Western U.S. Stream Flow Metric Dataset:

Modeled Flow Metrics for Stream Segments in the Western United States under Historical Conditions and Projected Climate Change Scenarios

User Guide

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http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml

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Overview

The flow regime is of fundamental importance in determining the physical and ecological characteristics of a river or stream, but actual flow measurements are only available for a small minority of stream segments, mostly on large rivers. Flows for all other streams must be extrapolated or modeled. Modeling is also necessary to estimate flow regimes under future climate conditions. To date there are few databases of modeled stream flows that have broad coverage, fine resolution, and are available for both historical and future climate scenarios. Here we present such a database.

Daily runoff and baseflow from the Variable Infiltration Capacity (VIC) macroscale hydrologic model were used to estimate historical and projected future stream flow metrics for stream segments in the Western U.S. This dataset updates the previous Western U.S. Stream Flow Metric Dataset (Wenger, Luce, Hamlet, Isaak, & Neville, 2010) (link to old dataset is available on website for the current dataset) by using updated VIC data (http://cses.washington.edu/cigdata/wus.shtml) which has expanded coverage to include California, among other updates. Projections were based on an ensemble of ten global climate models from CMIP3 using the A1B emissions scenario. For each stream segment in the National Hydrography Dataset Plus Version 2 (NHDPlusV2) in the Western U.S. we estimated hydrographs for the historical period (1915-2006, then filtered to October 1, 1977 to September 30, 2006), the 2040s (2030-2059), and the 2080s (2070-2099). From these we calculated summary flow metrics to describe flow regimes for each stream segment and each time period, and joined these to the NHD stream segments for visualization and analysis.

Data Coverage

The flow metric files cover ten Western U.S. NHD regions/production units (Figure 1). Canadian and Mexican land areas are not included in this dataset.

Figure 1. NHD production units: the western production units (10-18) are included in this dataset.

Methods

VIC is a fully-distributed and largely physically-based model that balances surface energy and water fluxes. Infiltration, runoff, and baseflow processes are based on empirically derived relationships (Liang, Lettenmaier, Wood, & Burges, 1994) and characterize the average conditions over each grid cell. We used the VIC data from the Western U.S. Hydroclimate Scenarios Project (http://cses.washington.edu/cig/data/wus.shtml). For this project, grid cells were 1/16° (~5km) on a side, except in the Great Basin, where 1/8° cells were used. For the historical simulations, meteorological forcing data were produced using interpolated weather station data, corrected for biases in temperature and precipitation using PRISM products (Daly, Neilson, & Phillips, 1994; Hamlet & Lettenmaier, 2005; Maurer, Wood, Adam, Lettenmaier, & Nijssen, 2002). Simulations were performed on a daily time step from the period 1915 through 2006. The VIC modeling methods are described in more detail in Elsner et al. (2010).

For the projected climate scenarios, meteorological data from global climate models (GCMs) for the 2040s and 2080s associated with the A1B greenhouse gas emissions trajectory (Parry et al., 2007) were used. The A1B scenario is a middle-of-the-road scenario in terms of its assumptions for the accumulation of atmospheric greenhouse gases (Parry et al., 2007). For each of the future time periods mean projections from an ensemble of the ten models with the lowest bias in simulating observed climate across the region of interest were calculated (Littell et al., 2011). GCM simulations were downscaled using a spatially explicit delta method (Littell et al., 2011). The traditional delta method involves perturbing the historical time series of meteorological data with spatially uniform monthly changes in temperature and precipitation derived from GCMs. This method has the advantage of preserving natural interannual variability in precipitation, which tends to be underestimated by GCMs (Elsner et al., 2010), and allows straightforward comparisons between current and future conditions. The spatially explicit delta method incorporates spatial variability in temperature and precipitation trends from the GCM projections, making the method more appropriate for broad-scale analysis.

To create stream hydrographs, we combined the baseflow and runoff values from the VIC modeling to yield an estimated daily flow produced by each cell. We then used a simplified routing procedure to translate cell-based flows into flows for stream segments in the 1:100K NHDPlusV2 stream network, based on stream drainage area and a lag to simulate the time required for flows to exit a cell (Wenger et al., 2010).

These calculations resulted in three long term time series of daily stream flow for each stream segment: one for the historical period, one for the 2040s, and one for the 2080s. Analysis of metrics was restricted to the time corresponding to October 1, 1977 to September 30, 2006 in each period. (VIC's modified delta approach takes the historical time series and produces a shifted time series of inputs for each projected future. Thus, the output for the 2040s is a shifted version of the historical time series.) For each stream segment and time period, we extracted 11 flow metrics described below.

We removed stream segments without values for these flow metrics, to improve display speed. To see all stream lines, use an NHD flowline dataset; versions of the streamflow metric datasets including the segments with null values are also available upon request. A simplified version of this dataset was prepared to improve display speeds for maps over large spatial extents, using the Simplify Line tool in ArcGIS Pro with the Retain Critical Bends algorithm and a 10 km simplification tolerance.

File Naming and Organization

Flow metrics are organized as file geodatabase feature classes or shapefiles for the historical, 2040s, and 2080s time periods, and for absolute and percent changes between the historical and future time periods. Generalized versions of each of these datasets, for use in large-extent maps, are indicated by the '_Gen' suffix.

Flow Metrics

Each feature class contains a series of fields from the NHD, including the "COMID", which provides a unique identifier for each NHD stream segment, as well as other basic hydrological information. It also contains the "Region" field, which indicates the NHD region (2-digit hydrologic unit codes) or a subdivision of regions based on NHDPlus "production units" (http://www.horizonsystems.com/NHDPlus/). Production units are designated by letters appended to the region code, such as “10U” (the upper Missouri River basin), as shown in Figure 1.

The remaining 11 columns are the flow metrics. Column names are composed of the metric abbreviation (such as “MA” for mean annual) and the time period (such as “2040”). The 11 metrics are described below:

a. MA: Mean annual flow is calculated as the mean of the yearly cumulative discharge values. units: cubic feet per second
b. MS: Mean summer flow is the average of daily flow between June 1 and September 30. Units: cubic feet per second
c. MAug: Mean August flow is the average of daily August flows. VIC is known to have trouble simulating baseflow and some snowpack dynamics, leading to underestimates of August flow. Thus, we recommend not using this metric, or using it only in basins without significant groundwater contributions or drifting snow. Units: cubic feet per second
d. W95: Winter 95 is the number of daily flows between December 1 and March 31 which exceed the 95th percentile of daily flows across the entire year. Units: number of days
e. Q1_5: The 1.5-year flood is calculated by first finding the annual maximum series of flows (i.e. the highest flow each year). The 33rd percentile of the annual maximum series defines the flow which occurs every 1.5 years, on average. Units: cubic feet per second
f. Q10: The 10-year flood is calculated as above, but for the flow which occurs every 10 years on average. Units: cubic feet per second
g. Q25: The 25-year flood is calculated as above, but for the flow which occurs every 25 years on average. Units: cubic feet per second
h. Max: The maximum modeled flood is calculated by finding the highest flow occurring in any year. Units: cubic feet per second
i. CFM: Center of flow mass/center of timing is calculated using a weighted mean:

$$CFM=(flow_1*1+flow_2*2+\ldots flow_{365}*365)/(flow_1+flow_2+\ldots flow_{365})$$

where $flow_i$ is the flow volume on day i of the water year. Units: day of the water year (October 1 to September 30)
j. CFMd: Center of flow mass (date) is calculated by converting the CFM to a non-leap year date in month-date format for easier interpretation (e.g. a CFM value of 125.385 is converted to 02/03).
k. BFI: The baseflow index is the ratio of the average daily flow during the lowest 7-day flow of summer (May 1-Sept 30) to the average daily flow during the year overall. Units: n/a

Using the Files

More information about NHDPlusV2 can be found in the NHDPlusV2 User Guide: https://s3.amazonaws.com/nhdplus/NHDPlusV21/Documentation/NHDPlusV2_User_Guide.pdf.

Alternatively, an edited version of the NHDPlusV2 flowlines, called the National Stream Internet (NSI), is available from the Forest Service website at: http://www.fs.fed.us/rm/boise/AWAE/projects/NationalStreamInternet.html. These data have been edited to remove braids, diversions, and converging flow, and all stream reaches that do not participate in the NHDPlus value added attribute schema. Hence, this dataset is fully dendritic and may be more applicable to basic hydrography applications, since much of the superfluous data are removed. The flow metric data can be linked to the NSI flowlines through the COMID field. Please see the NSI User Guide for detailed information about how to use the dataset: http://www.fs.fed.us/rm/boise/AWAE/projects/NationalStreamInternet/downloads/NationalStreamInternetProtocolandUserGuide.pdf

Additional Information

Requests for additional data and any questions or comments can be directed to:

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