Abstract

We examined trends and variability in low flows over the eastern U.S. (S. Carolina to Maine) and their attribution in a changing climate. We selected 149 out of 478 USGS stations over the eastern U.S., taking into account data availability and minimal direct management. Annual 7-day low flows (Q7) were computed from the series of daily stream flow records for 1962-2011 and compared to an antecedent precipitation (AP) index calculated over the corresponding basin for each station.

A north-south increasing-decreasing pattern in low flow trends was found that is associated with trends in AP. The exception is in the southern part of the domain where increasing trends in AP may have been offset by water withdrawals and increasing potential evapotranspiration (PET) as driven by increasing temperature and vapor pressure deficit. Teleconnections between detrended Q7 and nine atmospheric and oceanic climate indices indicate that the North Atlantic Oscillation (NAO) and Pacific North America (PNA) pattern show statistically significant correlations for Q7 at one and two month lead, respectively. Our findings suggest that the risk of future hydrological droughts is increased during a strong negative phase of the NAO and positive phase of the PNA during the summer, and may be further enhanced with temperature driven increases in PET.

Background: Low Flow Hydrology

Stream flow is a hydrological response of the land surface at the catchment scale to precipitation and is a major water resource available for human use and ecological needs. During the dry season, low precipitation (low supply) and high evapotranspiration (high demand) conspire to reduce stream flow and water availability. This natural seasonal hydrological phenomenon is known as the low flow period (Smakhtin, 2001). With variations in climate, decreases in seasonal precipitation and increases in potential evapotranspiration can lead to reductions in low flows, with adverse effects on human activities and ecosystem function (Bradford and Heimonen, 2008).

Drivers of low flow variability are complex, and include antecedent precipitation, atmospheric demand, surface water management (urbanization, dams, reservoirs, and irrigation), and groundwater withdrawals.

Changes in Stream Flows over Eastern United States

• 1950-1990s: Increasing (+) trends in low and median flows due to increasing fall precipitation

• 2000s-2010s: Decreasing (−) trends in low flows (e.g. low flow volumes) due to increasing trends in temperature-driven potential evapotranspiration

Figure 1: (a) Time series of daily stream flow and precipitation at one station (USGS 01112500) for 1996. (b) Time series of annual 7 day low flow and 30-day total antecedent precipitation at one to three month lead before the date of the annual low flow event (e.g. the antecedent precipitation accumulated during 0-29, 30-59, and 60-89 days, respectively) for 1962-2011.

Recent Weakening in Associations of Antecedent Precipitation


Figure 2: Map of the locations of the 149 USGS stations and the masks of their corresponding upstream basins. The sizes of blue circles represent the sizes of the basins.

Figure 3: Spatial distribution of the trends in annual 7-day low flows (Q7) and 90-day accumulated antecedent precipitation (AP-90) from three versions of Mann Kendall test (MK-0, MK-1, MK-2) over 1962-2011. Dots represent stations with no regulation.

Figure 4: Same as Figure 3 except for the period (a) and (c): 1962-1991 and (b) and (d): 1982-2011.

Associations with Atmospheric Circulation

• North Atlantic Oscillation (NAO)

July–September (JAS): Significant and positive (+) correlation with the Mid-Atlantic region

• Pacific North American (PNA) Oscillation

June–August (JJA): Significant and negative (−) correlation with West Virginia and Virginia

(a) 3-month for Maximum Correlation (Low flow vs. NAO)

(b) 3-month for Maximum Correlation (Low flow vs. PNA)

Figure 5: Spatial distribution of the trends in six-month warm season (May–October) potential evapotranspiration (PET) from the MK-0 test for (a) 1962-2011, (b) 1962-1991, and (c) 1982-2011.

Conclusions

1) A dipole pattern of increasing and decreasing (north-south) trends in Q7 low flows exists.

2) Decreasing trends in Q7 over the Mid-ATL region and the southern part of the SE region including North and South Carolina and Virginia.

3) The decreasing trends are possibly linked to increasing trends in PET driven by warming temperature.

4) NAO (−) and PNA (+): A favorable condition for drought over the Mid-ATL and SE regions.

Relevance of Results

Adverse effects for water and energy:

• Food Production

• Domestic Uses

• Public Health

• Electricity Production

• Ecological Quality

References


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