



INTRODUCTION

European cooperation in plant phenology

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Phenology has emerged from the shadows to become a major component of climate change studies. In part this is because the phenological responses of species to temperature, particularly in plants, are very strong. Phenological change is relatively easy to identify, especially in comparison with changes in distribution, fecundity, population size, morphology, etc. Even with the relatively modest levels of climate warming experienced so far, phenological change has become very evident. Phenology formed a large part of the evidence on climate impacts in the most recent IPCC report (Rosenzweig et al. 2008). *ISI Web of Knowledge* reports that publications containing 'Phenolog*' as a topic have risen from 162 in 1990 to 1099 in 2008 (with an unexplained outlier of only 70 in 2001). The proportion of these that also contain 'Climate' as a topic has risen steadily (Fig. 1) emphasising the growing importance of phenology in climate studies.

The advantages of phenology include that it is relatively simple to record, that it is robust to differences in collection protocols, and there exists extensive archive material. The latter may not yet be fully identified, and is certainly not completely available in digital form. Long-term phenological series have been recorded in Japan and China; the former has a record of cherry flowering going back to 705 AD (Menzel & Dose 2005). Europe, too, has a long tradition in phenology; Theophrastus (ca. 371 to ca. 287 BC), a student of Aristotle, produced a Calendar of Flora in Athens, Greece (Stillingfleet 1762). There are probably a number of archaeological records with phenological data yet to be discovered.

Collaborative European networks have several precursors, the most widespread of which was the coordination of records by Professors Ihne and Hoffmann from Giessen, Germany between 1883 and 1941 (Nekovar et al. 2008). The current Special of Climate Research (CR)

represents one of the outputs of COST 725 of the 'European Cooperation in the field of Scientific and Technical Research' funded by the European Science Foundation. For the 5 years ending in 2009, COST 725 'Establishing a European Phenological Data Platform for Climatological Applications' brought together researchers from 27 European countries, enabling them to meet twice a year, and funded scientific exchange visits as well as encouraged collaboration.

An early output of COST 725 was an extensive analysis of >125 000 phenological series for a standardised time period (Menzel et al. 2006). Previous to this, papers summarising phenological change relied on published studies, potentially biased in favor of those showing significant change, whereas Menzel et al. (2006) summarised all available data series from across Europe. This meta-analysis was featured prominently in the IPCC report and suggested average advances in phenological phenomena of 7.5 d in the period 1971–2000. Furthermore, countries that had experienced greater temperature increases were associated with greater phenological advances.

A book summarising the history and current status of phenology in Europe (Nekovar et al. 2008) is also an output of COST 725. This is the first time that such an extensive summary has been compiled, and it will remain a valuable reference for phenological researchers for many years to come. A major component of COST 725 was the construction of a European database of phenological observations. Despite the differences in languages, protocols, and species, this database, hosted by ZAMG (Zentralanstalt für Meteorologie und Geodynamik) in Vienna, Austria, is nearing completion. Proposals are being considered that would enable it to be kept up to date.

This CR Special presents 9 studies based on the work of 36 scientists from 11 countries.

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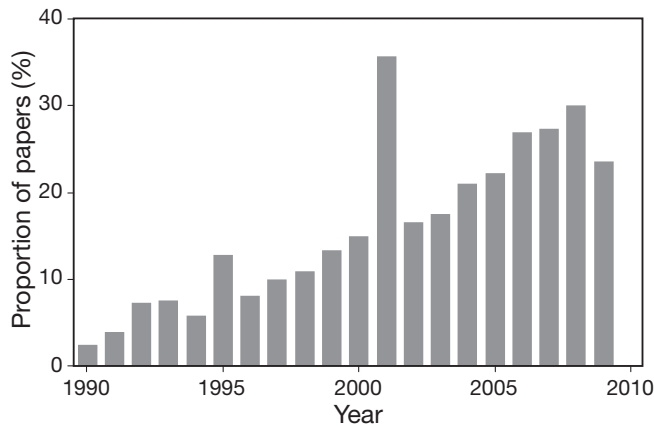


Fig. 1. Percentage of papers associated with the *ISI Web of Knowledge* with the topic 'Phenolog*' that also contain 'climate' as a topic has been rising steadily (2009 incomplete). The percentage for 2001 may be an outlier, as the total number (denominator) of papers with the topic 'Phenolog*' was unusually low

Rutishauser et al. (2009, this Special) look at some very long data series from Europe, examine correlations between them and investigate temporal changes in both trends and temperature responsiveness. Phenologists tend to work with climatic data that is readily available; either monthly mean shade temperatures or daily temperature accumulations. Whenever climate change is considered it is usually monthly or annual mean temperatures that are examined. Sparks et al. (2009a, this Special) examine changes in a number of potentially important summaries of daily temperature data, including thresholds and temperature accumulations. Maps of changes in European temperatures illustrate the spatial context.

Kalvāne et al. (2009, this Special) show how recent temperature changes have expressed themselves as phenological changes in the Baltic countries of Latvia and Lithuania. The influence of the North Atlantic Oscillation and of precipitation is also examined. The subsequent study by Sparks et al. (2009b, this Special) looks at phenological change in flowering within Europe's last remaining primeval lowland forest. Change is apparent in this pristine environment, reminding us that the consequences of a changing climate extend beyond those areas directly modified by humans.

Ziello et al. (2009, this Special) study changes in phenology with increasing altitude in the European Alps. A strong relationship of delayed phenology at higher altitude was found. Recent advances in flowering dates may have been greater at higher altitude. Estrella et al. (2009, this Special) use 36 000 data series to examine changes in phenology in relation to location, phase timing and human population density. Phenological events are divided into different categories and differ-

ences in the strength of phenological advance in different categories were revealed. Schleip et al. (2009, this Special) use Bayesian methods to examine phenological changes in 2600 European data series. This approach confirmed that recent phenological change has not been linear; rather it has been abrupt, associated with rising temperature. Phenological trends were most marked in NW Europe.

Technological applications of phenology are considered in the final 2 studies. Ahrends et al. (2009, this Special) investigate the use of digital photography on flux towers and the relationship between phenology and gross primary productivity. Different parts of the forest canopy were identified for examination of the development of individual tree species. Karlsen et al. (2009, this Special) use satellite imagery on an 8 km grid to examine the beginning and end of the growing season in Fennoscandia. They compare these data with local records of *Betula* phenology and conclude that changes in the growing season over the study area are heterogeneous, but average a lengthening of the growing season by 6 days per decade.

COST 725 has made a substantial contribution to phenological collaboration between European countries. The importance of phenological records is now acknowledged by some countries and organisations that had considered cutting back phenological programmes. New schemes, for example in the Republic of Ireland and Sweden, have been inspired by this work. The prospects for increased phenological research have never looked so encouraging.

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