Air, Water and Aquatic Environments Science Program

Rocky Mountain Research Station

Stream Temperature Modeling

Research | Technology Transfer | Science Application

Key Findings:

- Stream temperatures are sensitive to management actions and natural disturbances and are likely to increase as the climate warms.
- Understanding spatial variation in stream temperatures and predicting future trends on USFS lands is necessary for proactive management of aquatic resources.
- Advances in GIS and remote sensing technologies make it possible to characterize landscape features that affect stream temperatures from digital maps.
- Modeling stream temperatures from landscape features using new spatial statistical models provides strong predictive ability.
- The temperature models can be used to predict suitable habitats for aquatic species, determine compliance with water quality standards, or optimize stream temperature sampling designs.

Challenge

Stream thermal regimes are important within regulatory contexts and strongly affect the function of aquatic ecosystems. Alteration of stream temperatures has traditionally been linked to management activities that alter stream flows and riparian shade or natural disturbances driven by fires and debris flows. Climate change will exacerbate many of these factors, but will also warm streams through air temperature increases. Warming rates will be spatially variable and contingent on geomorphic context, local environmental trends, and management responses. Understanding and accurately predicting stream temperature responses across USFS lands and tens of thousands of stream miles will be needed for prioritization of management actions.

Context

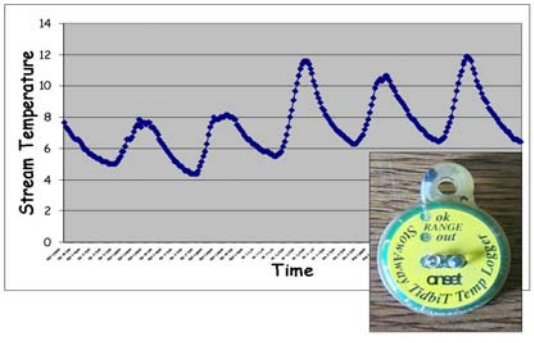
Numerous approaches have been developed for modeling stream temperatures, but broad application of these models to USFS lands has been constrained by data requirements, poor predictive ability, and inability to accommodate dynamic processes related to fires, air temperatures, and trends in stream flow. Recently, however, inexpensive digital temperature loggers have been developed and numerous natural resource agencies now routinely collect stream temperature data. Advancements in GIS and remote sensing technologies make it possible to characterize many features that affect stream temperatures from digital maps.

Actions

A large stream temperature database (~800 records) spanning years from 1993–2006 was compiled for the 2,500 km stream network within the 6,900 km^2 Boise River Basin in Idaho. Automated GIS routines were used to measure geomorphic features that affected stream temperature and Thematic Mapper satellite imagery was used to determine effects of fires on stream shade. Climatic determinants of stream temperatures were obtained from weather and flow stations in the basin. A new class of spatial statistical model that accounts for network topology (Ver Hoef et al. 2006) was used to predict stream temperatures from these features.

Results

The modeling approach accurately predicted (R^2 ~ 0.90) summer mean and maximum temperatures across the Boise River network. The temperature models are being used to map past and future trends in thermal habitat networks for native salmonid species, but could also be used to improve understanding of factors that affect stream temperature, determine compliance with water quality standards, or optimize temperature sampling strategies. More details are at: http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml.



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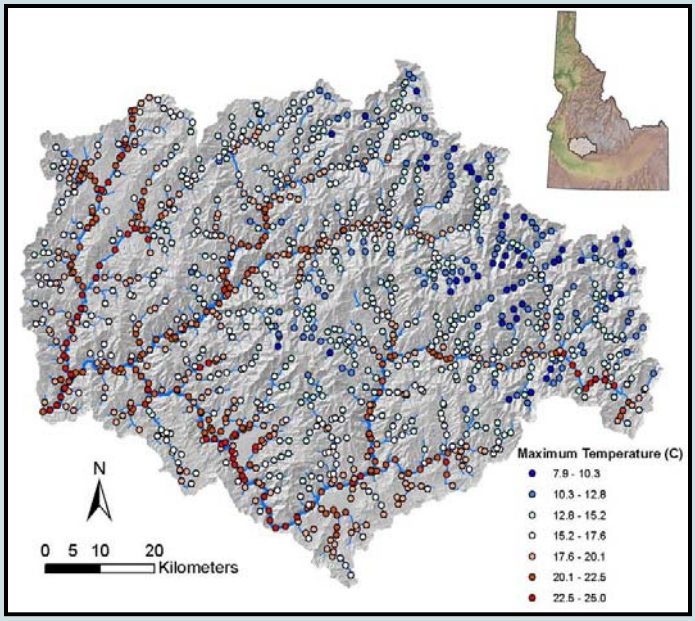
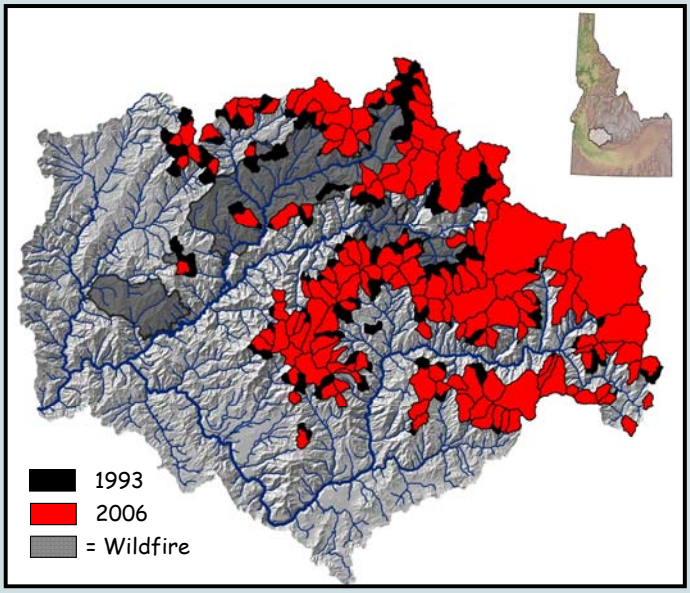
Stream temperature = geomorphology (valley form, elevation, glaciation, etc.) + climate (air temperature, stream flow) + solar radiation (fire effects, riparian vegetation)



Predicted maximum summer stream temperatures across the Boise River basin in central Idaho.

Observed changes in thermally suitable habitat for bull trout from 1993 - 2006 due to an increase in mean summer stream temperatures of 0.38°C (0.27°C/decade), driven primarily by long-term (30 – 50 year) trends in air temperature and declining stream flow (Isaak et al., in review). It is estimated that bull trout habitats in this basin are being lost at ~1%/year.



Publications and Presentations

Isaak, D., C. Luce, B. Rieman, D. Nagel, and E. Peterson. 2007. Effects of Climate and Fire on Thermal Habitats within Mountain Stream Networks: An Example with a Native Charr Species. American Geophysical Union annual meeting. San Francisco, CA, December 10–14. (www.fs.fed.us/psw/cirmount/meetings/agu/agu2007.shtml).

Isaak, D., C. Luce, B. Rieman, D. Nagel, and E. Peterson, D. Horan, S. Parkes, and G. Chandler. 2010. Effects of recent climate change and wildfires on stream temperature and thermal habitat for two salmonids in a mountain river network. Ecological Applications. 20(5): 1350-1371.

Ver Hoef, J.M., E. Peterson, and D. Theobald. 2006. Spatial statistical models that use flow and stream distance. Environmental and Ecological Statistics 13:449-464.

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