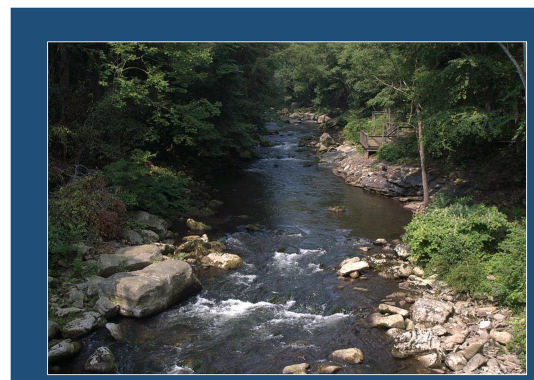
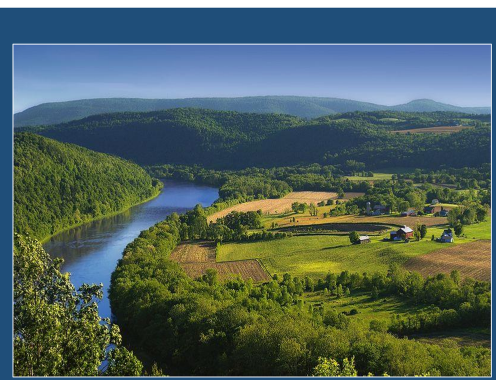


Simulating the Impacts of Projected Climate Change on Streamflow Hydrology for the Chesapeake Bay Watershed

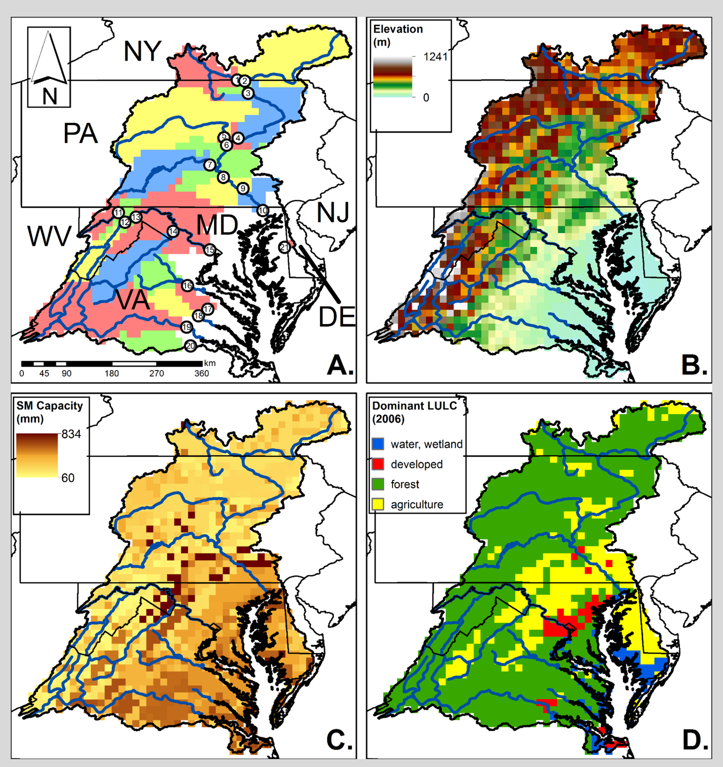
Timothy W. Hawkins, Department of Geography and Earth Science, Shippensburg University



I. Abstract

A gridded model was developed to simulate the hydrology of the Chesapeake Bay watershed (CBW), the largest estuary in the United States. CMIP3 and CMIP5 climate projections were used to drive the model to assess changes in streamflow and watershed-wide hydrology. Index of agreement values indicated good model performance. Annual average temperature is projected to increase 1.9 to 5.4°C by 2080-2099, with the greatest warming occurring in summer and fall in the northern part of the watershed. Annual total precipitation is projected to increase 5.2 to 15.2% by 2080-2099 with the largest increases generally occurring in winter. Average evapotranspiration and rainfall are projected to increase while snowfall, snow water storage, and snowmelt decrease. Subsurface moisture is projected to decrease during the warmer months and the time to recharge increases and in some cases, never actually occurs. Changes in annual runoff for all 346 climate projections averaged 0% (2020-2039), -1.5% (2050-2069) and, -5.1% (2080-2099). There is a 48%, 52%, and 60% chance respectively for the future time periods that annual runoff will be less than baseline values (1950-1999). Extreme runoff projections are overwhelmingly associated with the negative end of the distribution. Runoff increases are confined to January-March and to higher elevations. This study is novel in its use of a large number of climate models, the gridded nature of the hydrologic model, and the simulation of several hydrologic variables all of which allowed for the assessment of both uncertainty in the projections and variation across multiple spatial and temporal scales.

II. Study Area and Hydrologic Model



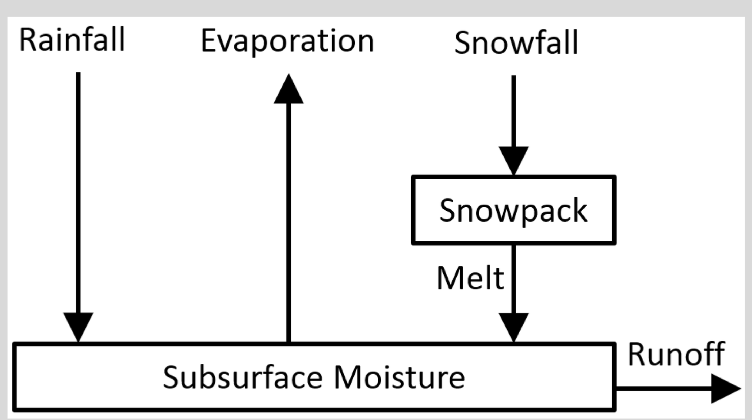


Figure 2 (above). Schematic of the hydrology model. Processes operate on a monthly time step and are calculated for every grid on the watershed.

Figure 1 (left). Stream gages and their subwatersheds (A), elevation (B), subsurface moisture capacity (C), and dominant land use (D) for the model grid cells of the CBW.

III. Model Validation

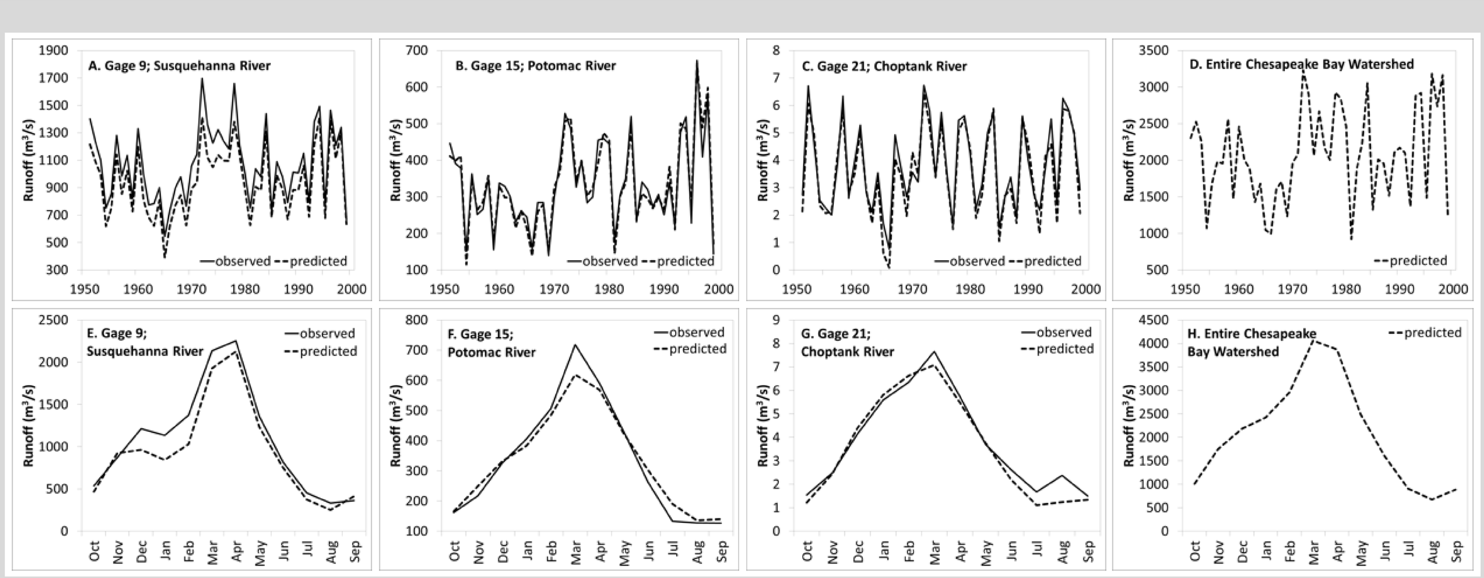


Figure 3. Observed and predicted water year total (a-d) and monthly average (e-h) streamflow for selected gages and the entire CBW from 1950-1999. The average annual index of agreement value for all gages (not shown) was 0.973.

IV. Watershed-Wide Hydroclimate Trends

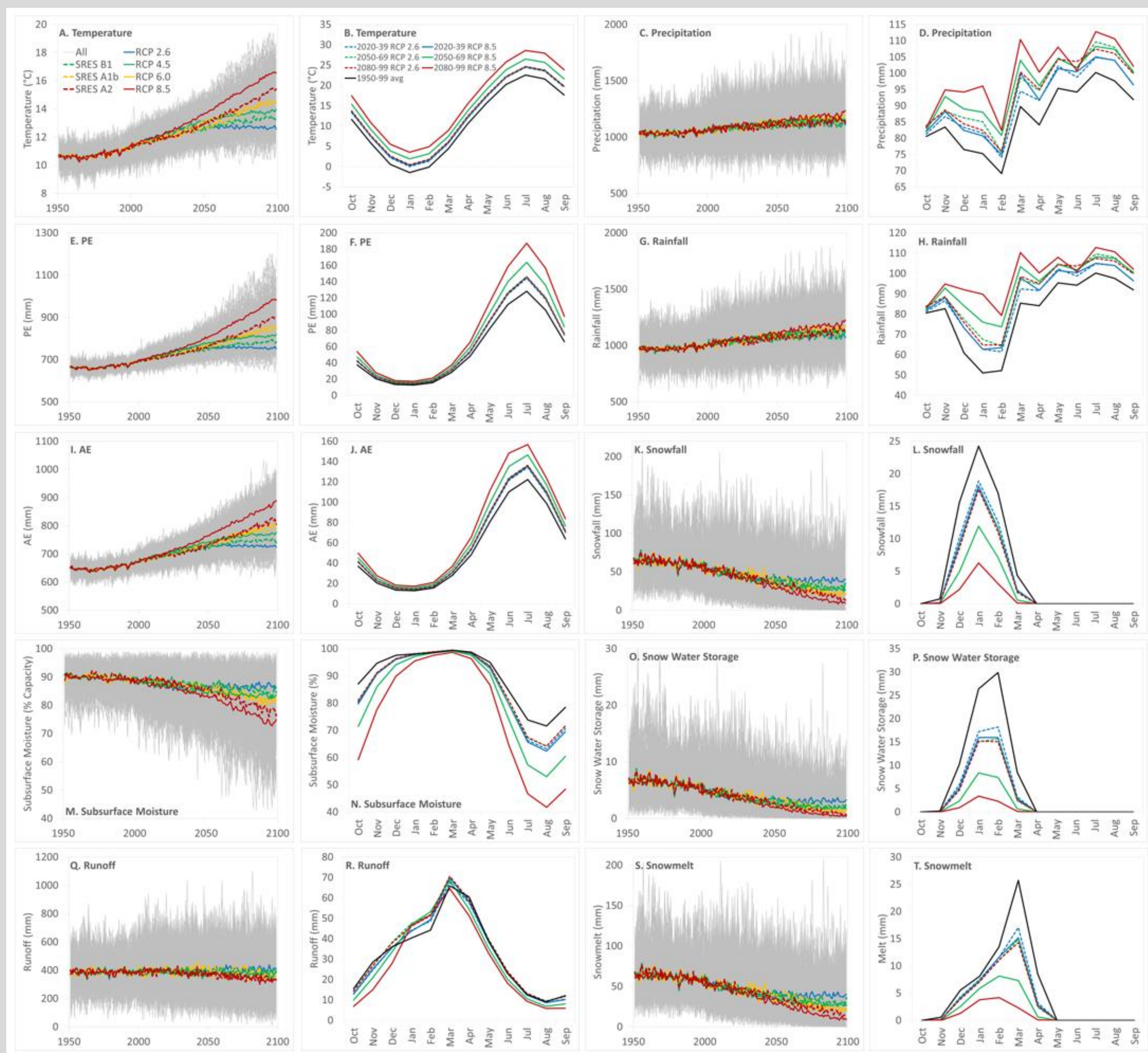


Figure 4. Modeled annual average or annual total (columns 1 and 3) of model output data for the entire Chesapeake Bay Watershed. Results for all 346 projections are shown in gray and averages based on SRES or RCP are colored. Also shown are monthly averages (columns 2 and 4) by SRES or RCP for the same variables for selected time periods. Legends in a and b apply to all components of the figure.

V. Patterns of Hydroclimate Change

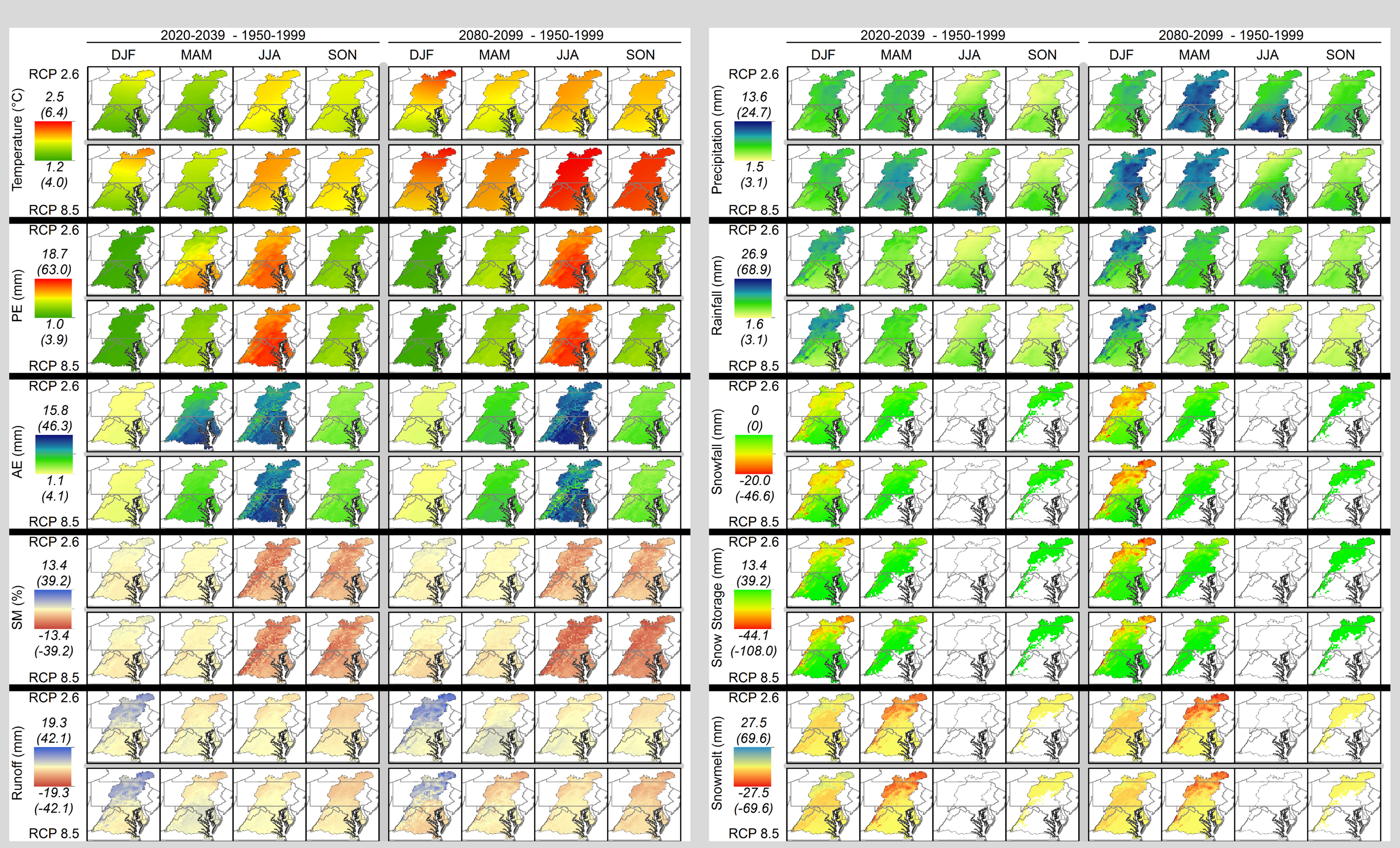
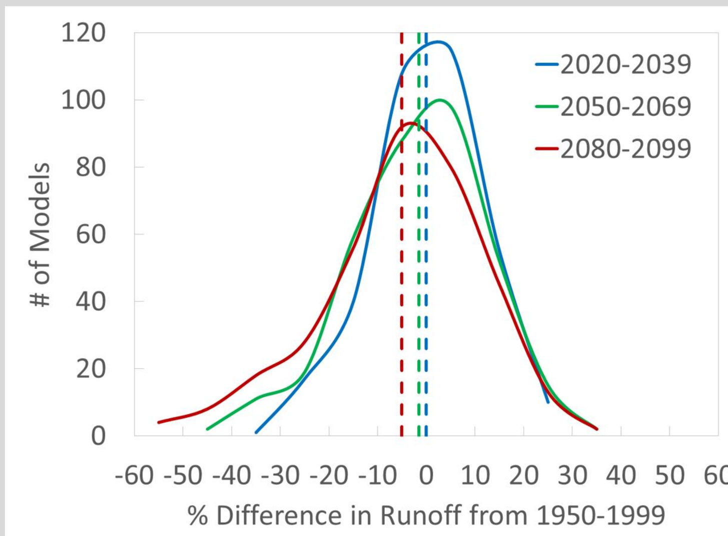


Figure 5. Differences between two future time periods and 1950-1999 for model data based on RCP 2.6 and RCP 8.5. The lower right 4 panels for each variable use a different scale and scale values are indicated by ( ).

VI. Projected Changes in Runoff

Figure 6 (right). Distribution of the percent difference in annual runoff of the entire CBW for three future time periods compared to the baseline period of 1950-1999 that resulted from the hydrologic model being driven by data from 346 climate projections. Vertical lines represent the average percent difference for each future time period.



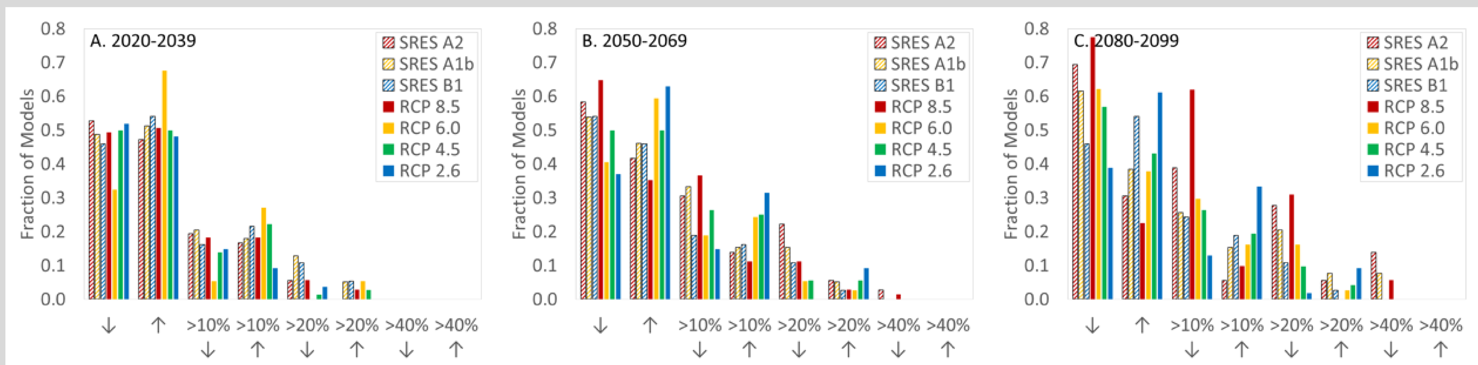


Figure 7. Fraction of models, sorted by SRES or RCP, for three future time periods, whose projected annual runoff decreased or increased by a given percentage compared with the baseline period of 1950-1999.

VII. CMIP3 vs. CMIP5

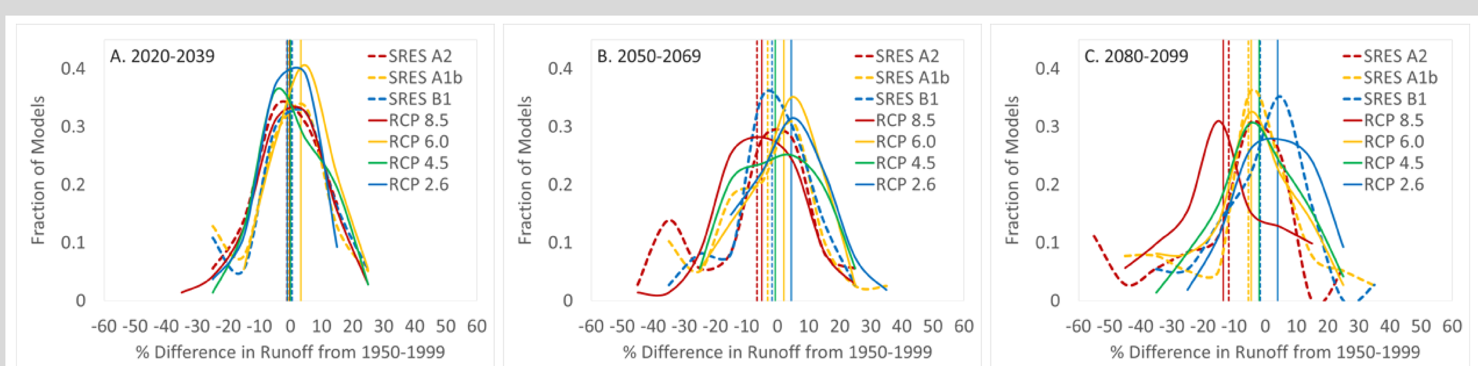
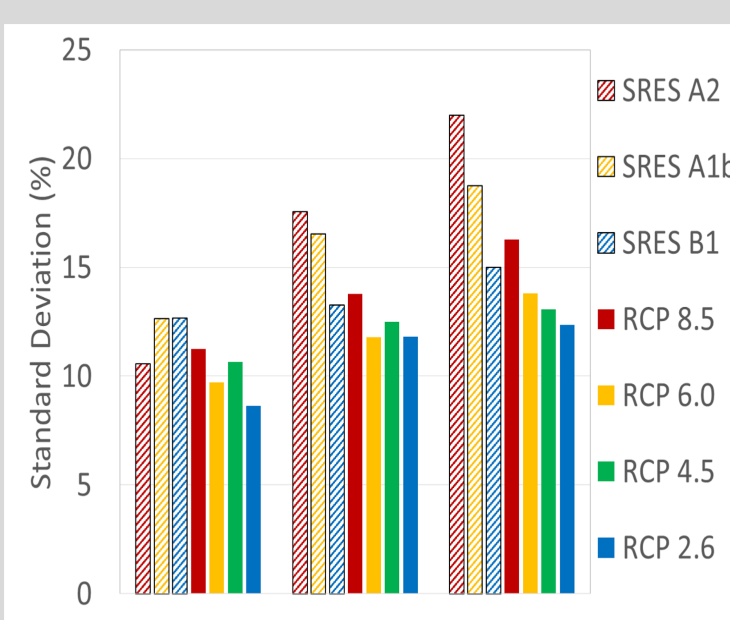


Figure 8 (above). Distribution of the percent difference in annual runoff of the entire CBW for three future time periods compared to the baseline period of 1950-1999 that resulted from the hydrologic model being driven by data from 346 climate projections. Distributions of projections are separated based on SRES or RCP and are displayed as fractions to account for each SRES or RCP having a different number of projections associated with it. Vertical lines represent the average percent difference for each future time period.

Figure 9 (right). Standard deviations associated with the distributions in Figure 8.



SHIPPENSBURG UNIVERSITY

Timothy W. Hawkins, twhawk@ship.edu
Dept. of Geography and Earth Science
Shippensburg University
1871 Old Main Drive
Shippensburg, PA 17257