

# Integrating Historical Phenological Observations into a 280-Year Long Series

This Rutishauser <sup>1</sup>, Jürg Luterbacher <sup>1,2</sup>, François Jeanneret <sup>1</sup>, Heinz Wanner <sup>1,2</sup>

<sup>1</sup>*Institute of Geography, University of Bern, Hallerstrasse 12, CH-3012 Bern, Switzerland (rutis@giub.unibe.ch);* <sup>2</sup>*National Centre of Competence in Research on Climate, University of Bern, Bern, Switzerland*

## Introduction

Statistical analysis of observations from various phenological networks across Europe indicated a prolongation of the growing season by 10.8 days with an earlier start of approximately one week during the period 1951 to 2000 (Menzel and Fabian 1999). This trend is not seen in every species and has different slopes as well as significance levels. Still, an overall trend towards earlier flowering can be attributed to climatic influences on phenological events. This relationship of earlier flowering with synchronously rising air temperatures is presented in several studies for many single species for different European regions (Vestheim 1998 in Norway, Chmielewski 2003, Menzel 2003 in Germany, Defila and Clot 2001 in Switzerland, Peñuelas 2002 in NE Spain). The focus of analyses has been on network observations where data is available from a large number of stations in a digitised form. Guidebooks distributed to the observers aim at increasing homogeneity and comparability. Since phenological networks were re-established in the 1950s, phenological time series have been limited to a relatively short period in comparison with climatic time series where station series of temperature and precipitation reach back to the 1600s.

In order to extend phenological observation records, it is useful to assess the quality of single phenological observation series in comparison with network observations. Single phenological records are found in various forms, in which observers noted phenological events just out of interest. In many cases they continued to observe over several decades. The quality of the observations can be assessed based on metadata providing background information on the definition of observed phenophases, observation habits, intentions as well as information about the observation site. Before 1950, observations from various sources were known but rarely used for phenological studies, most of all because of lacking homogeneous observation methods.

In this paper the preliminary results are presented of a study that attempted to integrate phenological observations of the flowering of the cherry tree (*Prunus avium*) for the Swiss Plateau region for the period 1721 to 2000. To assess the reliability of the cherry date observation as from 1721, we created a second series with a multivariate statistical approach based on independent station temperature series from European sites. Further, we critically discuss the reliability of the results and compare the two reconstruction approaches.

As the cherry tree indicates the beginning of the growing period, this method allows us for the first time to create an approximately homogeneous record for this spring event based on documentary phenological observations for the last 280 years. Furthermore, it may prompt further work on historical observations that still lie buried in many archives and private attics.

## Data

Observations of the flowering of the cherry tree came from 14 independent sources from the Swiss Plateau and the Basel region in the south and north of the Jura mountains, respectively (altitude 259-860 m a.s.l.; Table 1). The source information such as the exact site, a description of the phenological phase and information about the observer varied between sources. As to all the historical observations, the observation site was known within the range of a village. Biographical information about the observers was partially available. Comparative observations of the flowering of the cherry tree from the Swiss Phenological Network for the same region were used. In addition, observations from an independent observer at Grossaffoltern (approximately 20 kilometres NW of Berne; alt. 520 m a.s.l.), were used for the period 1978 to 2000. Flowering dates of the long observation series were corrected by applying a mean altitude gradient of 2.5 days per 100 meters. The gradient was derived from the Meteo Swiss network data where a linear regression was fitted to the flowering date in relation to the altitude of the observation station. The years were only used if all 21 stations reported their observations (6 years, calculations not shown). The gradient is in accordance with the mean gradient of data from a Swiss phenological proto network that was in place from 1864 to 1873 (SMB 1864-1873). For temperature data for first comparisons with phenological observations, the station at Zürich was chosen after testing representativity.

In order to verify the reliability of the Swiss Mean cherry tree flowering series, we gave a statistical estimate by using European temperature station series. Over the period 1951 to 1995, empirical orthogonal functions (EOFs) explaining 90% of the variance of the station temperature data were regressed against the Swiss Mean cherry tree flowering series. Model performance was assessed by splitting the period in two 30-year calibrating and 15-year verifying periods (Verification periods: 1951-1965, 1981-1995, respectively). Due to the time-varying database of the station temperature series, 88 regression models had to be developed. These regression equations from the 1951-1995 period were applied to the corresponding predictor variables for the period 1721-1950 in order to derive the mean flowering date for the Swiss plateau region. For a detailed mathematical treatment of the reconstruction method, is referred to Luterbacher et al., (2002).

## Results

In a first step the data from the Swiss Phenological Network was compiled into a mean series for the period 1951 to 2000 in order to reduce microclimatological and individual plant factors as well as unknown differences in cultivars. All available station data of the same year were averaged. From 1970 onward the minimum number of stations is 16; earlier the number of observing stations before was lower. The dates of the flowering were averaged into one series

In order to assess the quality and representativeness of independent observations, the mean series was then compared with two independent records at Liestal for the period 1951 to 2000 and at Grossaffoltern for 1978 to 2000, respectively (Fig. 1). The Pearson correlation between the mean series and Liestal was 0.79 (n=50). The systematic earlier flowering can be attributed to a distinct altitude difference and a mountain range separating the two regions. This fact was supported by the strong correlation between the mean series and the single series at Grossaffoltern of 0.91 (n=23). This strong correlation seems to reflect that the Grossaffoltern series represented a station in the middle of the altitude range of the network. In addition, this series was more representative for the whole observation area. In general, interannual variability was well represented in all three

series. As expected, the single series revealed stronger extremes such as the latest (1986) and the earliest (1990) flowering date compared with the mean series.

A preliminary 280-year long series of cherry tree flowering dates for the Swiss Plateau region is presented (Fig. 2, missing 1842, 1844) on the assumption that historical data (Table 1) have the same representativeness as the single observation series of the 20th century in analogy to the comparison given in Figure 1. Some missing data (see Table 1) were completed with observations of the first appearance of vine buds and flowering of vines from nearby sites. Figure 2 points to strong interannual to decadal variability. Several extreme years exceed the two standard deviation-values derived from the 1951 to 2000 period. The earliest date of cherry tree flowering over the whole period was March 20, 1830, the latest May 17, 1879. Including substituted vine dates, the latest flowering was May 26, 1740. The 9-year triangularly filtered time series revealed a decadal variability with later flowering between 1770 and 1850. The 20<sup>th</sup> century did not show the influence of the distinct warming as the long series at Liestal (Defila and Clot 2001), which reflects the trend at one site. Due to the break in the series and the change to the Swiss Mean series (Table 1) continued warming was not seen in the long observation series. The last decade of the century was nevertheless the warmest in the second half of the 20<sup>th</sup> century, simultaneously showing a shift towards earlier flowering.

Furthermore, the comparison of the Mean-Series with the mean February-April temperatures shows a negative correlation of -0.88 (Fig. 3). Interannual variability is clearly shown here, too. Trends for flowering date and temperature thus point in opposite directions with 2 days and 0.2 °C per decade for the period 1951 to 2000, respectively. The results are in accordance with the findings of Beaubien and Freeland (2000) for Western Canada, Peñuelas et al., (2002) for NE Spain and Chmielewski et al., (2003) for Germany. These findings were used to determine the predicting temperatures of February to April monthly means of the multivariate regression model (see next section). We selected this period after testing all combinations of various monthly mean temperatures with computing Pearson correlation coefficients. The findings are in accordance with Vestrheim (1998) and Peñuelas (2002).

The historical observations record was then compared with the model record with estimations based on multivariate regression (Fig.4). The correlation between the compiled observations and the reconstructed series over the period 1721 to 1995 is 0.55. The correlation in the calibration season is  $r = 0.82$  (Period 14 in Fig. 4). The variability is rather well reconstructed. The partition into the periods of different observers (vertical lines) shows distinct biases for certain periods and observers that can be explained with source analysis. Period 2 (1739-1764) shows a substituted period with vine buds in which the observed mean flowering is clearly earlier than in the statistically reconstructed series. Period 10 (1854-1874) shows observations from the Basel region with distinct height differences and therefore constant earlier flowering compared with flowering dates from the Swiss Plateau region derived from the reconstruction dates.

## Conclusions

Single historical observations of the flowering of the cherry tree *Prunus avium* are available to create the longest phenological record with yearly observations from 1721 to 2000 (2 years missing).

The first comparison of records by independent observers with mean network observations can provide phenological information representing a larger area. In particular, later flowering dates between 1770 and 1850 and earlier flowering dates in the 20th century are shown. Comparisons

between independent observations compiled from several sources and statistical estimations of flowering dates from temperature averages in February-April from European stations, show that the variability is clearly seen in both time series. Biases during several subperiods can be explained with careful source analysis. By using phenology-temperature-interrelations it is possible to approximate the beginning of the growing season from documentary phenological records until 1721.

### **Acknowledgements**

Thanks to Christian Pfister (Institute of History, Bern) with the help of Urs Dietrich and Max Burri in providing 11 historic series of the flowering of cherry trees (<http://www.euroclimhist.com>), Dr. Christian Röthlisberger (Observer at Grossaffoltern) for 1 independent cherry flowering series and Claudio Defila (Meteo Swiss, Swiss Phenological Network, Zürich) for the network series.

### **References**

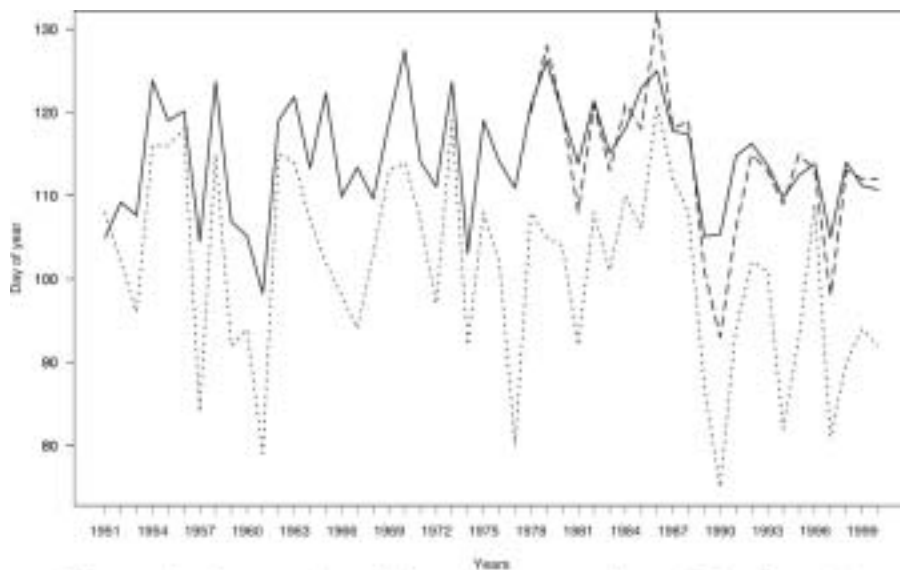
- Beaubien, E. and Freeland, H.J. (2000), Spring phenology trends in Alberta, Canada. Links to ocean temperature, *International Journal of Biometeorology*, 44 (2) 53-59.
- Chmielewski, F. et al. (2003), Climate changes and trends in phenology of fruit trees and field crops in Germany 1961-2000, *Beiträge zur Klima- und Meeresforschung*, p. 125-134.
- Defila, C. and Clot, B. (2001), Phytophenological trends in Switzerland, *International Journal of Biometeorology* 45, 203-207.
- Luterbacher J. et al. (2002), Extending North Atlantic Oscillation reconstructions back to 1500, *Atmospheric Science Letters* (2), 114-124.
- Menzel, A. and Fabian, P. (1999), Growing season extended in Europe, *Nature* 397, 659.
- Menzel, A. (2003), Plant phenological anomalies in Germany and their relation to air temperature and NAO, *Climatic Change* 57, 243-263.
- Peñuelas, J. et al. (2002), Changed plant and animal life cycles from 1952 to 2000 in the Mediterranean region, *Global Change Biology* 8, 531-544.
- Pfister, Christian (1984), *Klimageschichte der Schweiz 1525-1860. Das Klima der Schweiz von 1525-1860 und seine Bedeutung in der Geschichte von Bevölkerung und Landwirtschaft*, Paul Haupt, 1984.
- SMB (1864-1873), *Schweizerische Meteorologische Beobachtungen*, Published annually by the Meteorologischen Centralanstalt der Schweizerischen Naturforschenden Gesellschaft, Zürich.
- Vassella, A. (1997), *Phänologische Beobachtungen des Bernischen Forstdienstes von 1869 bis 1882. Witterungseinflüsse und Vergleich mit heutigen Beobachtungen*, Buwal Umweltmaterialien 73, pp. 9-75.
- Vestrheim, S. (1998), Flowering in Cherries as Affected by Pre-bloom Temperatures, in: *Proceedings of the Third International Cherry Symposium*, ed. by J. Ystaas, *Acta Horticultura* 468 (2) 551-555.

**Table and Figures:**

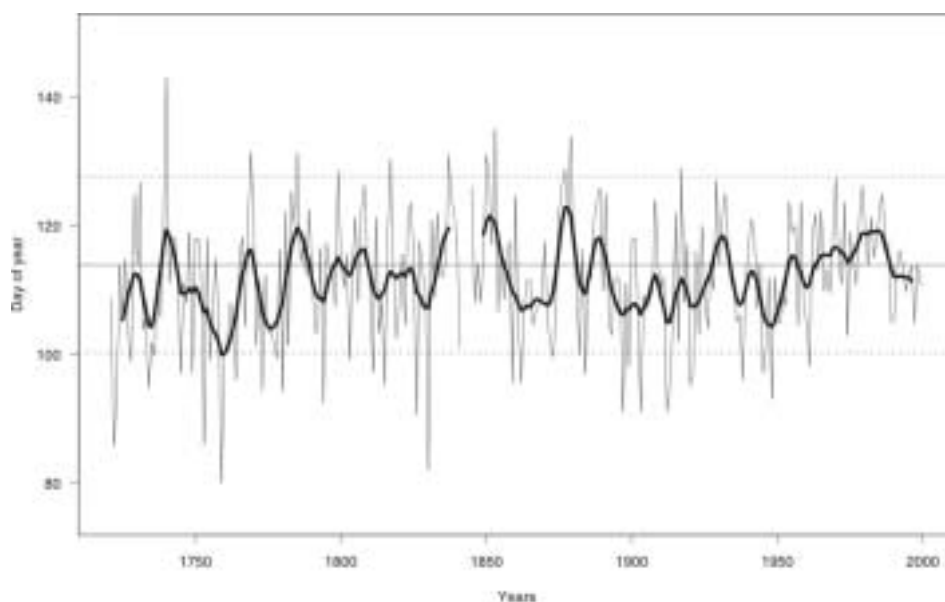
Period	Place	Altitude [m a.s.l.]	Observer	Source
1721-1738	Winterthur	442	Rieter	Pfister 1984
1739-1764	<i>substituted</i>	480		Pfister 1984
1765-1783	Gurzelen	591	Sprüngli	Pfister 1984
1784-1785	Glarus	472	various	Pfister 1984
1786-1802	Sutz	463	Sprüngli	Pfister 1984
1803-1818	Glarus	472	various	Pfister 1984
1819-1827	Bern	540	Studer	Pfister 1984
1828-1838	Lenzburg	405	Hofmeister	Pfister 1984
1839-1853	<i>substituted</i>	480		Pfister 1984
1854-1874	Basel	259	various	Pfister 1984
1875-1880	Canton of Berne	275-812	various	Vassella 1997
1881-1893	Schaffhausen	400	various	Pfister 1984
1894-1950	Liestal	320	E.+ F.Heinis	Defila & Clot 2001
1951-2000	Swiss Mean	370-860	various	Defila & Clot 2001

*missing: 1842, 1844*

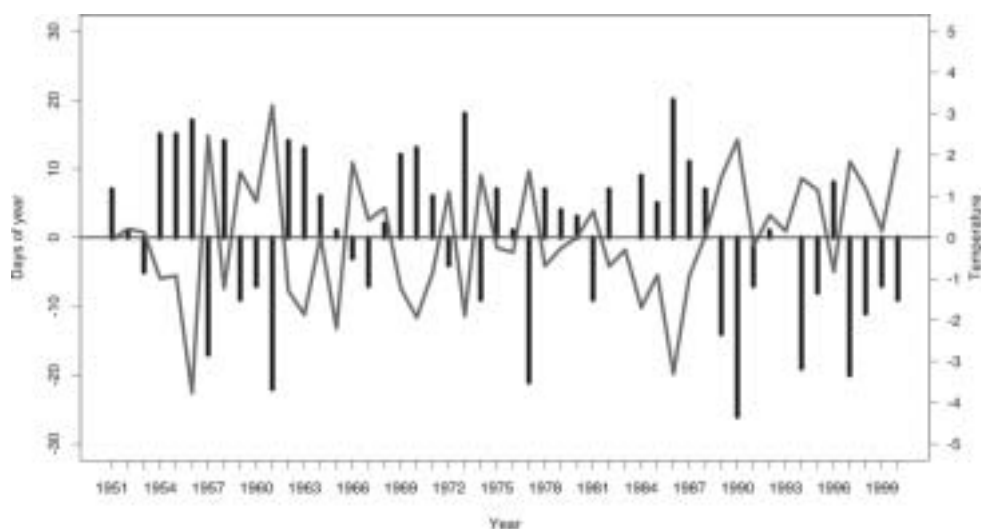
**Table 1:** Period, location and observers of the flowering of cherry trees in Switzerland 1721-2000.



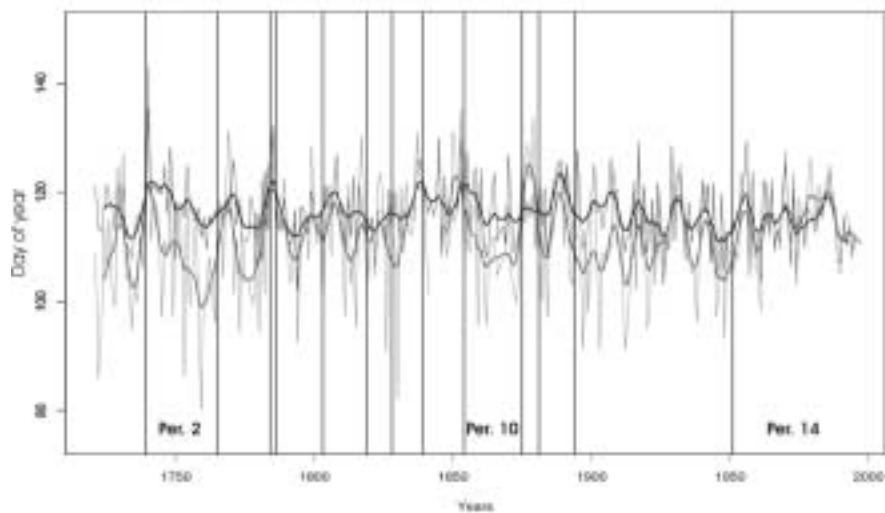
**Figure 1:** Comparison of network mean date of the flowering of cherry trees (solid line) with single observations at Liestal (dotted line) and Grossaffoltern (dashed line) for 1951 to 2000.



**Figure 2:** Phenological records of the flowering of the cherry trees for the Swiss Plateau Region and Liestal (alt. 320-620 m a.s.l.) 1721 to 2000; bold line: 9-year triangular filter; mean (solid line): 1951 to 2000; dashed lines represent 2-standard deviation range based on the period 1951 to 2000.



**Figure 3:** Anomalies of the flowering date of cherry tree at Liestal (columns) and monthly mean temperatures February to April at Zürich-SMA (line) to the reference period 1951-2000. Negative correlation ( $r=-0.88$ ).



**Figure 4:** Comparison of the observed (red) and statistically reconstructed (black) flowering of the cherry tree for 1721-1995. 9-year triangular mean. 14 periods of independent data from Table 1 (vertical lines).  $r_{1721-2000} = 0.55$ .  $r_{\text{calibration}} = 0.84$  (Period 14).

PROCEEDINGS

## Challenging Times

Towards an operational system  
for monitoring, modelling and  
forecasting of phenological changes  
and their socio-economic impact

Editor:  
Arnold J.H. van Vliet



31 March to 2 April, 2003  
Wageningen, The Netherlands

[Http://www.dow.wau.nl/msa/epn/](http://www.dow.wau.nl/msa/epn/)

# Proceedings

International Conference

## **Challenging Times**

Towards an operational system for monitoring,  
modelling and forecasting of phenological  
changes and their socio-economic impact

**Edited by:**  
**Arnold J.H. van Vliet**

31 March to 2 April 2003  
Wageningen, The Netherlands

<http://www.dow.wau.nl/msa/e pn/>