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Peak Summer Vegetation Greenness Decreases across Northern America Ecosystems in Response to Spring Warming

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Abstract In the Northern mid- and high-latitude, plant growths are typically sensitive to climate warming. In the recent decades, snow-dominated Northern America ecosystems have experienced largest warming during winter and spring seasons. Warming related shifts towards earlier springs and longer growing seasons could have profound impact on plant productivity in late summer due to water limitation. Here, we analyze relationships between longer non-frozen period (indicative of length of growing season), peak summer vegetation greenness index (NDVI) and a drought index Palmer Drought Severity Index (PDSI) at inter-annual time scale by using the three decades (1982-2010) of satellite vegetation records, microwave based daily Freeze-Thaw (FT) record and climatic data. All satellite data and climate data were aggregated (pixel aggregation) or downscaled (nearest neighbor) to a common 0.25° x 0.25° spatial resolution. We find that longer non-frozen period caused decline in summer soil moisture availability. This suggests a mechanism of *'longer non-frozen period- summer drought'* and led to widespread decline in peak summer vegetation greenness or productivity across the snow-dominated Northern America ecosystems. The most vulnerable ecosystems to this mechanism are boreal forests and woody savannas (ca. one-third of its areal proportions of statistical significance at $p<0.1$) followed by grasslands and open shrublands (ca. 15% of its areal proportions). Further, this mechanism operates more prominently at higher elevation regions. In future under accelerated spring warming, this mechanism may be exacerbated owing to longer non-frozen period. With projections of accelerated spring warming in response to rising greenhouse gases in the atmosphere and associated shift to longer non-frozen period is likely to have a larger influence on peak summer plant productivity owing to persistent soil moisture deficit over the Northern America ecosystems. This may be an effective mechanism for regional-scale 'boreal forest dieback' through adverse impacts on plant productivity and tree mortality.