DEVELOPING SEASONAL STREAMFLOW FORECASTS

TO INFORM SURFACE WATER MANAGEMENT IN OKLAHOMA

2018 // BY TYSON OCHSNER, BRIANA WYATT, ERIK KRUEGER, AND ERIC JONES

Report Guidelines

Title: Developing seasonal streamflow forecasts to inform surface water management in Oklahoma

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Student Status	Number	Disciplines
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Total		

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Publications and Presentations:

- Wyatt, B.M., T.E. Ochsner, and E.S. Krueger. 2019. Improving seasonal streamflow forecasts by incorporating soil moisture data. SSSA International Soils Meeting. San Diego, CA.

- Wyatt, B.M., T.E. Ochsner, E.S. Kreuger, and E.T. Jones. 2019. Improving seasonal streamflow forecasts by incorporating soil moisture data. National Soil Moisture Network annual meeting. Manhattan, KS.

- Wyatt, B.M., T.E. Ochsner, E.S. Kreuger, and E.T. Jones. 2019. Improving seasonal streamflow forecasts by incorporating soil moisture data. Oklahoma State University Plant and Soil Sciences Department Research Symposium. Stillwater, OK.

- Wyatt, B.M., T.E. Ochsner, E.S. Kreuger, and E.T. Jones. 2019. Improving seasonal streamflow forecasts by incorporating soil moisture data. Oklahoma Clean Lakes and Watersheds Association Annual Meeting. Stillwater, OK.

- Wyatt, B.M., T.E. Ochsner, E.S. Kreuger, and E.T. Jones. 2019. Improving seasonal streamflow forecasts by incorporating soil moisture data. Oklahoma State University Plant and Soil Sciences Department Seminar. Stillwater, OK.

- Wyatt, B.M., T.E. Ochsner, E.S. Krueger, and E. Jones. 2018. Improving seasonal streamflow forecasts by incorporating soil moisture data. National Institutes for Water Resources Regional Symposium. Lincoln, NE.

- Wyatt, B.M., T.E. Ochsner, E.S. Krueger, and E. Jones. 2018. Improving seasonal streamflow forecasts by incorporating soil moisture data. Marena, Oklahoma In-Situ Sensor Testbed (MOISST) annual meeting. Lincoln, NE.

- Wyatt, B.M., T.E. Ochsner, E.S. Krueger, and E. Jones. 2018. Improving seasonal streamflow forecasts to inform surface water management in Oklahoma by incorporating soil moisture data. Oklahoma State University Plant and Soil Sciences Department Research Symposium. Stillwater, OK.

Problem and Research Objectives:

Worldwide, an increasingly variable climate and the growing water demands of a rising world population continually threaten the security and sustainability of surface water resources essential for agricultural production, domestic and industrial water use, recreation, and other beneficial uses (Brekke et al., 2010; Wood, 2007; Garbrecht et al., 2004). These threats are amplified by the relatively low skill of many hydrological forecasting systems for adequately predicting future streamflows (Nash and Sutcliffe, 1970). While operational models applied in snow-dominated watersheds have been widely studied and improved (Pagano et al., 2004), seasonal forecasting methods (i.e., forecasts which estimate streamflow volumes over several months) for rainfall-dominated watersheds remain less skillful, reducing their efficacy for water resource management (Cuo et al., 2011; Pagano et al., 2004). Increasing the accuracy of seasonal streamflow forecasts in rainfall-dominated watersheds is critical for improving reservoir operations, drought management, sustainable water use, hydropower production, and irrigated agriculture (Raff et al., 2013; Maurer and Lettenmaier, 2004).

An alternative forecasting method commonly used to predict streamflow in the snow-dominated, mountainous Western U.S. is principal components analysis and regression (or principle components regression, hereafter referred to as PCR), a rigorous statistical method utilized by the Natural Resources Conservation Service (NRCS) (Garen, 1992; Garen and Pagano, 2007). Harpold et al. (2017) showed that the inclusion of soil moisture data in PCR analysis improved operational streamflow forecast skill in 12 snow-dominated watersheds in the Western U.S. Our objective was to evaluate the potential improvements from including in situ soil moisture data in PCR-based streamflow forecasts in *rainfall-dominated* watersheds.

Methodology:

Our study focused on two Oklahoma watersheds- Fort Cobb and Little Washita- as well as two watersheds outside the state- Walnut Gulch, Arizona and Little River, Georgia (Figure 1). Similar to Harpold et al. (2017), we chose to use a two-step PCR analysis in order to distinguish the presumably first-order control of antecedent precipitation on streamflow from the presumably second-order control of soil moisture. In our case, this involved an initial PCR analysis using only antecedent precipitation data as inputs (hereafter called the “baseline” scenario) to estimate seasonal streamflow totals and a secondary PCR (hereafter called the “two-step” scenario) which estimated the residuals between estimated and observed streamflow volumes from the baseline scenario using five soil moisture metrics- volumetric water content, percent saturation, total storage, available storage, and the Soil Moisture Index (SMI). Baseline and two-step models were each used to predict streamflow totals during the four months of greatest streamflow in each watershed at lead times of up to 3 months.

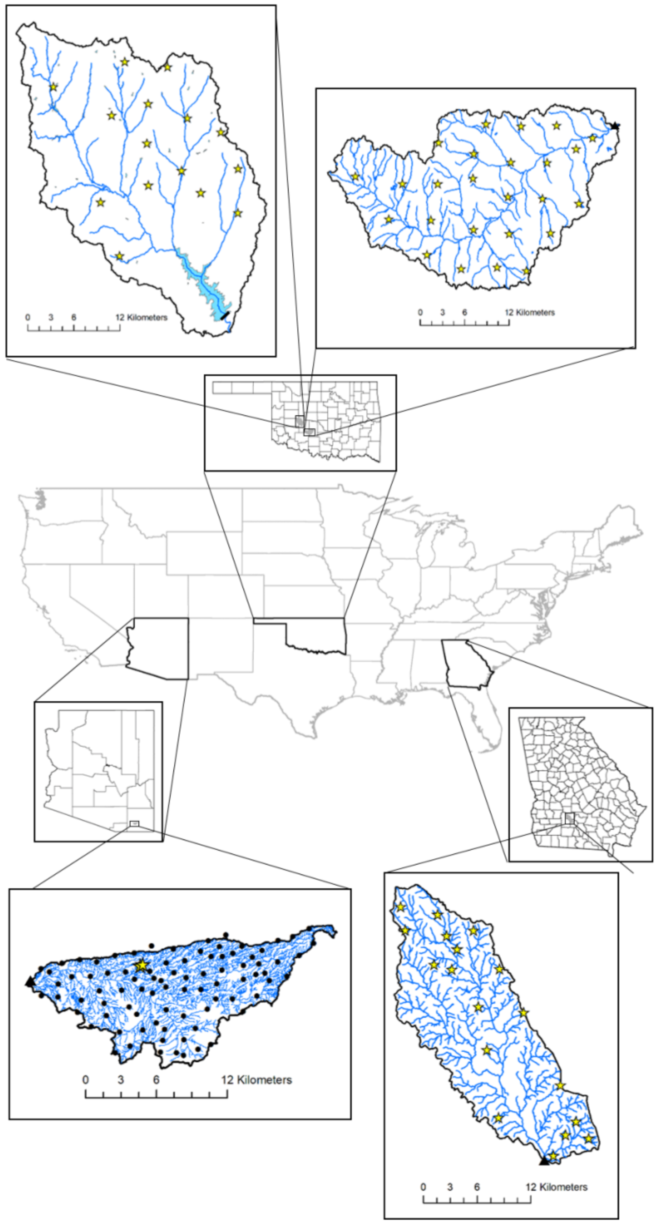

Figure 1. The Walnut Gulch (a) watershed in Arizona, Fort Cobb (b) and Little Washita (c) watersheds in Oklahoma, and the Little River watershed in Georgia (d). Yellow stars represent the locations of co-located precipitation and soil mositure monitoring stations, except for in the Walnut Gulch watershed, where yellow stars indicate the location of soil moisture monitoring stations and black circles indicate the location of precipitation stations. Streamflow gauges are indicate by black triangles in all watersheds, except at Fort Cobb where lake inflow levels were used rather than stream gauge data and where the Fort Cobb Dam is marked by a black bar.

Principal Findings and Significance:

Baseline forecasts made using only antecedent precipitation data were only able to produce forecasts at the 0-month lead time in two of the four watersheds, and no forecasts could be made at longer lead times. The two 0-month baseline forecasts that were made were for the Fort Cobb and Little River watersheds, and explained 27% and 19% of seasonal streamflow variability, respectively. Additionally, both forecasts were classified as unsatisfactory based on performance criteria described by Moriasi et al. (2007).

Conversely, the inclusion of soil moisture data in the two-step forecasts led to forecasts being made in all watersheds at all lead times. These forecasts explained between 35% to 87% of seasonal streamflow variability, with 0-month forecasts explaining an average of 78% of variability. Of forecasts made using soil moisture data, 88% were rated as satisfactory or better based on performance criteria described by Moriasi et al. (2007). Forecasts for all watersheds are shown in Figure 2, where each point represents one water year's streamflow volumes. Figure 2 demonstrates how the inclusion of soil moisture data in PCR forecasts improves forecast accuracy, particularly in years when baseline forecast error is high. These results represent the first evidence that the PCR method can produce accurate seasonal streamflow forecasts in rainfall-dominated regions and that including soil moisture data in the PCR model increases forecast accuracy over forecasts made using antecedent precipitation data alone.

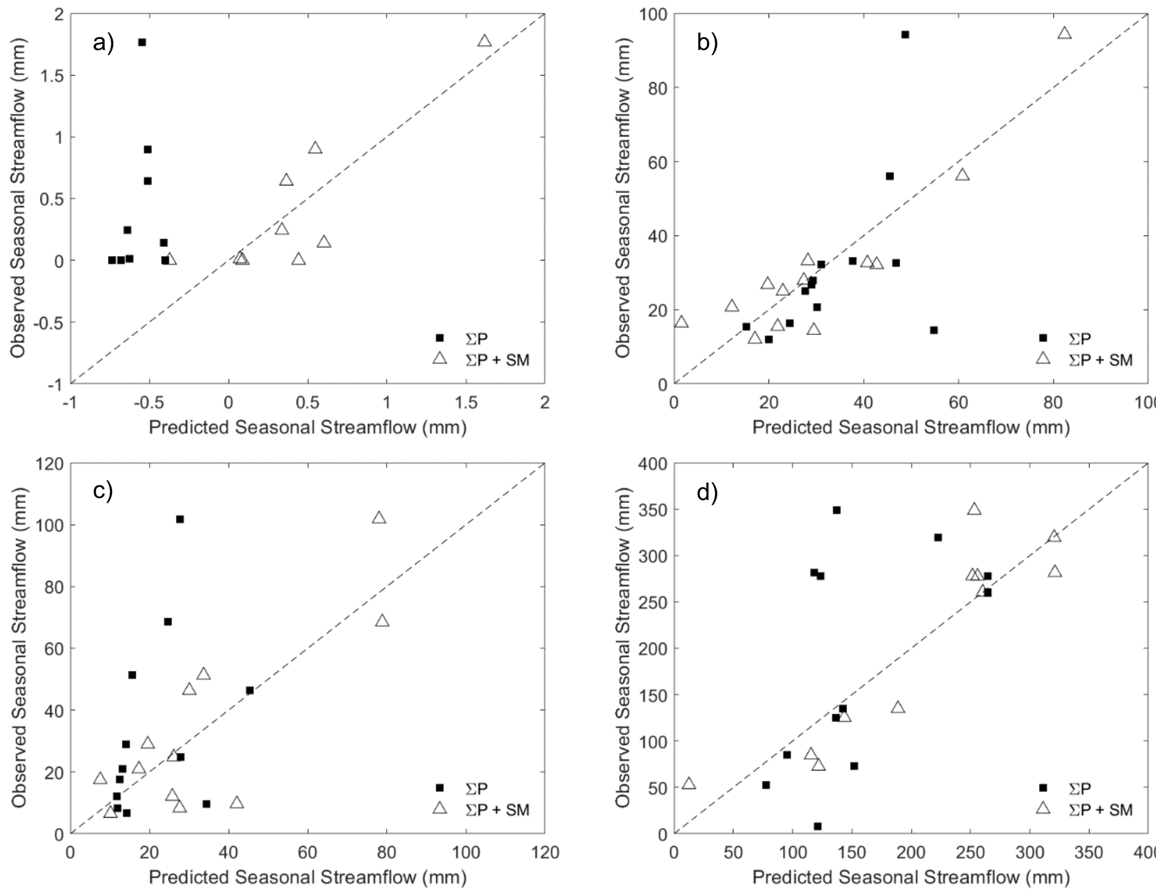

Figure 2. Yearly observed and predicted seasonal streamflow volumes for baseline (black squares) and two-step (triangles) forecasts in the Walnut Gulch (a), Fort Cobb (b), Little Washita (c), and Little River (d) watersheds at the 0-month lead time. Dashed line is 1:1 line. Baseline forecasts were based only on cumulative precipitation prior to the forecast date (ΣP), whereas two-step forecasts included both ΣP and soil moisture (SM) information. Baseline forecasts for the Walnut Gulch and Little River watersheds did not meet the criteria for statistical validity, but baseline streamflow predictions are shown here to demonstrate improvements due to soil moisture data inclusion.

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