Assessing climate change impacts on streamflow in South Carolina River Basins

A. Patel[1], D. Tufford[1,2], G. Carbone[1], P. Gao[1], L. Felker[1]

AUTHORS: [1]Carolinas Integrated Sciences and Assessments (CISA), Department of Geography, University of South Carolina, Columbia, SC 29208 USA
[2] Department of Biological Sciences, University of South Carolina, Columbia, SC 29208 USA
REFERENCE: 2012 South Carolina Water Resources Conference, held October 10-11, 2012 at the Columbia Metropolitan Convention Center

ABSTRACT. Water resource impacts of future climate change in the southeast United States may include lower base flows, longer droughts, higher peak flows, increased flow variability and coastal flooding from extreme precipitation and tropical events. The likelihood of such impacts can be assessed by driving hydrologic models with climate model projections. We are currently using the EPA's BASINS-Hydrologic Simulation Program-Fortran (HSPF) model to simulate stream discharge in the Greater Winyah Bay basin and the Catawba-Wateree and Broad-Saluda basins. This modeling effort is a part of two multi-disciplinary studies to assess potential impacts of climate change on the floodplain habitat in the Congaree National Park and on water resource management issues such as coastal salt-water intrusion. Here, we present some results from a preliminary analysis of changes in streamflow under projected climate change (2041-2070/future interval) in the Lower Broad, South Fork, Saluda (upstream of Lake Greenwood), Little Pee Dee, Lynches and Lower Pee Dee rivers. For simulating streamflow under current climatic conditions we used the GCM modeled input (1981-2010/current interval). This comparison allows us to isolate and compare the magnitude of change in streamflow resulting from the different climate models.

Methodology. Continuous simulation watershed-scale models like HSPF need meteorological inputs at a finer temporal and spatial scale than a typical GCM output. We used Dr. Katharine Hayhoe's statistically downscaled projections from four Global Circulation Models (GCM), CCSM3 (National Center for Atmospheric Research (NCAR), USA), GFDL CM2.0 (Geophysical Fluid Dynamics Laboratory, USA), ECHO (Meteorological Institute, University of Bonn, Germany and Meteorological Research Institute of KMA, Korea) and PCM (NCAR, USA) for the A2 emission scenario. The dataset is made available under the USGS Geo Data Portal (GDP) project and is based on a modified quantile regression approach. This downscaling method allows the mean as well as the shape of the distribution of meteorological variables to change with time (in contrast to some other simpler methods) and is expected to work well for impacts that are sensitive to daily and weekly mean and variability (Terrando, 2010; Vrac, 2007)**.** The dataset is produced in the form of 12km grids of daily maximum (Tmax) and minimum (Tmin) temperature, and precipitation (P) and we aggregated it to the scale of our sub-watersheds. Prior to using the downscaled output, we disaggregated the temperature and precipitation from a daily time-scale to an hourly time-scale as required by HSPF, and calculated hourly potential evapotranspiration (from Tmax and Tmin) using the built-in algorithms in the WDMUtil tool in BASINS. However, we are also currently evaluating the performance of two additional precipitation disaggregation methods that may better replicate the observed rainfall intensity than the simple triangular distribution method of BASINS.

Results. As expected, the direction of change in monthly temperature and precipitation was not the same for all the GCMs. To visualize the projected change we used one month each as a representative of spring (April), summer (July), fall (October) and winter (January) seasons. The projected rise in Tmax for these four months ranged from 0.97°c to 3.31°c and rise in Tmin from 1.10°c to 3.37°c. The change in precipitation ranged from -20% to 35%. We began by constructing flow-duration curves for both GCM-simulated time intervals as well as the observed streamflow and compared them for each watershed. Future exceedence curves clearly differ from their current (1980-2010) counterparts, but for none of the GCMs are they consistently higher or lower across all watersheds. For Little Pee Dee, Lynches and Lower Broad, flows projected to equal or exceed 90-95% (Q90/Q95) of the time were higher than the observed record. The opposite is true in case of Lower Pee Dee, South Fork and, to some extent, in Saluda (See Figure 1 as an example and the accompanying PowerPoint presentation for the rest). The Q90 was projected to be significantly lower in the future as compared to both, the observed and the GCM-modeled current intervals; three out of four GCMs predicted no-flow days.

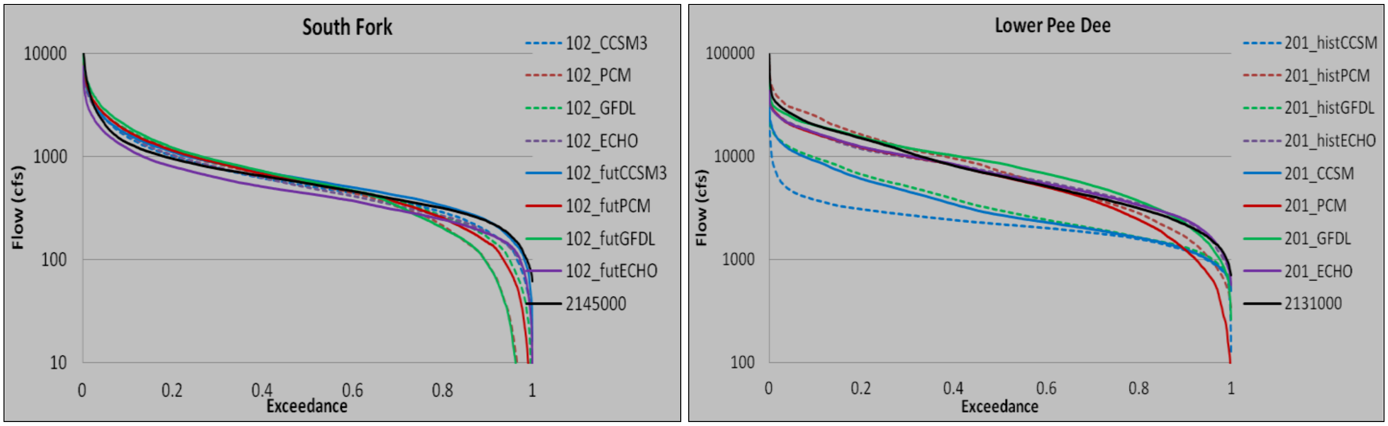

Figure 1: Flow duration curves for South Fork and Lower Pee Dee rivers for the current (observed and simulated) and future intervals and observed gage.

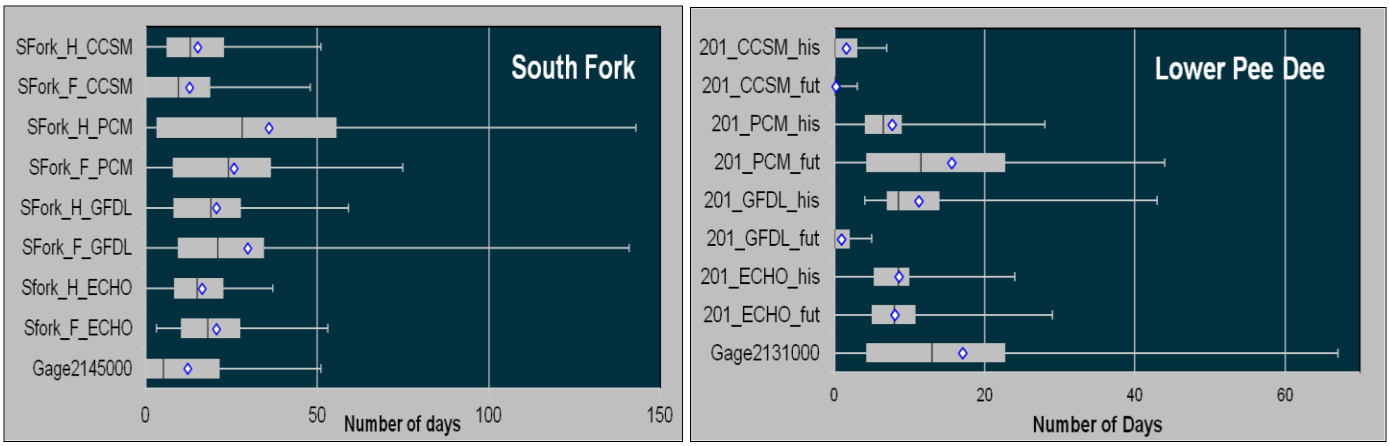

Figure 2: Number of days of longest annual low-flow periods for South Fork and Lower Pee Dee rivers for the current (observed and simulated) and future interval.

Next, we calculated the duration of longest annual low-flow period for both time intervals. The low-flow threshold was set at discharge equaled or exceeded 90% of the time in the 30-year (1980-2010) observation record. The result is summarized in the form of box and whisker plots for both time intervals (for example, Figure 2) – it is important to note here that the average and median durations in all cases also include values for years where flow does not fall below the threshold for a single day. The median longest low-flow duration for the future interval increases for all watersheds under the GFDL scenario which is likely due to a projected decrease in precipitation for all seasons but winter. In Lynches River, the median duration for the future was equal or lower than the 1981-2010 interval for all four GCMs. CCSM3 is the only GCM out of the four that projects increased precipitation for all four seasons; the flow-duration curve and the low-flow statistic reflect this wet outlook.

Conclusion. There is considerable variation in the streamflow response amongst the different watersheds in our study area; thus, this analysis highlights the importance of considering the appropriate scale for assessing impacts on water resources. A more in-depth analysis is needed to evaluate potential changes in different components of the stream-flow regime seasonally and in individual watersheds. Although global circulation models are not the only source of uncertainty in impact assessments, they are usually the biggest contributing sources along with emission scenarios (Graham, 2007; Prudhomme, 2009). Hence, use of scenarios generated by a large ensemble of climate models is recommended for policy-relevant assessments (Knutti, 2010). We plan to incorporate some of the dynamically- downscaled datasets from the North American Regional Climate Change Assessment Program (NARCAAP) in this study.

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