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THE ATMOSPHERE AND THE SPATIAL AND TEMPORAL VARIABILITY OF PHENOLOGICAL OBSERVATIONS IN CENTRAL EUROPE

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Introduction

Significant trends in the seasonal behaviour of plants and animals belong to the group of Global Change phenomena, which have been observed in many regions in the world during the last decades (Walther et al., 2002). The length of the vegetation period of many plant species has been increasing through an advanced onset of spring phases and a forward shift of autumn phases in midlatitudes (e.g. Post and Stenseth, 1999; Menzel and Fabian, 1999, Menzel, 2000 and Menzel et al., 2001; Jaagus and Ahas, 2000; Defila and Clot, 2001). Apart from recording changes in seasonal plant behaviour, there is a great interest in understanding the possible links with the climate variability of the midlatitudes. It has turned out that the seasonal cycle of plants is to a large degree linked to the temporal and spatial variability of hemispheric scale atmospheric circulation patterns. The North Atlantic Oscillation (NAO) is thought to play a key role in governing the temporal variability of the lower atmosphere and thus phenological dates in Europe (Post and Stenseth, 1999). The latitudinal pressure gradient between Iceland and Southern Europe has been increasing during the last winters, causing an intensified westerly flow of mild maritime air from the Atlantic into continental Europe (Hurrell, 1996). An increase of the intensity of the west wind drift is thought to be the cause for the winter and early spring temperature increase during the last 15 years in Europe. The aim of this work is to explain the temporal and spatial variability of phenological time series as a result of processes in the lower atmosphere at different spatial scales, including the NAO, the seasonal shift of midlatitude circulation systems, but extending it also to more local factors.

Data

For this investigation phenological data from Germany, Austria, Switzerland and Slovenia have been available with more than 6500 stations and 17 selected phenological phases from 1951-1998. Apart from plausibility tests, two additional selection procedures help to exclude outliers, which are described in more detail in Scheifinger et al. (2002). All investigations of this paper are based on gridded phenological time series. For phenological data height reduced inverse distance weighting is applied as interpolation method based on long term mean slopes of the elevation – phenological date relationships. During the ALPCLIM project long instrumental temperature time series from Alpine countries have been collected (Böhm et al., 2001). After careful checking and homogenising 97 Alpine temperature times series with monthly resolution are available for further analysis, some of them beginning in the 18th century. In this work monthly anomaly series are used, referenced to the monthly means of the time period 1901 – 1998 and interpolated to a 1°x1° grid (Fig. 1). Monthly North Atlantic Oscillation (NAO) time series stem from the data set publicly available from the Climate Research Unit in the UK (Jones, 1997).

Temporal features

Trend, standard deviation (not shown) and common variance values between phenological time series and NAO start with largest values at the beginning of the year and drop during the course of the spring (Fig 2). One might conclude that the influence of the NAO on the variability of phenological phases goes through a seasonal cycle. The maximum influence of the NAO on phenological dates is found on early phases and decreases with increasing yearday. The seasonal northward shift of the westerlies overlaps with the occurrence of most phenological spring phases. This means a gradual loss of influence of the North Atlantic weather regime during the advancement of spring, which could be termed the **temporal loss of influence of the NAO on the timing of phenological events**.

Another feature of the westerlies is their intensification during January, February and March from 1951 to 1998, when NAO index values show strong positive trend values, whereas in April, May and June they show negative values (Fig. 3).

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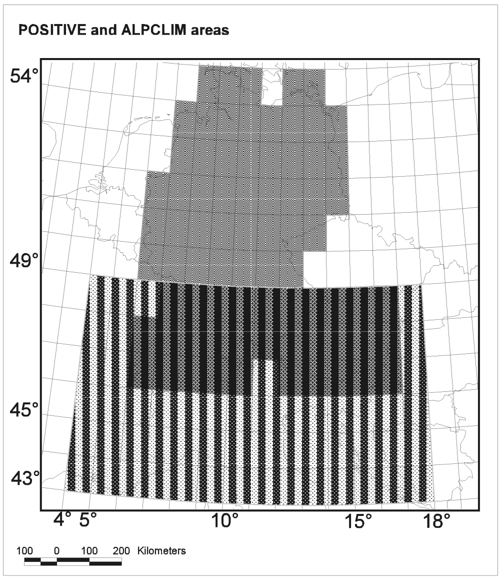

Figure 1: Areas of the 1°x1° grid covered by the phenology (dark shaded area) and ALPCLIM (striped area) station network.

From January to March the trend towards higher positive NAO values could be interpreted as an increase of advection of comparatively warm maritime air into the continent connected with higher temperatures during this time of the year.

Another phenomenon in the temporal domain is a discontinuity in time series behaviour in the late eighties, which has been recognised by the phenology and climate community (Watanabe and Nitta, 1999) and can be observed in phenological, temperature and NAO time series. The trend matrices of Fig. 4 visualise discontinuities in trend behaviour, especially that of the late eighties (1989 = year 39).

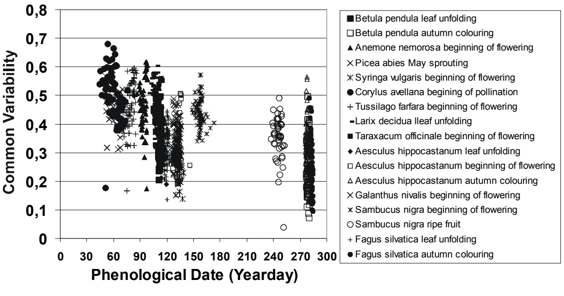

Fig. 2: Common variance between NAO and phenological time series as function of mean phenological date at the 1°x1° grid.

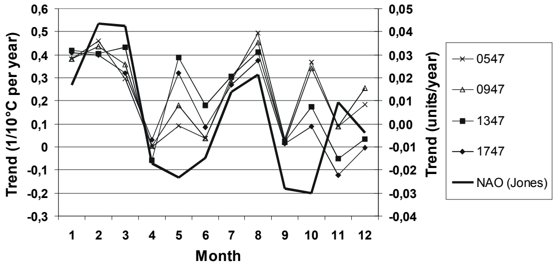

Fig. 3: Monthly trends of ALPCLIM temperature time series along 47°N and the monthly NAO trend values.

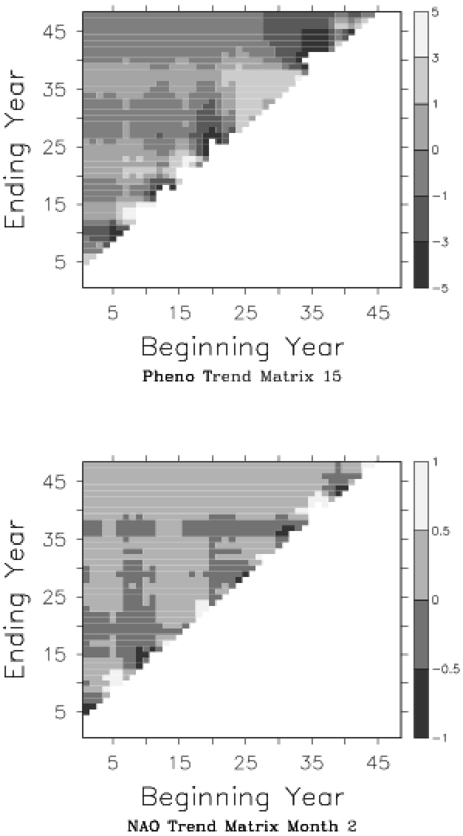

Fig. 4: Trend matrices of ‘*Corylus avellana* beginning of pollination’ time series at 13°E 47°N (top panel, units are days/year) and the February NAO time series (lower panel, in index units/year). The x-axis represents the beginning years and the y-axis the ending years of the partial time series. For each grid point of the matrix with a certain defined beginning and ending year a linear trend is calculated and plotted according to the grey scale.

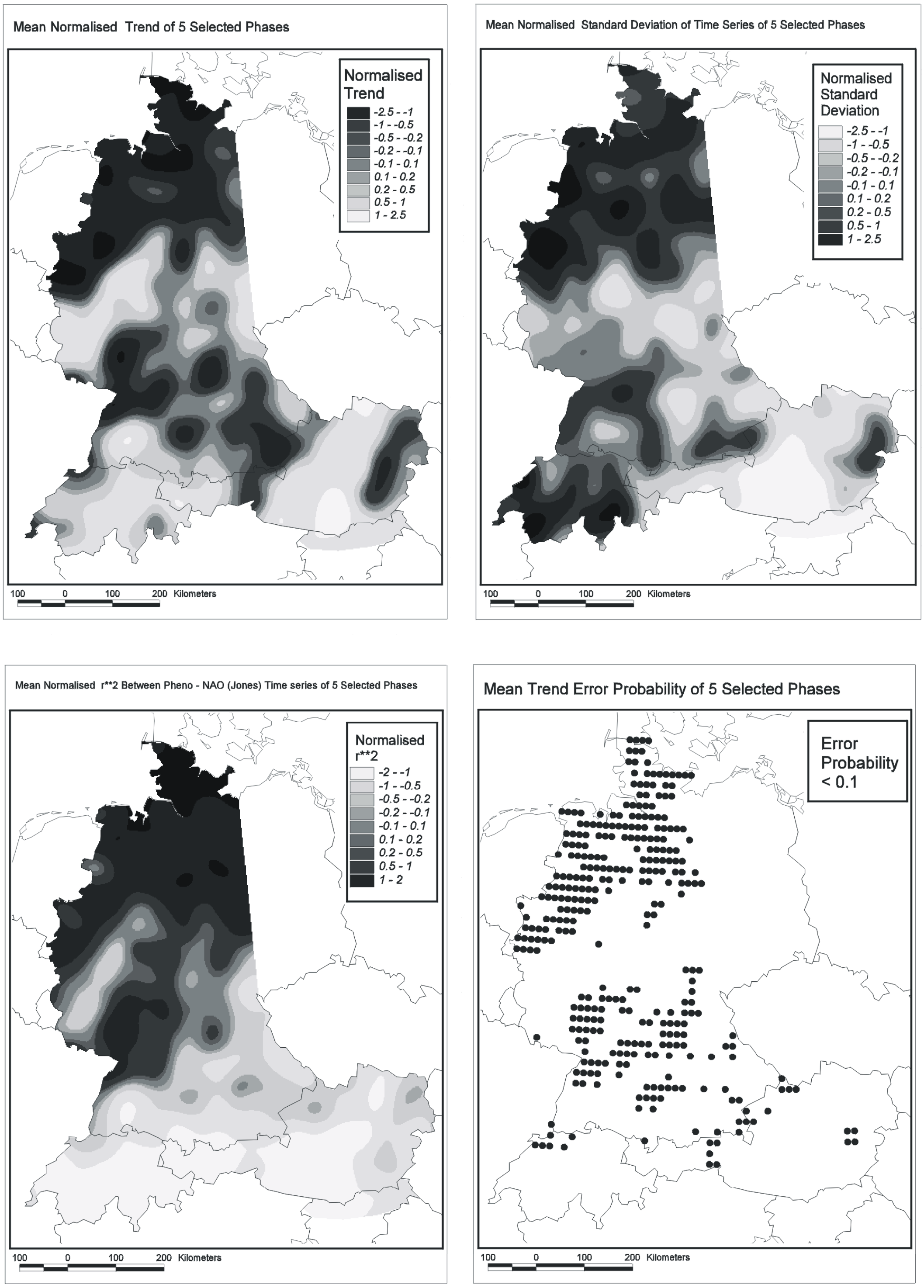

Fig. 5: Spatial distribution of trend (top left), standard deviation (top right), common variance between phenological time series and the NAO (bottom left) and trend error probability (bottom right). All representations are based on 5 phenological species ('*Corylus avellana* beginning of pollination', '*Larix decidua* beginning needle unfolding', '*Aesculus hippocastanum* beginning of leaf unfolding', '*Sambucus nigra* beginning of flowering' and '*Fagus sylvatica* beginning of leaf unfolding'). Before averaging, variables are normalised according to their mean and standard deviation. In case of the trend error probability the average has not been normalised.

Spatial features

Spatial trend representations of phenological phases are still problematic. Neighbouring stations often show contradicting trend values (Menzel et al., 2001). Through spatial interpolation and averaging of 5 phenological phases a picture of the spatial variability of phenological behaviour seems to emerge also on a smaller spatial scale (Fig. 5). 5 phenological phases with high data availability and good spatial coverage are selected for calculating average spatial distributions of following 4 parameters: trend, standard deviation, common variance with the NAO and Mann Kendall trend test error probability ($p < 0.1$). Before averaging, the values of each of the 5 phenological phases are normalised with respect to the mean and standard deviation of each variable.

In case of the common variance values between phenology with NAO there is a N – S gradient with decreasing values from N to S, from the Atlantic coast towards the interior of the continent, which could be termed the **large-scale spatial reduction of influence of the NAO on the phenological timing** (Chmielewski and Rötzer, 2001).

The variables of Fig. 5 indicate a spatial modification of their distribution on a smaller scale, which seems to be linked with topographical features. On a local and regional scale mountainous terrain reduces the influence of the large-scale atmospheric flow from the Atlantic via a 'decoupling mechanism'. Valleys in mountainous terrain have the inclination to harbour temperature inversions over extended periods of time during the cold season, which isolate the valley climate from the large scale atmospheric flow at higher altitudes. Most phenological stations reside at valley bottoms and are thus decoupled in their temporal variability from the influence of the westerly flow regime. This phenomenon could be called **local-scale spatial reduction of the influence of the NAO on the timing of phenological events**.

Conclusion

Vegetation does react to variations of its atmospheric environment in a sensitive way and it is astounding as to which precision subjective observations of plants are able to reflect the spatial and temporal variability of atmospheric processes across various temporal and spatial scales.

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