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Responses of spring phenology to climate warming reduced over the past decades

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The phenology of spring leaf unfolding is one of the key indicators of the climate change on ecosystems, and influences regional and hemispheric-scale carbon balances and plant-animal interactions. Changes in the phenology of spring leaf unfolding can also exert biophysical feedbacks on climate by modifying the surface albedo and energy budget. Recent studies have reported significant advances in spring phenology as a result of warming in most northern hemisphere regions. Climate warming is projected to further increase, but the future evolution of the phenology of spring leaf unfolding remains uncertain — in view of the imperfect understanding of how the underlying mechanisms respond to environmental stimuli. In addition, the relative contributions of each environmental stimulus, which together define the apparent temperature sensitivity of the phenology of spring leaf unfolding (advances in days per degree Celsius warming, ST), may also change over time. An improved characterization of the variation in phenological responses to spring temperature is thus valuable, provided that it addresses temporal and spatial scales relevant for regional projections. Using long-term in situ observations of leaf unfolding for seven dominant European tree species at 1,245 sites, we show here that the apparent response of leaf unfolding to climate warming (ST, expressed in days advance per °C) has significantly decreased from 1980 to 2013 in all monitored tree species. Averaged across all species and sites, S_T decreased by 40% from 4.0 $\pm$ 1.8 days $^{\circ}C^{-1}$ during 1980-1994 to 2.3 $\pm$ 1.6 days $^{\circ}C^{-1}$ during 1999-2013. The declining ST was also simulated by chilling-based phenology models, albeit with a weaker decline (24%-30%) than observed in situ. The reduction in S_T is likely to be partly attributable to reduced chilling. Nonetheless, other mechanisms may also play a role, such as 'photoperiod limitation' mechanisms that may become ultimately limiting when leaf unfolding dates occur too early in the season. Our results provide empirical evidence for a declining S_T, but also suggest that the predicted strong winter warming in the future may further reduce S_T and therefore result in a slowdown in the advance of tree spring phenology.