Climate-Aquatics Blog #25: NorWeST: A Massive Regional Stream Temperature Database

Lucky region "finds" $10,000,000 of useful data lying around

Hi Everyone,
As we saw with regards to NoRRTN last time, it's easy to design and deploy temperature monitoring networks inexpensively these days with the advent of modern sensor technology (blog #24). Just as importantly, however, we sometimes also have tremendous resources available to us in the form of existing measurements if these can be aggregated into useful forms. So this week we're introducing NorWeST, which is a comprehensive interagency stream temperature database being assembled for Oregon, Washington, Idaho, Montana, Wyoming and bits of northern Colorado, Utah, and Nevada. Development of this database has been an ongoing effort the last year (& we still have a ways to go…) made possible only through the willingness of 100's of individual biologists and hydrologists & 10's of state, federal, tribal, and private partners to share copies of their data. The NorWeST compilation effort is phase I of a project funded through one of the U.S. Fish & Wildlife Service's Landscape Conservation Cooperatives that have sprung up across the country the last few years (http://www.fws.gov/science/shc/lcc.html). Phase II of the project will use NorWeST to develop a regional stream temperature model for use in climate vulnerability assessments for cold-water fishes across the Northwest US. More on that & other potential uses of the database in a bit, but first a few of the raw statistics…

At present, NorWeST contains digital copies of temperature data from 15,000+ unique stream sites (& still growing daily), some 45,000+ summers of measurements at those sites, and perhaps 45,000,000 individual temperature measurements (graphic 1). As is obvious from these statistics, we don't monitor temperatures very long at most stream sites, averaging only 3 summers/site (and it's a very skewed distribution with a median of 1 or 2 years), which limits our ability to describe long-term trends associated with climate change (blog #'s 10, 11, & 23). We also usually monitor only in the summer and rarely during other times of the year, which is why we've taken to reporting the number of "summers" as a standard summary metric. Even with the various imperfections, NorWeST still contains an awesome amount of data, perhaps the largest compilation of its kind in the world, & the aquatics community in the Northwest U.S. deserves major kudos for their dedication to stream temperature monitoring efforts.

I like to call NorWeST a stealth sensor network because it's been flying under the radar as it's slowly & steadily grown the last few decades while collecting massive amounts of useful data. Yet we didn't even know the darn thing existed because the work to measure all those stream temperatures was spread across hundreds of different people scattered among dozens of agencies and coordinated monitoring efforts have rarely been done

across agencies or at large spatial scales. If we had to start from zero and collect all the data in NorWeST again, a back-of-the-envelope estimate would put the cost somewhere around $10 million. Figure a temperature sensor runs ~$100 & we'd have to put one at each of those 15,000 stream sites with a small army of field technicians. Since we'd be collecting primarily summer data, we'd have to visit each site twice a year (which is another reason full year monitoring & one site visit/year makes more sense) and be paying for a lot of gas and vehicle mileage in the process.

As an aside, it's worth noting that temperature data are just one example of the proliferation of data that's becoming available for streams. As much or more data exists for fish distribution/abundance surveys and increasing numbers of surveys are being done for genetic attributes and other water quality parameters. Moreover, the covariates to predict these biophysical attributes are steadily improving and oftentimes already available in some form for many streams (think USGS NHD+ national hydrography layer or satellite imagery of riparian vegetation or other watershed attributes). We are entering what some have called the era of "Big Data" wherein modern sensors, geospatial technologies, and advances in computing power & memory are making mountains of data available that can be used to better describe, understand, and manage stream environments (for an interesting recent perspective on this topic, see "Staying Afloat in the Sensor Data Deluge" (attached)).

Regarding the potential applications of NorWeST, that's where the true value of the database lies and ultimately dwarfs that $10 million valuation. First, temperature monitoring efforts in the Northwest can now potentially be done much more efficiently (graphic 2). Nothing is more efficient than simply sharing copies of existing data rather than going to the field to collect redundant information, so by the end of the year, the plan is to post the NorWeST database to its own website where those datasets we have permission to disseminate can be downloaded. With that information available, regional planning efforts might be undertaken to implement a strategic monitoring design that builds most efficiently from existing data collection efforts (blog #4 & #24). Even in the absence of any centralized & formal monitoring plan, however, many of us will still be out there monitoring stream temperatures for a variety of reasons & to help facilitate those efforts, we've developed high-resolution maps showing where within each state data do & don't exist (archived here at the project website (http://greatnorthernlcc.org/technical/stream-temp). Armed with this spatial information, we can all be more thoughtful about where new data are collected & my guess is we'll choose more often to measure temperatures in streams where information is lacking. Simple self-organizing principles, therefore, will help fill current spatial gaps in regional coverage.

Second, NorWeST will facilitate more temperature research & accelerate the pace at which we're learning about thermal regimes in streams. The experiences I've had doing temperature research in the past suggest that developing & organizing the database often

takes at least as much effort as the analysis & preparation of a manuscript. Those preliminary steps will be eliminated after NorWeST is made publicly available and interested parties need only develop useful research questions to guide queries of the database before proceeding to the analysis stage.

Third, as mentioned above, we'll build a regional stream temperature model using all the data in NorWeST so that a means exists of making consistent predictions of thermal conditions across all the ~350,000 kilometers of perennial streams in the Northwest (blog #7). These predictions will be made for a variety of historical and possible future scenarios to facilitate better climate vulnerability assessments for aquatic organisms. A common limitation of previous such assessments has often been the use of air temperature as a surrogate for stream temperatures, despite the fact that these variables may be weakly correlated in complex mountainous landscapes like those characterizing much of the Northwest (graphic 3). As such, we've often had poor representations of the most fundamentally important variable when it comes to understanding climate & climate change effects on stream biotas. The hope is that much of the previous imprecision will be eliminated by developing standardized "maps" of stream temperature predictions so it's possible to see how species, aquatic communities, and other forms of biodiversity relate to thermal characteristics across the region. The other hope is that because these maps are developed from everyone's data & will cross jurisdictional boundaries, they may facilitate better coordination of conservation efforts among agencies (graphic 4).

At a time when everyone's budget is shrinking, aquatic resources are under greater duress, & we're perpetually being asked to do more with less, developing comprehensive databases like NorWeST & extracting useful information from them is one easy way of making everyone's dollars go a lot farther and working more efficiently. Not to say that there aren't issues with these aggregated databases that are often characterized by varying degrees of spatial non-randomness, clustering, and gaps in coverage, but as long as the stream attributes being measured are assessed accurately & the location of the survey is georeferenced, then there's going to be some useful information there. Moreover, new analytical techniques, developed specifically for data on stream networks (which we'll explore in future blogs), not only deal with this sort of non-randomness, but actually use it to their advantage to improve the predictive accuracy of models while yielding unbiased parameter estimates and providing access to a host of previously impossible types of analyses for stream data. It all sounds too good to be true, but so does finding $10,000,000 of useful data lying around…

Until next time, best regards.

Dan

p.s. One last good question is how the heck one goes about using the entire mass of data from NorWeST in a single model? Well, just as is the case with collecting that much

data, one person doesn't do it. To quote a famous politician, it literally "takes a village" & we have our own small village of 17 or so people scattered across 5 states and 2 countries working on this project in various capacities. About half our village is composed of scientists, but most of the real work is being done by database engineers, GIS/spatial analysts, technicians, webpage designers, statisticians, etc. that are digitally connected in a virtual office as we build the infrastructure for the regional model. I'd grappled with finding a name to describe this thing we're doing & then ran across a recent paper by Michener & Jones (attached). In this paper, they coined the term "Ecoinformatics" to describe the rapid evolution of ecology toward a more open, interdisciplinary, collaborative, and data-rich endeavor in response to the challenges and opportunities of the day. And so, as best I can figure, we're doing an Ecoinformatics approach to stream temperatures as we attempt to better understand and predict how climate change may affect aquatic resources across the Northwest.
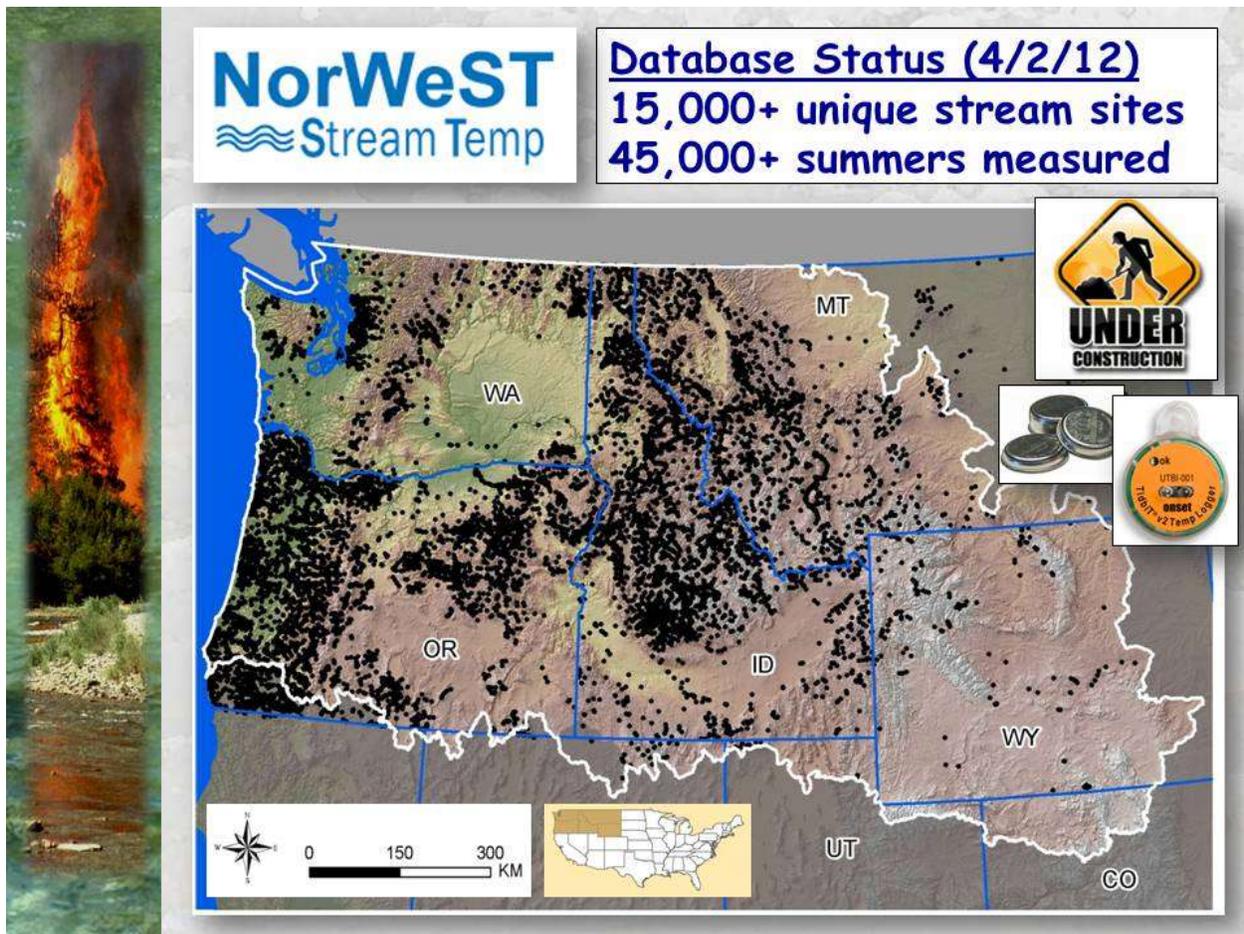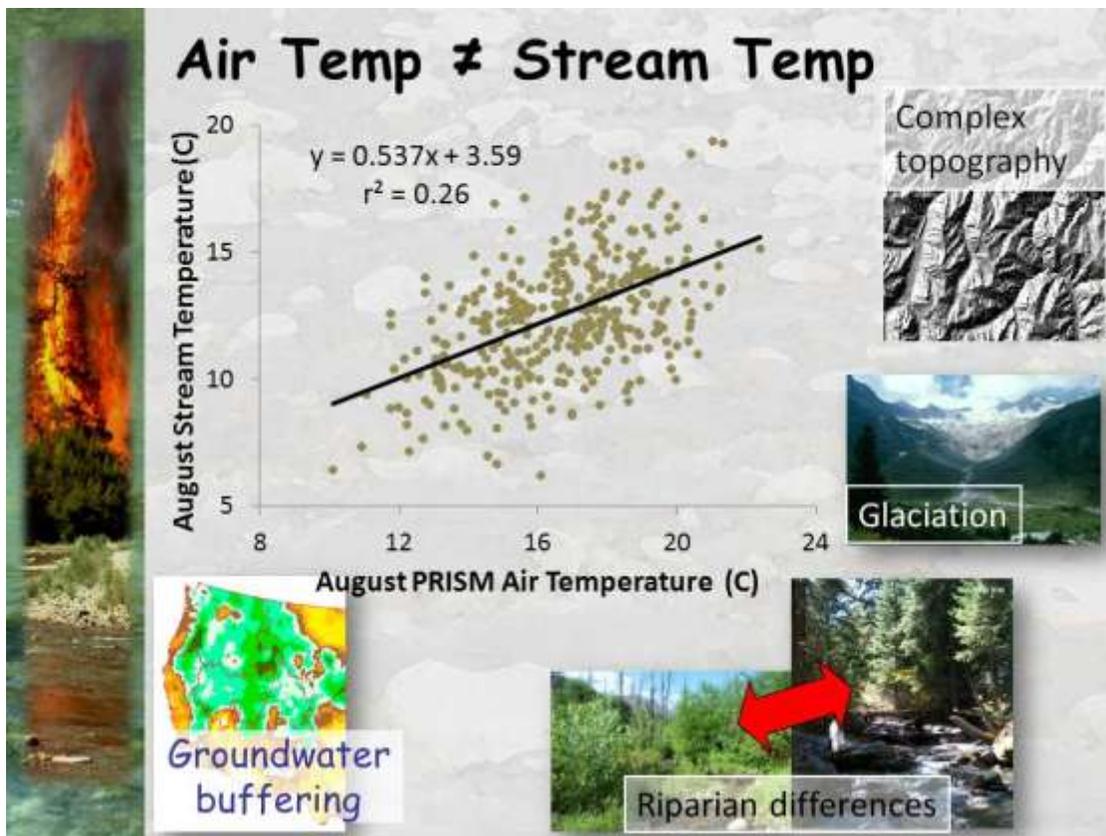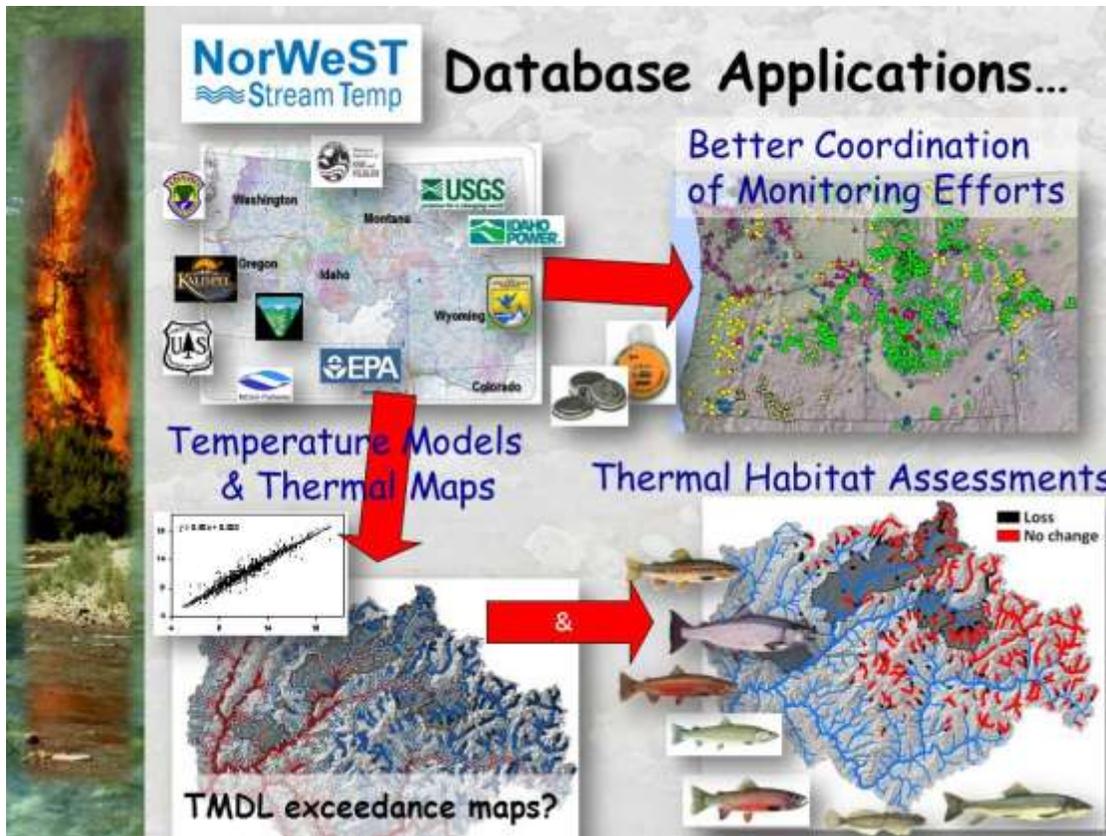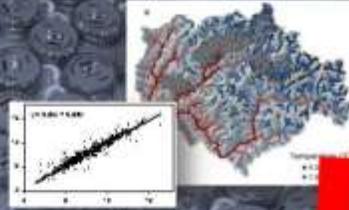
Regional Temperature Model Outputs

Large amounts of data across agencies
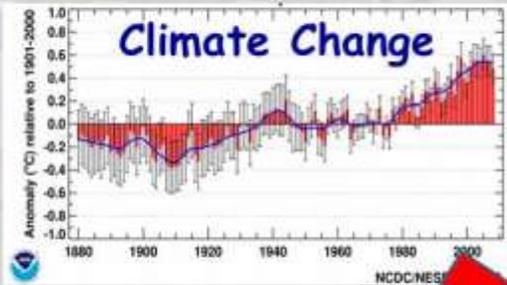
Accurate models

Stealth Sensor Network

Cross-jurisdictional "maps" of stream temperatures

Consistent datum for strategic assessments

Moscow • Missoula
• Bozeman
• Boise
• Logan
• Ogden

More Pressure, Fewer Resources

Climate Change

Anomaly (°C) relative to 1901-2000

1880 1900 1920 1940 1960 1980 2000

NCDC/NES

Urbanization & Population Growth

Shrinking Budgets

Need to do more with less

Welcome to the Climate-Aquatics Blog. For those new to the blog, previous posts with embedded graphics can be seen by clicking on the hyperlinks at the bottom or by navigating to the blog archive webpage on our Forest Service site at: (http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/stream_temperature_climate_aquatics_blog.html). To discuss these topics with other interested parties, a Google discussion group has also been established and instructions for joining the group are also on the webpage. The intent of the Climate-Aquatics Blog and associated discussion group is to provide a means for the 3,952 (& growing) field biologists, hydrologists, anglers, students, managers, and researchers currently on this mailing list across North America, Europe, and Asia to more broadly and rapidly discuss topical issues associated with aquatic ecosystems and climate change.

Messages periodically posted to the blog will highlight new peer-reviewed research and science tools that may be useful in addressing this global phenomenon. Admittedly, many of the ideas for postings have their roots in studies I and my colleagues have been a part of in the Rocky Mountain region, but attempts will be made to present topics & tools in ways that highlight their broader, global relevance. Moreover, I acknowledge that the studies, tools, and techniques highlighted in future missives are by no means the only, or perhaps even the best, science products in existence on particular topics, so the hope is that this discussion group engages others doing, or interested in, similar work and that healthy debates & information exchanges will occur to facilitate the rapid dissemination of knowledge among those most concerned about climate change and its effects on aquatic ecosystems.

If you know of others interested in climate change and aquatic ecosystems, please forward this message and their names can be added to the mailing list for notification regarding additional science products on this topic. If you do not want to be contacted regarding future such notifications, please reply to that effect and you will be removed from this mailing list.

Previous Posts
Climate-Aquatics Overviews
Blog #1: Climate-aquatics workshop science presentations available online
Blog #2: A new climate-aquatics synthesis report

Climate-Aquatics Thermal Module
Blog #3: Underwater epoxy technique for full-year stream temperature monitoring
Blog #4: A GoogleMap tool for interagency coordination of regional stream temperature monitoring
Blog #5: Massive air & stream sensor networks for ecologically relevant climate downscaling
Blog #6: Thoughts on monitoring air temperatures in complex, forested terrain
Blog #7: Downscaling of climate change effects on river network temperatures using inter-agency temperature databases with new spatial statistical stream network models
Blog #8: Thoughts on monitoring designs for temperature sensor networks across river and stream basins
Blog #9: Assessing climate sensitivity of aquatic habitats by direct measurement of stream & air temperatures
Blog #10: Long-term monitoring shows climate change effects on river & stream temperatures

Future topics…
Climate-Aquatics Biology Module
Climate-Aquatics Management Module
Climate-Aquatics Cool Stuff Module