Assessment of Water Availability and Streamflow Characteristics in the southeastern United States

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Administrative

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Public Summary

Estimates of flows in the stream are critical to inform natural resource managers of the water availability for both human and ecological needs. Monitoring flow in the stream using a streamgage provides information about the amount and timing of surface water resources. However, not every

stream has a streamgage and decisions about water resources may need to be made in a watershed where there is no flow information. Hydrologic models can be used to provide estimates of streamflow in the absence of streamflow information. These models depend upon available streamflow data for calibration, and can be very inaccurate without the use of those data. This research developed a method to group watersheds that are gaged with watersheds that are not gaged so that accurate estimates of water availability can be provided regionally. To accomplish this, various models, techniques, and data were used to group watersheds across the southeastern United States. This means that watersheds were not necessarily grouped by proximity to one another, but instead were grouped based on their response to climate and their landscape setting. This results in consistently developed regional estimates of water availability for current and potential future climate and land cover in the southeastern United States.

Technical Summary

The goal of this project was to support ongoing research on hydrologic simulation in the southeastern United States. This project expanded the geographic extent of a multi-model synthesis study funded by the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC). The expanded area included parts of the Tennessee River Basin, the southeastern Gulf of Mexico basins, and the Altamaha River Basin (figure 1). Daily and monthly time step hydrologic models were developed for the study area. The hydrologic model domain for this project covers 1.16 million square kilometers divided into 20,251 HRUs, connected by a stream network of 10,743 segments. Streamflow data for 1,080 streamgage locations were used for model calibration or evaluation. The Precipitation Runoff Modeling System was used for the daily hydrologic modeling and the Monthly Water Balance Model (MWBM) was used for the monthly hydrologic simulations. A comparison of measured streamflow against the MWBM simulated output was used to check the streamflow data for non-stationarity and potential flow alteration. The hydrologic simulation of both gaged and ungaged watersheds required the development of new regionalization algorithms. These algorithms use a global sensitivity analysis and remotely sensed data products to group and inform hydrologic calibration regions.

Purpose and Objectives

The ability to base decisions upon quantitative analyses of aquatic resources is a critical need of managers today, with increasing attention placed on the need for water availability information at ungaged locations. Understanding the changes in the distribution and quantity of, and demand for, water resources in response to climate variability and change is essential to planning for, and adapting to, future climatic conditions (Lins and others, 2010). In order to plan for future conditions and challenges, it is important that land-, water-, and cultural-resource managers understand the limitations and uncertainties associated with the characterization of these changes when making management decisions. A number of methods to predict streamflow in ungaged watersheds have been proposed; however, no one method has been universally accepted or demonstrated to work in all environments (Bloschl and others, 2013).

Every watershed has a unique set of hydrologic, topographic, biologic, land-use, and geologic characteristics that affect how much water is available, the sources of water, and how it flows through the system. This means water availability in every watershed can be affected differently, depending on the specific precipitation and hydrologic conditions in that area. The objective of the original funded research was to provide an automated methodology and data products to the GCPO LCC partners by (1) developing a multi-model synthesis to simulate streamflow using a monthly water balance model and daily time step hydrologic models (physical process-based and statistical) for all watersheds of the

GCPO LCC geographic region and (2) providing products from these models (flow characteristics – magnitude, timing, duration, rate of change, and frequency) for a range of configurations (current and future climate and landscape) through a web interface hosted on the ScienceBase (http://www.sciencebase.gov/catalog/) platform which can be used to inform management decisions. The objective of the work funded by the SE CSC was to support the expansion of the project domain to include basins to the east of the GCPO LCC (figure 1).

Organization and Approach

The specific tasks associated with this project were: 1) select and evaluate USGS streamflow gages in the spatial expansion that would be used for model calibration and evaluation, 2) process climate and land cover datasets into model input files, and 3) execute and evaluate a sensitivity analysis of watersheds in the southeastern United States. Streamgages were selected based on available contemporary daily streamflow data, requiring at least 10 years of data in the period 1980-2013. Climate datasets developed as part of the Coupled Model Intercomparison Project 5 multi-model ensemble available through the USGS GeoData Portal (http://cida.usgs.gov/gdp/) were summarized to the model Hydrologic Response Units (HRUs). A dynamic land cover dataset developed by the USGS Earth Resources Observation and Science Center was converted to hydrologic model parameters (those describing impervious area and vegetation cover type, density, and interception) for the period 1938 to 2100. A sensitivity analysis using the Fourier Amplitude Sensitivity Test (McRae and others, 1982) was used to identify dominant hydrologic processes and parameters. Watersheds of the study area were grouped based on the correlation of their sensitivity matrices and physiography. Each group of watersheds was calibrated for all streamgages identified in Task 1 that were located in that group's geographic range. This method prevents over-calibrating the model to any one streamgage and instead optimizes the model objective function for many streamgages simultaneously.

Project Results

Daily and monthly time step hydrologic models are being developed for the study area which covers 1.16 million square kilometers divided into 20,251 HRUs, connected by a stream network of 10,743 segments. Streamgage data for 1,080 streamgage locations were used for model calibration or evaluation. The Precipitation Runoff Modeling System was used for the daily hydrologic modeling (Leavesley and others, 1983; Markstrom and others, 2015) and the Monthly Water Balance Model (MWBM; McCabe and Markstrom, 2007) was used for the monthly hydrologic simulations. A comparison of measured streamflow against the MWBM simulated output was used to check the streamflow data for non-stationarity and potential flow alteration.

Analysis and Findings

The study area of this research project is relatively large and is very diverse, from the southeastern Coastal Plain to the southern Appalachian Mountains, the Mississippi Alluvial Plain, and the Ozarks. Grouping watersheds based on similar sensitivity and dominant hydrologic processes is being tested as a way to quantify the effects of scale and setting on hydrologic response. To improve hydrologic model development and calibration in areas without streamflow data, termed ‘ungaged basins’, remotely sensed data of evapotranspiration and snow water equivalent are being considered for use in hydrologic model calibration of the models in this study. These ancillary datasets may provide a way to reduce the uncertainty of hydrologic simulations in the absence of measured streamflow.

Conclusions and Recommendations

The objective of this research was to develop a multi-model synthesis of hydrologic response for the southeastern United States. This research project relied heavily on previously completed work performed by the USGS Modeling of Watershed Systems group. Their development of the Geospatial Fabric (http://wwwbrr.cr.usgs.gov/projects/SW_MoWS/GeospatialFabric.html), an aggregation of the NHDPlus hydrography dataset, provided a national framework in which the southeastern United States applications of PRMS and the MWBM could be parameterized. The USGS GeoData Portal (http://cida.usgs.gov/gdp/) provided a way to obtain climate information from several historical and future climate datasets. Summarizing and downloading the climate information was very time consuming, as there are hundreds of climate model simulations available, but would have taken even longer without the GeoData Portal. In addition, the scales of these hydrologic models are pushing the limits of computational power of individual computers. The use of high performance computing (a network of computers) to simulate regional to national hydrologic simulations is a must. The USGS Core Science Systems mission area has invested in these resources making larger, more complex hydrologic applications possible.

Management Applications and Products

This project supplemented ongoing work to provide baseline simulations of the hydrologic cycle for historical and potential future time periods in the southeastern United States. Simulated time series information will be available through a web portal for access by end users. Products were informed by input from a Technical Advisory Committee from the GCPO LCC. These products can inform decisions regarding general water availability in the southeastern United States and the potential impacts of climate and land cover on human and ecological needs.

Outreach

Outreach associated with the overall research project includes a web portal for displaying and retrieving the modeling results, a USGS series report to document the application of the models, a journal article to describe the newly developed regional calibration scheme, and a USGS series fact sheet. A final presentation to the GCPO LCC and its partners will take place upon project completion.

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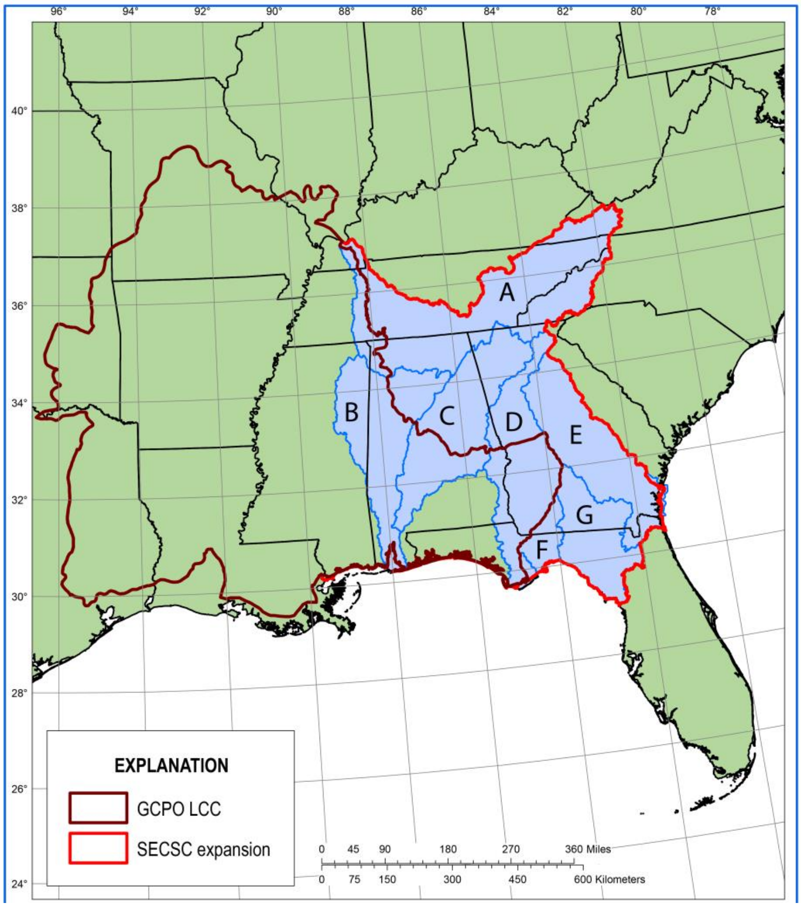

Figure 1. Study area map of the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC) and the expanded area in the Southeast Climate Science Center (SECSC) domain. River basins included in the SECSC expansion include A) Tennessee River Basin, B) Tombigbee River Basin, C) Alabama-Coosa-Tallapoosa River Basin, D) Apalachicola-Chattahoochee-Flint River Basin, E) Altamaha River Basin, F) Ochlockonee River Basin, and G) Suwannee River Basin.