

# Extreme warm temperatures alter forest phenology and productivity in Europe

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## Abstract

Recent climate warming has shifted the timing of spring and autumn vegetation phenological events in the temperate and boreal forest ecosystems of Europe. In many areas spring phenological events start earlier and autumn events switch between earlier and later onset. Consequently, the length of growing season in mid and high latitudes of European forest is extended. However, the lagged effects (i.e. the impact of a warm spring or autumn on the subsequent phenological events) on vegetation phenology and productivity are less explored. In this study, we have (1) characterised extreme warm spring and extreme warm autumn events in Europe during 2003-2011, and (2) investigated if direct impact on forest phenology and productivity due to a specific warm event translated to a lagged effect in subsequent phenological events. We found that warmer events in spring occurred extensively in high latitude Europe producing a significant earlier onset of greening (OG) in broadleaf deciduous forest (BLDF) and mixed forest (MF). However, this earlier OG did not show any significant lagged effects on autumnal senescence. Needleleaf evergreen forest (NLEF), BLDF and MF showed a significantly delayed end of senescence (EOS) as a result of extreme warm autumn events; and in the following year's spring phenological events, OG started significantly earlier. Extreme warm spring events directly led to significant ( $p=0.0189$ ) increases in the productivity of BLDF. In order to have a complete understanding of ecosystems response to warm temperature during key phenological events, particularly autumn events, the lagged effect on the next growing season should be considered.