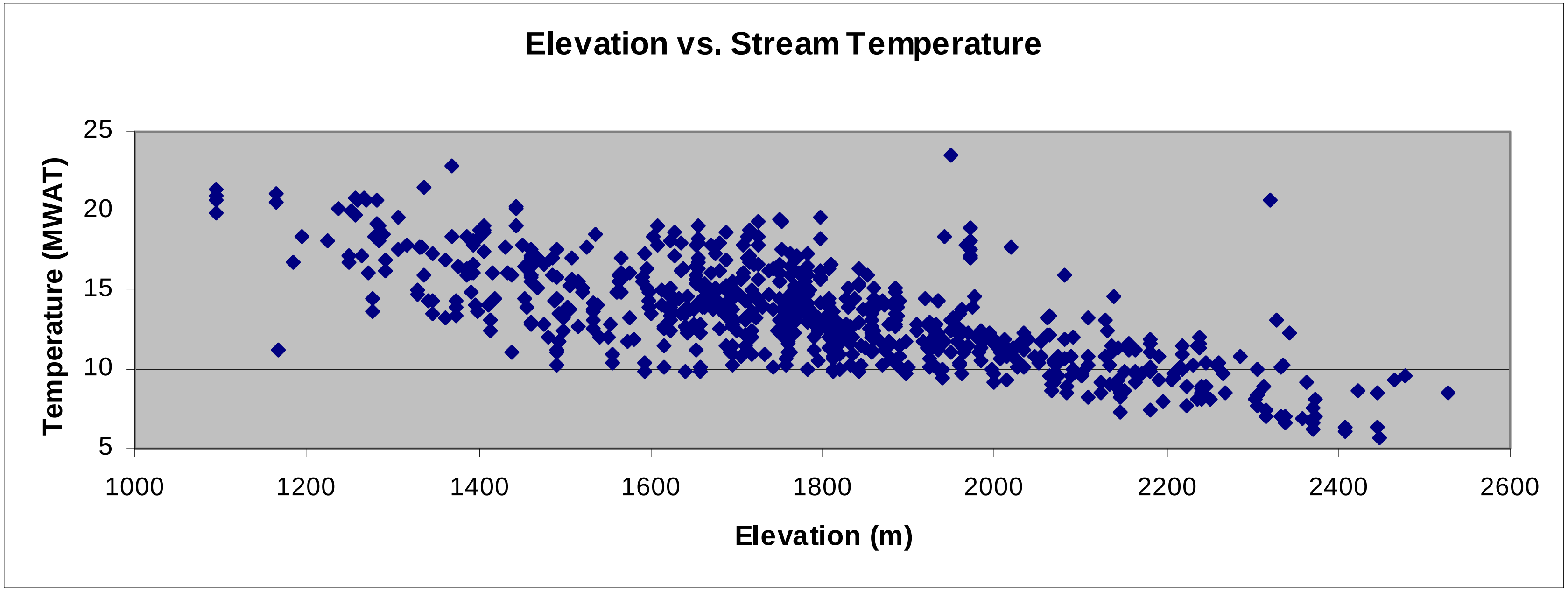
Finally – Correlate Temperature Data With Physical Variables





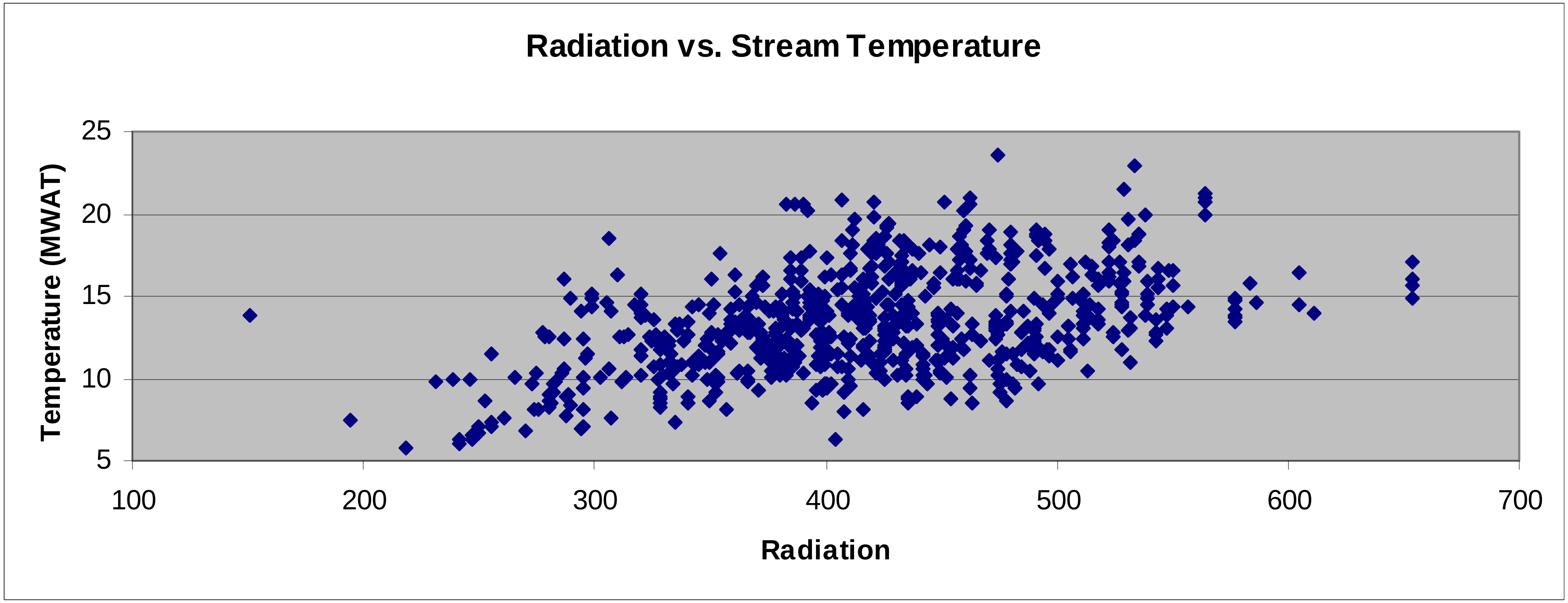


Elevation



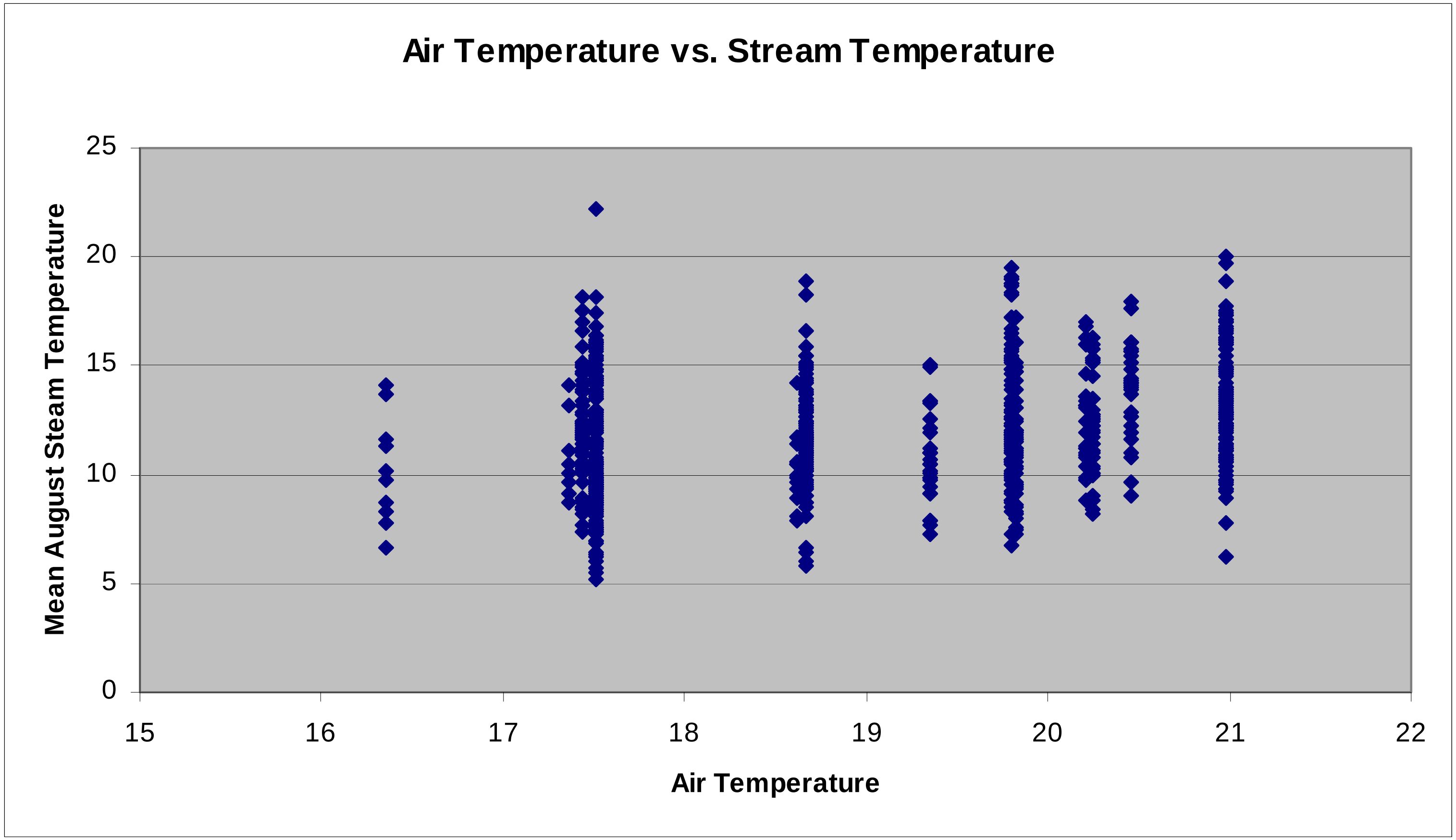
$r = -0.71$

Radiation



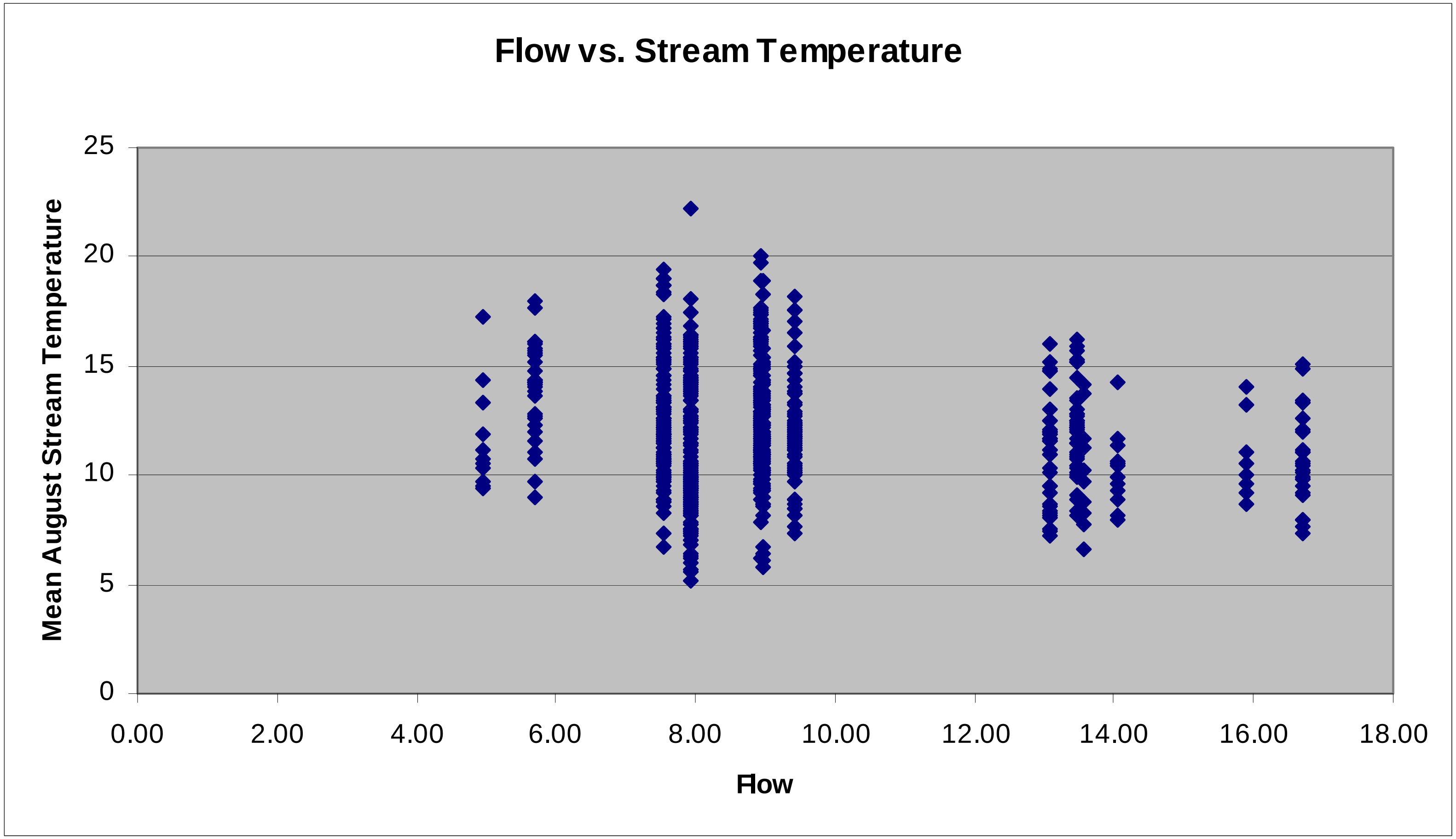
$r = 0.47$

Air Temperature



r = 0.23

Flow



Flow vs. Stream Temperature
Mean August Stream Temperature
25
20
15
10
5
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
Flow

r = –0.18

Regression Results

Response variable: Highest average 7-day stream temperature

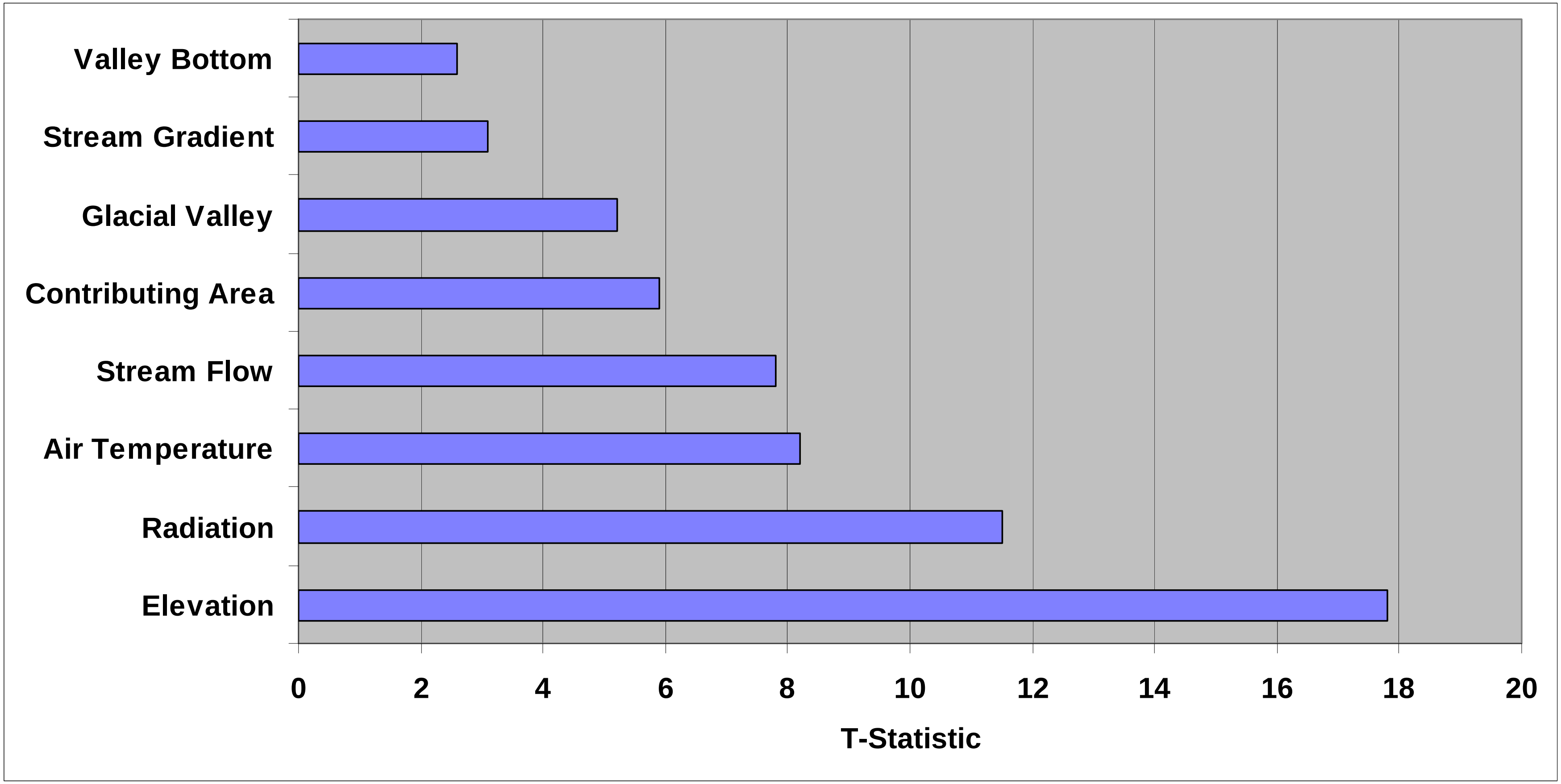
Multiple regression, R-squared: 0.85

Meaningful predictors:

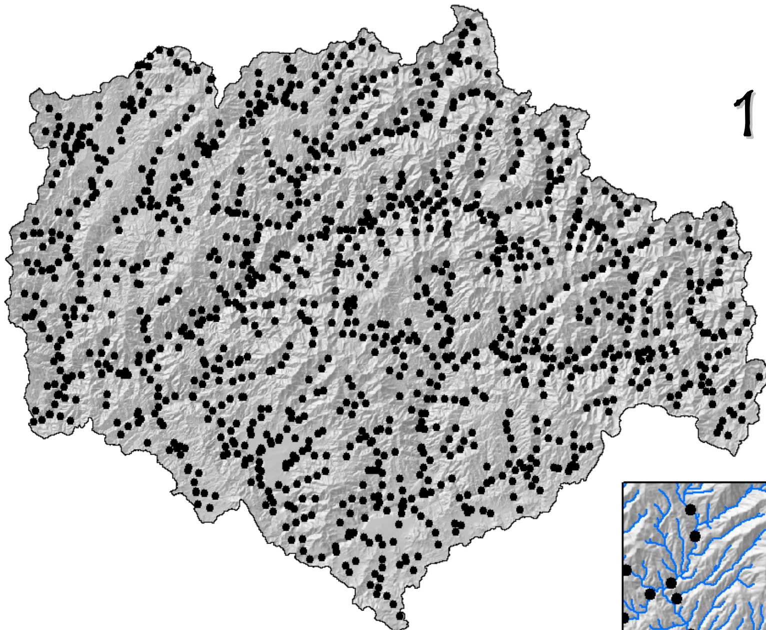
1) Basin elevation
2) Radiation (shade)
3) Air temperature
4) Stream flow
5) Contributing area (stream size)
6) Glacial valley
7) Stream gradient
8) Valley bottom

Drainage density and lakes (not significant)

Relative Importance of Each Significant Variable

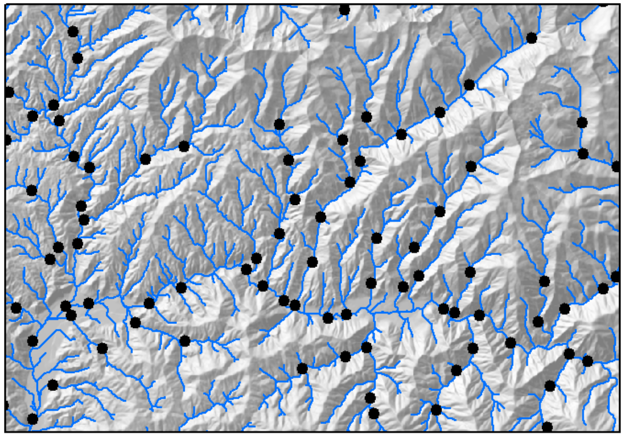


Temperature Prediction Points



1 km spacing in fish bearing streams

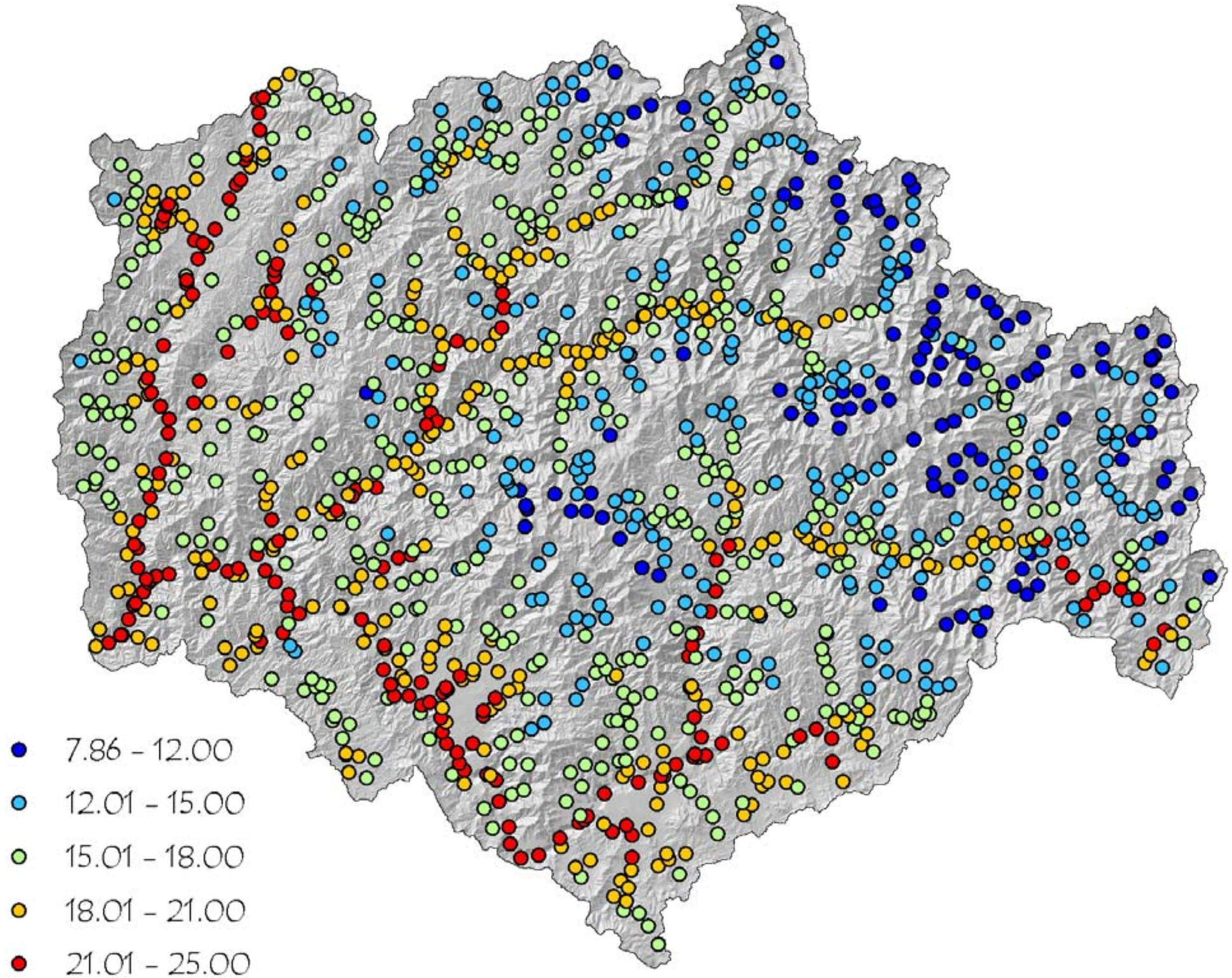
• Prediction Points



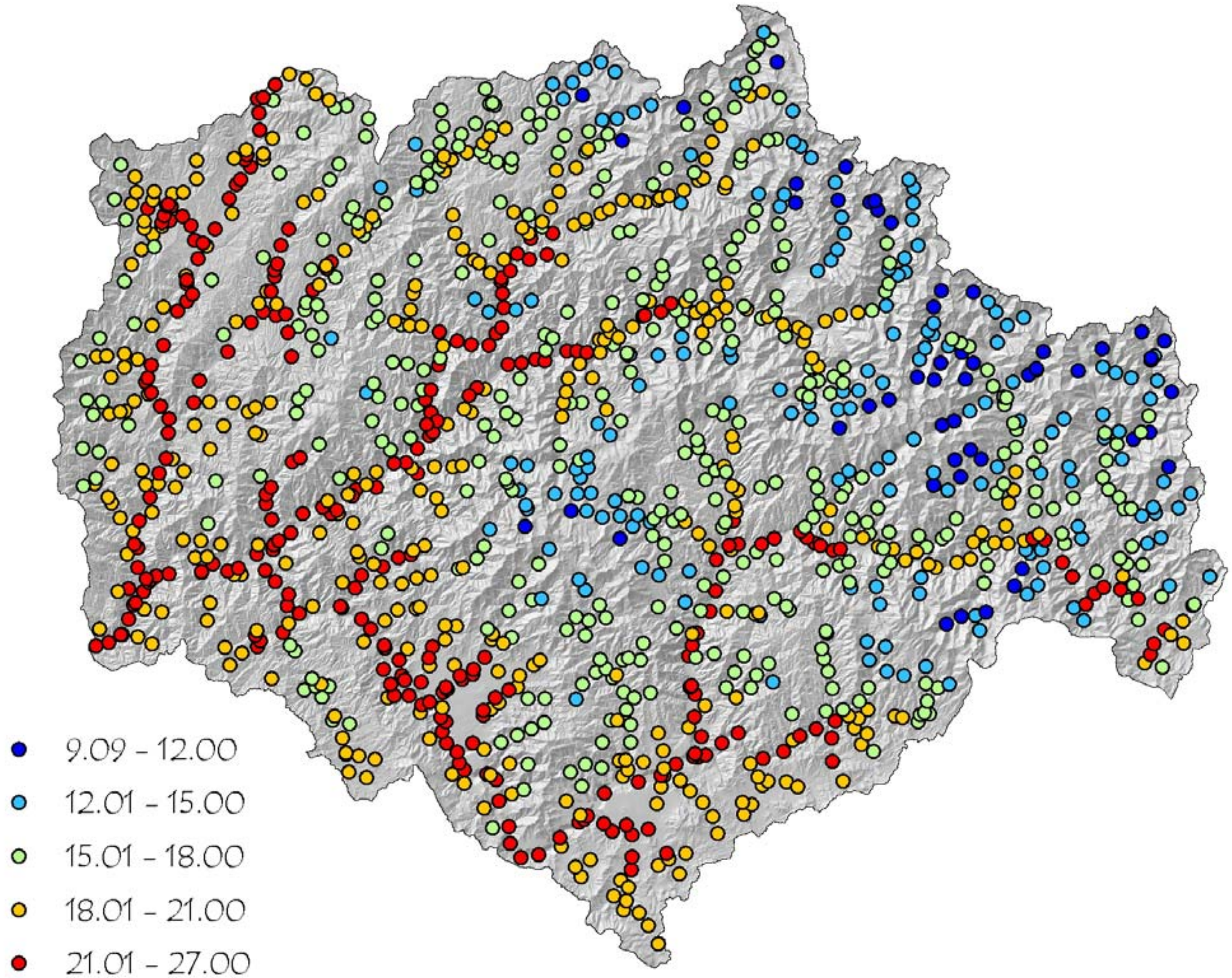
Make predictions using FLoWS software

http://www.nrel.colostate.edu/projects/starmap/flows_index.htm

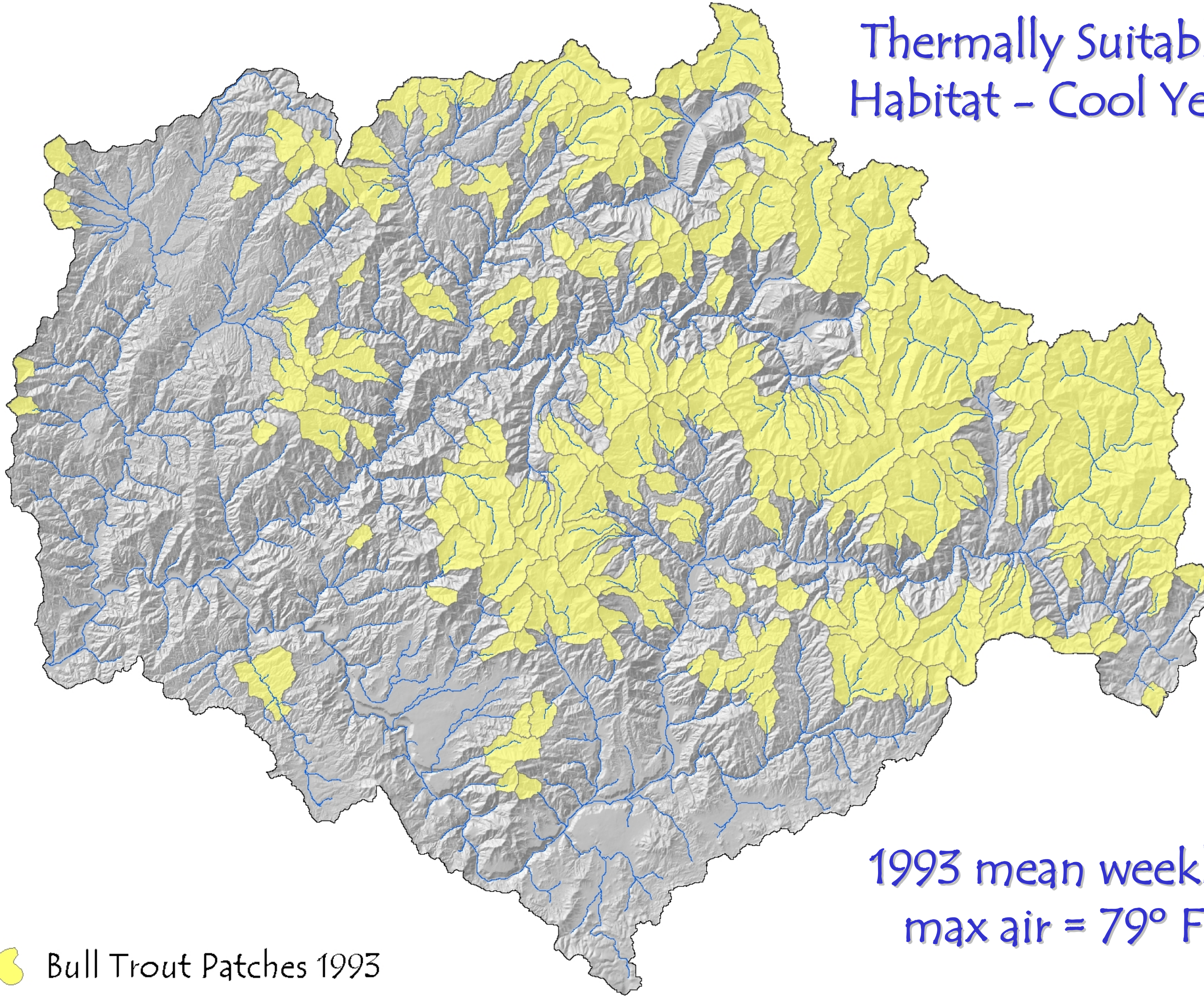
Mean Weekly Maximum Temperature °C - 1993



Mean Weekly Maximum Temperature °C - 2006



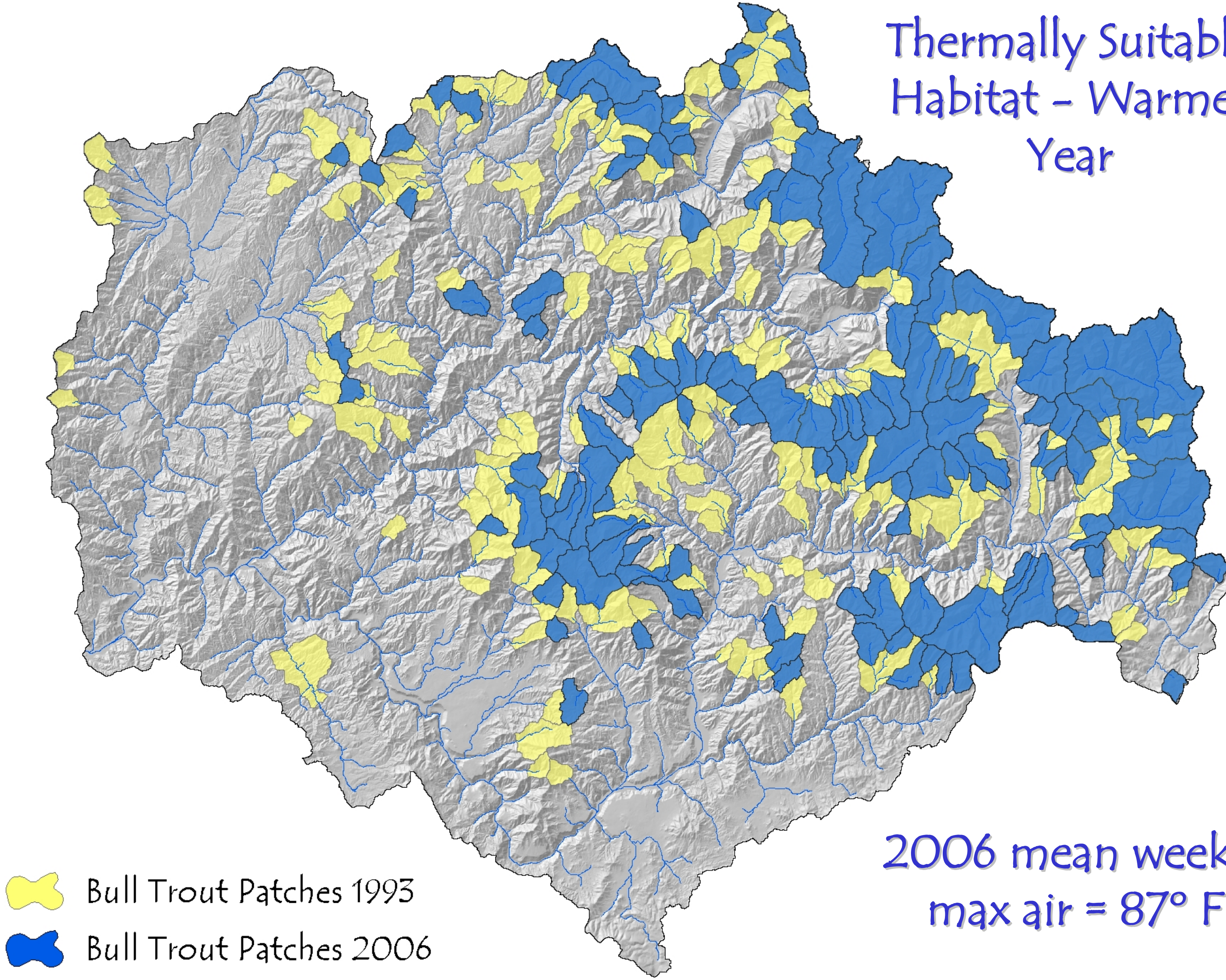
Thermally Suitable Habitat - Cool Year



1993 mean weekly max air = 79° F

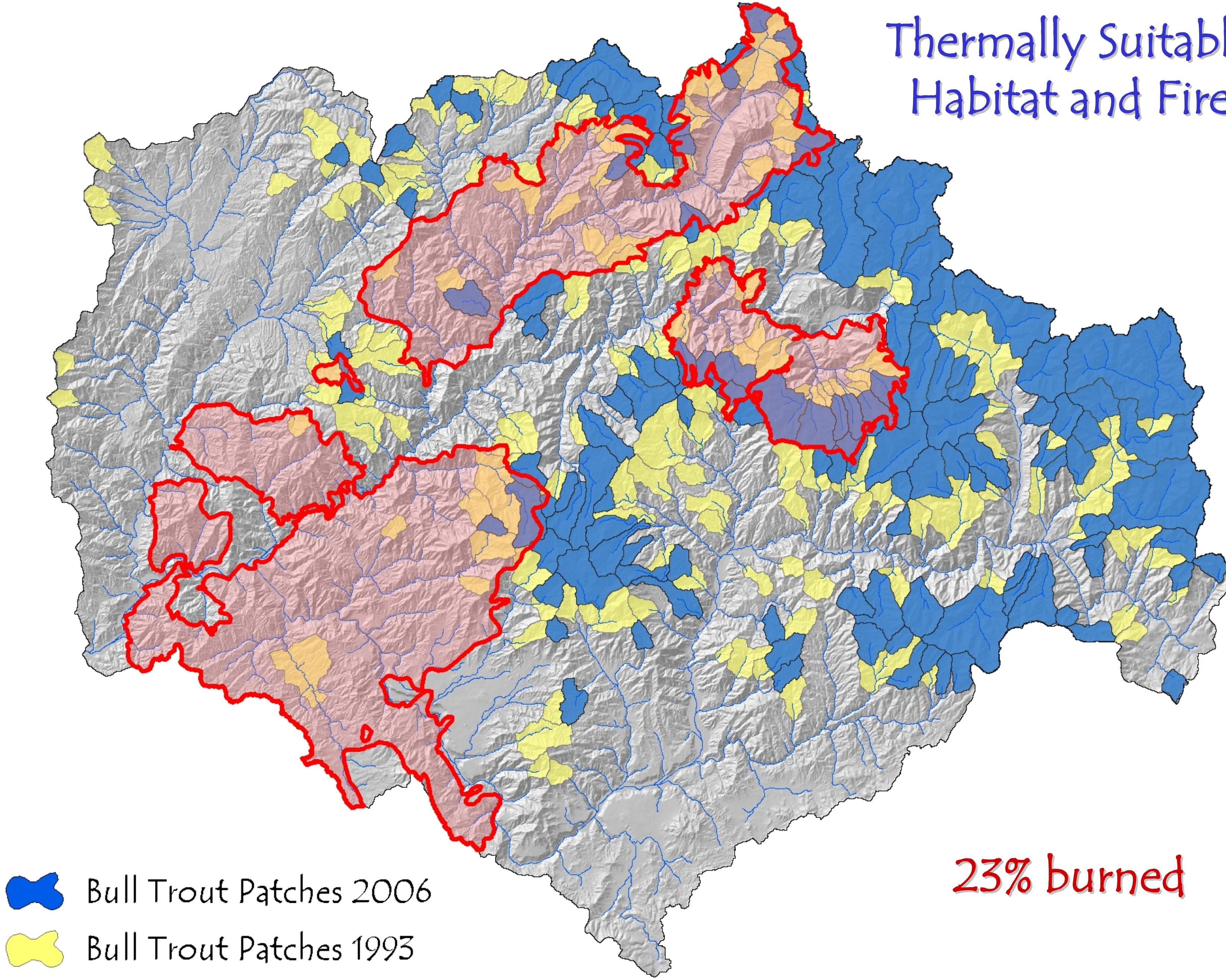
Bull Trout Patches 1993

Thermally Suitable Habitat – Warmer Year

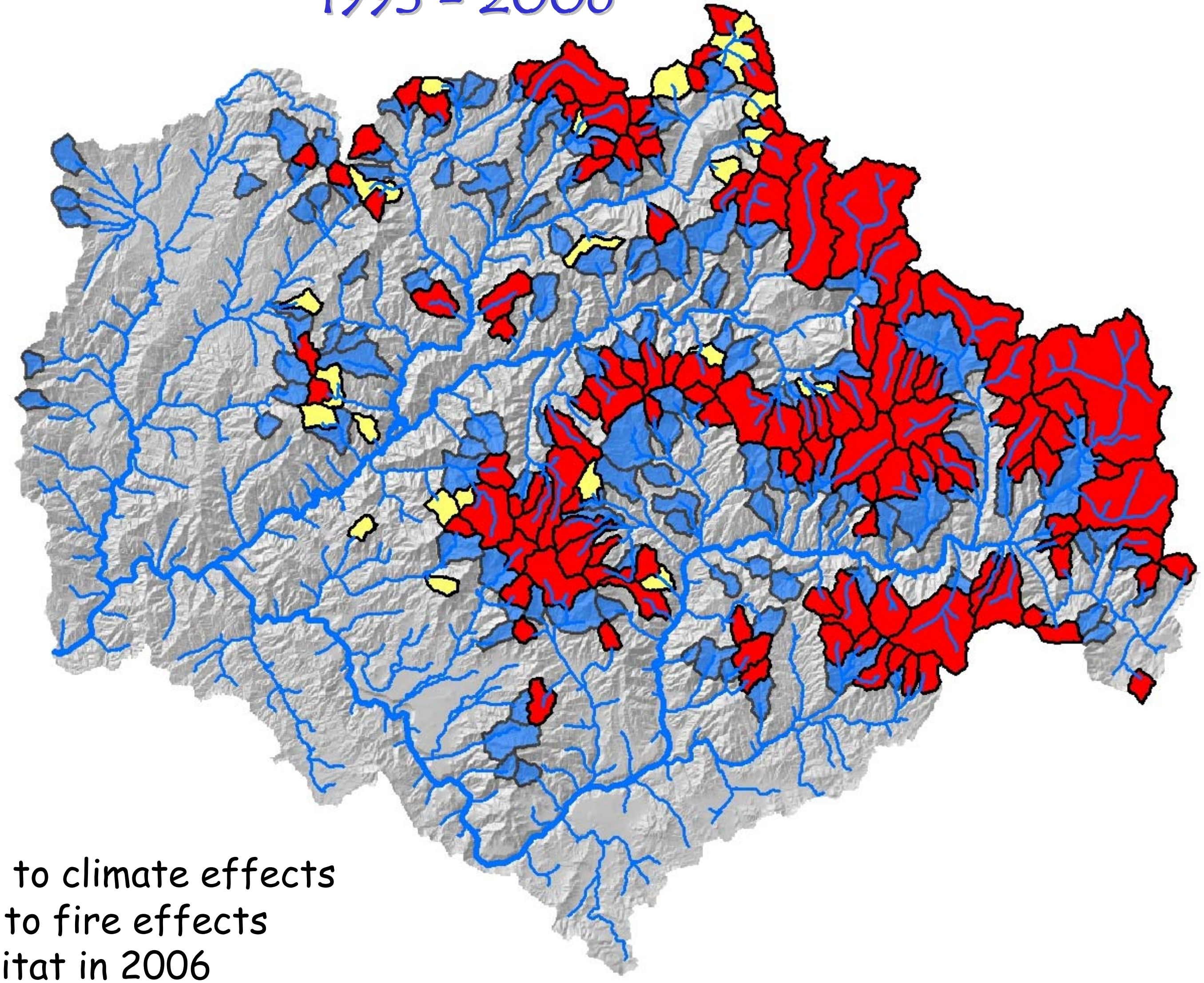


2006 mean weekly max air = 87° F

Thermally Suitable Habitat and Fire



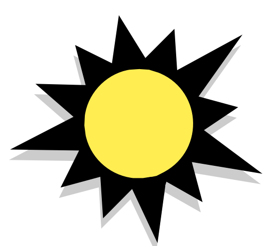
Thermally Suitable Habitat - Fire vs. Climate Affects
1993 - 2006



= Habitat lost to climate effects
= Habitat lost to fire effects
= Suitable habitat in 2006

Summary

- GIS and remote sensing data (along with air temperature and flow) can be used to explain about 85% of the variance in stream temperature
- TM satellite imagery provides a reasonable estimate of radiation for stream networks
- Stream temperature can be mapped at the drainage basin scale
- Thermally suitable habitat can be estimated from these data



Acknowledgements

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