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EDITORIAL

PHENOLOGY AND CLIMATE: THE TIMING OF LIFE CYCLE EVENTS AS INDICATORS OF CLIMATIC VARIABILITY AND CHANGE

From 5 to 7 December 2001 the conference entitled *The times they are a-changin'; Climate change, phenological responses and their consequences for biodiversity, agriculture, forestry, and human health* was held in Wageningen, the Netherlands. The objective of this conference was to present the latest results of phenological research to demonstrate the importance (added value) of phenological studies to understand better the effects of climate change on ecology, agriculture, forestry and human health. Furthermore, it aimed to strengthen cooperation, networking, and exchange of information among phenologists from different disciplines, meteorologists, and other stakeholders, and to discuss options for better exploitation of existing data and adaptation of phenological observing systems. Over 120 participants from more than 20 countries presented and discussed the latest developments in the field of phenology.

The conference was organized in the context of the European Phenology Network (EPN), which is funded by the Fifth Framework Programme of the European Commission and coordinated by the Environmental Systems Analysis Group of the Wageningen University and Research Center in the Netherlands. The main objective of EPN is to increase efficiency, added value, and use of phenological monitoring and research in Europe in the context of global climate change. EPN was set up after several years of increasing communication between phenologists from all over the world, facilitated by the Commission on Vegetation Dynamics, Climate and Biodiversity (formerly known as the Phenology Study Group) of the International Society of Biometeorology. It was recognized that phenological changes had the potential to contribute to the climate change impact debate because many historic observations exist (gathered by numerous phenological monitoring networks, many of which were still functional). The problem, however, was that there was almost no communication and cooperation between the existing networks. Such cooperation is required in order to develop a large-scale overview of climate change impacts.

This special issue of the *International Journal of Climatology* includes a selection of papers presented at the conference, which focused on 'observed changes in the timing of life cycle events and assessing the role of climate variables'. In recent years, interest in phenology has increased substantially, caused to a large extent by the publishing of a large number of research articles that demonstrate an observed change in the timing of life cycle events. At the conference, we were able to add to the increasing amount of evidence that the timing of life cycle events of a large number of species is closely linked to climate and, more importantly, that species have responded to the observed increase in temperature. In the last century temperatures increased substantially, and often resulted in new meteorological records. Further, the speed of change has been the highest in at least 1000 years. Concurrently, we see spring starting earlier on dates that would have been extremely rare several decades ago.

The papers of this issue clearly demonstrate that changes in the timing of life cycle events are obvious on different spatial scales (sites to continents), from all over the world, and from a large number of different types of datasets. Sparks and Menzel bring together a number of examples and conclude that the emphasis of phenological analysis is on an advance in spring, which can be linked to an increase in temperature, whereas detection of change in autumn is more difficult to determine, although the general pattern may be towards delay. Ahas *et al*. show that spring phases have advanced 4 weeks in western and central Europe and have been delayed up to 2 weeks in the eastern region of Europe. Scheifinger *et al*. have made a detailed analysis of the potential causes of these changes whereby the North Atlantic Oscillation seems to be having an important role in explaining the timing of phenology. Their results also show a discontinuity of the time series in 1989. A similar discontinuity has also been found by van Vliet *et al*. Based on pollen data, they found that the start of flowering in the Netherlands has advanced up to 19 days if you compare the 1990s with the 1970s. Keatley *et al*. analysed historic phenological data from Australia and demonstrated the explanatory power of temperature and rainfall in the seasonal variation of flowering commencement date. Chen and Pan demonstrate that a combination of remote sensing data and a combination of climate variables can help us to calculate the growing season length. Although satellite data can assist in determining the start and end of the growing season, the paper of Schwartz *et al*. emphasizes the limits of remote sensing 'phenology' and the need to calibrate remote sensing images with surface observations.

The most important message from these types of study is that the observed changes in climate (of 'only' 0.6 °C globally) have already significantly impacted natural systems. It gives a first indication and warning of the potential large changes that might occur if mean temperature continues to increase by 1.4 to 5.8 °C globally in this century.

Recently, several phenological monitoring networks have been under financial pressure. Furthermore, several historical archives have been lost. Increased interest in phenology, in the context of climate change, should send a clear signal that there is a need to safeguard the continuation of existing monitoring networks and seriously plan to invest in expansion and creation of new networks to provide better global coverage. New (Internet) technologies create a whole range of new possibilities for monitoring networks. These technologies can address several challenges that have hampered large scale monitoring networks in the past. It is now easier to (a) instruct observers; (b) locate the observation site geographically; (c) gather observations; (d) do quality check procedures; (e) add observations to a centralized and standardized database; (f) give regular feedback to the observers; (g) inform and involve a large number of observers; and (h) analyze the results.

Although it is still important to continue monitoring and analysis of the relationship between timing and climate, the main challenge for the coming years will be to move on to assessing the environmental and socio-economic consequences of phenological changes in response to (future) climate change. At the phenological conference we started to look at this, and we foresee a large number of studies that focus on these questions. At the same time, multiple activities are moving forward to expand and upgrade existing monitoring networks. We are therefore looking forward to the rest of this decade, in which we expect to contribute significantly to climate change impact assessments, and perhaps even more importantly to informing the general public and policy makers about the climate change issue.

Lastly, we want to stress the importance of phenologists exchanging information and ideas with scientists from other disciplines. There are many opportunities for collaborative studies, including methods of data analysis, scenario development, ecological complexity, and monitoring. We welcome ideas and suggestions in this regard.

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