Climate-Aquatics Blog #19: Squeezing water from rocks and why fish care

Hi Everyone,
It's been a bit of a break since the last blog post, so just a refresher regarding where we are in the climate aquatics – hydrology module. First, it's getting warmer & snowpacks are shrinking in many parts of the western US (blog #16), streams are running off sooner, flood risks are changing (blog #17), and summer flows are trending lower in some regions for a variety of reasons, of which climate is likely one (blog #18). Broad regional trends in hydrologic responses to climate change are emerging (graphic 1) as was the case with stream temperatures (blogs #7, #9, #10, #15). Though trends in temperature or hydrologic attributes usually (but not always) move in the same direction across a region, these trends may also occur at slightly different rates from site to site. Multiple factors contribute to this site-level variation as we saw in previous posts regarding spatial variation in the degree of climate forcing (blogs #13 &#16) or elevation gradients/thresholds associated with runoff/flooding patterns (blog #17).

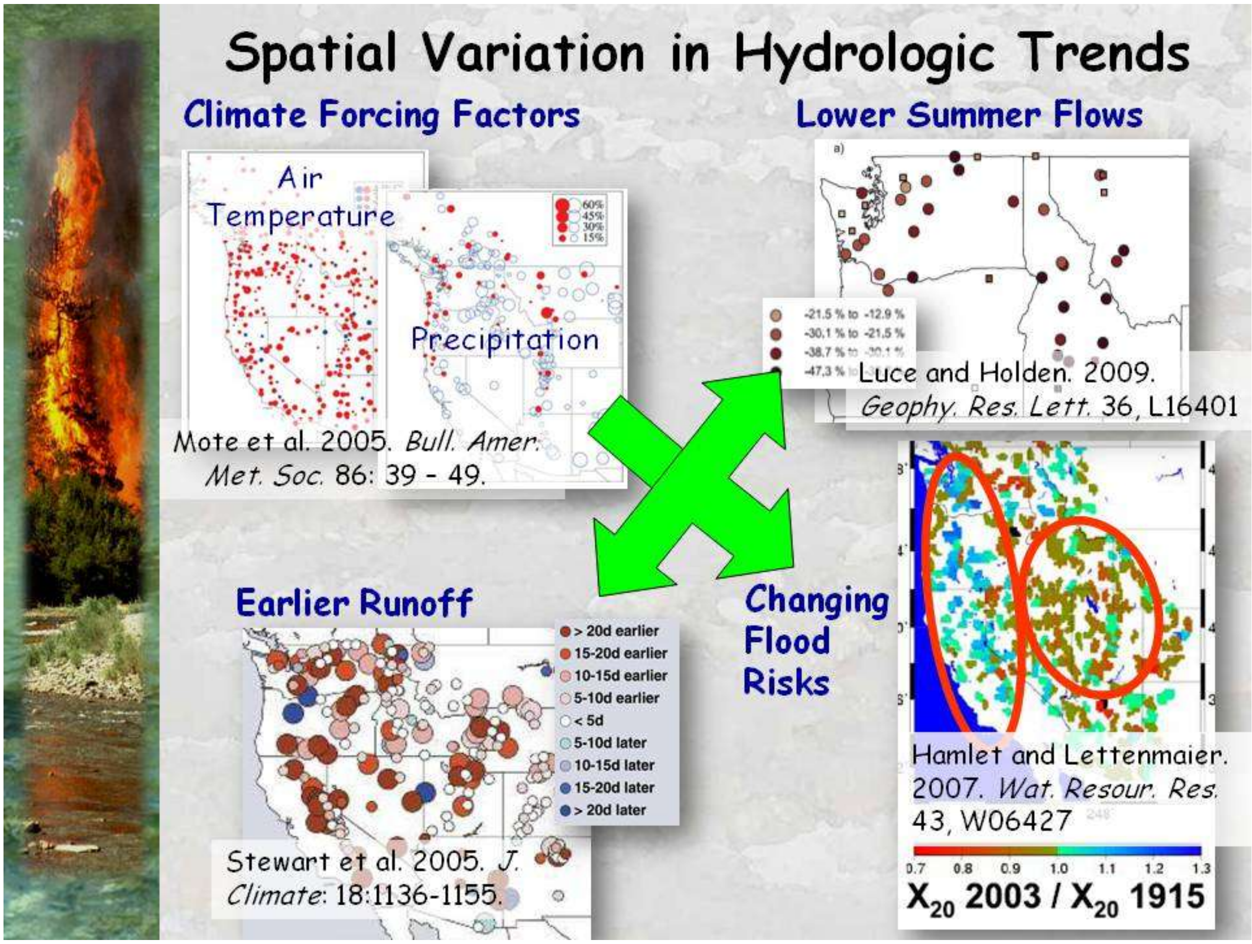
Another factor to consider with regards to hydrologic responses to climate change is underlying geology because different types of rocks and soils store and release water differently. The first paper this week by Tague et al. examines this issue in detail within the Cascade Range of western Oregon. The authors study hydrologic regimes of two streams in close proximity with contrasting geologies and groundwater baseflows (graphic 2). A hydrologic model is calibrated to the two streams so that the effects of different future climate scenarios on each can be simulated. In both cases, the future scenarios suggest slightly higher and earlier peak runoff and that the summer low-flow season will start earlier in the year. Paradoxically, however, the stream with the larger groundwater contribution is predicted to have a larger proportional decline in summer flows than is the stream with small groundwater contributions. The authors suggest this occurs because the low groundwater stream is already as low as it can go whereas the high groundwater stream is declining from a higher baseline.

Tague et al. did their research in an area with especially strong geologic contrasts, so their results are more indicative of the range of possible responses rather than "average" differences between streams in adjacent basins. To get a better contextual sense of their study systems and the importance of groundwater baseflows across a larger area, a recent study by Santhi et al. provides a useful reference (graphic 3). Santhi et al., based on earlier work by Wolock, describe a Baseflow Index (BFI) that is simply the ratio of average annual baseflow to average annual flow (see manuscript for more specific details). The BFI is calculated from stream flow records at gaging stations and estimates are then interpolated between gage sites to provide a consistent spatial data layer across the US. BFI values vary considerably across the country and sometimes within regions and the highest baseflow indices are usually related to deep groundwater sources from porous bedrocks like young volcanic flows or thick limestone deposits.

Factors like BFI and differences in geologic setting will no doubt play a role in how stream environments respond to a changing climate, but whether it's a dominant role has yet to be determined. An important challenge to understanding, and hence, predicting future responses of stream environments is teasing apart the relative importance of site-level variability (and the factors that cause it) versus systemic changes associated with climate forcing. It could be that most of the temporal variation associated with stream responses to climate change ends up being systemic in nature, at least within broadly define process domains. That sort of world is much easier to conceptualize and model, but is also rather more boring than one in which site-level variation stemming from a diversity of landscape and stream elements are also important.

Once we sort through this basic dichotomy and the necessary information is incorporated to physical models that predict relevant stream features at broad spatial scales, the next logical step is defining biological thresholds and habitat suitabilities relative to the physical model outputs. Then we'll be able to map where within individual streams across a region suitable habitats exist for different species of concern now and in the future. The complexity of it all becomes a bit daunting, but when broken down into the component parts, it becomes a series of tractable problems given today's datasets and analytical capacities. We'll keep working our way through the logic in future months of blog posts (and then, of course, the subsequent years of research and monitoring to build and refine the components), but next time out we'll highlight a few of the tools and datasets that are already available for assessing the effects of climate change on the hydrology of western streams.

Until next time, best regards,
Dan



Spatial Variation in Hydrologic Trends

Climate Forcing Factors

Mote et al. 2005. *Bull. Amer. Met. Soc.* 86: 39 - 49.

Lower Summer Flows

Luce and Holden. 2009. *Geophy. Res. Lett.* 36, L16401

Earlier Runoff

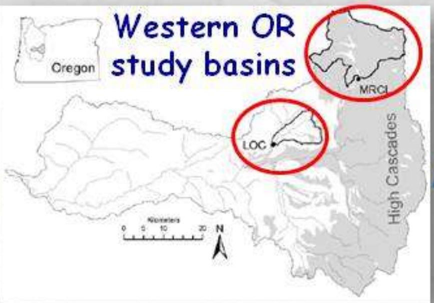
Stewart et al. 2005. *J. Climate*: 18:1136-1155.

Changing Flood Risks

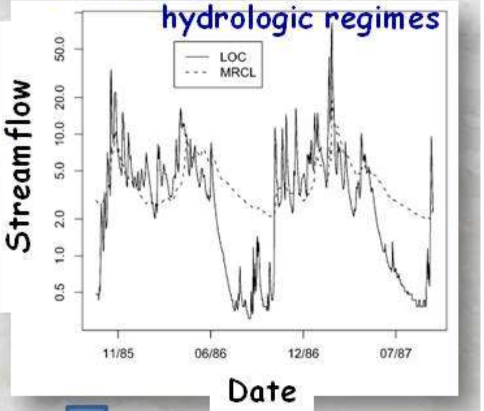
Hamlet and Lettenmaier. 2007. *Wat. Resour. Res.* 43, W06427

Geologic Mediation of Hydrologic Response

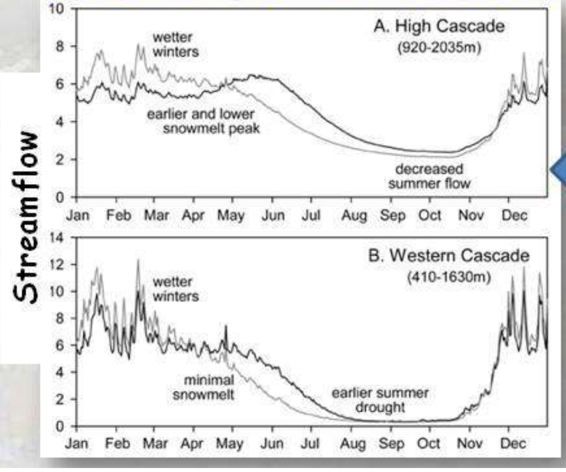
Western OR study basins



Contrasting historical hydrologic regimes



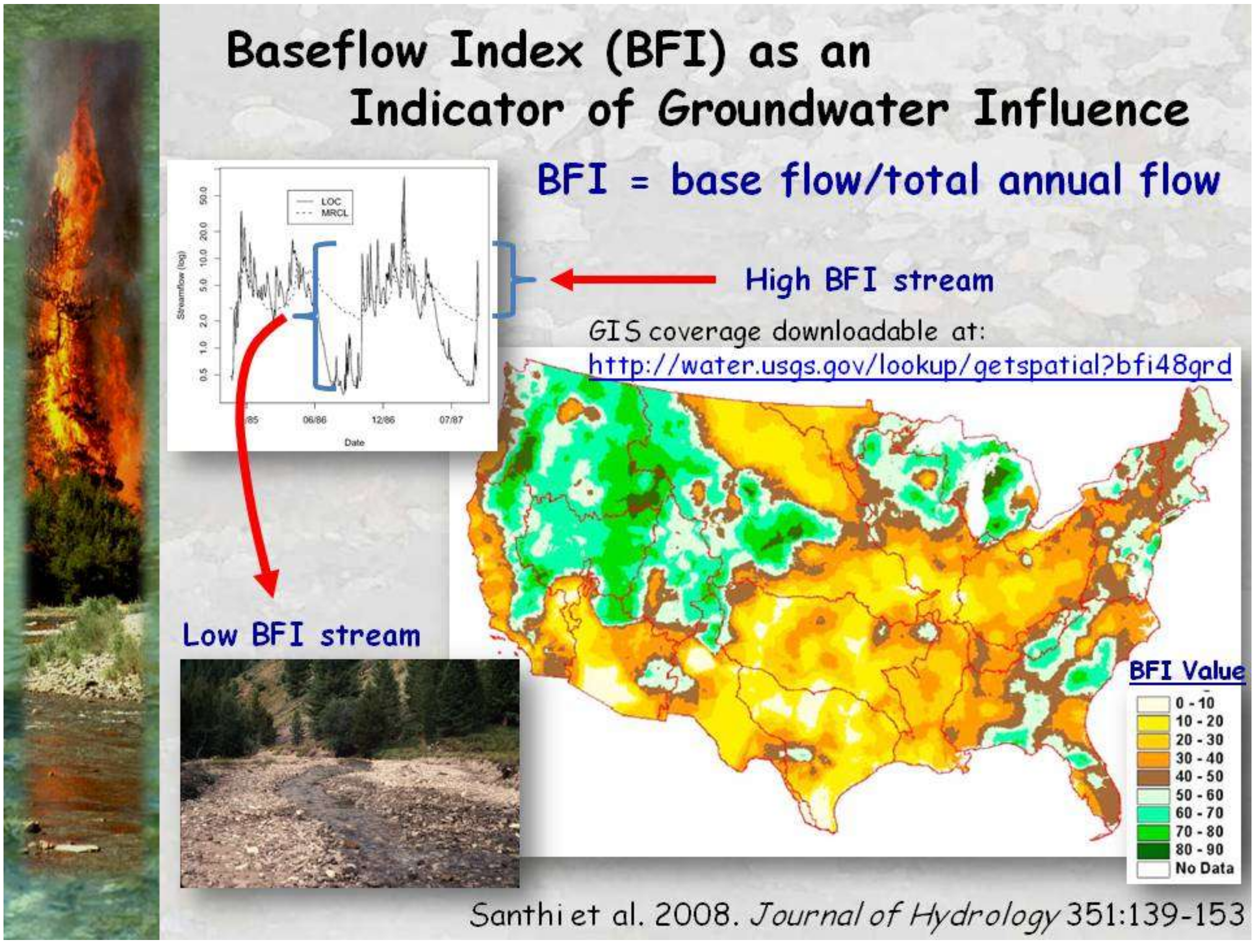
Contrasting responses to future climate change (+1.5 °C scenario)



Black line = historic scenario

Gray line = future scenario

Tague et al. 2008.
Climatic Change 86:189-210.



Baseflow Index (BFI) as an Indicator of Groundwater Influence

BFI = base flow/total annual flow

High BFI stream

GIS coverage downloadable at: http://water.usgs.gov/lookup/getspatial?bfi48grd

Low BFI stream

Santhi et al. 2008. *Journal of Hydrology* 351:139-153

Welcome to the Climate-Aquatics Blog. For those new to the blog, previous posts can be seen by clicking on the hyperlinks below or by navigating to the blog webpage at this hyperlink (Climate-Aquatics Blog). 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 2,596 (& 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: Accurate downscaling of climate change effects on river network temperatures through use of inter-agency temperature databases and application of new spatial statistical stream 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
Blog #11: Long-term monitoring shows climate change effects on lake temperatures
Blog #12: Climate trends & climate cycles & weather weirdness
Blog #13: Tools for visualizing local historical climate trends
Blog #14: Leveraging short-term stream temperature records to describe long-term trends
Blog #15: Wildfire & riparian vegetation change as the wildcards in climate warming of streams

Climate-Aquatics Hydrology Module

Blog #16: Shrinking snowpacks across the western US associated with climate change
Blog #17: Advances in stream flow runoff and changing flood risks across the western US
Blog #18: Climate change & observed trends toward lower summer flows in the northwest US

Future topics…

Climate-Aquatics Biology Module
Climate-Aquatics Management Module