ABSTRACT


At global and regional scales, long-term changes in climate have been observed. Several studies have reported a sharp increase in global average air temperatures, with most of the warming happening in recent decades. Warming in air temperature has resulted in the reduction of frost days by up to two weeks and shorter winters in the Great Lakes region. Climate projections suggest that the Midwest will experience warmer air temperatures and a shift in precipitation from the summer into the winter and spring; this is likely to change regional hydrology especially during the cold seasons.

Cold season processes, such as seasonally frozen soil and snow accumulation, play an important role in the hydrology of the Midwestern United States. Melting of snow or rainfall events over a frozen soil surface may result in increased runoff as soil frost impedes infiltration rates. The process of soil freezing and thawing also weakens soil bonds, increasing the risk of soil erosion. These processes are likely to change in response to climate change. Therefore, the present study identifies spatial and temporal patterns in cold season processes in response to past and future climate change.

This study analyzed historic observations jointly with simulations from a large-scale hydrology model to identify trends and significant changes to cold season hydrology in the Midwestern United States. Historical observations for six states in this region were tested for trends in soil frost variables such as freeze-thaw cycles and number of soil frost days. These observations as well as streamflow data were used to calibrate
and evaluate the Variable Infiltration Capacity (VIC) hydrology model. The resulting model setup was then used to extend the observational record spatially within the six state region and temporally from 1917 through 2099 using a mixture of observed and projected climate data.

Analysis of historical observations at several sites located in the study domain identified significant increases in mean maximum and mean minimum cold season soil temperatures, leading to reductions in the annual number of soil frost days since 1966, the earliest occurrence of available observational records. Model predicted variables such as soil temperature, soil ice content, freeze-thaw depths and snow accumulation for the study domain indicate that there has been a delay in the onset day of soil frost in the Midwestern U.S. since 1917 by up to 36 days and that much of the region has experienced a reduction in the annual number of soil frost days by up to 18 days. Future climate projections for the Midwest extend many of these trends so that by the end of the 21st century, the number of days with soil frost may decrease by as much as two months from the current conditions.