# Climate-Aquatics Blog Post #7: Accurate downscaling of climate change effects on river network temperatures through application of new spatial statistical stream models to inter-agency temperature databases

## You may already have all the data necessary to accurately predict thermal responses to climate change for rivers and streams in your area.

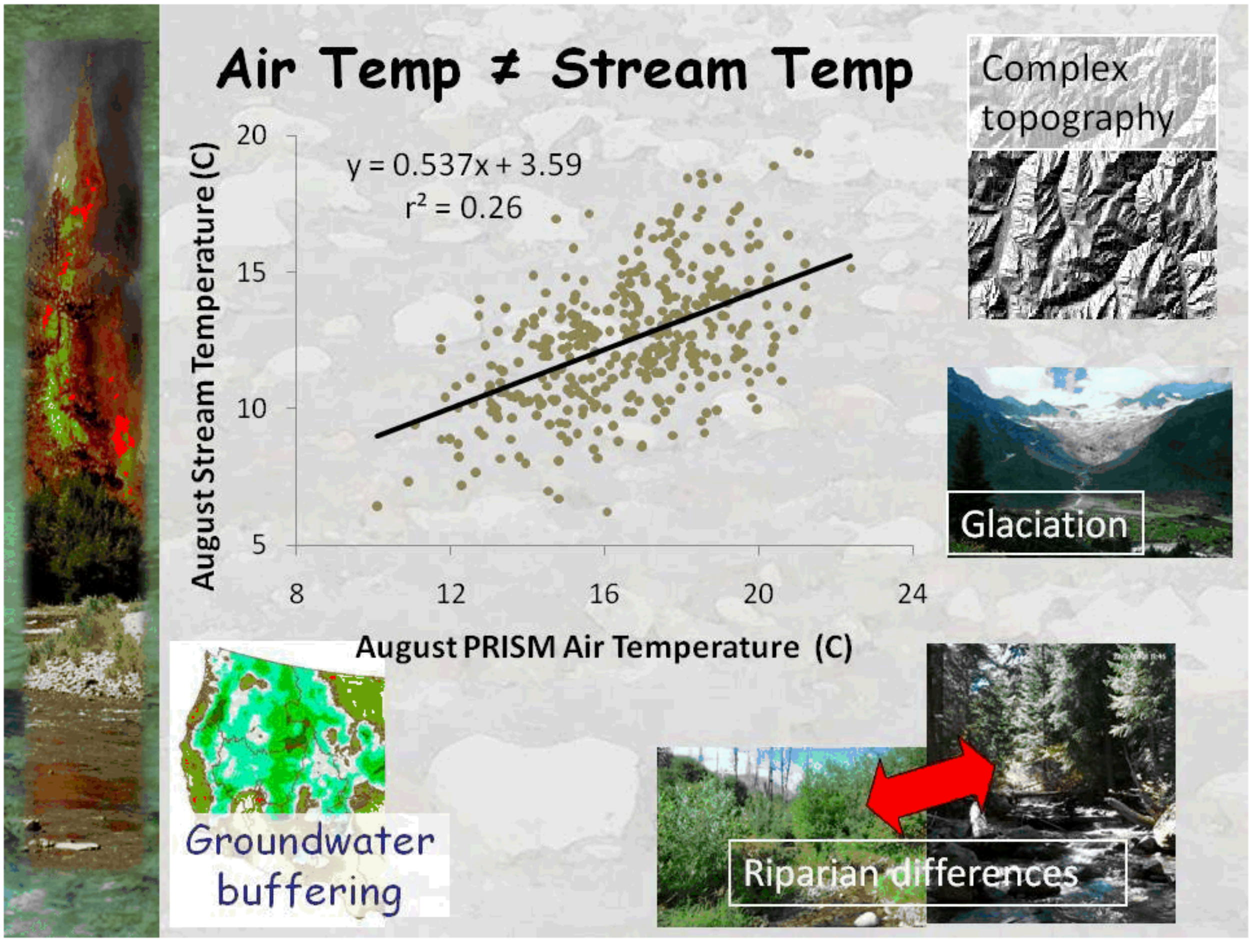
Increasing temperatures associated with climate change are cause for concern to managers of aquatic ecosystems given that most aquatic organisms are ectothermic and strongly regulated by thermal conditions. Despite relatively weak correlations between air temperatures and stream temperatures in complex terrains, however, most broad-scale assessments of climate effects on stream organisms rely on air temperatures. Historically this has occurred because of a general lack of stream temperature data and difficulties associated with accurately modeling stream temperatures across broad domains. Development of inexpensive digital temperature sensors in the 1990s dramatically increased the amount of stream temperature monitoring by natural resource agencies and 1000’s – 10,000’s of observations now exist in many regions. By centralizing these data in integrated, interagency databases and applying new spatial statistical techniques for stream networks, it is possible to develop very accurate stream temperature models across broad areas to predict historical and future climate change effects. An example application to a river network in central Idaho is referenced below and a short 1-page briefing paper describing the research is attached. In the Idaho application and several others associated with stream temperature databases of comparable size, the models have proven to be consistently accurate and yield unbiased results, with $r^2 \geq 90\%$ and average prediction errors < 1°C. Once an accurate stream temperature model has been developed, the subsequent steps in the process are straightforward: 1) the model is used to interpolate a continuous temperature map throughout the river network of interest, 2) species-specific thermal criteria are applied to highlight suitable habitats, 3) the distributions and temporal trends in these thermal habitats are summarized for the climate scenarios of interest.

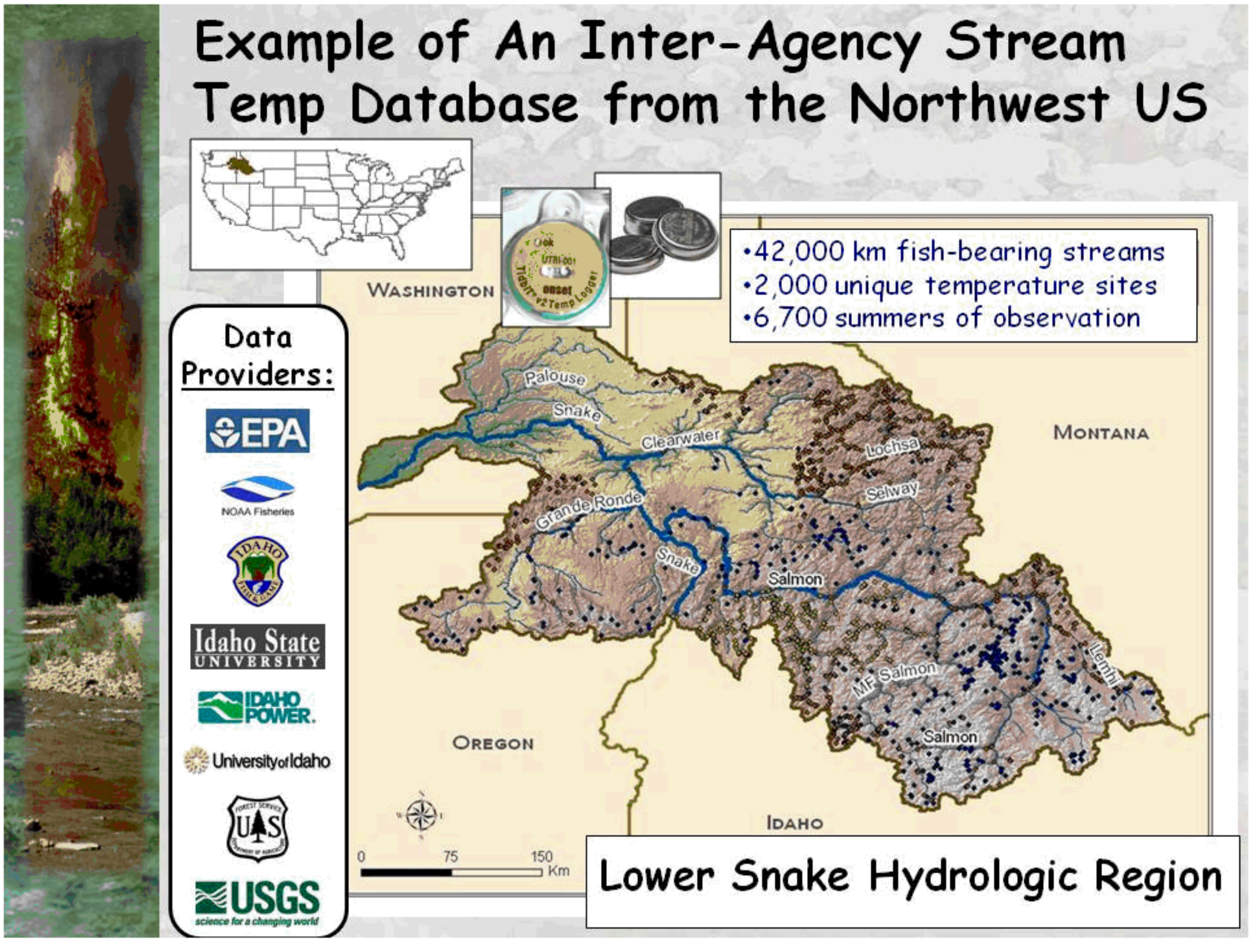
The spatial statistical stream models applied to the temperature databases are analogous to the geostatistical models long employed in terrestrial applications but incorporate covariance structures that accommodate the unique forms of spatial dependence on stream networks (e.g., flow direction, network topology, stream size weighting). The spatial models are particularly well suited for use with *ad hoc* databases compiled from numerous agency sources in which the sites are often non-randomly distributed and clustered because they account for spatial correlation among sites. Moreover, the models actually use information from those spatial correlations to provide more accurate predictions near sites with observations. In practical terms, a stream temperature observation 10 km downstream from a site provides a lot of useful information about temperatures at the site and these models allow us to harness that information. This ability to leverage off of neighboring sites provides a strong incentive to develop comprehensive, interagency databases because the net result is greater overall accuracy if everyone’s data is included. Models built from integrated databases also have a greater chance of getting 'buy-in' from diverse agencies and user-groups because multiple partners are invested in the process and have collected some of the data. *At a time of declining budgets and the perpetual need to do more with less, therefore, simple sharing of data, paired with new analytical* *techniques, could take us a long way towards having fundamentally better information with which to manage aquatic resources.*

As is probably obvious by now, the utility of the spatial stream models is not solely limited to applications involving stream temperature but potentially includes any commonly measured stream attribute (e.g., fish abundance, genetic structure, habitat characteristics, water chemistry) and we'll explore some of those additional applications in future blog posts. The downsides to the spatial models at present are that they require larger amounts of data (e.g., > 100 observations), custom code developed for the R statistical package, and considerable GIS expertise to develop the spatial data structures needed to fit the models. Work is actively ongoing to develop software packages that will make the spatial models more user-friendly and a couple solutions to these limitations will be provided in the next year.

Best regards,
Dan

Isaak, D.J., C.H. Luce, B.E. Rieman, D.E. Nagel, E.E. Peterson, D.L. Horan, S. Parkes, and G.L. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350-1371. Archived online at Treesearch http://www.treesearch.fs.fed.us/pubs/35471



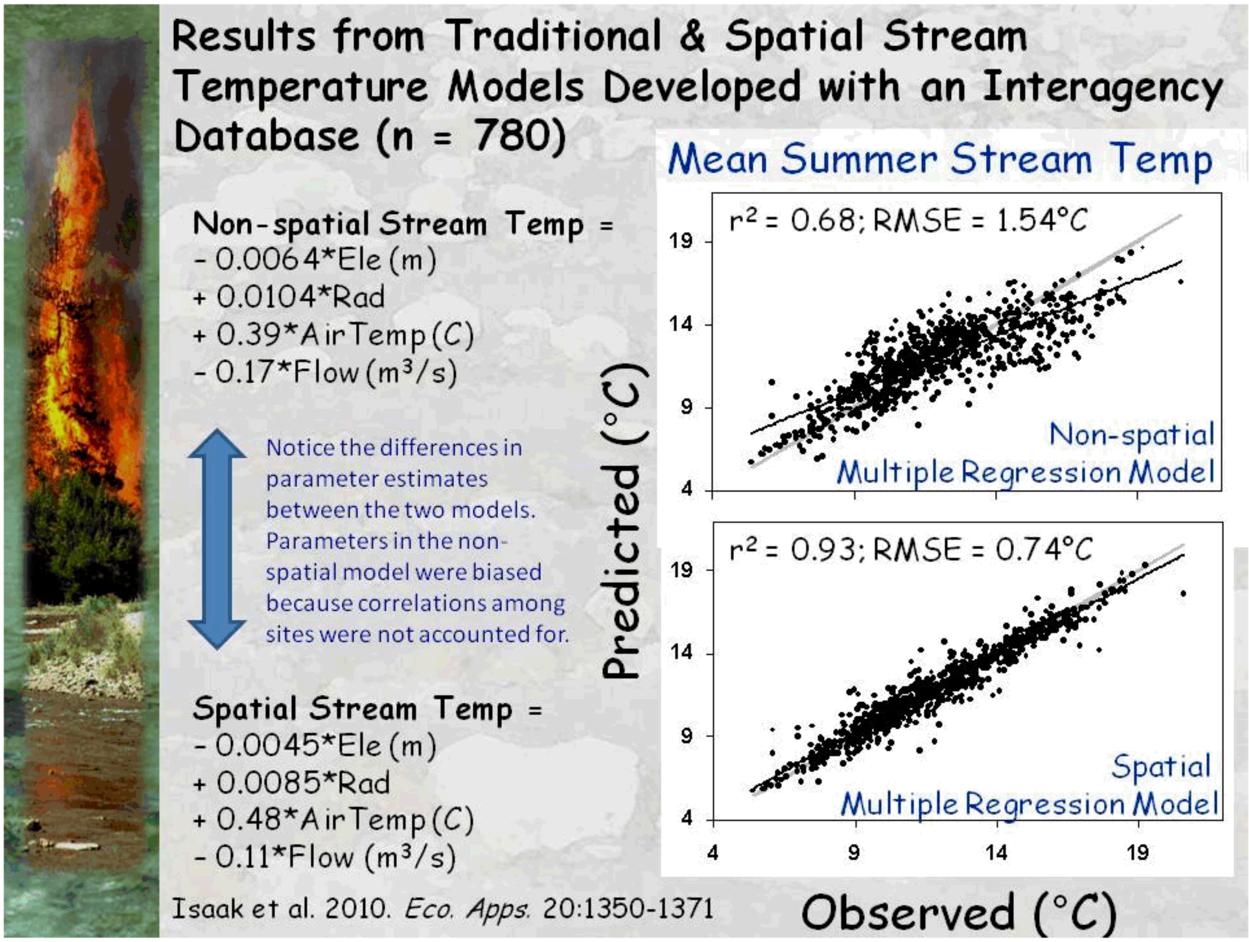


# Example of An Inter-Agency Stream Temp Database from the Northwest US

- 42,000 km fish-bearing streams
- 2,000 unique temperature sites
- 6,700 summers of observation

**Data Providers:**

Lower Snake Hydrologic Region



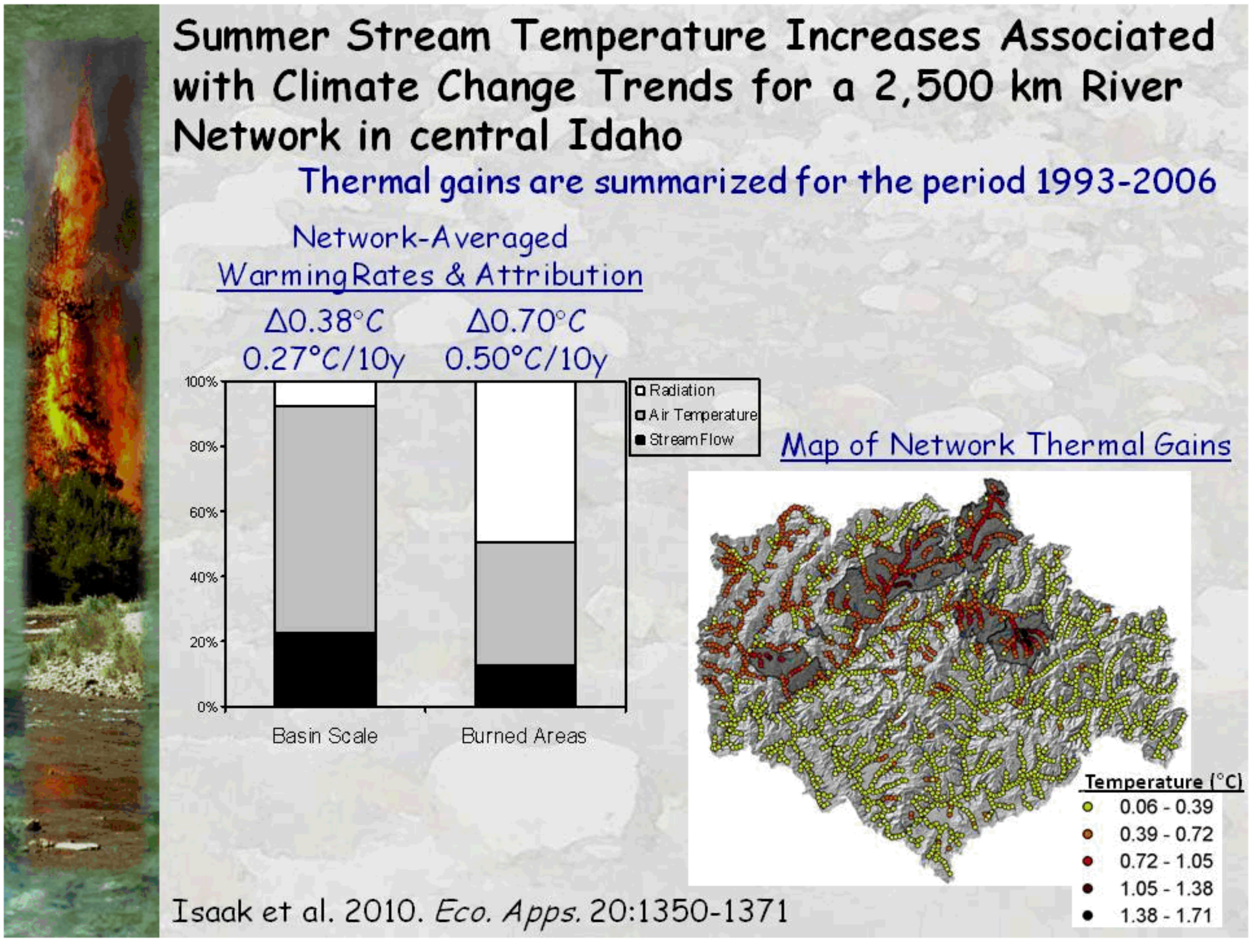
# Results from Traditional & Spatial Stream Temperature Models Developed with an Interagency Database (n = 780)

**Non-spatial Stream Temp =**
- 0.0064*Ele (m)
+ 0.0104*Rad
+ 0.39*AirTemp (C)
- 0.17*Flow ($m^3$/s)

Notice the differences in parameter estimates between the two models. Parameters in the non-spatial model were biased because correlations among sites were not accounted for.

**Spatial Stream Temp =**
- 0.0045*Ele (m)
+ 0.0085*Rad
+ 0.48*AirTemp (C)
- 0.11*Flow ($m^3$/s)

Isaak et al. 2010. *Eco. Apps.* 20:1350-1371



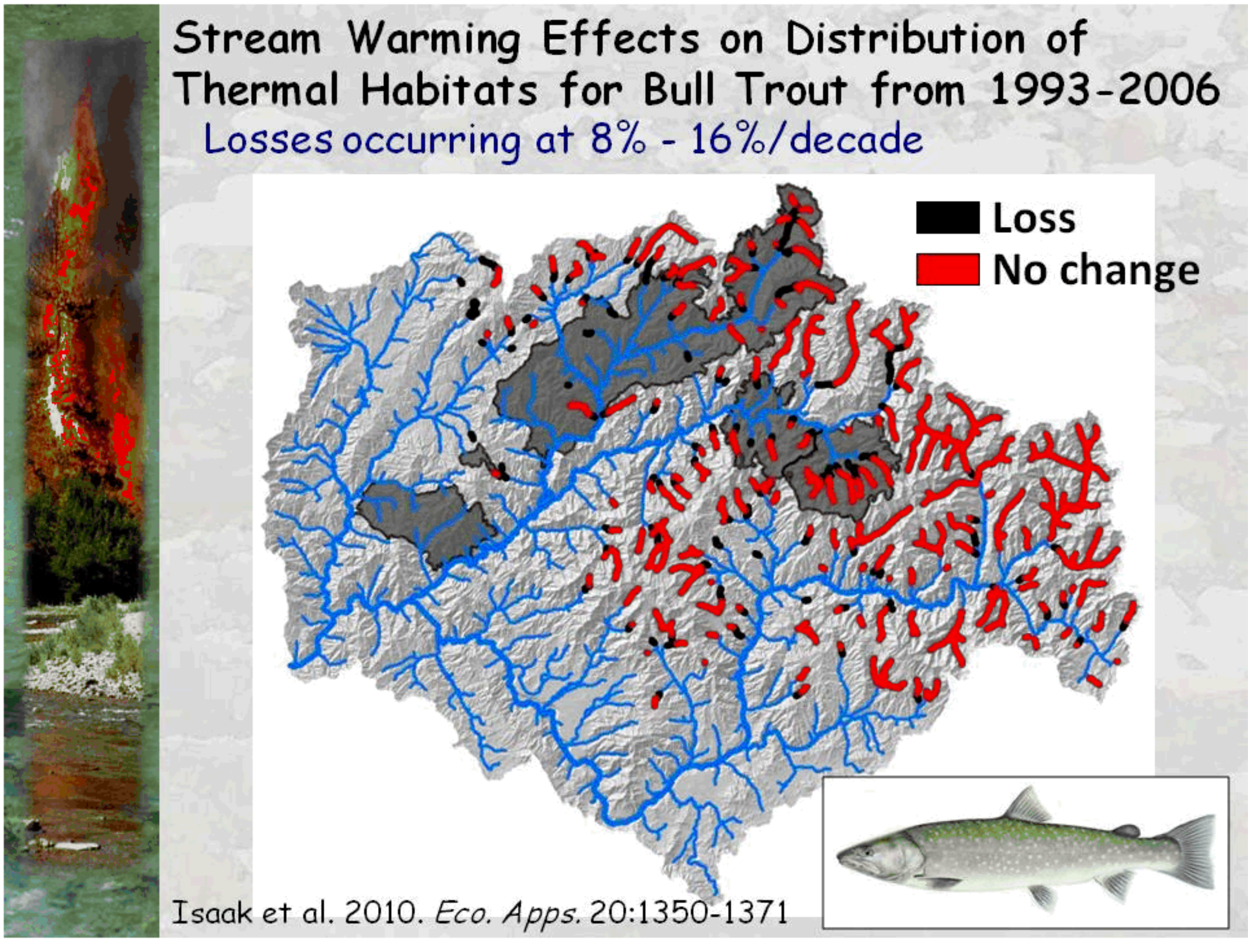
# Summer Stream Temperature Increases Associated with Climate Change Trends for a 2,500 km River Network in central Idaho

Thermal gains are summarized for the period 1993-2006

Network-Averaged Warming Rates & Attribution

Map of Network Thermal Gains

Isaak et al. 2010. *Eco. Apps.* 20:1350-1371



# Stream Warming Effects on Distribution of Thermal Habitats for Bull Trout from 1993-2006

Losses occurring at 8% - 16%/decade

Isaak et al. 2010. *Eco. Apps.* 20:1350-1371