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Digitizing the plant phenological dataset (1750–1875) from collections of Professor Adolf Moberg: Towards the development of historical climate records

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ABSTRACT

Long records of phenological observations are commonly used as data in global change and palaeoclimate research and to analyse plants' responses to climatic changes. Here we delve into the historical archives of plant phenological observations (1750–1875) compiled and published previously by Professor Adolf Moberg (Imperial Alexander University of Finland). The digitized dataset represents 44,487 observations of 450 different plant species for their 15 different phenological phases made in 193 sites across Finland, and results in 662 different phenological variables. The five most frequently observed variables are the blooming of rye, the sowing of barley, the blooming of bird cherry, the leaf outbreak of birch, and the sowing of oat. The spring and summer observations demonstrate positive relationships between the onset date and the site latitude, this relationship becoming negative for observations made in the autumn. This latitudinal effect is evident in the raw data as demonstrated by the temporal correlations between the unadjusted mean phenological records and the mean latitude of the sites. After the latitudinal effect is removed from the original data such correlations are much reduced and the new set of phenological records based on the adjusted dates can be computed. The resulting mean phenological records correlate negatively and statistically significantly with the mean temperatures from April through July. Linear trends indicate (i) summer onsets having become delayed by more than one week over the full period and (ii) shortening of the growing seasons since 1846. The dataset is made available in an open repository.

1. Introduction

Phenological datasets consist of observations made on natural seasonal events. The changes in the annual cycle of plants are closely linked to the seasonal course of temperature and water availability and the phenological data constitute first-hand evidence of plants' responses to these changes. First, these data contribute strongly to our understanding of global change biology (Menzel, 2002). Between 1971 and 2000, the plant phenological data demonstrated an average advance of spring/summer 2.5 days per decade within European countries, in accordance with instrumentally observed warming (Menzel et al., 2006). Yet, the long records help to identify the ways the enhanced warming may alter the climatic drivers of phenological phases by changing the relationships between the seasonal courses of temperature, moisture, and plant development (Cook and Wolkovich, 2016). Second, the long phenological data provide the palaeoclimate reconstructions with written records of past climate variability (Craddock, 1974; Kington, 1974). Phenological data of various plant species have indeed been used to reconstruct temperature variations over the past centuries in order to assess the character of recent climate regime (Chuine et al., 2004; Rutishauser et al., 2007; Holopainen et al., 2009). Compared to other natural proxy archives, such as pollen and sedimentary records, phenological records benefit from being time-series directly comparable with meteorological records without chronological uncertainties.

Longest of the phenological records originate from notes and diaries of early naturalists and enthusiastic volunteers (Margary, 1925; Lappalainen and Heikinheimo, 1992; Holopainen et al., 2012). These data make it possible extending the phenological records over the 19th and 18th centuries and evaluation of their trends and climatic signals on decadal to centennial time intervals and scales (Sparks and Carey, 1995; Holopainen et al., 2006, 2013; Rutishauser et al., 2009). Such documents may have survived over decades and centuries in

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institutional or personal archives (Margary, 1925; Chuine et al., 2004; Holopainen et al., 2013) or they may have been published as yearbooks or larger collections of data by contemporary scholars soon after the initial observations had been recorded. In Finland, the collection of phenological observations started already in 1750s, following the general recommendations set by Carl von Linné (Terhivuo et al., 2009), and has continued since then as a more or less coherent national effort by a number of universities and societies (Holopainen et al. 2012). In practice, the phenological observations have been made by hundreds of volunteers collectively contributing to the effort by returning their formal notebooks to the organizations that coordinate the process of data collection and maintain the repositories of such materials. During the early days of this process, an enormous effort of his own was made by Professor Adolf Moberg (1813–1895), the Imperial Alexander University of Finland, who compiled a large amount of original 18th and 19th century notes into what became four volumes of books published in Swedish. These volumes present the phenological data collected in Finland until then in well-organized format, as tabular lists of various natural events and their seasonal timing, the data originally obtained from a number of individual contributors across the country (Moberg, 1857, 1860, 1885, 1894).

Here we present this data after having digitized the information from the books of Moberg (1857, 1860, 1885, 1894). We concentrate on plant phenological observations and demonstrate the characteristics of this data as available between the years 1750 and 1875. This data have not been largely studied. The dates of rye harvests from three sites were previously used, along with much larger collection of Estonian proxy data, to reconstruct spring and summer temperature variability over the past centuries (Tarand and Kuiv, 1994; Tarand and Nordli, 2001). The flowering dates of two tree species, the rowan and the bird cherry, were analyzed since 1750s (Terhivuo et al., 2009). Other analyses have used the dates of flowering and leaf bud burst of birch to statistically demonstrate their usefulness to detect the signals of climate variability and warming in the region since 1846 (Linkosalo et al., 2009; Hari et al., 2017). Moreover, a limited portion of this data has been used for indicating (Holopainen et al., 2006, 2013) and reconstructing past variability in spring temperatures, along with other proxy data, in south-west Finland since 1750s (Holopainen et al., 2009). However, the dataset has not yet been studied in full. Our analysis classifies the data by plant species and their phenological phases recorded, and makes a geographical presentation of the available sites and thus of a spatiotemporal coverage of the dataset. Although these data are not covering the 20th and 21st century era of warming climate, the data have value to climate and plant scientists for assessing the variability in plant responses to climatic variations over the pre-industrial era. Moreover, the interval of available data (1750–1875) overlaps with the period of climate anomalies attributable to the Little Ice Age conditions, inferred as a climatic cooling between 1570 and 1900 from many palaeoclimate records around the Northern Hemisphere and especially the North Atlantic/European sector (Bradley and Jones, 1993; Matthews and Briffa, 2005). In terms of palaeoclimatology, this data (Moberg, 1857, 1860, 1885, 1894) will contribute to high-resolution assessments of seasonal climate variability over the period when the regular observations of meteorological phenomena were only scarcely made in the region and over which the proxy data as indicators of climate variability are therefore needed (Holopainen, 2006).

Having digitized the data, the main goals of this study were (i) to standardize the nomenclature (including the names of sites, plant species, and their phenological phases) and the calendar and coordinate formats used in the four books (Moberg, 1857, 1860, 1885, 1894), (ii) to illustrate the spatiotemporal coverage of the dataset and to characterize the corresponding variations in the number of observations, (iii) to demonstrate the relationships between the onset dates and the site latitudes, (iv) to calculate mean phenological records over the study period, and (v) to identify their climatic signals by comparing their variability to existing, historical mean monthly temperature series.

2. Material and methods

Plant phenological data was digitized from the books of Moberg (1857, 1860, 1885, 1894) by manually typing the information into electronic format and saved in Microsoft Excel. Each observation was characterized by the plant species expressed in Latin name, the phenological phase (e.g. budburst, flowering), the year, month, and the day of the month, as well as the site name and its geographical coordinates. In the case of agrophenological observations, the phase was often related to seasonal human activity (e.g. sowing, haymaking). These are the data of which collection was coordinated by the Royal Academy of Turku, the Finnish Economic Society, the Pro Natura Society and the Finnish Society of Sciences and Letters. This coordination included more or less the manufacturing and sending of the official cards, on which the phenological observations were formally written down by the volunteers, as well as the reception of the completed cards and their administration thereafter. Below, the issues that need to be addressed to create a homogenized database are shortly described.

2.1. The two calendars

The Gregorian calendar we use today was preceded by the Julian calendar that was subject to the vernal equinoctial drift in the calendar (Dutka, 1988). The former calendar was introduced in 1582 but it was not widely used until later time. In this study region, the transition took place in 1753 when February 17th (Julian) was followed by March 1st (Gregorian). Another part of the revision dealt with centurial years not divisible by 400 that became ordinary years of 365 days. As a consequence, the phenological observations made before the date of transition need to be realigned to Gregorian calendar. Accurate conversion can be done using the available tables (Kerzhner, 1984) or using the equations tailored for the purpose (Hatcher, 1984).

2.2. The vernal equinox

An important detail of recording the timing of phenological events, especially in the case of long series of data, relates to the mismatch between the length of the solar year and the slightly longer average year on the Gregorian calendar (Sagarin and Micheli, 2001). In phenological data, this bias causes an overestimation of trends towards earlier spring signals but can be corrected by adopting the dates of phenological observations in relation to beginning of astronomical spring (vernal equinox) rather than by calendar day (Sagarin, 2001, 2009). Here we overcome this potential bias by not reporting the dates of phenological events using both the Gregorian calendar dates (in practice, the number of days elapsed since March 1st) but as the number of days elapsed since the vernal equinox i.e. the date the sun crosses the celestial equator from the austral to the boreal hemisphere that have varied between March 19th and 21st (Gregorian).

2.3. A new meridian

It was not until 1884 when the International Meridian Conference established the Greenwich meridian as the initial meridian for longitude (Sadler, 1978). Before that the Ferro Meridian (18°W) was commonly used (referring to the westernmost point of the once-known world, El Hierro in Canary Islands) as the prime meridian in many countries in continental Europe as it was also employed in the three volumes of Moberg (1857, 1860, 1885). The new Greenwich meridian was adopted not until the last book of Moberg (1894). This Ferro-Greenwich shift (17°40′) was corrected consistently for the longitudinal coordinates published in the earlier volumes (Moberg, 1857, 1860, 1885) by subtracting the corresponding value (17.67) from the site longitude.