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Effects of recent warm and cold spells on European plant phenology

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Numerous studies have concurrently documented a progressively earlier start for vegetation activity in spring and a lengthening of the growing season during the last 2 to 5 decades in the temperate northern hemisphere. In contrast to climatic factors influencing autumn phenology, the climate signal controlling spring and summer phenology is fairly well understood: nearly all phenophases correlate with temperatures in the preceding 1 to 3 months. The changes currently experienced by emergence of vegetation may reach 6 to 8 d per °C.

But how will this well-known, often linearly described relationship change in case of more frequent and more stronger temperature extremes? We thus studied the temperature response of European phenological records to cold and warm spells using the COST725 data base (www.cost725.org). We restricted our analysis to the time period 1951-2006 due to the relatively better coverage of Europe by phenological records. Up to now, 20 European countries contributed more than 7 Mio. phenological observations to this data base including 64 species and 22 different phases. The phenological observations compiled originated from different sources and phenological networks. Unfortunately there is no entire coverage and the data are very lumped.

Cold and warm spells were identified using daily mean temperature data (1951-2006) on a 0.5° grid for Europe provided by the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org, http://eca.knmi.nl). The study area covered Europe and was limited to 40°E. For the whole study period, mean monthly and seasonal mean temperatures well as the corresponding standard deviations were calculated for each grid point. The annual monthly or seasonal temperature at a grid point was defined as cold (very cold, warm, very warm) by its deviation from the long-term average (more than 1.5 or 3sd, respectively). Warm and cold spells were selected when either the percentages of crossing 1.5sd were greater than 50% for the total Europe or the percentages of crossing 3sd were greater than 1%, respectively. For spring phases, e.g., we analysed the warm spring spells of March, April and spring 1989, February and March 1990, March 2001, February 2002, and the cold spells of February 1952, spring 1955, February 1956, and March 1996.

Due to the restrictions of the COST database, we used as phenological reference 1930-1939 average data from European maps published by SCHNELLE in 1965. They comprise mean starting dates of five phenological seasons from spring to autumn include beginning of (1) sowing of summer cereals for the season of earliest to early spring, (2) flowering of apple in full spring, (3) formation of ears of winter wheat in the middle of early summer, (4) harvest of winter wheat at the end of full summer, and (5) sowing of winter wheat in the later part of full autumn. The maps were scanned in two pieces on a A3 scanner. A highly novel semi-automatic procedure for classification and digitalisation in ArcGIS and Definiens Developer was set up to orthorectify the map, to eliminate all background artefacts, redundant mapping, such as the grid, altitudinal shading, rivers, annotations, and to digitise the isoline information as shape files. Finally, the mean onset dates were re-assembled on a 0.5° grid. Phenological extremes were calculated as deviations of the actual onset dates in the COST725 database from the corresponding seasonal mean by SCHNELLE seasons at the nearest grid point.

The results highlight that cold and warm spells are in general very well mirrored by phenology. Apparent spatial differences might result from different chilling conditions in winter leading to non linear responses of warming in spring. Warm spells may result in spatially heterogeneous acceleration of plant development, the impact of cold spells should be more homogenous in space.