MORE THAN A CENTURY OF PHENOLOGICAL OBSERVATIONS: MODEL ANALYSES AND ISSUES RELATED TO THE ASSESSMENT OF CLIMATE CHANGE EFFECTS

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Abstract
We present a new WEB-based phenological data base that provides public access to visualisation and download of phenological data series. The Plant-Phenological Online Database PPODB comprises plant-phenological observations collected in Central Europe between 1880 and 2009 with a special emphasis on Germany. We present trend analyses performed with these data, models parameterised with the extensive data base and an evaluation of critical issues related to the use of models for the assessment of climate change impacts.

Keywords: Plant Phenology, Online Database, climate change, long time-series, trends.

Introduction

Phenology, as a scientific discipline, has a long history, however tended to decline in the early second half of the 20th Century. Subsequently, phenological studies experienced a remarkable renaissance from the late 1980ies onwards when their potential to describe the effects of ongoing anthropogenic climate change on natural systems attracted the attention of scholars in climate change research (Badeck *et al.*, 2004 Parmesan, 2006). Here, we present a unique online database that provides unrestricted and free access to over 16 million phenological observations from Central Europe between 1880 and 2009 with a focus on Germany and examples of their application.

Materials e Methods

Data publicly available from the data bases of the German weather service (DWD) for the time periods 1951-2009 and 1890-1941 were fed into a data-base together with data digitalised from several printed sources covering observations made between 1921 and 1955. One of the main reasons to construct this database and to merge stations from different databases was to enable the construction of long phenological time series, so-called combined time series, in order to study the effect of climate change on plant phenology (Schaber, 2002; Schaber, *et al.*, 2010; Schaber and Badeck, 2002). Shortly, a combined times series is a sophisticated average over many time series that corrects for artefacts introduced by simple averages due to the unequal distribution of time series in time and space.

Many analyses of trends in phenology caused by recent climate change performed with relatively short time-series (2 to 5 decades long) have identified responses that were expected from the temperature sensitivity of the target organisms. These responses are mainly related to the period of strong warming that occurred from the 1980ies onwards. Longer time series are required to assess in how far similar responses characterised phenology already throughout earlier phases of global warming and if trend reversals occurred. Large data sets are also required for model parameterisation based on which questions about the persistence of shifts in phenology under future climate warming (Koerner & Basler, 2010) can be tackled.

Results and Discussion

The Plant-Phenological Online Database (PPODB) comprises a more than 16 million plant-phenological observations made at 9403 stations between 1880 and 2009. It is accessable on the web at: www.phenology.de (Fig.1). There are three ways to access the database, i.e. access to time series for single stations or Natural Regions via a used interface or access via SQL-inquiries. The user interface provides graphical representations of the time series and options for data download.

Routines for data analyses as proposed by Schaber & Badeck (2002) and Schaber et al. (2010) are available as an R-package (Schaber, 2012).

Schaber & Badeck (2005) used data from the data-bases combined with PPODB for the period 1890-1999 to perform trend analyses for selected natural regions. They identified two periods in the mid (1931-1948) and at the end (1984-1999) of the 20th Century with significant trends for

Fig. 1 - Start page of the Plant-Phenological database accessable at www.phenology.de.

progressively earlier onset of spring phenophases, separated by a period within which early spring phases tended not to change and late spring phases showed a progressively later onset.

Koerner & Basler (2010) recently challenged the extrapolation of temperature response ratios determined with phenological observations into future climate conditions because tree phenology is not exclusively controlled by temperature: “It is thus a misconception to linearly extrapolate a few days advance of leafing during warm years into a proportional lengthening of the growing season in climate warming scenarios”.

We parameterised several models for leaf and flower bud-burst using the 1951-1999 data after outlier detection and construction of combined time-series as decribed in Schaber & Badeck (2002, 2003): a Temperature (T) Sum Model (TSM), summing forcing T above a threshold T; the Cannel-Smith Model (CSM), accumulating chilling units below a chilling threshold T with the critical limit for forcing decreasing with accumulated chilling units and summing of forcing T above a threshold T; a new family of Promotor-Inhibitor Models (PIM) that is based on synthesis and decomposition of a promotor, and decomposition of an inhibitor in response to T and daylength plus interaction terms. The parameterisation of PIM implied a daylength dependence of beech bud burst (Schaber & Badeck, 2003).

Applying these models to the A1B SRES scenario (climate model ECHAM, downscaling with CLM and interpolation to daily resolution at station level) up to 2090 the role of non-linear day-length and chilling dependent response functions for the future trends in bud-burst phenology was evaluated.

The PIM models projected the non-linear response (due to daylength and chilling dependence) into the future, while CSM and TSM still respond nearly linearly. The conclusions drawn from this study were:

1) Elevation gradients, inter-annual variation in bud-burst and model parameterization indicate a decisive role of temperature for bud-burst phenology. Claims that temperature is not the most important factor cannot be substantiated.

2) The change in phase onset with monthly average temperatures, $\Delta d_{po}/\Delta T$, is a crude approximation of the response of phenophases to thermal conditions. Thus, $\Delta d_{po}/\Delta T$ should not be used for extrapolation to future climates.

3) Experimental results and model parameterization evidence the relevance of chilling requirements and day-length responses for several species.

4) State of the art models already describe these effects, reproduce the non-linear response to thermal conditions, and predict a slowing down of the advancement of spring phenophases under global warming.

5) However, the claim that the response to rising temperatures should come to a halt is overly simplifying. Cold, high elevation environments, and inter-annual climate variability comprising relatively cool years leave a substantial lee-way for for further advancement in bud-burst phenology in response to 21st Century warming trends.

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