Trends in Streamflow in the Missouri River Basin from 1957 to 2006

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Abstract

The hydrologic consequences of the late 20th century atmospheric warming are of great interest to water managers and agricultural producers in the Northern Great Plains and the Missouri River Basin (MRB). For several other regions of North America, changes in streamflow characteristics are attributed to atmospheric warming, such as the earlier snowmelt runoff from the Sierra Nevada Mountains of California. The MRB streamflow record was examined for evidence of long-term trends in the mean annual flow, minimum flow, and seasonality for all stations (205) with continuous record for the last 50 years (1957-2006). Trends were statistically analyzed using the non-parametric Kendall Tau test.

Fifty-five stations demonstrate an upward trend in streamflow, whereas 26 stations demonstrate a downward trend for the study period. No trends were significant for most stations, presumably due to the large interannual variability that is characteristic of the Northern Great Plains. Stations with trends are distributed in regional patterns. Downward streamflow trends were found in western Montana, Wyoming, Nebraska, and Kansas. Upward trends were found in North Dakota, South Dakota, Nebraska, and Iowa.

Minimum flows for the period were examined using 62 stations of the Hydro-Climatic Data Network that have continuous record for the period 1957–2006. Twenty-three stations in North Dakota, South Dakota and Iowa demonstrate an upward trend of minimum flows. Three stations in Montana and Wyoming demonstrated a downward trend of minimum flows. Monthly streamflow records at 205 stations were analyzed for seasonality using the temporal centroid of streamflow (CT) or center of mass approach. At 28 stations, runoff occurs earlier in the year. At six stations, runoff occurs later in the year but these sites are below reservoirs where changes in release patterns may explain the later trend.

Introduction

The Missouri River drains parts of 10 states including the Rocky Mountains in the west, vast prairies of the Great Plains, and agricultural cropland in the east. If streamflow characteristics are changing, reservoir management, water availability for domestic and agricultural use, waterfowl production, and ecosystem function could be complicated and in some cases adversely affected. At issue is whether streamflow changes, documented for other regions of North America, are occurring in the Missouri River Basin (MRB). Change in streamflow characteristics documented elsewhere include earlier snowmelt runoff (Roos, 1991; Stewart and others, 2003; Dettinger, 2005), declines in summer flows in the Desert Southwest (Anderson and others, 2005), and changes in seasonality in New England (Hodgkins and others, 2003). Qian and others (2007) report an upward trend in evapotranspiration over the Mississippi River Basin during 1949–97.

Approach

Streamflow records were examined for stations in the MRB with 50 years of continuous record for evidence of change in mean annual flow and seasonality. A 50-year period was selected to optimize relations for the period of record and the number of stations (the number of stations declines rapidly as the period of record is increased). Trends were statistically analyzed using the Kendall Tau test for non-parametrics (Conover, 1980). A loess best-fit curve was plotted for individual stations. Annual streamflow records were analyzed for seasonality using the temporal centroid of streamflow (CT) or center of mass approach (fig. 1) (Stewart and others, 2004).

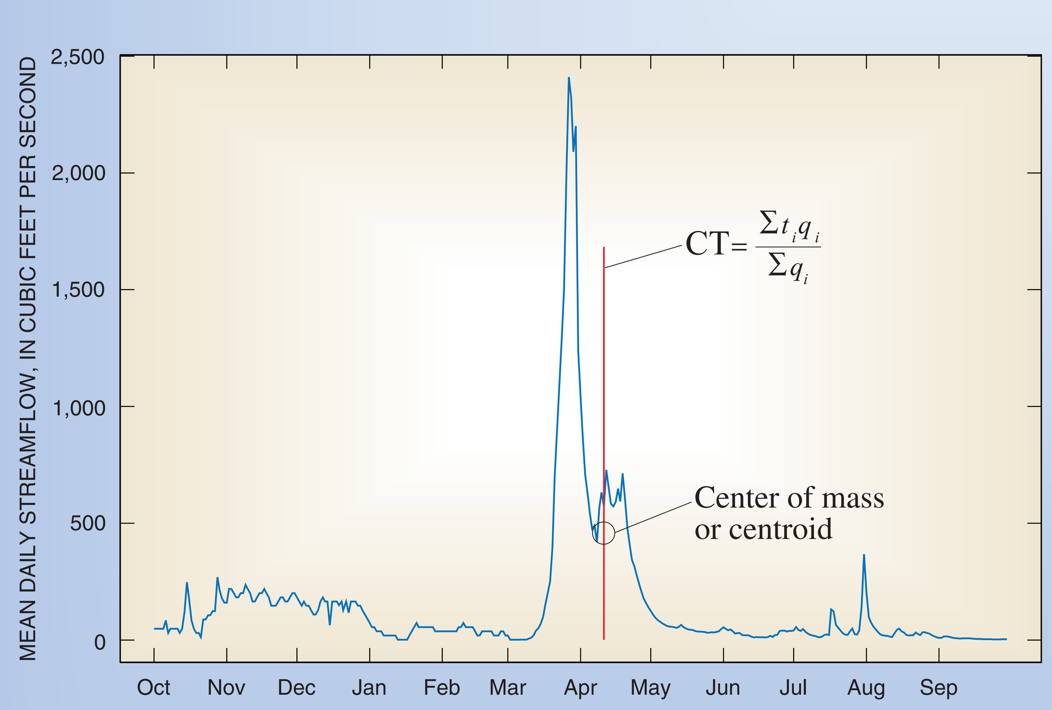


Figure 1. Sample annual streamflow hydrograph.

American bison.

Results

Of the 205 stations with 50 years of record, 55 stations demonstrate statistically significant ($p \leq 0.05$) downward trends in annual flow, while 26 stations demonstrate upward trends. The stations demonstrating trends are geographically grouped (fig. 2), with the downward trends in the mountainous west and upward trends in the Dakotas and eastern portions of the basin. Also, several stations with downward trends are in southern Nebraska and northern Kansas (fig. 2). The downward trends in streamflow in the western part of the MRB help explain the low water levels in recent years in the mainstem Missouri River reservoirs, such as Oahe (fig. 3). The Missouri River at Ft. Benton station has the longest period of record in the MRB (115 years). This station was examined for a trend to compare with the downward trends evident in the 50-year period. Streamflow at the Ft. Benton station is declining over the 115 period of record (fig. 4). An example of a station with a downward trend in flow is the Yellowstone River at Billings, Montana (fig. 5). An example of an upward trend in flow is the James River near Scotland, South Dakota (fig. 6).

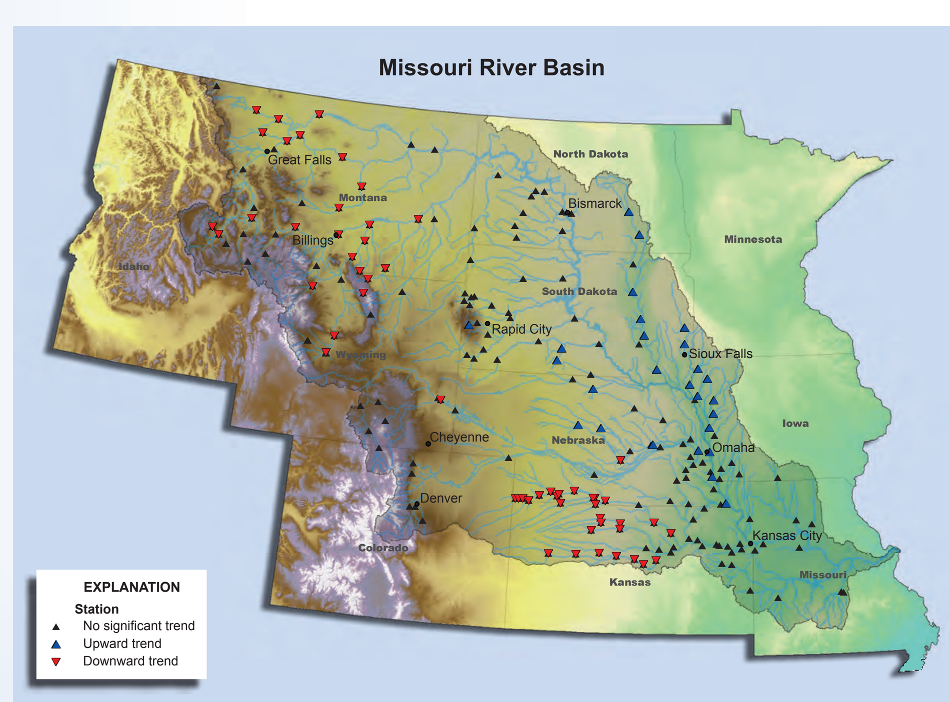


Figure 2. Annual streamflow trends for 205 stations with 50 years of record, 1957–2006.

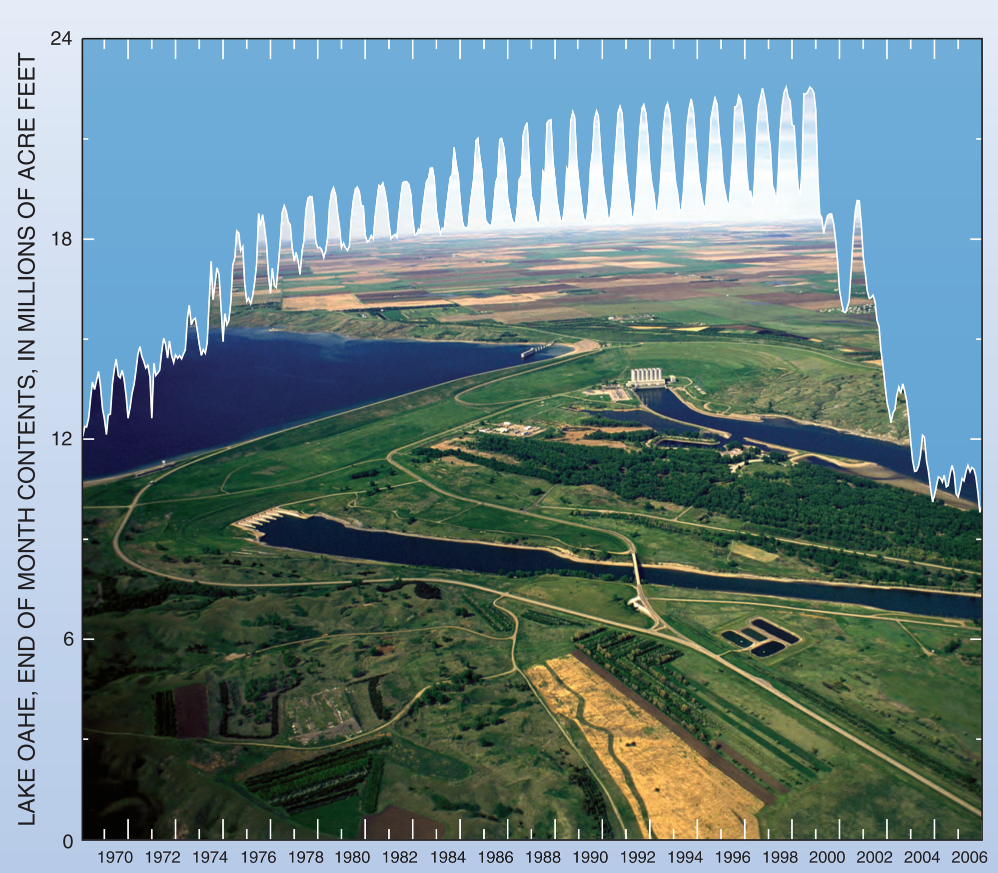


Figure 3. End of month contents for Lake Oahe, South Dakota.
(Oahe Dam and power plant photograph by South Dakota Tourism.)

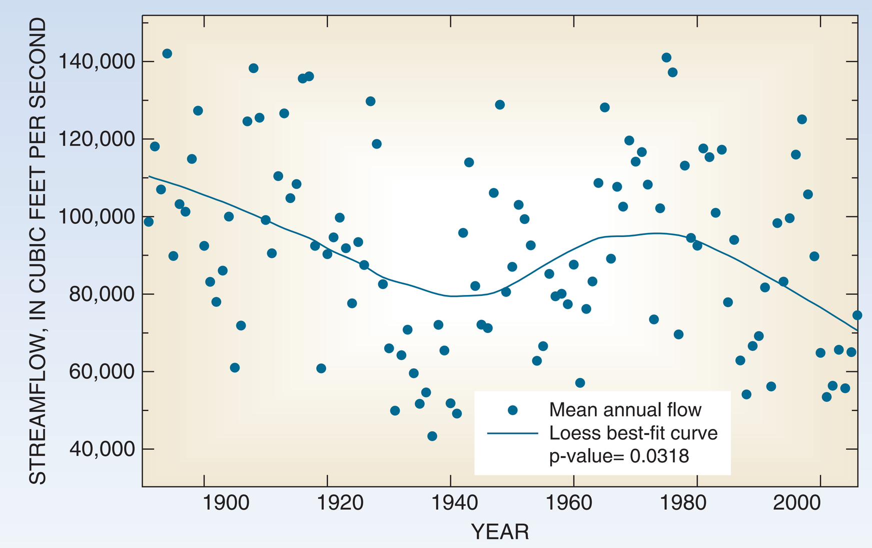


Figure 4. Mean annual streamflow and loess best-fit curve for the Missouri River at Fort Benton, Montana, 1890–2006.

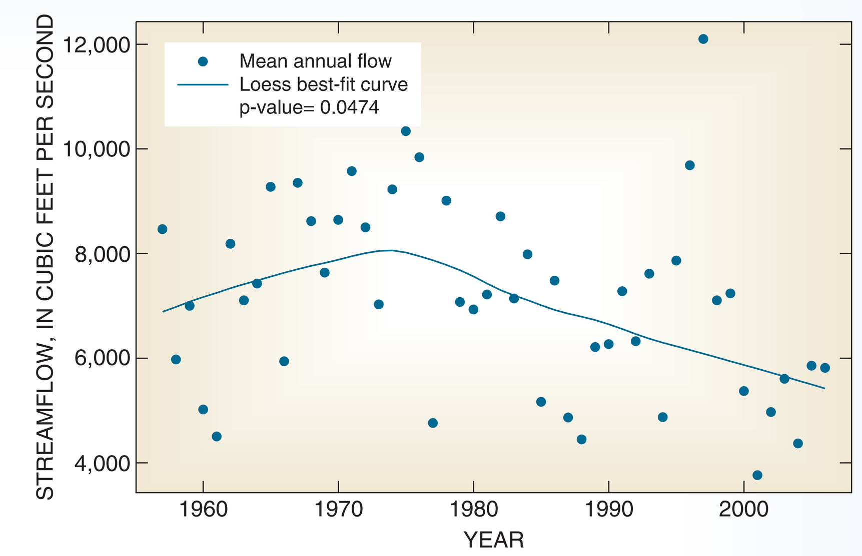


Figure 5. Mean annual streamflow and loess best-fit curve for the Yellowstone River at Billings, Montana, 1957–2006.

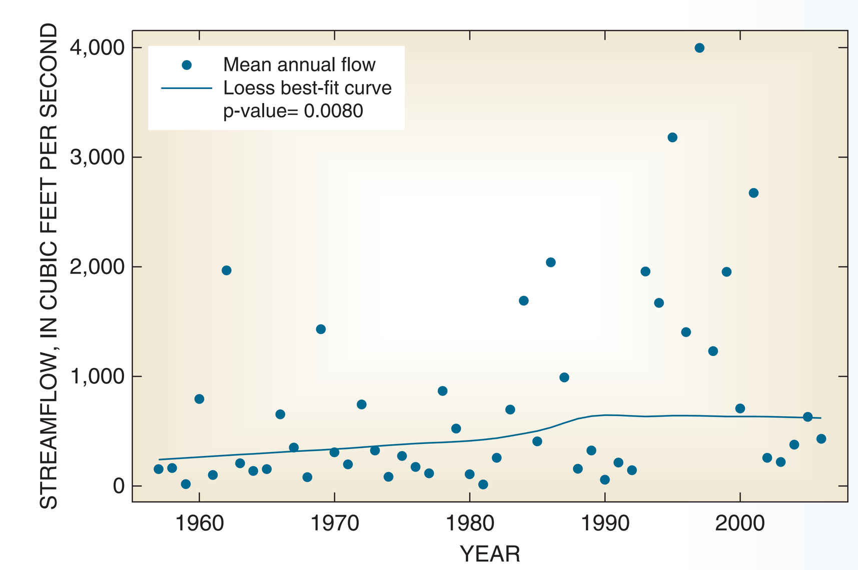


Figure 6. Mean annual streamflow and loess best-fit curve for the James River near Scotland, South Dakota, 1957–2006.

The U.S. Geological Survey operates streamflow gaging stations that are considered climate sensitive—known as the Hydroclimatic Data Network (HCDN). Trends in minimum flows were examined using monthly values for the HCDN stations in the MRB (fig. 7). Upward trends were found in the eastern part of the basin where annual flows also are trending upward. Downward trends were found at three HCDN stations in the mountainous west, where annual flows also are trending downward.

Nearly all of the 205 stations show a trend towards an earlier center of mass, but only 28 stations exceed the significance threshold of ($p \leq 0.05$) (fig. 8). An example of a station with a trend towards earlier spring runoff is the Cheyenne River at Edgemont, South Dakota, where the seasonality (as determined by the center of mass approach) changed substantially from early June in the 1950s to mid-March in 2006 (fig. 9).

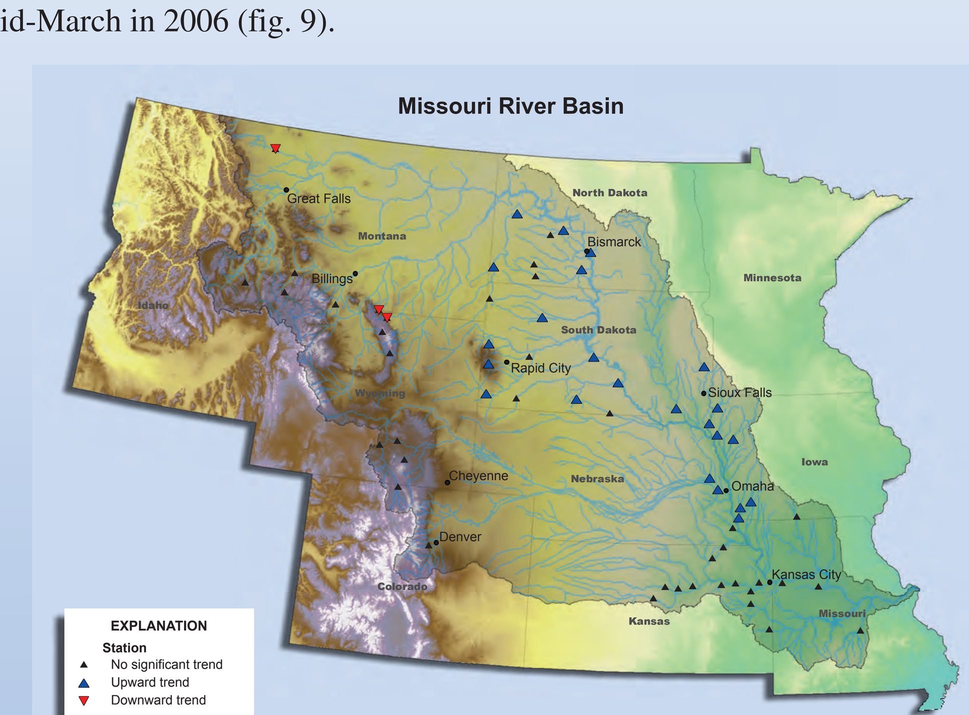


Figure 7. Minimum streamflow trends for Hydro-Climatic Data Network (HCDN) stations, 1957–2006.

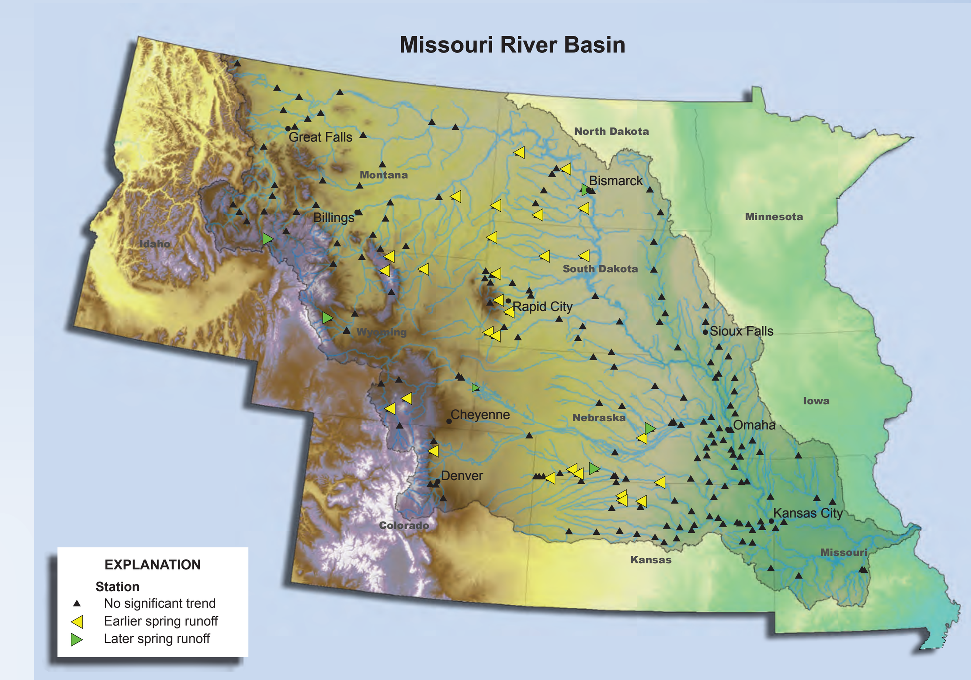


Figure 8. Seasonal streamflow trends for the 205 stations with 50 years of record, 1957–2006.

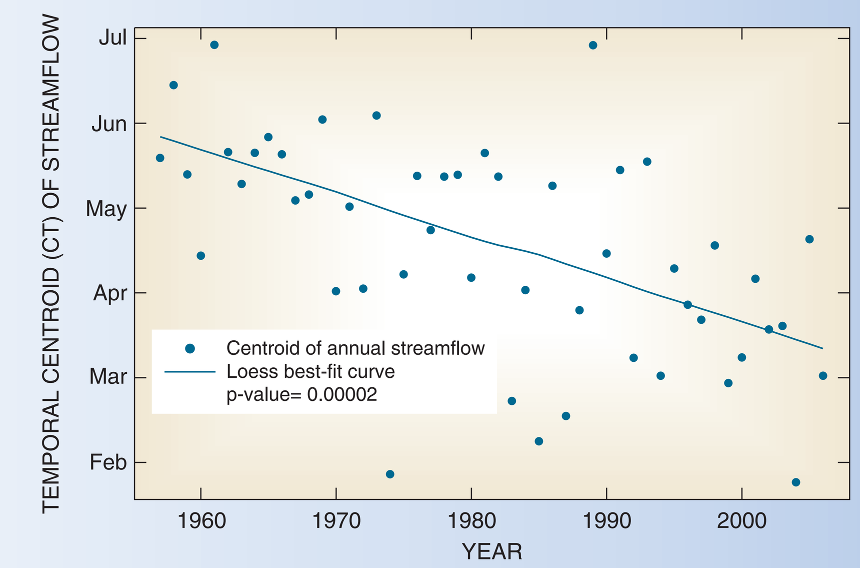
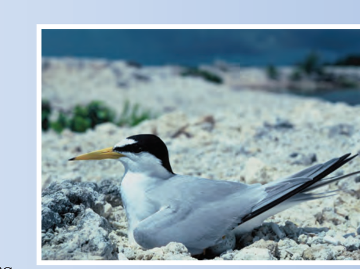


Figure 9. Seasonality (CT) of streamflow for the Cheyenne River at Edgemont, South Dakota, 1957–2006.

Pallid Sturgeon (photograph courtesy of U.S. Fish and Wildlife Service)

Implications

For much of the United States, the implications of changes in streamflow timing are most important for water-supply management and reservoir operations. For the MRB, water supply for communities has grown in importance because of the extensive construction of rural water pipelines in the Dakotas. Downward trends of streamflow for the mainstem reservoirs may have profound effects for endangered species such as the Pallid Sturgeon and the Least Tern. Downstream navigation on the Missouri River and the Mississippi River also depend upon sufficient flows and reservoir releases from the major upstream reservoirs such as Oahe.



Least Tern (photograph courtesy of U.S. Fish and Wildlife Service)

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