

Interdecadal changes in the freeze depth and period of frozen soil on the Three River Source Region in China from 1960 to 2014

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The freeze depth and period (including freeze first date, freeze last date and duration) are important indexes of frozen soil. In this study, we used observed soil freeze depth data from meteorology stations to investigate the interdecadal changes in the freeze depth and period on the Three River Source Region (TRSR) in China from 1960 to 2014. Using data from 14 stations, we analyzed trends in the freeze depth, first date, last date and duration of frozen soil, and examined their relationships to air temperature, thawing index, snow depth, precipitation, as well as each other. The results showed: 1) a continuous, accelerated decreasing trend in freeze depth appeared in the TRSR during the 1985-2014 and 2000-2014 periods, compared with that during the 1960-2014 period. The rates of decrease were $-3.98 \text{ cm decade}^{-1}$ over the past 55 years, $-8.93 \text{ cm decade}^{-1}$ over the past 30 years and $-13.98 \text{ cm decade}^{-1}$ over the past 15 years. 2) The freeze first date had been delayed and the freeze last date had been advanced significantly over the past 55 years. The advanced trends in freeze last date were more significant than the delayed trends in freeze first date in all three study periods. The freeze duration also experienced an accelerated decrease during 1960-2014, 1985-2014 and 2000-2014. The rates of decrease were $-7.52 \text{ day decade}^{-1}$ over the past 55 years, $-14.74 \text{ day decade}^{-1}$ over the past 30 years and $-16.90 \text{ day decade}^{-1}$ over the past 15 years. 3) The freeze depth and period were strongly affected by air temperature, thawing index and soil moisture (precipitation), but not by snow. The freeze depth, freeze first date, freeze last date and duration also influenced each other. 4) These decreasing trends in freeze depth and duration are expected to continue given the increasing trends in air temperature and precipitation in this region.