

## **Climate-Aquatics Blog #20: GIS tools for mapping streamflow responses to climate change across the western U.S.**

### **Planning for the future requires seeing the possibilities now...**

Hi Everyone,

So as was alluded to in the last blog, this time out we're highlighting a few of the tools and GIS outputs that are available for visualizing the sorts of hydrologic responses to climate change that we've been discussing through the series of blog posts in the climate-aquatics hydrology module. In a sense, these tools are like the air temperature/climate change mapping tools that were the subject of Blog #13, but take things out of the atmosphere and into the stream by translating air temperature trends to effects on streamflows by running different climate conditions through a hydrologic model. These sorts of tools are a great way of making the science readily available and can serve as powerful planning & coordination tool by bringing various stakeholders together within a common framework. We'll no doubt see more of these tools in future years given the ease with which they are now developed and because new models are increasingly coming online that are linked to spatial datasets and real-world coordinate systems.

Both sets of tools we're looking at today are derivatives of outputs from the Variable Infiltration Capacity (VIC) model, which was first developed in the early 1990's and has since been used extensively to model stream hydrology at broad scales across many parts of North America. VIC is a mechanistic land-surface hydrological model that simulates runoff generation within a specified area like a grid cell in a climate model or digital elevation model as a function of the relevant physical processes. For more details on those processes or the guts of the model, please consult your friendly local hydrologist as most are probably familiar with it or consult some of the key references associated with VIC model development and application (graphic 1).

The first tool that maps VIC outputs was developed by the Climate Impacts Group and a consortium of partners across the Pacific Northwest and provides means of accessing and downloading historic and future hydrologic scenarios at 300 locations on large rivers (graphic 2; <http://www.hydro.washington.edu/2860/>). Future climate scenarios were developed using outputs from 20 global climate models run with the B1 (moderate warming) and A1B (faster warming) greenhouse gas emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). To access the data for a specific river site, simply select a site through the convenient GoogleMap interface and you'll be taken to a webpage hosting maps, graphs, and data summarized at various time-steps for download and subsequent use.

Pretty darn slick to be able to see future climate scenarios on a local river at the click of a button, but the large rivers that the preceding tool was developed for ultimately comprise only 5% - 10% of the stream length within a regional network. What about all those other rivers and streams, which resource agencies also need information on? That problem was tackled by Wenger and colleagues (attached pdf), who translated the VIC model results to individual reaches in the 1:100,000-scale NHD+ hydrologic layer that the USGS has developed for the entire U.S. (<http://www.horizon-systems.com/nhdplus/data.php>).

Because it was rare to have used VIC like this previously, the authors went to some lengths to validate the model predictions against observed flow data at 55 stream gage sites in the Pacific Northwest (graphic 3) before the model was used to forecast climate-related hydrologic changes. The validation work suggests VIC predicts things like the timing of runoff and the frequency of high winter flows relatively well but doesn't do as well with other metrics related to summer flows for example. The validation work suggests VIC predicts things like the total annual flow and the frequency of high winter flows consistently well over the region but doesn't consistently perform as well with other metrics related to extreme high or low summer flows for example. Annual runoff timing showed an interesting and correctable bias with rain dominated locations having late hydrographs while snow dominated locations had early hydrographs, sometimes on the order of a month. The validation work also plays an important part in improving the VIC model, and future versions will benefit from the insights gained by looking at performance across these 55 stations.

Once the VIC model's performance on smaller rivers and streams was understood, it was then used to describe historical and future hydrologic patterns across much of the western U.S. (graphic 4) using the same A1B scenario that fed into the Climate Impacts Group scenario tool above. The outputs of these model runs are stored as table attributes that are easily linked to the NHD+ hydrolayer and it's all available on the "Western US Stream Flow Metric Dataset" website ([http://www.fs.fed.us/rm/boise/AWAE/projects/modeled\\_stream\\_flow\\_metrics.shtml](http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml)); (a quick-start guide on downloading the NHD+ hydrolayer prior to adding the flow metrics data can be found here:

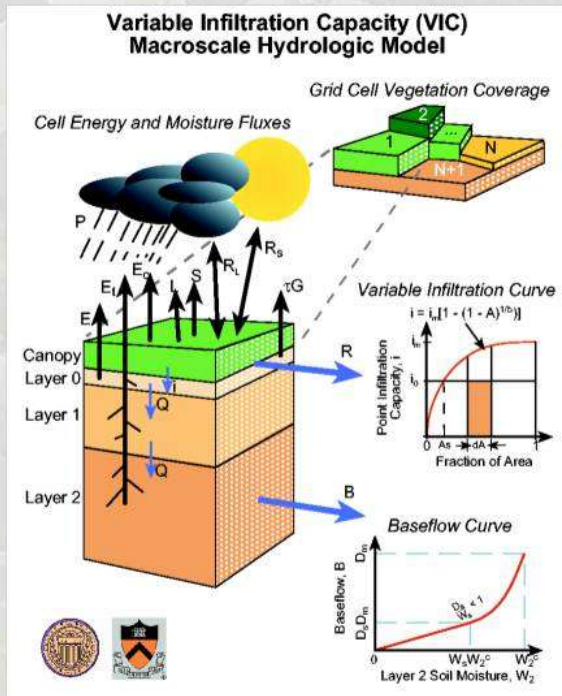
[http://www.fs.fed.us/rm/boise/AWAE/projects/stream\\_temp/multregression/downloads/2\\_N\\_HowToDownloadStreamsUsingNHDPlus.pdf](http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/multregression/downloads/2_N_HowToDownloadStreamsUsingNHDPlus.pdf))

As with any model, there's a certain amount of "buyer beware" and it's necessary to kick the tires and fully understand what the strengths/weaknesses are before using it as a basis for decision making, so please read the metadata on the website. Even with the warts, however, the Western Flow Metrics Dataset derived from VIC serves a useful function by providing a nearly continuous spatial map of several important hydrologic characteristics. That makes it possible to understand how climate change may affect hydrology throughout entire river networks and to understand the context associated with individual points in those networks, which are often necessary for planning efficient conservation strategies. These continuous maps also make it possible to do apples-to-apples comparisons across broad areas or to clip the VIC flow metrics to any jurisdictional boundary (e.g., a national forest, a BLM district, a fish & game management unit, etc.) and develop custom climate assessments for those areas.

So lots of useful models, tools, and descriptive studies out there for understanding & predicting how climate change is/will affect stream hydrologies (blogs 16 – 19). We'll wrap up the climate-hydrology module next time out with a few concluding thoughts, then will move into the biology module where the fun will really start. Before making the shift, however, we'll take a short break from our regularly scheduled programming to do one or two 'house-keeping' blogs that will keep us current on recent research regarding stream temperature responses to climate change and we'll also do a 'mini-module' to present some powerful new analytical techniques and programs for spatial statistical analyses of data on stream networks that are becoming available and can yield fundamentally more accurate information for climate change and other stream assessments.

Until next time, best regards,  
Dan

# Variable Infiltration Capacity (VIC) Hydrologic Model



## VIC Outputs

- Snowpack
- Soil water moisture
- Evaporation
- Flood timing, freq, & size
- Daily streamflows

## References

- Liang et al. 1994. *J. Geophys. Res.* 99:14,415-14,428.
- Christensen et al. 2004. *Climatic Change* 62: 337-363.
- Hamlet & Lettenmaier. 2007. *Water Resour. Res.*, 43, W06427, doi:10.1029/2006WR005099.
- Hidalgo et al. 2009. *J. Climate* 22:3838-3855.

# Stream Hydro-Climate Tool for Pacific Northwest Rivers

Website: <http://www.hydro.washington.edu/2860/>



Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal Drainages

St. Joe River, Idaho

Site Specific Data

Use the pull-down menu or map links to access data and summary figures for individual streamflow locations.

Research Site Data Spreadsheet

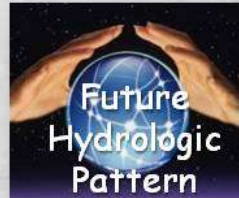
Site: ST JOE RIVER AT CALDER

ST JOE RIVER AT CALDER

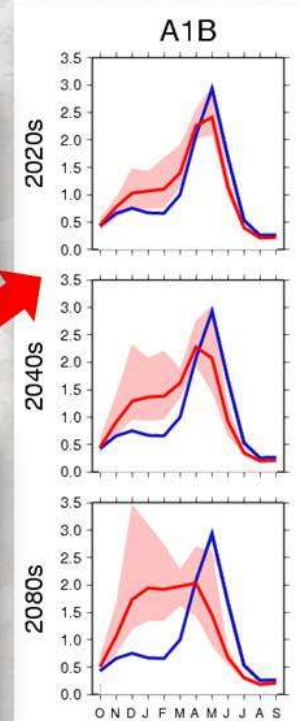
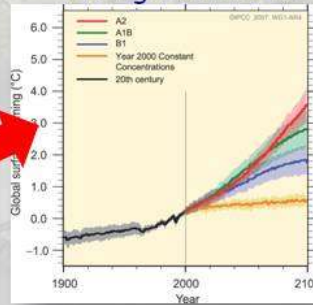
Site Info: JOECA (2007)

USGS ID: 12414500  
Latitude (DMS): 47 16 29  
Longitude (DMS): 116 51 17  
Latitude (Decimal): 47.2747  
Longitude (Decimal): -116.1881  
Area: 1030 miles<sup>2</sup>  
Nash Sutcliffe Efficiency = 0.97

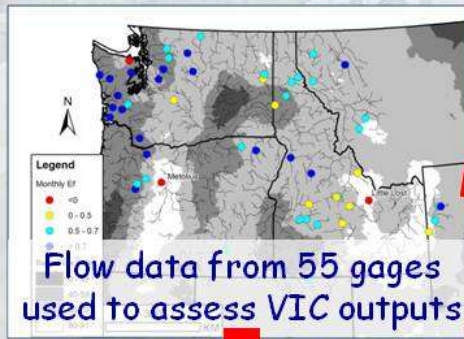
General FTP directory



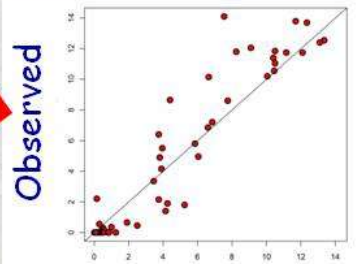
IPCC climate change scenario



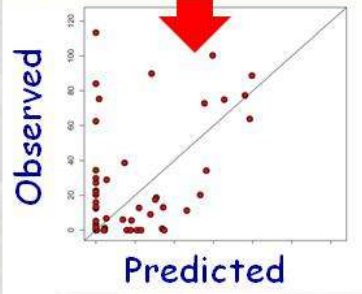
# Validation of Stream Flow Metrics Predicted by VIC



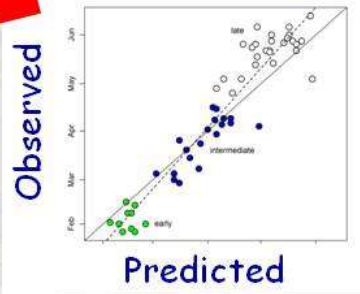
Frequency of winter high flows



Frequency of low summer flows



Run-off timing

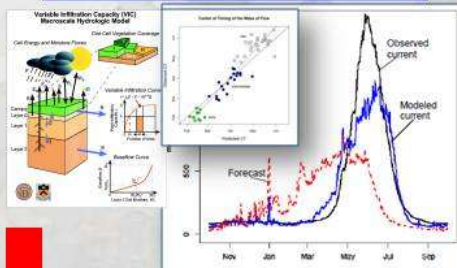


Wenger et al. 2010. Macroscale hydrologic modeling of ecologically relevant flow metrics. *Water Resources Research* 46, W09513, doi:10.1029/2009WR008839

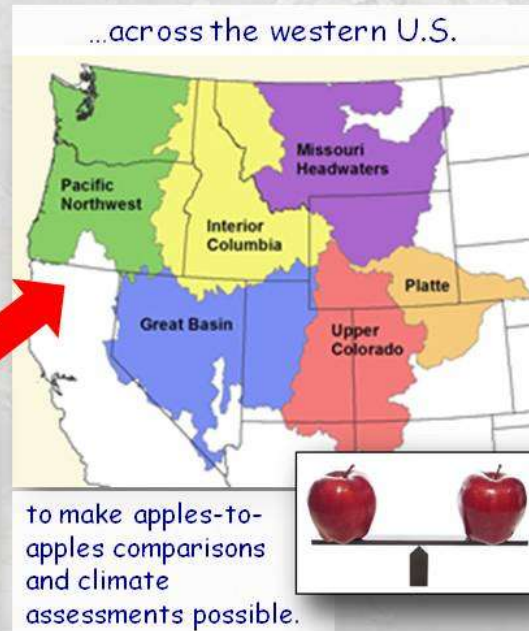
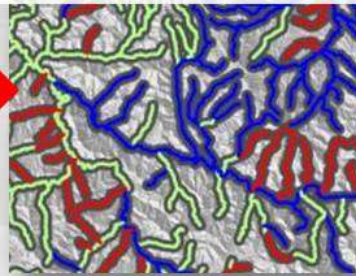
# Western U.S. Flow Metrics Webpage

Website: [http://www.fs.fed.us/rm/boise/AWAE/projects/modeled\\_stream\\_flow\\_metrics.shtml](http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml)

## VIC Modeled Flow Metrics



...are available for all NHD+ stream segments & historic or future climate scenarios



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 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 3,229 (& 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](#)

Blog #19: [Groundwater mediation of stream flow responses to climate change](#)

#### Future topics...

Climate-Aquatics Biology Module

Climate-Aquatics Management Module