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/

Proceedings

International Conference

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Cover designed by Grafisch Atelier Wageningen
Printed by Copyservice Ede

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"Challenging Times" in the context of The European Phenology Network

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Phenology and climate change

Phenology is the study of the times of recurring natural phenomena especially in relation to climate and weather. Many phenological processes such as the date of first flowering, unfolding of first leaf, and first bird migration, are clearly linked to climate. In the past century, changes in climate were observed (*Figure 1*) which seem to affect plants and wildlife behaviour as demonstrated by long-term phenological observation records (e.g., Figure 2). It is expected that the timing of phenological processes will continue to change with the change in climate.

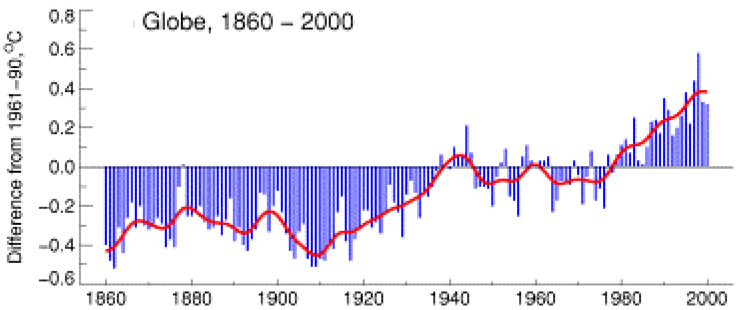

Figure 1: Changes in global mean temperature (1860-2000) compared with the mean temperature in 1960-1990. The red line is the running mean over 15 years (source: WMO at http://www.wmo.ch/).

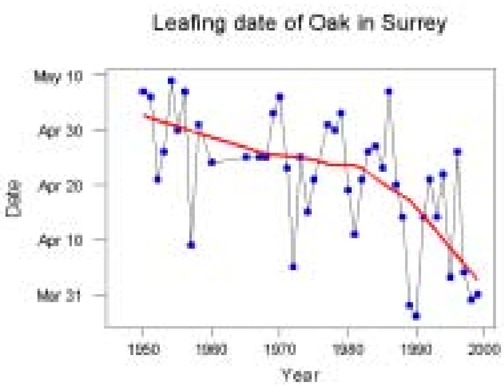

Figure 2: Observed change in start of Oak leaf unfolding in Surrey, United Kingdom (Source, T.H. Sparks).

Nature’s calendar as a clear indicator of climate change

It is increasingly recognised that phenological records provide an integrative indication of the sensitivity of natural systems to climate change, and that they are of great value to climate impact assessment. Long-term phenological monitoring over a wide range of latitudes and altitudes is therefore an essential component of earth observation programmes and global change monitoring. It can function as an important "early warning mechanism" (for examples http://www.dow.wau.nl/msa/epn/). Therefore, phenology is presently developing rapidly as a world-wide discipline. The value as an indicator increases even more as changes in phenological processes have far-reaching consequences for biodiversity, agriculture, forestry, and human health. Furthermore, changes in processes like flowering and leaf unfolding are easy to communicate to the general public and therefore can help informing the public on climate change.

The challenge for the European Phenology Network

Europe has a considerable monitoring capacity with many professionals and volunteers involved in monitoring and research. There are also many long-term datasets available, which provide important information on the relation between climate and natural systems. However, the efficiency and use of monitoring, assessment, and prediction of climate induced phenological changes and their effects in Europe, have been surprisingly low and could substantially be improved. This lack of efficiency and use was caused by the following problems:

- There was only limited cooperation and communication between the existing regional and national phenological monitoring networks in Europe.
- There was only limited access to and integration of data. This was partly because information on available datasets, the definitions and techniques used, and the quality of the data was short.
- There was an inefficient use and exchange of existing knowledge within and between the different scientific disciplines (ecology, agriculture, and human health) on tools and techniques already available for monitoring, data storage, and data analysis; and finally,
- There was not enough insight into the potential applications of phenological data.

These problems formed the basis for the objectives of the European Phenology Network (EPN). The EPN-project ran from January 2001 to October 2003 and was funded by the Fifth Framework Program of the European Commission.

Objectives of EPN

The European Phenology Network aims to improve monitoring, assessment and prediction of climate induced phenological changes and their effects on biodiversity, agriculture forests and human health in Europe. Its overall objective is to increase the efficiency, added value and use of phenological monitoring and research, and to stimulate the practical use of phenological data in the context of global (climate) change.

More specific objectives of the European Phenology Network are:

- To facilitate integration and cooperation between existing phenological monitoring networks and to stimulate actively the expansion of existing and the creation of new monitoring networks.
- To improve integration of and access to phenological data in Europe in a systematic, structural and user-friendly way.

- To exchange knowledge between phenologists from different scientific disciplines (ecology, agriculture, forestry, human health) on tools and techniques used for phenological monitoring, database development, (statistical) data analysis, model development, and impact assessment.
- To demonstrate the wide variety of possible applications of phenological research and its benefits for ecology, agriculture and society (human health and education) and realising a stronger involvement of end-users.

Strategy of EPN

The underlying idea of the EPN-project was that a cost-effective, productive, and long-lasting network can only be achieved by providing information on the above mentioned objectives from one central point that is easily accessible and structurally embedded.
To achieve these objectives and thus to realise a Phenological Thematic Network the EPN-project focused on the following four activities:

1. Coordinating the integration, cooperation, and further expansion of phenological networks in Europe (including: network management, clarifying definitions used, establishing links with educational programmes, non-European networks, international organisations, and potential funding organisations).
2. Establishing an on-line phenological metadatabase and a phenological bibliographical database.
3. Organising specialist workshops on essential topics (modelling, use of earth observation data, phenology and human health, phenology and agriculture, bird migration, and communication, dissemination, and capacity building).
4. Organising two international conferences on phenology involving data providers, scientists, (international) organisations, commercial enterprises, policy makers, and educational organisations.

Rationale "Challenging Times"

The European Phenology Network held its first conference from 5 to 7 December 2001 in Wageningen, The Netherlands. The main aims were to demonstrate the importance of phenological research and to strengthen the cooperation, networking and exchange of information. This conference was an important milestone in the development of an operational phenological monitoring, modelling and forecasting network in Europe. In the year 2002 many people contributed to the development and construction of this network. At the second EPN conference new important steps have been taken to improve the network. As there have been many developments in the past year, it may be useful to outline the state of the art.

State of the art

- It became clear that the timing of life cycle events is largely determined by the climate.
- Consequently, the recent changes in temperature have resulted in marked changes in the timing of life cycle events. The changes can be considered the clearest examples of climate change ecological impacts.
- It has been proven to be easy to communicate the changes in timing of life cycle events to millions of people with relatively little effort.
- Applying (new) information and communication tools played an important role.
- The variability and recent changes in climate have large consequences for a wide range of environmental and socio-economic disciplines like biodiversity conservation, agricultural management, human health, forestry, fisheries, and transportation.

- Potential future changes in climate are likely to have very large consequences for these environmental and socio-economic disciplines.
- A better understanding of the variability and changes in timing of life cycle events is needed in order to enable the different environmental and socio-economic sectors to adapt to and make use of the changes that currently occur and that are likely to occur in the future.
- This better understanding can only be realised if we:
    - observe the variability and changes;
    - analyse the data;
    - develop models to forecast future (short and long term) change;
    - effectively communicate the results to the people involved in management or policy making and
    - include in our communication of data and information concrete instructions / suggestions on what can be done .
- A large number of stakeholders should be involved in this whole process (data providers, researchers, policy makers, international organisations, commerce, NGOs, media, public).
- In addition, each step requires its own tools and technologies.
- In the last few years the European Phenology Network has made much effort to identify these tools, technologies and stakeholders. EPN has also improved the cooperation and communication between all actors involved in phenology.
- So, EPN has paved the way for the next step: The creation of an operational European phenology network that is able to integrate monitoring, modelling and forecasting interactions between climate, biosphere, and society.
- At the second EPN conference we presented and discussed a draft for an overall framework and its different components.

Demand for operational networks

The ideas for an operational phenological network perfectly match with the European and international developments concerning observation networks and applied research activities.

GMES

One of these developments is the Global Monitoring for Environment and Security (GMES) initiative (http://www.gmes.info/). The overall objective of GMES is to support Europe's goal regarding sustainable development and global governance, in support of environmental and security policies, by facilitating and fostering the timely provision of quality data, information, and knowledge. Two main objectives are addressed:

- the implementation of Sustainable Development;
- the integration of the environmental dimension in European policies, which requires a much higher level of coordination between policy areas, the dialogue with stakeholders, and much more public participation than ever before. Information on environmental issues and on the effects of policy measures constitutes an indispensable platform for policy making, dialogue and participation.

The GMES objective is to 'establish a European Capacity for Global Monitoring of Environment and Security' by the year 2008 (A sustainable Europe for a better world: A European Union Strategy for Sustainable Development. COM(2001)264 of 15 April 2001.)

FP6

Another important European Activity is the Sixth Framework Programme (FP6) of the European Commission. FP6 has a budget of 17.5 billion Euro for Science and Technology in Europe. FP6

was launched in early November 2002. One thematic sub-priority for phenology is Global Change and Ecosystems (1.1.6.3). Our plans for an operational network closely link up with area VI Operational forecasting and modelling including global climate change observation systems.
The objective is to observe systematically atmospheric, terrestrial, and oceanic parameters, including climatic parameters, so as to improve forecasting of the marine, terrestrial and atmospheric environment, to consolidate long-term observations for the modelling and in particular prediction, to establish common European data bases and to contribute to international programmes. The research will focus on developing observing and forecasting systems such as the Global Climate Observing System, Global Terrestrial Observing System and Global Ocean Observing System.

Why a thematic approach?

The European Phenology Network applies a thematic approach in constructing the network. There are simple reasons for this: Efficiency and Support.

Efficiency: Many different groups of people work on phenology, but they do not communicate with each other or exchange knowledge, data, tools, and techniques. They do not communicate because they are working on different subjects (agriculture, ecology, etc.), work in different countries (Germany, Netherlands, Spain, etc.), work in different fields of expertise (data monitoring, research, policy making, communication). There is an enormous potential for exchanging knowledge, data, tools, and techniques and thus for improving efficiency, as the way to deal with variation in timing of life cycle events does not vary much in the different subjects, countries, and expertise fields.

Support: Networks aimed at integrating monitoring, modelling and forecasting can only survive over longer time-spans, if they provide products that are valuable (economically, socially or environmentally) to critical consumers. So, if more people are interested in the products of the network, public support for the network activities will be more likely. As phenology has a large number of very different applications, it should be possible to receive sufficient support to maintain a long-term operational network.

From these factors, it can be concluded that an operational phenological network, discussed at the conference, can substantially contribute to achieving the aims and objectives of activities like GMES and FP6.

Why 'Challenging Times'?

The definition of 'Challenging' is: Calling for full use of one's abilities or resources in a difficult but stimulating effort. This clearly covers the situation that we are currently dealing with. There are a large number of challenges that we will and can face within the network. Many of these challenges deal with integration. Examples are:

- To integrate local, regional, national, and international monitoring networks.
- To integrate observations on biotic, abiotic, and socio-economic variables.
- To integrate in situ (field) and remote sensing observations.
- To integrate activities of and communication between different user groups (data providers, researchers, policy makers, NGOs, commerce, media, public).
- To integrate activities that take place in different disciplines (biodiversity conservation, ecology, agriculture, human health, etc.).

- To integrate activities that take place in the context of different environmental problems (climate change, air pollution, biodiversity loss)
- To integrate new information and communication technologies with 'old' tools and techniques.
- To integrate different funding sources (funds from governments at different levels (European Commission, national, local), the public, commercial sector, NGOs)
- To integrate knowledge and activities on different species groups (plants, birds, insects, amphibians)
- To integrate knowledge and activities on terrestrial and aquatic systems.

The proposed phenological network will be able to meet all these challenges successfully because we have representatives from all actor groups and we will be able to bring them together in a coherent framework around an issue important to all of them (although often in a different way).

Objectives of the conference “Challenging Times”

The overall objective of the conference was to present and discuss the future structure and set-up of an operational international phenological network. This network will be based on the European Phenology Network and other existing networks.

Specific objectives:

- To identify partners from different user groups that could participate in the future network (Policy, research, NGOs etc., and different disciplines: agriculture, human health, biodiversity, transportation, etc.).
- Strengthen cooperation, networking, and exchange of information.
- To identify specific demands concerning information needed by the different users (e.g. quality, quantity, spatial and temporal resolution of the information).
- To identify and discuss the main problems that need to be addressed in the future network (gaps in technology, knowledge, standardisation, cooperation, data policy).
- To identify how different user groups should and could benefit from each other in a future network.
- To demonstrate the importance of phenological information.
- To show the latest scientific developments.

Developing a strategy for the future

The basis for discussions on the future structure and set-up of an operational international phenological network was provided by the TIMING project proposal. TIMING (Timing of Life Cycle Events; A European phenological monitoring, assessing, and forecasting infrastructure) was prepared for submission to the Sixth Framework Programme of the European Commission. As the deadline for submission was only three weeks after the conference, the overall structure of the proposal was already clear and the Activity coordinators were known. The conference started with plenary presentations by (Activity) coordinators on the contents and structure of the TIMING project. Consequently, all participants knew whom to contact for which subject during and after the conference. The discussions during the conference on the future structure were pragmatic and constructive because of the clear structure of the strategy and the little time available after the conference to finalise the proposal. The conference clarified the structure, the roles of different organisations, the gaps, the points of concern, new partners, and the official procedures and documents required for finalising and submitting the proposal. The conference proved to be an essential step in the whole process of drawing up the strategy for the future. It would have been better if the conference had taken place a few weeks earlier, so more time would have been available to take all conclusions into account. However, the tight schedule facilitated the decision

making process at various (political) levels and made it easier to bridge the gaps between people and organisations.
The fact that all participants had the opportunity to be involved in working out a future strategy for phenology, strengthened the bond between the participants. Although the participants represented various thematic disciplines and user groups, the conference proved that we all belong to one community with one common objective and that we will all benefit from close cooperation between the various stakeholders (data providers, research, policy makers, media, public), the various thematic disciplines (agriculture, human health, ecology, ICT, education, etc.), and the various countries. As representatives of almost all groups were present during the conference, we were able to find new partners to join the consortium.

Application of phenology

Just as at the first conference, the emphasis was very much on potential applications of phenology. On the first day, after the presentations of the TIMING Activities, there were a number of key-note presentations stressing the importance of phenology. The experiences of the UK phenology Network Nature’s Calendar demonstrated that it is possible to communicate climate change to the general public effectively and that phenology has shown itself capable of reconnecting people with nature. Another presentation demonstrated the important role of phenological information in providing analyses and forecasts of crop yields at European and national levels in near real time to DG-Agriculture and Eurostat. The forecasts are produced by the MARS-Stat programme of the Joint Research Centre. Because of its importance, MARS-Stat is committed to contribute to a Pan-European Data Base on agro-phenology. This presentation made clear that although phenology is an old science it is still relevant to present day activities and policies. Via improvements of crop forecasts, phenological information can contribute to a more effective implementation of the Common Agricultural Policies. Two other relevant aspects of phenology were presented: The Global Monitoring of Environment and Security (GMES) activity of the European Commission and the European Space Agency and the indicator reports of the European Environmental Agency. During the key-note presentation sessions EPN also linked up with two research networks and application fields that had not yet been involved in the EPN-network: the European Marine Biometeorological network and the Bird Avoidance modelling network.
On the first day we also presented future possibilities of communicating phenological observations and results to the public. We approached phenology from a weather forecast perspective. The role of ecology in aquatic systems and the role of phenology in transportation: bird migration in relation with airplanes were also discussed.

Action points for the near future: what is important?

In the final discussion session at the conference we outlined important issues that need to be addressed in the future in order to increase the value of phenology.

- Meetings like the conferences and workshops that took place in the context of EPN are important. We need to continue meeting on a regular basis.
- Continuing the standardisation of observations is seen by many participants as an essential precondition for future cooperation and communication, but especially also for improving the value of phenology as an indicator of the ecological impact of climate change;
- Furthering an increase in awareness of the ecological and socio-economic importance of phenological information by a proper quantification of the importance and by actively disseminating the information.

- Improving the cooperation between Europe and other parts of the world. With EPN, Europe has made significant progress in many areas related to phenology. Other parts of the world may benefit from this knowledge.
- Improving access to non-phenological data like information on climate and land use.
- Phenological research should not only focus on climate change but broaden its scope;
- The phenological community should contribute more actively to large global activities in the context of global change like the Millennium Ecosystem Assessment and the IPCC.
- Continuing the use of ICT-technologies for the gathering, storage, exchange and visualisation of data. Effective cooperation and communication with the ICT-sector will be essential.
- Concentrating more on forecasting the timing of life cycle events in order to increase the socio-economic value of phenology.
- Improving the education of MSc and PhD students in phenology.
- Continuing to break down barriers between the various networks.
- Various applications like the one for agriculture require real time access to phenological information. More development is needed.
- For the agricultural application of phenology it is important to monitor also the timing of certain human activities like e.g. the timing of planting, harvesting, pest control, and nutrient supply.
- The Earth Observation and phenology communities have the same objectives and, therefore, should work together more closely. Existing knowledge is not always used effectively.
- The phenological community should realise for whom they produce the information (politicians, public or environmentalists?). The language of the message will depend on the target group.
- The phenological community should continue to communicate actively with monitoring networks and users of phenological information to determine the information and data needs.
- There is also a need for more experimental approaches to test analyses and models. Furthermore, more attention should be paid to the role of genetics and the impact of phenological changes on genetic information.
- The phenological community should start to address issues such as ownership of data, to facilitate easier access to phenological data.
- Phenological networks should have more contact with other ecological monitoring networks like e.g. the LTER networks.

Extended abstracts

Monitoring phenological changes in Germany and Slovakia: Part 2: Long-term changes with time and relation to climate

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Temporal variability of phenophases

Within a bilateral project of the two meteorological services of Germany and Slovakia, trends of phenological phases and statistical evaluations, the variability of the phases and its relation to climate for the period 1951-2000 were the main part of the study. The objectives of the project and the spatial variability of phenophases have already been described in another paper in this volume (part 1, Dittmann et al.). This paper describes the time aspect of this project.
The following analysis hypothesises that global, regional and also local climate has an impact on phenological phases. This is indicated by

- long-term changes of phases (trends, shift of mean dates),
- year-to-year variability (described by statistical analysis),
- relation to climate parameters, e.g. the air temperature near the ground.

To analyse long-term changes in particular, it was necessary to choose a time period long enough for such an analysis, but with a sufficient data coverage. For the 50-year period 1951-2000 there are at least at some stations and for some phases time series available in both countries. It was decided to use this period, a limited number of 8 stations (5 in Germany, 3 in Slovakia) and 6 phases at each selected station. Statistical analyses were made not only for the whole 50-year period, but also for the subperiods 1951-1985 and 1986-2000 to look for possible climate shifts. The following statistical parameters were computed:

- mean date, median,
- earliest and latest date, quartiles, standard deviation, skewness, kurtosis,
- linear trends,
- correlation with monthly temperature averages.

Selected stations and phases

The selected stations in both countries and their locations are shown in Fig. 1. They represent different climatic regions within the two countries and different elevation levels, except the mountainous regions.
The selected phases are the following:

- Hazel, beginning of flowering,
- Birch, unfolding of leaves,
- Apple, beginning of flowering,
- Winter wheat, beginning of heading,
- Red currant, first fruit ripe,
- Birch, colouring of leaves.

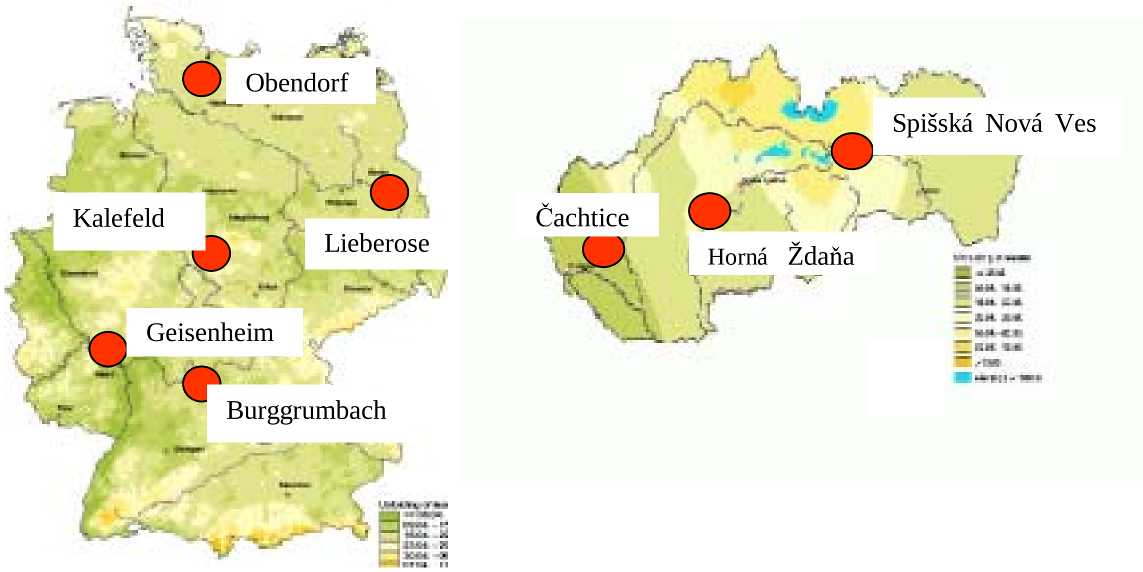

Figure 1: Selected stations for time series analysis in Germany (left) and Slovakia (right).

Results

Tabel 1: Mean, first and last date of the phases “birch, leafing” and “birch, leaf colouring” at the selected stations, period 1951-2000.

Birch, leafing

Station	Country	Latitude	Longitude	Altitude	Mean	First	Last
Obendorf	Germany	54□ 07' N	10□ 10' E	45 m	26.04.	27.03.	12.05.
Kalefeld	Germany	51□ 48' N	10□ 02' E	130 m	22.04.	02.04.	22.05.
Lieberose	Germany	51□ 59' N	14□ 19' E	58 m	22.04.	02.04.	05.05.
Geisenheim	Germany	49□ 59' N	07□ 58' E	120 m	10.04.	26.03.	29.04.
Burggrumbach	Germany	49□ 53' N	10□ 02' E	260 m	17.04.	26.03.	15.06.
Cachtice	Slovakia	48□ 43' N	17□ 47' E	173 m	23.04.	06.04.	08.05.
Horn‡ Zdana	Slovakia	48□ 34' N	18□ 45' E	300 m	22.04.	06.04.	08.05.
Spissk‡ Nov‡ Ves	Slovakia	48□ 57' N	20□ 34' E	460 m	30.04.	07.04.	25.05.

Birch, leaf colouring

Station	Country	Latitude	Longitude	Altitude	Mean	First	Last
Obendorf	Germany	54□ 07' N	10□ 10' E	45 m	17.09.	09.08.	12.10.
Kalefeld	Germany	51□ 48' N	10□ 02' E	130 m	16.10.	22.09.	06.11.
Lieberose	Germany	51□ 59' N	14□ 19' E	58 m	04.10.	12.09.	27.10.
Geisenheim	Germany	49□ 59' N	07□ 58' E	120 m	11.10.	20.09.	06.11.
Burggrumbach	Germany	49□ 53' N	10□ 02' E	260 m	05.10.	10.09.	27.10.
Horn‡ Zdana	Slovakia	48□ 34' N	18□ 45' E	300 m	09.10.	16.09.	30.10.
Spissk‡ Nov‡ Ves	Slovakia	48□ 57' N	20□ 34' E	460 m	05.10.	05.09.	27.10.

The mean date for the spring phase “birch, leafing” varies from April 10 in Geisenheim (near the river Rhine) up to April 30 at Spisská Nová Ves in eastern Slovakia (Tab. 1). The earliest date is about 2-4 weeks sooner than the mean date, the latest date about 2-4 weeks later. For the autumn phase “birch, leaf colouring” the mean date varies from September 17 at the northern German station Obendorf up to October 16 in Kalefeld (central Germany). Again there is a variability of a few weeks between the earliest and the latest date.
Country averages (Tab. 2) show that on average the spring phases (e.g. flowering of sallow, birch leafing) occur in Germany sooner than in Slovakia, for the summer phases (e.g. red currant, first fruit ripe) there is hardly any difference, and the autumn phases (e.g. birch, leaf colouring) are sooner in Slovakia than in Germany. It is interesting that 1990 was the year with the earliest spring phases in both countries. In that year spring was quite mild in Central Europe, and this points to the hypothesis that large scale climate factors have an impact on the onset date.

Table 2: Country averages of mean, first and last onset date of some phases (period 1986-2000, due to better data coverage).

Beginning of flowering of sallow

Country	Mean	First	Year	Last	Year
Germany	19.03.	28.02.	1990	10.04.	1986
Slovakia	06.04.	18.03.	1990	18.04.	1987

Unfolding of leaves of birch

Country	Mean	First	Year	Last	Year
Germany	18.04.	05.04.	1990	30.04.	1986
Slovakia	23.04.	11.04.	1990	02.05.	1987

Fruit ripe of red currant

Country	Mean	First	Year	Last	Year
Germany	04.07.	24.06.	2000	16.07.	1987
Slovakia	02.07.	24.06.	1989	08.07.	1987

Colouring of leaves of birch

Country	Mean	First	Year	Last	Year
Germany	04.10.	30.09.	1993	09.10.	1999
Slovakia	29.09.	27.09.	1986	04.10.	1997

The comparison between the onset dates of the two subperiods (Fig. 2) reveals that in particular the early spring phases in Germany occurred earlier in the more recent period 1986-2000 than before. For the other phases such a systematic change cannot be seen. In many cases the trend analyses (not shown here) indicated quite strong and significant trends (to earlier dates) for the period 1986-2000 compared with the period 1951-1985. However, there is also a superposition of a strong year-to-year variability. For longer periods the trends are only significant for lower altitudes.

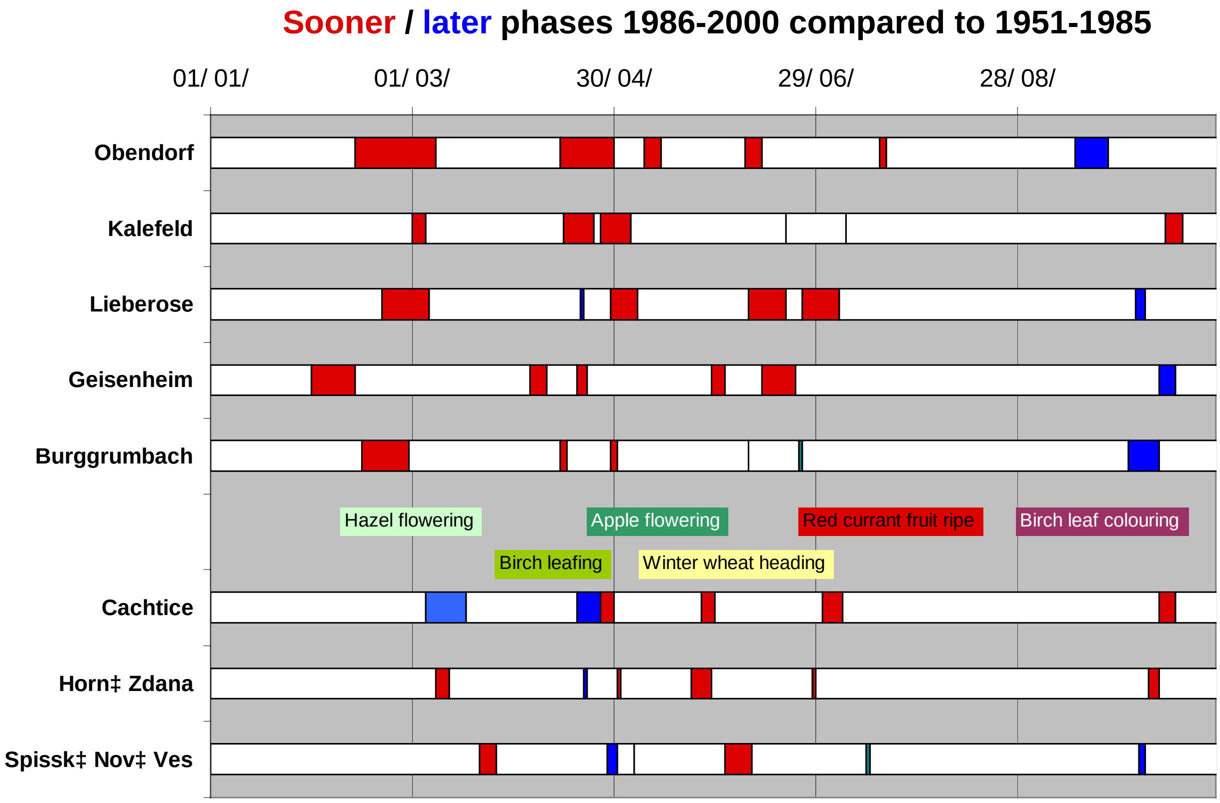

Figure 2: Comparison of the mean onset dates between the subperiods 1986-2000 and 1951-1985 of the 6 phases at the 8 stations mentioned. Red bars indicate that the mean onset date was sooner in the period 1986-2000, blue bars indicate a later onset date.

Especially the spring phases turned out to be strongly dependent on the air temperature of the three months before the onset date, as also found in other investigations. In the case of apple flowering in northern Germany, for example, a correlation of 0.8 with monthly mean maximum temperature can be found if the March temperature is weighted with a factor 2 and a quadratic regression is used. However, since the onset date changes with time, the correlation is not constant either.

Summary and conclusions

The results of the statistical analysis can be summarised as follows:

- There are large scale climate influences on phase onset dates in both countries.
- There are long-term impacts (trends), but there is also a high year-to-year variability.
- There are also small scale (regional and local) influences. The variability of the onset dates within one country is greater than the variability from country to country.
- There are strong inverse relations between spring phases and mean temperature, but they are not necessarily constant with time.

A more detailed analysis could be made after extending to a larger area (e.g. whole of Europe) using a comparable data base over the whole area. Such a reference data base is suggested by a future COST action (see Dittmann et al., Part 1 in this volume).

Phenological monitoring of forest trees

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Abstract

The paper presents an evaluation of phenological data from special phenological stations in forestry areas of Slovakia that were recorded on Birch, Beech, Oak, Larch, Rowan and Sycamore from 1986 to 2000. The variability and tendency in timing of phenological phases that limited the growing season (onset of leafing and general colouring of leaves) and the duration of interval between them were analysed. The results showed a tendency of shifting the leafing onset by 5 days earlier and the colouring of leaves by 5 days later and so a prolongation of the growing season by 10 days during the period 1986 – 2000.

Key words: forest trees, phenological phases, growing season

Introduction

The network especially observing forest plants belongs to the Partial Monitoring System of Meteorology and Climatology of the Slovak Hydrometeorological Institute. Chosen phenological events are recorded from the beginning to the end of the growing season. The variability and changes in the onset of leafing and colouring of leaves and in the duration of the growing season was analysed from 1986 to 2000.

Material and method

Phenological data were recorded at an altitude of 100 to 1400 meters above see level. Only those data series were evaluated from which no more than three years of recorded data were missing in the fifteen year time series. Phenological phases the beginning of leafing, general colouring of leaves and the interval (days) between their onset were chosen for the analysis of the variability and tendency in the onset, end and duration of the growing season. Phenological events were observed on the species:

- Birch (*Betula pendula*) – 19 localities,
- Beech (*Fagus sylvatica*) – 25 localities,
- Oak (*Quercus robur* and *Q. petraea*) – 21 localities,
- Rowan (*Sorbus aucuparia*) – 11 localities,
- Sycamore (*Acer pseudoplatanus*) – 15 localities
- Larch (*Larix decidua*) – 17 localities.

The average date of the onset of phenological phases and the average interval duration were calculated for each species in each year of the period 1986 – 2000. Then one yearly average date of leafing onset from the all average dates of leafing onset in one year – *leafing index* was calculated, one yearly average date of general colouring of leaves – *colouring index* and one yearly average of the interval duration - *interval index*.

Results

Beginning of leafing

The leafing period began with the leaves unfolding of Birch, then needles appearance of Larch and continued with leaves unfolding of Beech, Oak, Rowan and finished with the leaves unfolding of Sycamore. The latest average dates of leafing were recorded in 1987 and the species began with the leaves (needles) unfolding only in the first half of May. The earliest average dates were recorded depending on the species in 1989, 1990, 1999 and 2000.

The leafing index moved slightly, statistically not significantly to an earlier time period from the beginning of May to the second half of April (Fig.1).

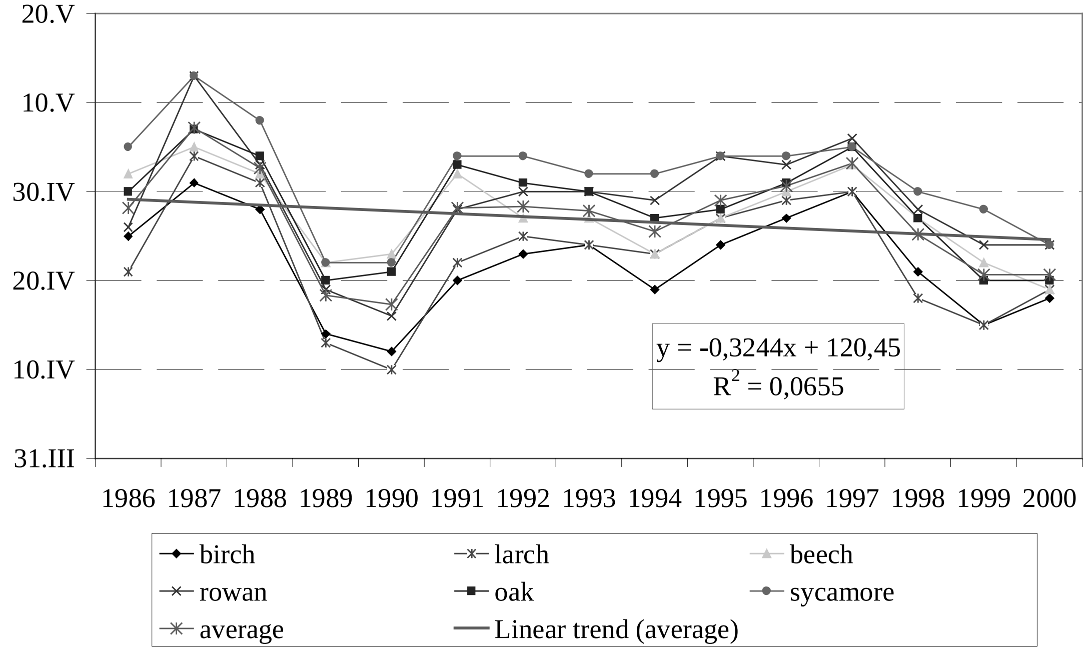

Figure 1: Course and tendency of the leafing indexes (date) in the period 1986 – 2000.

General colouring of leaves

The period of the general colouring of leaves began with Rowan, followed by Sycamore, Beech, Birch, and Oak. The general colouring of needles of Larch occurred last of all. The earliest (1986, 1993) and the latest (1987, 1997) average onsets differed depending on the species.

The colouring index moved slightly (opposite to the leafing index) to a later occurrence – from the second half of September to the first half of October (Fig.2).

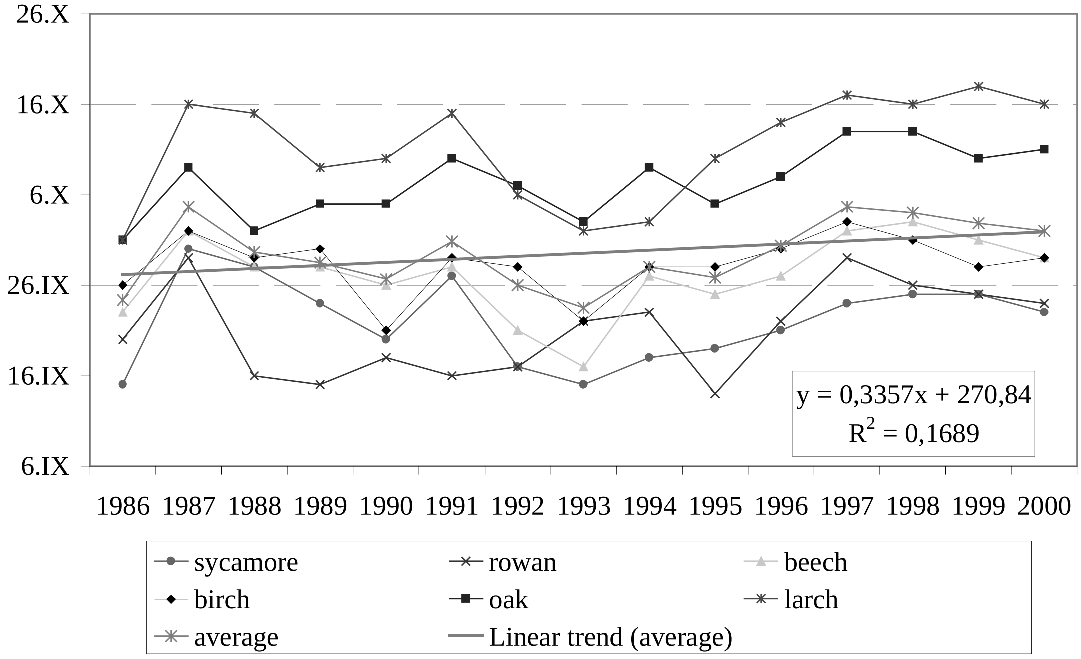

Figure 2: Course and tendency of the colouring indexes (date) in the period 1986 – 2000.

Interval leafing onset – general colouring of leaves

Days between leaves unfolding and leaves colouring approximately correspond with the duration of the growing season. The average value of the interval duration was shortest for Sycamore (144 days) and for Rowan (145 days) more than 5 months for Birch (153), for Beech (159 days) and for Oak (162 days). The longest average value of interval (nearly 6 months) was for Larch (171 days). The shortest average values of growing season were found in 1986 and 1993 except for Rowan (1995) and Oak (1988). The longest average values varied from Sycamore and Birch in 1989, Rowan in 1990, Beech and Oak in 2000, and Larch in 1999 (Fig. 3). As a consequence of an earlier leafing onset and on the other side, a later general colouring of leaves, the growing season tended towards a prolongation of 10 days approximately during the fifteen years time period from 1986 to 2000 (Fig.3).

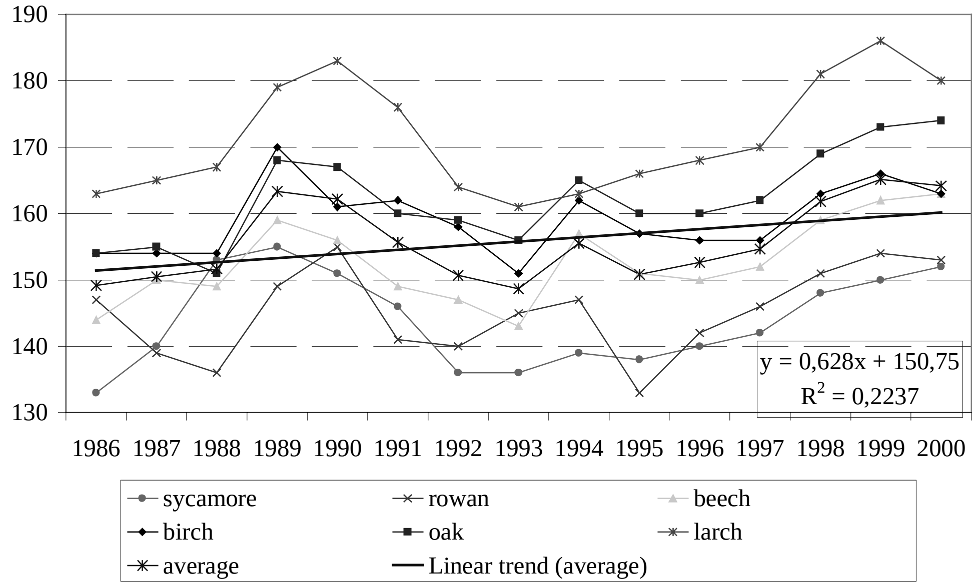

Figure 3: Course and tendency of interval index (days) in the period 1986 – 2000.

Conclusions

The positive and negative deviations of the yearly leafing indexes from the average value of the period 1986 – 2000 were higher in 10 years, those of the yearly colouring indexes in 5 years. The positive deviations of interval indexes were influenced both by an earlier leafing onset and a later colouring onset in the last three years of the evaluated time period, especially. If the leafing index was close to the long time average of leafing onset, the shorter interval duration usually influenced an earlier colouring of leaves (1986, 1992 and 1993).

The highest shift of the beginning of leafing to an earlier date was found for Beech and it was more than one week during fifteen years, and Oak one week, approximately. The highest shift of the general colouring of leaves to a later date (more than one week) was found for Oak.

The growing season was prolonged due to an earlier leafing by Beech, Birch and Sycamore. On the other side, this prolongation was also caused by a later general colouring of leaves or needles for Oak, Rowan and Larch.

The prolongation of the growing season was only 4 days during the fifteen years period for Sycamore but in 15 days in this time period for Oak.

Our results correspond with the results of data analyses from the International Phenological Garden (IPG) network coordinated by the Humboldt University in Berlin. A similar evaluation from the period 1969 – 1998 based on the leafing index and fall index showed a significant trend of moving the leafing to an earlier period and fall to a later period, so the growing season was prolonged by 3,5 days per decade (Chmielewski, Rötzer, 2001).

Similar results were presented on the basis of the estimation of phenological data from the network of the German Meteorological Service (DWD), which was chosen to cover the whole of the

growing season (Menzel, Estrella, Fabian, 2001). The authors detected an asymmetric prolongation of the growing season as a consequence of the higher shift of the beginning of leafing to an earlier period but only a moderate shift of colouring of leaves to a later period.
The same reasons for the prolongation of the vegetation season were also observed in Switzerland (Defila, Clot, 2001).

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Quantifying the environmental drivers of the phenological phases of woody species

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Summary

There is now a widespread interest in using observations of phenological stages in plants and animals as indicators of climate change. The existence of long-term phenological records has made it possible to model the relationship between temperature and the phenological development for a number of plant species. However, many of these models simply establish the relationship between temperature and phenophase development. They do not account for additional environmental signals that may also influence phenology.

This work describes an approach taken for refining the use of plant phenology as a bioindicator of climate change. Controlled environment experiments will be conducted to investigate the effect of environmental variables such as light, temperature, water and nutrient availability on phenophases. The experiments will be carried out using tree clones from the International Phenological Gardens, and the results are expected to be used to develop mechanistic models of tree phenology.

Introduction

It is now well established that climate change threatens natural and human systems on a global scale. In order to mitigate its impacts it is crucial to understand its effects on living organisms and detect their response at an early stage. Plant phenology is a biological indicator that can be used to monitor, quantify and assess climate change. The timing of the phenophases of plants has been found to be strongly related to temperature wherever long term records have been compared with meteorological data. In fact, mid-latitude spring phenophases are primarily a response to accumulated temperature-driven units above a threshold level with earlier plant development corresponding to higher temperatures (Beaubien and Freeland, 2000). The recent interest in using these types of observations as indicators of climate change has prompted a series of studies utilising phenological data sets to model the relationship between temperature and phenological development (Menzel, 2000, Chmielewski and Rötzer, 2000, Cannell *et al.*, 1999). This has been made possible because the existence of long term records allows the distinction to be made between general phenological trends from year-to-year fluctuation.

However, the physiological processes controlling plant phenology are still poorly understood. Temperature and photoperiod are almost certainly the most important factors triggering phenophases, but it is not clear how they act on the actual physiology of these events. Other environmental factors could also have an influence on phenology. Among them are water availability, soil fertility, air humidity and light intensity. Even though their role is secondary when compared with the effects of temperature, it is important to understand how they influence phenological events to refine their use as climate change indicators.

The phenological models that have been proposed so far are unsatisfactory because they have been based only on long-term observation from natural conditions (Hanninen, 1995). Even though such an approach is necessary, it is not sufficient for model testing. In fact, because such models lack

realism (i.e., they are not based on actual physiological processes), they might lose accuracy when tested in different environments (Hanninen, 1995).
In order to find realistic and accurate phenological models, the phenophases in question must be subjected to a series of varying environmental conditions (Fuchigami and Wisniewski, 1997). Only in this way will it be possible to obtain reliable models predicting phenological responses in extreme situations such as in a hypothetical global warming scenario (Hanninen, 1995).

The International Phenological Gardens (IPGs) network provide a Europe-wide database of comparable information on the timing of various growth phases of a number of tree species. Each of the gardens consists of a collection of tree clones vegetatively propagated from the same "parent garden" in Germany. Because the network was established at the beginning of the 1960s, decadal data sets are available. Four IPGs are located in Ireland, and their close proximity to meteorological stations has made it possible to test the relationship between climatic variables and the timing of tree phenophases (Sweeney *et al.*, 2002). The most sensitive indicators showing the most significant and pronounced response to temperature trends were found to be *Fagus sylvatica*, *Betula pubescens* and *Tilia cordata* (Sweeney *et al.*, 2002).

The aim of this study is to quantify the influence of various environmental drivers affecting the phenology of some of the indicator trees observed in the Irish IPGs. In order to refine their use as climate change indicators, their response to a broad range of scenarios will be tested in controlled environmental conditions. A deeper understanding of the environmental factors affecting phenology and more reliable phenological models will make it feasible to use the data from the IPGs (and from trees of the same species) to summarise climate patterns in Ireland and Europe and predict climate change impacts. As the project is in the early stages, there are no data to report. We will, therefore, only outline the approach that has been taken to conduct the study and the expected outputs.

Methodology

Phase 1. Vegetative propagation of tree clones taken from the IPGs.
The approach taken involves the vegetative propagation of several tree species grown in the Irish IPGs. This will allow to test the effect of different environmental conditions on trees with the same genetic make up and for which extended data sets are present. The trees selected are *Fagus sylvatica, Tilia cordata, Betula pubescens, Salix smithiana* and *Salix aurita*. These include the trees whose phenophases were found to have good correlations with temperature in the report on climate change indicators for Ireland (Sweeney *et al*., 2002). Their propagation is currently being carried out through cuttings (*Tilia cordata, Salix smithiana*, *Salix aurita* and *Betula pubescens*) and grafting (*Fagus sylvatica*). The cutting material was taken from the IPGs in Valentia and Wexford (JFK arboretum).

Phase 2. Experiments in controlled environmental conditions
Once the clones will be established, they will be given different treatments testing the effect of temperature, photoperiod, water availability, soil fertility and air humidity on tree phenophases. For each of these factors, different scenarios will be tested:

- *Interaction between photoperiod and chilling duration*: 5 chilling durations (0, 50, 80 and 110 chilling days at 4^{o}C) in conjunction with 2 day lengths (8 hours and 18 hours) treatments.
- *Water availability*: 3 soil water treatments (80%, 50% and 30% soil water contents).

- *Soil fertility*: 2 nitrogen treatments simulating a high fertility (nitrogen concentration of 28 mgL^{-1} will be applied to the pots 4 times monthly) and low fertility situation (nitrogen concentration of 14 mgL^{-1} will be applied to the pots once a month).
- *Air humidity*: two different treatments simulating dry (40% humidity) and humid (90% humidity) air conditions.

The phases under observation will include: bud burst, leaf unfolding, flowering and leaf fall.

Phase 3. Development of phenological models for the trees under investigation
Following the collection of phenological observations, mechanistic models of tree phenology accounting for all the factors tested will be developed. They will be utilised to refine the IPGs tree clones as bioindicators of climate change and to a better understanding of the impacts of global warming.

Expected outputs

Some of the expected outputs of the project are summarised below:

- Quantification of the effect of the different environmental variables on the timing of phenophases.
- Development of mechanistic models of tree phenology for the tree clones/species used as indicators in the IPGs.
- Integration of the phenological models into climate change impact studies.
- Creation of a phenological index summarising climate patterns.

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Spring phytophenological trends in Slovenia

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Abstract

This study analyses a long-term phenological time series (1955-2000) to assess the impact of increased winter and spring temperatures on plant development because spring phenological events are particularly sensitive to temperature. The 46-year series of leaf unfolding in beech, common silver birch, large-leaved lime and horse-chestnut, and of flowering of common silver birch, dandelion, goat willow, hazel, snowdrop, black locust, common elder, common lilac and large-leaved lime were studied at eight selected observation points in Slovenia. Phenological data were combined in an annual leaf unfolding index, early-spring flowering index and late-spring flowering index to determine the changes in the beginning of the growing season. There were significant differences in the trends of the different phenophases in spring. The mean linear trends (days per decade) ranged from -1.4 for leaf unfolding, -2.2 for late-spring flowering and -3.1 for early-spring flowering. This resulted in an earlier leaf unfolding of 6 days and an earlier flowering of 10-14 days. Observed changes (a 10-day shift to earlier spring) in the average beginning of the growing season in Slovenia corresponded well with changes in early-spring temperatures (February to April). The investigation showed that a warming of 1°C in early-spring promoted the beginning of the growing season by 4 days. Possible consequences of advanced spring on plants from an agricultural viewpoint are discussed as well.

Key words: Phenology · Growing season · Trends ·Air temperature changes · Slovenia

Introduction

Phytophenology deals with the recurring growth and development phenomena in plants in their annual rhythm (Lieth, 1974). The occurrence times of characteristic vegetation stages (phenophases) are closely related to the climate of the observation site and the current weather. Inter-annual changes in spring plant phenology may be the most sensitive and observable indicators of the plant response to climate change (Beaubien and Freeland, 2000). Earlier spring development is occurring in different parts of Europe. The earliest flowering species in the growing season show more variability in bloom time over the years than later-flowering species (Fitter et al. 1995). Ahas (1999) reported that springtime has advanced 8 days on average over the last 80 years; over the last 40 years even faster. Phenological data from the International Phenological gardens for the period 1969-1998 showed the average beginning of the growing season across Europe advanced by 8 days (Chmielewski and Rötzer, 2002). Earlier spring plant development has also been reported for North America (Beaubien and Freeland, 2000), a movement forwards of 8 days in the timing of spring development was noticed in the Edmonton area (Alberta/Canada) over the last six decades. The observed trends in the onset of spring corresponded well with the changes in air temperature and circulation (North Atlantic Oscillation) in Europe (Chmielewski and Rötzer, 2001; Črepinšek et al., 2002) respectively, with Southern Oscillation over western Canada (Beaubien and Freeland, 2000). Besides being influenced by the temperature and the length of the day, phenological dates are mainly induced by the weather during the actual vegetation period, the past vegetation period and the dormancy period (Defila and Clot, 2001). Man-induced changes are thought to be among the causes of global warming, and higher temperatures in late winter and early spring induce an earlier growing season (Bergant et al., 2002). This study analyses long-term phenological time series to asses the impact of air temperature changes on selected plants in Slovenia.

Materials and methods

For long-term phenological analyses only the qualitatively best phenological data over at least 30 years were selected. The study is based on eleven common plants at eight different observation sites (Table 1). These phenological dataseries were extracted from the historical phenological data set of the Environmental Agency of Slovenia. Spring phenophases (leaf unfolding, flowering) were selected for study because in Slovenia the effect of climate change is more pronounced in early spring. The selection was also dependent on the availability of quality data set. First, a logical and critical examination of the data was conducted including plotting all the phenological data. No data were added or corrected because filling in the gaps could change the trends of complete records. For this study the phenological data of eleven species were combined in an annual leaf unfolding index, early-spring flowering index and late-spring flowering index to determine the changes at the beginning of the growing season in Slovenia for the period 1955-2000 (Table 1). Combining species phenophases to derive an index value has the advantage of summarising plant responses to weather conditions over an extended period, respectively region (Castonguay and Dube, 1985; Beaubien and Freeland, 2000). Such phenological information, gathered from several stations, provides common but more reliable data (Schaber, 2002).

For the study of phenological and mean monthly air temperature time series the linear trend analysis was used. For the statistical analysis, the STATGRAPHICS Plus 4.0 and EXCEL 2002 standard modules were applied. Correlations were calculated between phenological data and mean monthly air temperatures over 46 years (1955-2000).

Results

Growing season index and its variability

As a long-term average (1955-2000), the beginning of the growing season (defined as Growing Season Index) in Slovenia started on 24 April. Standard deviation of the Growing Season Index is 6.7 days ,with a variation interval of 30 days. Between 1988 and 2000, 11 out of 13 years showed an earlier onset of spring, compared with the long-term average (Fig. 1). Five earliest springs were noticed in 1994, 1990, 1989, 2000 and 1998. The beginning of the growing season was extremely early in 1994 (10 April), and extremely late in 1956 (8 May).

Table 1: Phenological data: phenophases, indicator plants, phenological indexes and locations.

PHENOPHASES:
- First leaf unfolding date
- Flowering date

INDICATOR PLANTS:
1-**beech** (*Fagus sylvatica* L.); 2-**black locust** (*Robinia pseudoacacia* L.); 3-**common elder** (*Sambucus nigra* L.); 4-**common lilac** (*Syringa vulgaris* L.); 5-**common silver birch** (*Betula pendula* Roth.); 6-**dandelion** (*Taraxacum officinale* Weber/Wiggers); 7-**goat willow** (*Salix caprea* L.); 8-**hazel** (*Corylus avellana* L.); 9-**horse-chestnut** (*Aesculus hippocastanum* L.); 10-**large-leaved lime** (*Tilia platyphyllos* Scop.); 11-**snowdrop** (*Galanthus nivalis* L.)

PHENOLOGICAL INDEXES:
A phenological data set was used to calculate four phenological indexes:
Leaf unfolding index - LI
The leaf unfolding index is determined as the annual mean of leaf unfolding dates for beech, common silver birch, large-leaved lime and horse-chestnut.
Early-spring flowering index - F_1I
The spring-flowering index is determined as the annual mean of the flowering dates for common silver birch, dandelion, goat willow, hazel and snowdrop.
Late-spring flowering index - F_2I
The late-spring flowering index is determined as the annual mean of the flowering dates for black locust, common elder, common lilac and large-leaved lime.
Growing season index - GSI
The growing season index is the mean value of the three phenological indexes (LI, F_1I, F_2I) for eleven species at eight locations: **$GSI = (LI + F_1I + F_2I)/3$**

LOCATIONS:
1-**Celje** ($46^0 15'$, $15^0 15'$, 242 m a.s.l.); 2-**Ilirska Bistrica** ($45^0 34'$, $14^0 15'$, 414 m a.s.l.); 3-**Lesce** ($46^0 22'$, $14^0 11'$, 515 m a.s.l.); 4-**Ljubljana** ($46^0 04'$, $14^0 31'$, 299 m a.s.l.); 5-**Maribor** ($46^0 32'$, $15^0 39'$, 275 m a.s.l.); 6-**Murska Sobota** ($46^0 39'$, $15^0 12'$, 190 m a.s.l.); 7-**Novo mesto** ($45^0 48'$, $15^0 11'$, 220 m a.s.l.); 8- **Rateče** ($46^0 30'$, $13^0 43'$, 864 m a.s.l.)

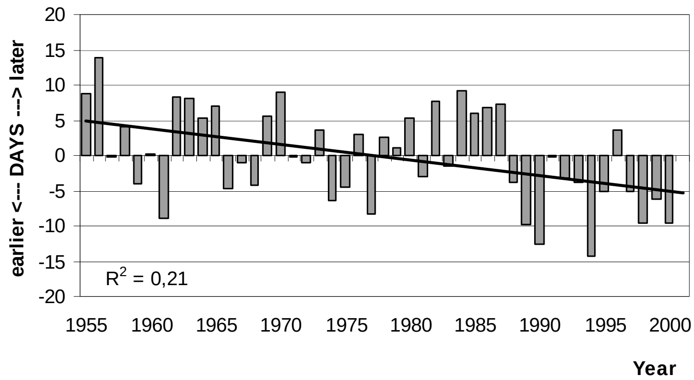


Figure 1: Long-term trend in the growing season index. The Julian days are shown as deviations from the mean growing season index for all data.

*Table 2: Long-term trends of spring phenological phases in Slovenia for the period 1955-2000. Significant trends are marked:**** *p<0.01,* ** *p<0.05,* * *p<0.10.*

Phenological phase	Change (days per decade)	Regression	R^2
Flowering of black locust	-2.6	-0.27	0.21***
Flowering of common elder	-2,6	-0.25	0.21***
Flowering of common lilac	-2.2	-0.21	0.16***
Flowering of common silver birch	-1.3	-0.14	0.06*
Flowering of dandelion	-1.7	-0.18	0.07*
Flowering of goat willow	-4.6	-0.45	0.24***
Flowering of hazel	-4.3	-0.44	0.13**
Flowering of large-leaved lime	-1.3	-0.14	0.08*
Flowering of snowdrop	-3.7	-0.37	0.17***
Leaf unfolding of beech	-1.1	-0.11	0.10**
Leaf unfolding of common silver birch	-2.0	-0.19	0.13**
Leaf unfolding of horse-chestnut	-1.7	-0.18	0.14**
Leaf unfolding of large-leaved lime	-0.6	-0.07	0.03

Trends

The trends of all phenological phases (each phenological phase is averaged for eight locations) are given in Table 2. All but one of the trends of the spring records were significantly negative (38% at the 0.01 level, 31% at the 0.05 level, 23% at the 0.10 level; 8% were not significant). Negative trends have indicated an earlier onset of leaf unfolding and flowering over the past decades. The mean linear trends (days/decade) ranged from -1.4 for leaf unfolding, -2.2 for late-spring flowering and -3.1 for early-spring flowering. This represented an advance of 6 days in the timing of leafing and of 10-14 days in the timing of flowering. The growing season index showed a significantly negative trend of 2.2 days per decade, corresponding to a 10 days earlier beginning of the growing season over the last five decades.

There are differences between the spring trends of the different phenophases observed, the higher trends being found for early-spring flowering of *Coryllus*, *Salix* and *Galanthus*, indicating that changes of events occurring in early spring are more distinct and related to considerable changes in late-winter and early-spring temperatures. Changes are more distinct for phenophases of flowering, which indicates that these phenophases are more sensitive to air temperature.

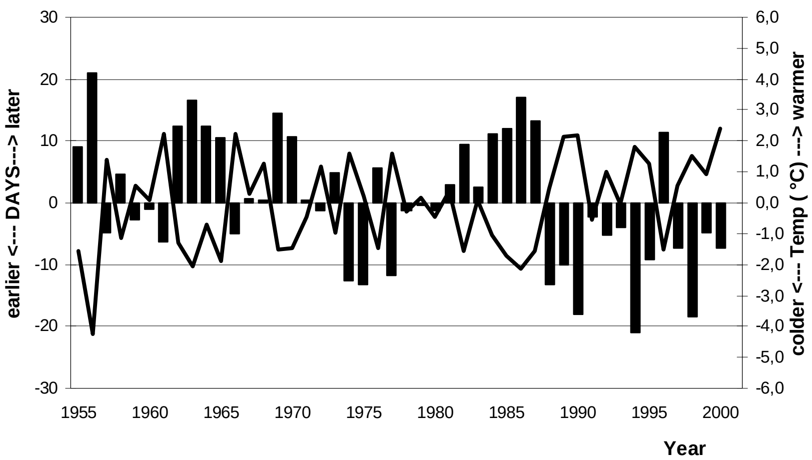
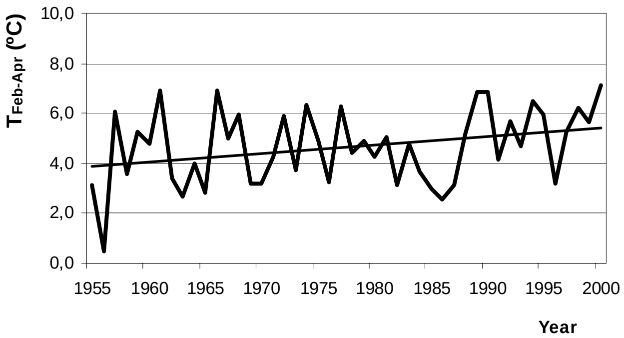


Figure 2: Early-spring flowering index and temperatures with deviations from the means (1955-2000). Vertical bars represent the annual early-spring indexes (the mean of flowering dates for Betula pendula, Taraxacum officinale, Salix caprea, Corylus avellana *and* Galanthus nivalis*) expressed as deviations in days from the mean 46-year value. The line represents the annual deviations of the temperature in °C from the 46-year spring mean temperature (February to April).*

Relations to air temperatures

The annual timing of spring phenophases is largely a response to temperature and reflects the thermal conditions of the specific year and the specific location. From February to April significantly negative correlation coefficients between GSI and temperature were found, meaning that higher temperatures in early spring promote earlier flowering and leaf unfolding (Fig. 3).



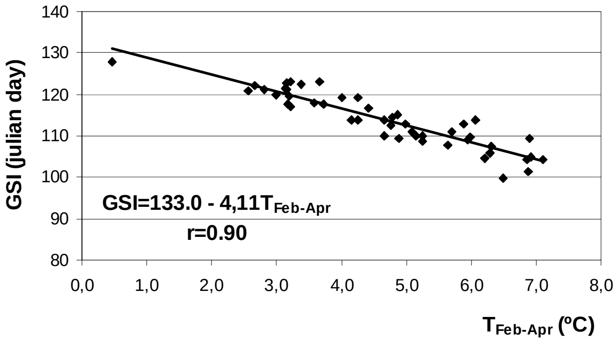


Figure 3: Long-term trend in mean air temperature from February to April ($T_{Feb\text{-}Apr}$) in Slovenia for the period 1955-2000 (left). Relationship between mean spring temperature $T_{Feb\text{-}Apr}$ (February to April) and Growing Season Index–GSI (right). A warming of 1ºC in $T_{Feb\text{-}Apr}$ means approximately a 4 days earlier beginning of the growing season in Slovenia.

The monthly temperatures for eight locations in February, March and April were averaged for each year. These temperatures and GSI correlated at a correlation coefficient r=-0.90. A comparison with the simpler relationship with the temperatures per month confirmed that relationships were stronger when the temperatures of many months were treated together. The later beginning of the growing season was related to temperatures lower than average (Fig. 2). According to the regression equation, a warming of 1°C promoted the beginning of the growing season by 4.2 days in Slovenia.

A trend analysis of air temperature was made in order to investigate the cause of spring phenological trends. Mean temperatures for February, March and April were averaged for each year for eight selected locations. We found positive trends in air temperature (+1.6°C) for

February to April for the last 46 years, which accounts for the observed trend in the beginning of the growing season.

Discussion

Our investigation showed that there has been a trend to earlier leaf-unfolding and flowering in Slovenia over the last 46 years. The obtained results concerning the regional trend in the beginning of the growing season in Slovenia agreed with the Europe-wide trends of Chmielewski and Rötzer (2002) and Menzel et al., (2000). Spring phenological trends corresponded well with changes in air temperature in early spring (February-April). The results of our analysis confirm findings of others authors concerning the influence of air temperature on the timing of spring events (Chmielewski and Rötzer, 2001). The result that an increase in mean spring temperature of 1°C is associated with an advanced beginning of the growing season by 4 days coincides with the findings of Fitter et al., 1995 and Sparks et al., 2000.

There is no doubt that global warming has led to an earlier beginning of the growing season. What are the implications of this trend for plant species? Plants have different sensitivities to climatic oscillations; this may lead to changes in population dynamics. Differences in phenological response may affect the competition between plant species (Kramer et al., 2000) and promote those with a better adaptive response. Changes in species distribution and abundance are expected to result from climate change, which may have positive or negative effects. New crop varieties can become more productive in specific regions, and, on the other hand, new pests, diseases or weeds may turn up. We expect that flowering will remain in approximate synchrony with the pollinating species, but implications of trends in phenological responses need to be examined for all levels of system plant-environment system (Beaubien, 1996). An increase in warmer winters and springs may result in serious damage because of late spring frosts in agronomy or forestry resulted in a loss of a year's seed production or a change in species composition in forests.

If the predicted winter and spring warming over the next decades will materialise, we have to expect a continued trend towards earlier development, but a linear extrapolation of the statistical trends, found in our or in other investigations would, of course, not be correct. The lower limit for a spring phenophase date is probably best determined by examining the species phenology at the southern limit of their distribution (Sparks et al., 2000). The early spring phenophases are the best timing predictors for subsequent plants events and thus, phenological data and trends could assist us in adapting to climate change and variability.

Conclusions

The most important results of this study can be summed up as follows:

1. Spring phenological data for the period 1955-2000 were combined in an annual leaf unfolding index, early spring flowering index and late spring flowering index to determine the changes in the beginning of the growing season in Slovenia.
2. In the last five decades, the average beginning of the growing season in Slovenia has advanced by 10 days, whereby the extreme early dates were observed in the last decade.
3. There were significant differences among the trends of different phenophases in spring: the mean linear trends ranged from -1,4 days/decade for leaf unfolding; -2,2 days/decade for late spring flowering and -3,1days/decade for early spring flowering.
4. The leaf unfolding was 6 days earlier and the flowering 10-14 days earlier over the 46 years studied.

5. The observed trends in the beginning of the growing season correspond well with the changes in air temperature in the early spring (February to April).
6. A warming in early spring (February to April) of 1°C leads to an advanced spring by approximately 4 days.

Acknowledgements. Phenological and meteorological data sets were kindly offered by the Environmental Agency of Slovenia of the Ministry of the Environment, Spatial Planning and Energy.

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Monitoring phenological changes in Germany and Slovakia: Part 1: spatial variability

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Motivation of a German-Slovak pheno-climatological project

The date of occurrence of phenological phases is dependent on local and regional climate conditions. Therefore, a considerable spatial variability of the phases can be observed within Europe. For a further study a bilateral project was set up to compare the climatological properties of phenological data in two countries, Slovakia and Germany. At the meteorological services of the two countries, the German Meteorological Service and the Slovak Hydrometeorological Institute, appropriate networks and archives of phenological data were available, which offered enough material to analyse the spatial and temporal variability of phenological phases. The aim of the project was to evaluate and compare phenological data of both countries as a contribution to regional climate monitoring and to an understanding of the interactions between the biotic and abiotic elements of the environment. To realise this, two main objectives of the project were identified:

- Exchanging information on phenological observations, data processing, quality control and evaluation methods,
- Designing comparable climate monitoring products:
    - phenological maps,
    - trends of phenological phases,
    - statistical evaluations (diagrams, tables).

It was a three-year project (2000-2003). Every year, two meetings were organised (one in each country) to set up the work plan, to exchange information and to compare the results of the project work. The information exchange was necessary because data bases and also evaluation methods vary from country to country, so a common data base and common evaluation methods had to be found. Comparable climate monitoring products were designed with a spatial aspect (construction of maps) and a time aspect (trends and statistics). In this paper, only the spatial aspect is described. The results of time series evaluations are presented in a second paper in this volume (Bissolli et al.).

Selection of phases and evaluation period

It was agreed to choose the 15-year evaluation period 1986-2000 for the construction of maps. For this period, the data base is much better than for the years before 1986. The maps present averages of the onset date of phenological phases over these 15 years. For these maps the following 13 phenological phases were selected:

- **Spring phases:**
  - Oak, unfolding of leaves,
  - Birch, unfolding of leaves,
  - Locust tree, flowering,
  - Sallow, flowering,
  - Apple, flowering,
  - Winter wheat, heading.
- **Summer phases:**
  - Elder, first fruit ripe,
  - Red currant, first fruit ripe,
  - Rowan, first fruit ripe.
- **Autumn phases:**
  - Oak, leaf colouring,
  - Birch, leaf colouring.
- **Length of vegetation period (differences between the two phases):**
  - Oak, leaf colouring – unfolding,
  - Birch, leaf colouring – unfolding.

All these phases were observed in both countries. This selection considers all phenological seasons and different kinds of plants (agricultural and wild plants, fruits).

Method of map construction

Although the map construction methods differ slightly from each other, it was decided that each of the two countries would produce its own maps. As an example, the German method is described here.

The maps were constructed using a spatial inverse distance interpolation between the time averages of the observations at the stations. In the case of those phases which are significantly dependent on altitude (especially the spring and summer phases), the elevation was taken into account via a reduction of the phenological dates to mean sea level using a linear regression before applying the spatial interpolation (and recomputation to real altitudes afterwards). The regression equations were different for various regions within Germany, and also the number of regions differed from phase to phase. Only those stations were used for the regression which did not have more than 5 missing years. The results of the map construction were grid fields of 1 km pixels as averages for the period 1986-2000.

To facilitate the comparability of German and Slovak maps, the same colours, intervals and scale (1:2.5 millions) were used for both countries. Areas above the plant species line were left blank on the maps. These heights can be different for each phase and country.

Results

In the following figures some of the maps are shown as examples. These maps are still preliminary (e.g. the scale is not that of the final version). The final maps will be provided in a project report.

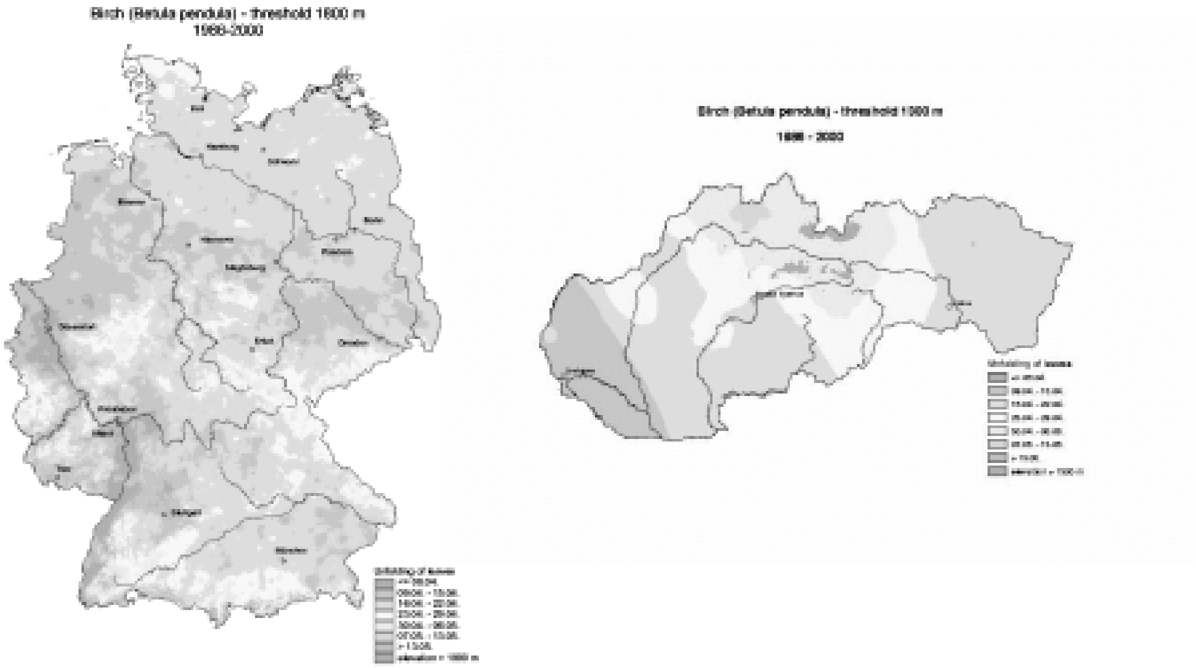

Fig. 1: *Maps of the onset of the phase "unfolding of leaves of birch" in Germany (left) and Slovakia (right).*

The maps reveal some characteristic patterns of spatial variability which can be attributed to geographical and climatic conditions, e.g. the dependency of some phases on the height above sea level and on continentality, especially for the spring phases. This means that these spring phases occur first in the lowlands and up to one month later in the mountains. Besides, they start on average earlier in Germany than in Slovakia. Maps of climate elements like temperature and precipitation show a similar variability in some cases. Not all the phases, however, show these patterns.

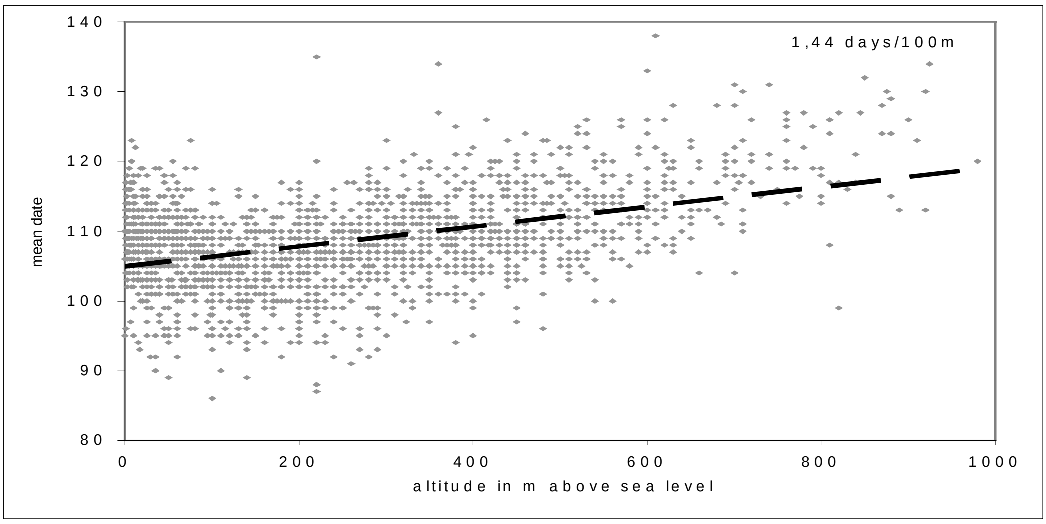

Fig. 2*: Mean date of the beginning of leafing of birch (Betula pendula) as a function of altitude in Germany, period 1986 –2000. In this case the dependency on altitude is 1,44 days per 100 m.*

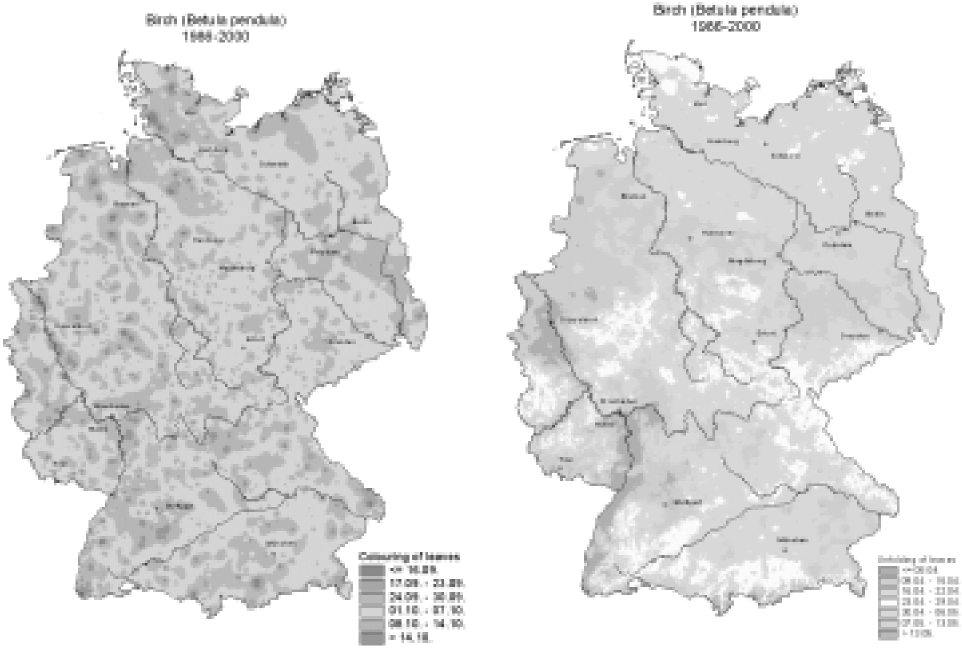

Fig. 3: *Maps of the two phases unfolding (left) and colouring (right) of leaves of birch in Germany 1986-2000. The phases have a different spatial structure.*

Future plans

For the future, an extension of this study to some more countries in Europe is proposed. In another preliminary study (Koch et al., this volume), the dependency of phenophases on the location (given by latitude, longitude, altitude) was analysed for an extended area of four countries (Germany, Austria, Czech Republic, Slovakia).

Furthermore, there is a proposal for a new COST action (a coordination action of the European Union) which should provide a reference data base of phenological phases within a large part of Europe. This reference data base should be based on the same time period, the same observation methods and the same phases for the whole area. Such a data base of comparable data could be used for climate monitoring purposes and especially for the proposed TIMING project (see this volume for further information about TIMING). On the other hand, the infrastructure of the TIMING project could also be very useful for the presentation of the reference data base.

A Satellite Based Phenology Project in Norway, PhenoClim

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Norway is characterised by a wide climatic diversity and comprises a nemoral zone in the south and a southern arctic zone in the north. There is a marked contrast in climate and vegetation between the coastal areas and inland areas and along the altitude gradient. Global climate model simulations with greenhouse gas forcing show enhanced warming on land at the northern latitudes. Climatic change and particularly variations in air temperature have significant impacts on the growth rhythm of plants when they occur at the limits of their natural distribution range, especially at northern latitudes. Accordingly, the region is well suited for studying the effects of climatic change.

Results based on a study of the GIMMS-satellite dataset indicate a surprisingly great change in the start of spring during the period 1982 to 1999. In most of southern Scandinavia the spring now starts more than two weeks earlier compared with the early eighties. In addition, we have also detected a delay trend in mountainous areas in Norway and in areas in northernmost Scandinavia and on Kola Peninsula.

A Norwegian phenology project has started in 2003 and will last for at least five years. "Phenology as an indicator of climate change effects", PhenoClim, is financed by The Research Council of Norway. The time period is 2003-2007 and the total budget is 1.5 mill. EUR. Eight different institutes in Norway participate, and the project includes scientists in physics, biology, computer sciences, economics, and sociology. The project is presented on the web at: http://www.itek.norut.no/projects/phenology. We are now working on an extension of the project to include the whole of Fennoscandia and hope for cooperation with European networks in the future, e.g. within the 6th Framework of EU.
The objective of the project is to use in-situ and satellite-based data to gain knowledge about ongoing large-scale changes in the phenological cycle and primary production of vegetation at the national and regional level, in order to investigate selected biological, economic, and social consequences of observed and predicted changes.

Sub-goals are:

- To identify important climatic variables for phenological events and primary production along the north-south, coastal-inland and altitude gradients, in order to model and predict future trends on phenological events and primary production.
- To coordinate and share in an open web interface the collected timeseries of satellite, phenological, meteorological, radiation, and other relevant data as far as legally possible.
- To present trends and predictions in the form of animations, trend maps and statistical analysis.
- To investigate consequences of climatic change for the biomass in the northern birch forest and for key plant communities in the reindeer pastures.
- To analyse the social and economic consequences of the predicted changes in the northern birch forest and in the Sápmi region.

The project will use several different satellite sensors, of which MODIS and NOAA AVHRR are assumed to be the most important. To collect phenological field data we will cooperate with the school network "The Environmental Education Network in Norway" and the research units belonging to The Norwegian Crop Research Institute. This will invigorate the project and hopefully result in an operational phenological network after the end of this project.

Species performance and phenology in the Arctic - SCANNET results

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Introduction

SCANNET is a network of field site leaders, research station managers and user groups in Scandinavia and northern Europe who are collaborating on improving comparative observations and access to information on environmental change in the North. The Danish Polar Centre and the field station at Zackenberg in the high Arctic north-east of Greenland leads a work package seeking to review the performance and phenology of terrestrial species in the SCANNET-region (figure 1). Phenology is in focus because it provides information on the early ecological impact of environmental change in this highly sensitive region.

We focus on past climatic events to learn how species respond. This process involves the gathering of time series of monitoring data from a broad range of species throughout the Arctic region. Data which cover a large spatial and temporal space, is very important for model building and predicting future responses to global climatic change. In SCANNET we have started to compile process existing information on species performance and phenology. Much of this information is unpublished and has not reached the international scientific community. Also valuable historic data sets have not been digitised and hence, prone to permanent loss. The task of tracking these data sources is difficult, but surely relevant, as old handwritten data files contain information that cannot possibly be reproduced by any new monitoring project.

Approach

Questionnaires concerning past and ongoing monitoring projects were sent to major field sites in the SCANNET region. The returned forms give information on the type of data, time slice, and availability of data, data-owners and publication of this data. This information is integrated in a database on the SCANNET web site: www.scannet.nu.

We exemplify the scientific potential of gathering monitoring data from a large geographical region by a case study on recruitment variability and population synchrony in the rock ptarmigan (*Lagopus mutus*). It is a wide-spread species in the SCANNET region and influential in the flow of energy in the ecosystem. The results of this study will be presented in the final work package deliverable available through the SCANNET secretariat. SCANNET also works in close connection with several other international networks. A coordinated effort is not only advisable, it is also necessary to achieve results beneficial to the broader science community. Furthermore, within the framework of SCANNET and this work package the performance of species in the region will be reviewed on the basis of published studies from the field sites within the SCANNET-network. Lastly, the work package aims at providing general information on the status of terrestrial Arctic species, beneficial to a great many of users e.g. schools, tourist operators, managers of natural resources and NGOs.

Results and discussion

The merging of information on monitoring programmes from field sites in the region has already produced a comprehensive meta-database soon available to the scientific community via the SCANNET web site: www.scannet.nu. Also, by compiling information from a large number of studies, a unique review of existing long-term data series on terrestrial species is being produced. A valuable outcome of this is the possibility to identify gaps and facilitate sound proposals for protocols in future monitoring projects. Furthermore, collating monitoring data from all parts of the European Arctic provides a basis for a better understanding of the influence of large-scale climatic consequences on terrestrial biota. We have already a good coverage of data on plants, birds and mammals and, to a lesser extent on arthropods. However, other groups of animals are lacking (figure 2). The studies focused mainly on growth and population estimates, but also phenology is well represented. As the process of compiling meta-data reaches completion it will be evident whether groups lacking so far will represent true gaps in the monitoring record.

We have established a mutual recognition with the International Long Term Ecological Research programme ILTER, the International Working Group on Biodiversity, Monitoring and Indicators IWG BioMIN forum at the European Environment Agency and Circumarctic Network of Environmental Observatories CEON and the European Phenology Network EPN. This linking with other ecological networks is extremely useful for a specific and non-overlapping effort to gain more accessible data on environmental consequences of climatic change. This is a very valuable tool for the future process of reviewing species performance and phenology in the Arctic.

Acknowledgements

Thanks to all members of SCANNET for contributing to this work and to the EC for their financial support. This work was supported by an EU Infrastructure award to SCANNET grant number EVK2-CT-2000-20007.

Figure 1. The current distribution of SCANNET sites.

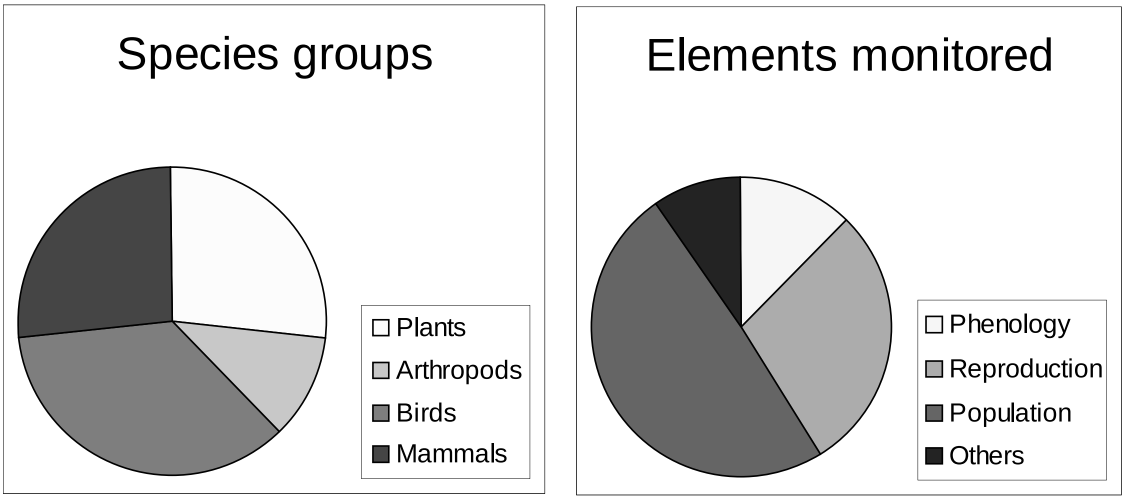

Figure 2. The distribution of monitoring projects compiled by the work package a) on different species groups (n=85) and b) on variables monitored (n=112). Some projects included several variables monitored on the same species. The element "population" includes estimates of population size, biomass production and aspects of growth dynamics.

A web-based Australian phenological monitoring network – the beginning of a challenge

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Past "Networks"

The need and benefits for a phenological monitoring network is not a new concept within Australia. Between 1891 and 1922 the establishment of such a network was called for by members of scientific societies or individuals within the Government (Commonwealth Meteorology 1907; Maiden 1910; Maiden 1922; Prince 1891).

Prior to this, the Royal Society of Tasmania monitored up to 650 species in the Botanical Gardens between 1858 and 1885. Forestry departments from five Australian States monitored commercial eucalypt species between 1925 and 1981. The Royal Society and Forestry Departments seem to have ceased monitoring because of a change in management. The data were then substantially lost.

In 1949, the Royal Australian Orthniologists Union (now Birds Australia) commenced a bird monitoring programme in conjunction with the nature magazine "*Wildlife*". This programme was coordinated by Crosbie Morrison who also conducted a weekly radio programme on nature-related topics (McCarthy 1994). The monitoring was probably undertaken for five years, ceasing with the death of Crosbie Morrison in 1954.

The Gould League, an environmental education organisation, has encouraged individuals since 1979 to undertake phenological observations (Gould League of Victoria 1979).

Current Need and Networks

The value of phenological monitoring has recently been highlighted by climate change and the need for natural indicators. In the southern hemisphere there is a lack of such data (Root *et al.* 2003). It cannot be assumed that ecosystems in the Southern Hemisphere will display similar responses as those detailed in the Northern Hemisphere.

Currently, there are three known phenological networks operating within Australia – The Timelines Australia Project, Faunawatch and Biowatch. Each has a different emphasis but all are run by volunteers.

Timelines' primary aim is to recover "natural event information held in diaries, library files and notes books, analyse them and seek patterns …. such as local seasonal cycles, succession sequences…" Timelines' national programme was launched in 1997, although individual programmes have operated at a local level from 1994. It is sponsored by The Gould League of Victoria, an environmental education organisation, and coordinated by Alan Reid. The Timelines Australia Project itself has had a long development phase with earlier versions of its recording diary published in 1979, 1984 and 1989 (Gould League of Victoria 1979; Mason 1989; Reid and Beckett 1984). Although Timelines has recently (late 2002) established a web page (www.geocities.com/liveattentively), there is as yet no facility to lodge data via the web. Currently, the data may remain with the observer or be forwarded to the coordinator either in summary form or complete sets.

Faunawatch, (known as "The Rhythms of Life" until September 2002 (K. Hickman, volunteer coordinator, personal communication, 2002)) is a community-based fauna monitoring project, covering the Sunshine Coast in Queensland (Jameson 2001). Observations are collected on birds (87.7% of observations, on 320 species), butterflies/moths (8.4%, 106 species recorded), mammals, fish, reptiles, insects and spiders (Hickman 2002). Data collected from this programme are fed into the Queensland government's 'Wildnet' and Birds Australia's Atlas. Initially inspired by the Timelines project (Jameson 2001), this programme commenced in 1998 with funding from the Federal government. It has nine aims that include raising public awareness and knowledge of wildlife in the area, and the creation of a comprehensive database of fauna occurring on the Sunshine Coast.

Biowatch http://www.bio.mq.edu.au/ecology/biowatch/ is a collaboration between Macquarie University, Royal Botanic Gardens, Sydney and the University of Melbourne. It is the most recent network (2003) and aims to encourage the collection of first dates for plants and birds (we are working on the butterfly and insect list) as well as uncovering 'closet phenologists'. It is also currently the only Network that will enable observers to lodge their data over the internet.

Challenges

One of the biggest challenges any Australian phenological network faces is the small number of people per square kilometre (Table 1). To be as successful as the United Kingdom's *Nature's Calendar*: Biowatch would need 112 participants in the first 2 years and 6,000 by year 5 (based on population).

Table 1: Area, population and population per km^2

Country	**Area (km^2)**	**Population**	**Population/km^2**
Australia	7,686,850	19,169,083	2.5
Canada	9,975,140	31,281,092	3.1
USA	9,629,091	275,562,673	28.6
Slovenia	48,845	1,927,593	95.2
Switzerland	41,920	7,262,372	175.8
Germany	357,031	82,797,408	231.9
United Kingdom	244,820	59,511,464	243.1
The Netherlands	41,532	15,892,237	382.6

Another challenge for the Biowatch network is the selection of species that are readily identifiable, and cover a wide area (e.g. Black-faced Cuckoo Shrike *Coracina novaehollandiae*). Species were also chosen to allow linkages between areas.

Presently, there are 4 introduced species of plants [Common dandelion (*Taraxacum officinale*), Purple Lilac (*Syringa vulgaris*), Salvation Jane (*Echium plantagineum*) and St. John's Wort (*Hypericum perforatum*)] and birds [European Goldfinch (*Carduelis carduelis*), Common Myna (*Acridotheres tristis*), Spotted Turtle-Dove (*Streptopelia chinensis*), and Common Starling (*Sturnus vulgaris*)]. There are also 25 native plant species and 24 bird species. The bird list was developed in conjunction with Timelines. The bird species are divided into migrants (such as the Shining Bronze-cuckoo (*Chrysococcyx lucidus*) and the Rainbow Bee-eater (*Merops ornatus*) and those for which first nesting etc. will be recorded [e.g. Australian Magpie (*Gymnorhina tibicen)* and Black Swan (*Cygnus atratus*)].

Some of the plant (e.g. Blackwood *Acacia melanoxylon*) and bird species (e.g. Black-faced Cuckoo Shrike *Coracina novaehollandiae*) initially considered are the same as those mooted in 1909 (Maiden 1910) and 1949 (Sedgwick 1949), respectively. The appropriateness of the current choice of species will be determined by their adoption rate.

Additionally, because of the large land base and small population base a 'simple' web page (i.e. one with few graphics) has been used as to enable the site to load quickly, as in country areas of Australia connection rates may be very slow.

Finally, maintaining a co-ordinated monitoring approach beyond five years, based on Australia's previous history in this area, remains a major challenge.

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Selected central European phenophases comparison

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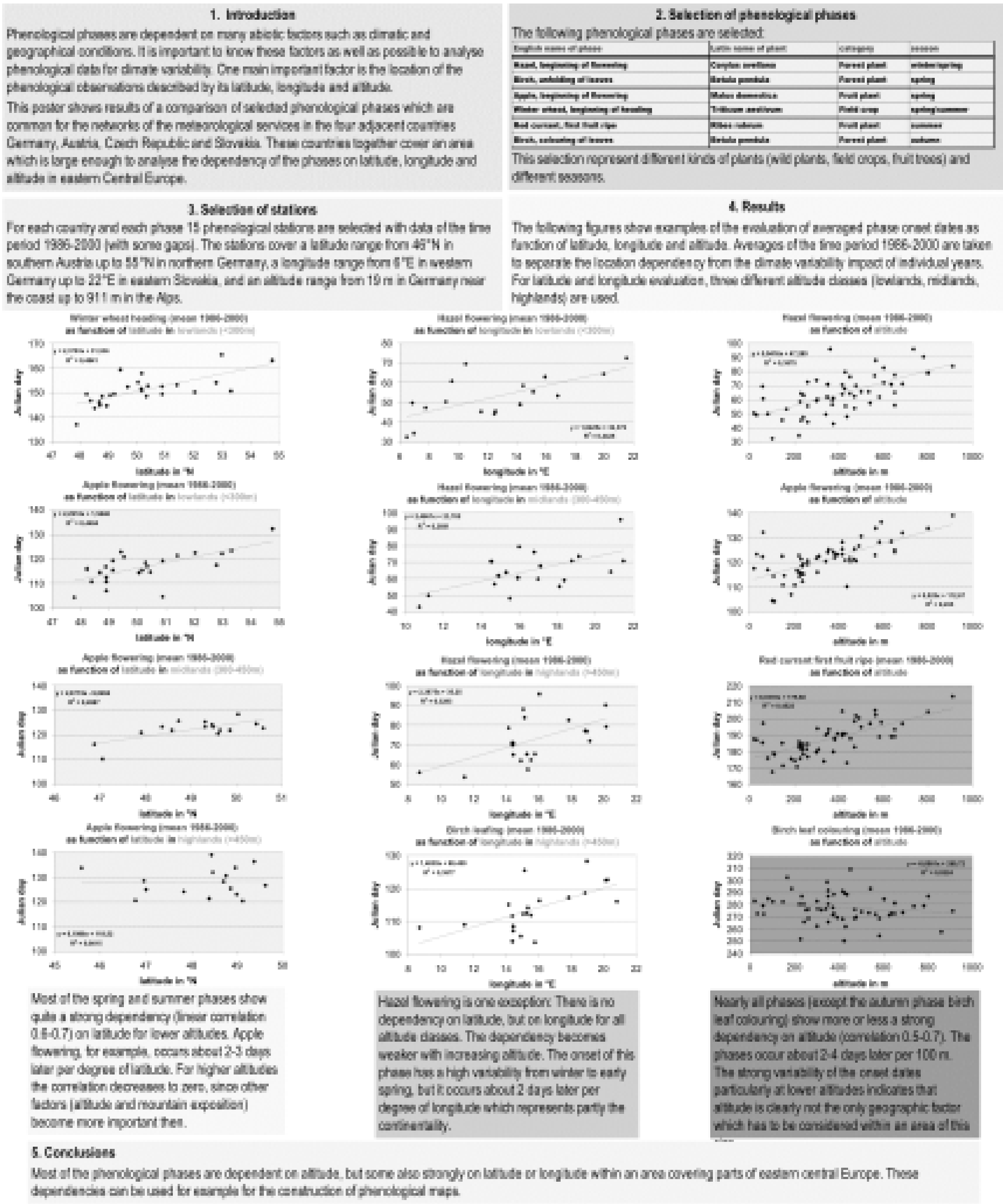

1. Introduction

Phenological phases are dependent on many abiotic factors such as climatic and geographical conditions. It is important to know these factors as well as possible to analyse phenological data for climate variability. One main important factor is the location of the phenological observations described by its latitude, longitude and altitude.

This poster shows results of a comparison of selected phenological phases which are common for the networks of the meteorological services in the four adjacent countries Germany, Austria, Czech Republic and Slovakia. These countries together cover an area which is large enough to analyse the dependency of the phases on latitude, longitude and altitude in eastern Central Europe.

2. Selection of phenological phases

The following phenological phases are selected:

English name of phase	Latin name of plant	category	season
Hazel, beginning of flowering	Corylus avellana	Forest plant	winter/spring
Birch, unfolding of leaves	Betula pendula	Forest plant	spring
Apple, beginning of flowering	Malus domestica	Fruit plant	spring
Winter wheat, beginning of heading	Triticum aestivum	Field crop	spring/summer
Red currant, first fruit ripe	Ribes rubrum	Fruit plant	summer
Birch, colouring of leaves	Betula pendula	Forest plant	autumn

This selection represent different kinds of plants (wild plants, field crops, fruit trees) and different seasons.

3. Selection of stations

For each country and each phase 15 phenological stations are selected with data of the time period 1986-2000 (with some gaps). The stations cover a latitude range from 46°N in southern Austria up to 55°N in northern Germany, a longitude range from 6°E in western Germany up to 22°E in eastern Slovakia, and an altitude range from 19 m in Germany near the coast up to 911 m in the Alps.

4. Results

The following figures show examples of the evaluation of averaged phase onset dates as function of latitude, longitude and altitude. Averages of the time period 1986-2000 are taken to separate the location dependency from the climate variability impact of individual years. For latitude and longitude evaluation, three different altitude classes (lowlands, midlands, highlands) are used.

Most of the spring and summer phases show quite a strong dependency (linear correlation 0.6-0.7) on latitude for lower altitudes. Apple flowering, for example, occurs about 2-3 days later per degree of latitude. For higher altitudes the correlation decreases to zero, since other factors (altitude and mountain exposition) become more important then.

Hazel flowering is one exception: There is no dependency on latitude, but on longitude for all altitude classes. The dependency becomes weaker with increasing altitude. The onset of this phase has a high variability from winter to early spring, but it occurs about 2 days later per degree of longitude which represents partly the continentality.

Nearly all phases (except the autumn phase birch leaf colouring) show more or less a strong dependency on altitude (correlation 0.5-0.7). The phases occur about 2-4 days later per 100 m. The strong variability of the onset dates particularly at lower altitudes indicates that altitude is clearly not the only geographic factor which has to be considered within an area of this

5. Conclusions

Most of the phenological phases are dependent on altitude, but some also strongly on latitude or longitude within an area covering parts of eastern central Europe. These dependencies can be used for example for the construction of phenological maps.

Phenological Observation Network in Finland

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Introduction

Phenology is a field of research which studies the rhythm of biological phenomena, for example the onset of leafing and flowering, and the effects of various factors on this rhythm (e.g. temperature). Finland is an excellent country for phenological studies because the seasons are so distinct and the rhythm in nature proceeds from the south to the north in the spring in a wavelike fashion and then in the autumn from the north to the south. Phenological research has a long history in Finland. The earliest observations date back to about the middle of the 18th century (Moberg 1852, Johansson 1945). The material then obtained was used in many research dissertations (Linkosalo 2000, Häkkinen 1999).
Systematic phenological monitoring using a nationwide observation network was begun at the Finnish Forest Research Institute (Metla) in 1995. The various points in this observation network are located at Metla's research stations and research areas, and at field stations of other research institutions and universities. During each observation period, some 40 trained observers in different parts of Finland made observations in a standardised manner at least twice per week. Monitoring included four broadleaved tree species; downy birch (Betula pubescens), silver birch (Betula pendula), aspen (Populus tremula), rowan (Sorbus aucuparia) and bird cherry (Prunus padus). Silver birch and downy birch were monitored regarding the timing of the following phenomena: bud burst, bursting into leaf, reaching of full leaf size, yellowing and shedding of leaves. Bird cherry and rowan were monitored only as to their flowering time. In addition to broadleaved trees the observation network was used to study phenomena such as height increment in conifers (Pinus sylvestris, Picea abies), flowering of juniper (Juniperus communis) and the flowering and ripening of forest berries (Vaccinium myrtillus L., Vaccinium vitis-idaea L.). The observation material is processed into maps and animations. The results are visible in real time on Metla's webpages in the form of animations and charts (http://www.metla.fi/metinfo/fenologia). The information of the phenological service provided over the Internet is updated twice a day during the growing season (Kubin etc. 1997).

Results

Nationwide surveys have been carried out since 1995. In 1997-2002, the bursting into leaf of downy birch (Betula pubescens) started earlier than average towards the end of the period studied and this happened throughout Finland (Fig. 1). This was more evident in northern parts of Finland. Birches in the southern and northern parts of the country differed very little as to the temperature sum required for bud burst. The average temperature sum needed was approx. 50 d.d.

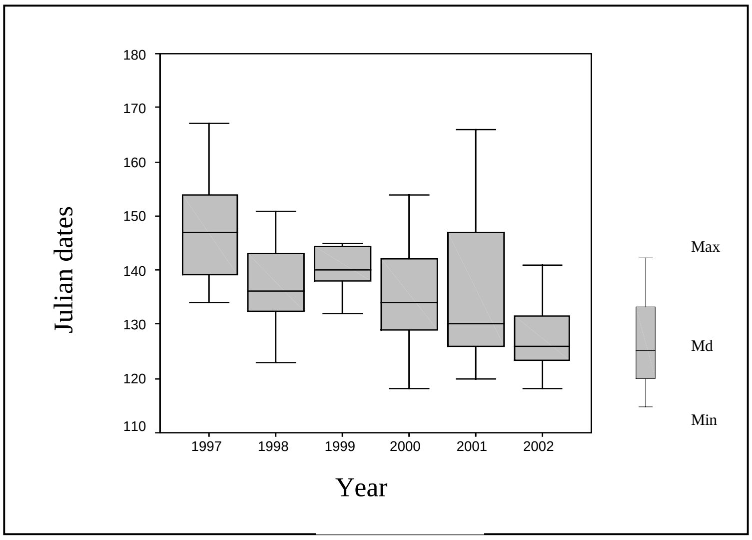

***Fig. 1**. The timing of bud burst in 1997-2002 in Finland.*

In the southern part of Finland (60ºN), the average onset of leafing for birch begins at the beginning of May and in the northernmost regions (69ºN) about one month later. Similarly, birch leaves yellowed in the northernmost parts of Finland at the beginning of September, along the Arctic Circle on average the 10th of September and in the southern part of the country about one month later. However, there have been large differences from year to year in the leafing and the yellowing of broadleaved trees.

Discussion

The foremost factor involved in bud burst is temperature (Häkkinen 1999). The onset of growth of birch leaves is launched when a certain temperature sum is reached. The bursting into leaf is also influenced by various site factors and genetic background (Hari & Häkkinen 1991, Lappalainen 1992). According to the results of the observation network the onset of bursting into leaf is also delayed by topographic elevation and the proximity of large bodies of water (Leppälä 2003).

The results showed that even over a short period of time there can be major differences in the leafing time of birch. The bud burst of downy birch during the period studied appeared to have occurred earlier in the northern parts of Finland. This may be caused by a rise in temperature, especially in northern Finland. However, further research and longer monitoring periods are needed in order to determine whether this earlier occurrence of bursting into leaf is a consequence of the predicted climate warming or just due to normal climatic variability.

Plant phenological research provides basic knowledge on the development rhythm of plant species and of the factors influencing it. Moreover, it provides excellent opportunities for predicting various phenological events and for monitoring climate warming. Phenological data can be used in phenological monitoring based on satellite-technology as a kind of a reference series, which offers unique opportunities, even globally speaking, to examine phenomena that impact plant life in northern regions (Chmielewski & Rötzer 2001).

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Clima & Pheno- Data Comparison In North Moravia

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Introduction & selection of stations

The paper presents a comparison between climatological and phenological data in two North Moravian microregions. The data from the meteorological station 11705 Sumperk (328 m above sea level, latitude 49°58' N, longitude 16°58' E) are compared with pheno-data of wild plants' station Sobotín (425 m, 50°N, 17°06'E), fruit trees' station Velké Losiny (415 m, 50°02'N, 17°03'E) and field crops station Sumperk (311 m, 49°59'N, 16°58'E) and data from meteorological station Luká (513 m above sea level, 49°39'N, 16°57'E) are compared with pheno-data of wild plants' station Krakovec (370 m, 49°36'N, 16°59'E), fruit trees' station Vilémov (380 m, 49°38'N, 17°E) and field crops station Cholina (250m, 49°40'N, 17°04'E).

Selection of climatological data

Meteorological data, such as the daily average temperature, maximum temperature, minimum temperature, ground temperature in 5 cm, accumulated effective temperatures above 0°C, 5°C, 10°C, daily relative humidity, daily cumulated precipitation amounts starting with 1.1., accumulated sunshine duration, soil temperatures in 5 and 20 cm depth, available water capacity (except 1994), soil moisture in volume % in the 10 cm depth (only Sumperk 2001), global radiation (only station Luká) and daily evaporation (only station Luká), for the years 1994, 1996 and 2001 was used. These years were chosen because they were extraordinary.

Selected years characterisation

<u>Station 11710 Luká</u>

1994

RR (precipitation): This year was ordinary as to the precipitation (101 % of longterm /1961-1990 according to WMO/ normal). June was an extraordinarily dry month (15 % N). April was very wet (196 % N) as was August (191 % N.

TT (temperature): Extraordinarily warm year (+1,6 °C) and month of July (+5,0 °C). January, August and November were very warm. March, June and September were warm. October was very cold.

1996

RR: Normal year of precipitation (105 % N). May (159 % N) was damp and December (54 % N) was dry.

TT: Cold year (-1,0 °C). March was extraordinarily cold (-4,2 °C), September and December were very cold. January, February, and July were cold, November was very warm, so was June.

2001

RR: Damp year (117 % N). July (224 % N) and September (215 % N) were very wet. January and March were damp. February was dry (46 % of normal precipitation).

TT: Normal year (+0,1 °C). October was extraordinarily warm (+2,8 °C), August was very warm, May was warm, whereas June, September, November and December were cold.

<u>Station 11705 Sumperk</u>

1994

RR: Normal year (103 % of longterm precipitation normal). June was extraordinarily dry (13 % N). April was very damp (201 % N).

TT: Extraordinarily warm year (+2,2 °C), especially January, July and August. March was very warm. June, November and December were warm. October was cold.

1996

RR: Normal year (90 % N). May was damp (171 % N), December was very dry (30 % N). January and July were dry.

TT: Normal year (+0,1 °C). August and November were very warm. May, June and October were warm and February, March, September and December were cold.

2001
RR: Damp year (119 % N). July (222 % N) and December (135 % N) were very wet. May and September were damp.
TT: Normal year (+0,2 °C). October was extraordinary warm (+2,6 °C), August was very warm. May and July were warm and June, September, November and December were cold.

Selection of phenological data

For a comparative evaluation, the following phenological data was used: Birch -first leaves/FL/, beginning of flowering/BF/, autumn leaves yellowing/YL/, defall of leaves/DL/, Spruce - FL, BF, Oak - FL, YL, Linden - FL, BF, DL, and BF concerning in Wild cornel, Hazel, Blackthorn, Coltsfoot and Snowdrop, together with Spring barley and Winter wheat (sowing, emergence, first nodes, heading, begin of flowering, full ripeness, harvest), Apple and Cherry trees (begin and end of flowering, harvest ripeness), Red currant (begin of flowering, harvest ripeness).

Results

Figures: From stations Sumperk and Luká (1994, 1996, 2001) clima graphs are presented. Usually in the upper third part of all 6 graphs the curves are shown of: daily relative humidity, daily maximum & mean & minimum & ground temperatures (all in 3-days overlapping averages). In the middle third part are given: daily cumulated precipitation amounts starting from 1.1., accumulated sunshine duration, accumulated effective temperatures above 0 °C, 5 °C, 10 °C, cumulated evaporation sums (from April to October, only Luká station) and cumulated global radiation (only from Luká station). In the lower third part of all 6 graphs are given: soil temperature in 5 and 20 cm depth and available water capacity (except 1994). At Sumperk 2001 graph is added soil moisture in volume % in the 10 cm depth.
Tables: In several tables the results of statistical evaluation are shown with the aim to appreciate the relationship between climatological and phenological data (chosen were: Spring Barley, Winter Wheat, Apple, Birch, Linden) to find to what extent, individual climatological elements determine the annual development of plants. The programme STATISTICA (StatSoft, Inc., Tulsa, OK, USA) is used.

Conclusions

Statistical evaluation showed that accumulated effective air temperatures, daily cumulated global radiation, accumulated sunshine duration, daily cumulated precipitation amounts, and daily cumulated evaporation were clearly correlated with a significance at $p< 0,05$ or higher. Also there is a marked interactive cross-correlation between different clima factors in these tables.
Concerning the phenological data, the best correlation was shown in field crop plants (Spring Barley, Winter Wheat), a good one on Birch and Linden. As to apples, the correlation were only good when accumulated factors are used and also with soil temperature in Luká station).

Selected results of POSITIVE

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POSITIVE (Phenological Observations and Satellite Data (NDVI): Trends in the Vegetation Cycle in Europe) was funded by the 5th Framework Programme of the European Commission under the key action Global Change, Climate and Biodiversity (EVK2-CT-1999-00012). It can be summarised as follows:

Objectives

POSITIVE (Phenological Observations and Satellite Data (NDVI): Trends in the Vegetation Cycle in Europe) was a joint project of 5 partners from 4 European countries and the GSFC, NASA, USA, which was funded over a period of two years and five months within the European Union's Fifth Framework Programme. The general idea of the project was to bring together young researchers from various disciplines to study phenological changes in Europe and to develop tools and techniques for the integration of phenological ground observations, climate data, and simulations by phenological models as well as NDVI satellite images for multi-purpose use in the field of global change research. The partners made an all-out effort to collect and integrate phenological observations and pollen surveys from various sources in 9 European countries into a common data base. The project investigated the variability and temporal trends of phenological phases during recent decades, especially on regional scales and for altitudinal gradients. The aim of POSITIVE was to develop and test phenological models for leaf unfolding and autumn phenophases for several temperate zone tree species alongside with an assessment of changes for the next century under two IPCC scenarios of future climate change. In addition, new models for pollen shedding forecasting have been developed and tested. The project investigated the temporal and spatial variability of the so called 'green wave' and quantified large-scale growing season duration and photosynthetic capacity for the northern hemisphere for 1982-1999. The start and end of the growing season derived from various NDVI products by different methods were compared with the 'ground truth' provided by phenological observations. These different methods from space and the ground as well as model output were (inter) compared and reasons for discrepancies were identified.

Scientific achievements and conclusions

- A common database of phenological variables was created including the selection of important species, a comparison of phase definitions, and a common coding system. With observations from nine European countries including data from the former USSR, the compiled data reached far beyond the initial goal.
- The analysis of the space-time variability of phenological and climatological calendars (1951 – 1998) for Europe revealed that spring phases start earlier in the southern part of Western Europe and later in the northern part of Eastern Europe. The speed of transition is slow in early spring and fast in summer. The highest rate of significant ($p<0.05$) change (-0.3 to -0.4 days per year) occurred in Western Europe and the Baltic Sea regions for the early phases in spring. Correspondingly, the duration of winter has decreased, and the duration of early spring and spring has increased. Spring phases and summer phases advance on average by -0.1 to 0.3 days per year.
- Using principal component and cluster analyses, regionalisation schemes were worked out for the Eastern European Plain. These regions show similar spatial and temporal variations and oscillations, and therefore it is possible to develop common seasonality strategies for adaptation, risk management, and sustainable management plans.
- Plant phenological observations in spring reflect the spatial and temporal variability of atmospheric processes across various temporal and spatial scales. This was shown by several statistical analyses, by comparing phenological and climatological seasons in phenological calendars as well as by phenological modelling.
- Frost events based on the last dates of daily minimum temperatures have been advancing faster than phenological phases in Central Europe during the last decades. This means that on average the risk of damage by late spring frosts will decrease, but also that plant species do not profit to the same extent from the potential frost free season as before.
- Photosynthetic capacity from 45°-75°N, studied by GSFC, as the mean May to September NDVI, increased by 9% from 1982-91, decreased by 5% from 1991-92 (cooling by Mt. Pinatubo eruption in Jun 91) and

increased by 8% from 1992-99. Variations in NDVI were associated with variations in the start of the growing season of –5.6, +3.9, and –1.7 days, respectively, for the 3 time periods.

- The start, end, and length of the growing season was determined by different methods from twice monthly 8km maximum value composite NDVI images for Europe, and their trends were calculated for the 1982-1998 period. The resulting means and trends clearly differ among the methods used. The spring 'green wave' proceeds from SW to NE, later in spring from S to N through Europe, no pattern for the end of the season was revealed.
- Leaf unfolding models for five species were developed which provide accurate predictions even in external conditions. Simulation of *B. pendula* leaf unfolding all over Europe mirrored the observations of the last 3 decades quite well.
- Simulations of *B. pendula* leaf unfolding under the HadCM3 CGM scenarios A2 and B2 demonstrate that Global Climate change will lead to earlier leaf unfolding of *B. pendula* in Europe except in a few regions.
- Simple, but process-based models can predict accurately the timing of the pollen release for many allergenic taxa solely using mean daily temperature data. Positive Pollen Forecast PPF has been developed and can be downloaded as a Microsoft® Windows oriented freeware from the POSITIVE web page: Users can obtain predictions of the relative pollen load of any of the thirteen taxa studied in Europe, only daily temperatures are required as input.
- A vast number of meteorological and other factors including the phenology procedures of the two global biosphere models, BIOME BCG and the FBM, were tested for their influence on autumn leaf colouring. However, the parameters selected for multiple linear regression models strongly differ between stations and their predictive value is often poor.

Socio-economic relevance and policy implications

- Phenology – the timing of seasonal activities of animals and plants – is perhaps the simplest process in which to track changes in the ecology of species in response to climate change. Thus, long-term monitored phenophases are important indicators of climate change and climate change impacts. POSITIVE has analysed the most recent and most comprehensive phenological data set available for Europe through the Ural mountains, and thus provided manifold examples and maps of the spatial variability of the observed changes. Phenological modelling and statistical analyses made it possible to determine the phenological response to temperature, and to link the observed changes to global change and observations of the 'green wave' by NDVI satellite images. Thus, POSITIVE makes phenological changes clearly visible for policy makers and the general public, and offers opportunities for raising public awareness of the climate change problem and of the policies to reduce greenhouse gases. Many of the potential impacts of climate induced changes in phenology will also affect to the general public (e.g. hay fever) as well as the agricultural and forestry sector (frost damage to agricultural and garden plants, length of the growing season). Understanding the spatial and temporal variations in the length of the growing season and their relation to the climate is a prerequisite for understanding and modelling vegetation – atmosphere CO_2 fluxes. POSITIVEs approach to link EO to 'ground truth' will contribute to a further interpretation and use of NDVI products. Concerning human health POSITIVE showed that phenology models provide a substantial improvement of the current models for pollen load, but most importantly, that they could substantially decrease the cost of the pollen networking. The PPF freeware may enable everyone to make use of predictions of the pollen load of a dozen of allergenic taxa in several European countries, so that medication against pollen allergies can be administered more adequately. The majority of the resources of the project have been utilised to fund young research scientists and to enable them to continue working in their field of expertise.

In the talk itself, related to that abstract, selected results of the POSITIVE project were shown.

The application of harmonic analysis in the operational use of AVHRR NDVI time series

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Abstract: In the course of developing an operational system to estimate annual net primary production (NPP) of European vegetation based on the use of imagery acquired with the Advanced Very High Resolution Radiometer (AVHRR), the problem of noisy and/or incomplete time series has been addressed through the use of harmonic analysis (HA). Based on a talk given at the 2003 EPN conference, this brief article will provide some background information on the NPP processing chain, the problems posed in the time series data, and the results obtained after using HA.

In recent years, the carbon cycle has been the focus of increased interest, especially in the light of the role it plays in the environment, and particularly in climate change. The ratification of international environmental treaties and conventions shows this interest and attention. Because CO_2 is the most prevalent of the so-called greenhouse gases, much research is being conducted in order to obtain more accurate estimates of its sources and sinks. It is also one of the gases which can be most easily affected by human activity, both in terms of sources and sinks - adding to the necessity to obtain more accurate estimates. This is especially crucial when considering the potential of carbon credit trading.

Vegetation is the largest sink of CO_2 which can be anthropogenically affected. Through photosynthesis,vegetation draws CO_2 from the atmosphere and converts it into biomass, commonly referred to as gross primary production (GPP). When plant respiration is taken into account, it is known as net primary production (NPP).

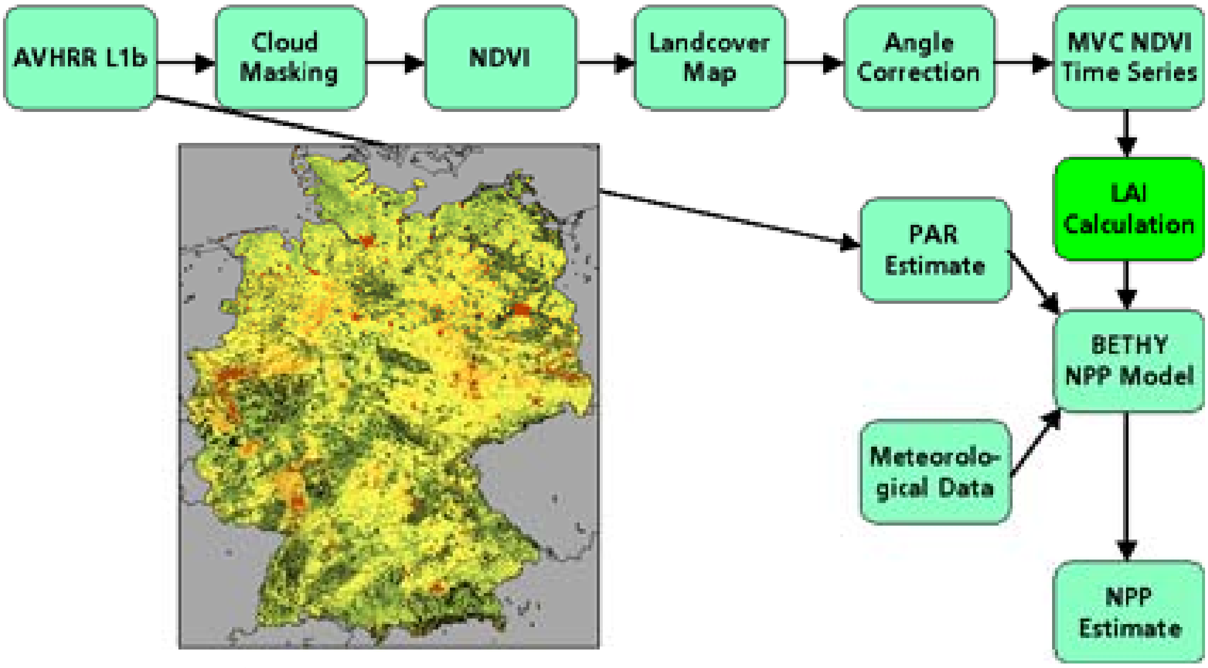

Figure 1: Schematic of DLR processing chain to obtain NPP estimates in Europe.

Modelling NPP can allow a better estimate of the size of the terrestrial carbon sink and thus, of the atmospheric CO_2 budget. Unfortunately, it is impossible for a model to take into account all environmental potentialities. The use of satellite remote sensing allows this deficiency to be mitigated. This is due to the fact that the radiance values collected at the satellite sensor can be interpreted through our understanding of the interaction between solar radiation and plant photosynthetic material. Since vegetation can be constantly monitored in this way, vegetation phenology can be observed using time series of remote sensing imagery and the effects of unexpected environmental conditions can be detected.

DLR is currently developing an operational processing chain to estimate annual European NPP as an indicator of the vegetative carbon sink. This processing chain makes use of the BETHY model (Knorr, 1997) with remote sensing inputs coming from AVHRR imagery, which has been obtained for over 20 years using DLR's own receiving station. The following figure shows schematically the steps that have been taken in producing the annual NPP estimate. The image shown is an estimate of the Leaf Area Index (LAI) for Germany in 1997 using a method of estimation by Sellers *et al*., (1996).

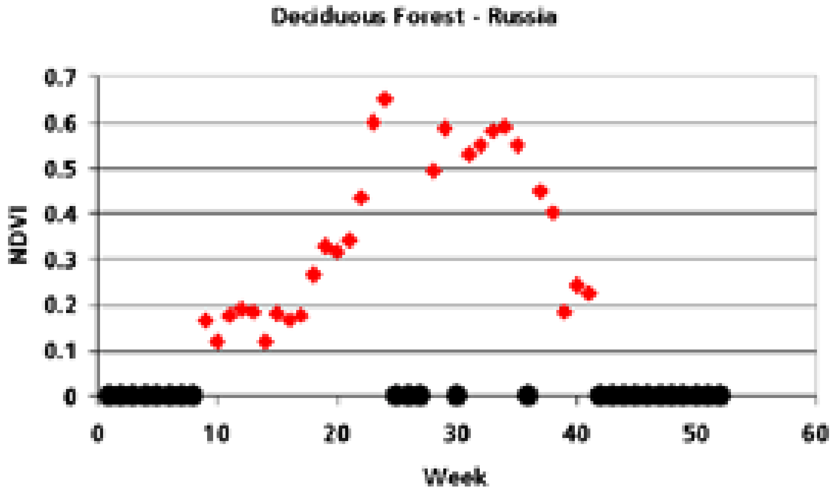

Figure 2: Example of NDVI time series with missing data points.

In addition to missing data points, there is often spurious "high frequency" noise in annual time series. This can be due to one or more factors such as uncorrected atmospheric effects, BRDF effects, or errors in satellite navigation, especially at the edges of scans. An example of such a noise is indicated in the circled data points in Figure 3 below.

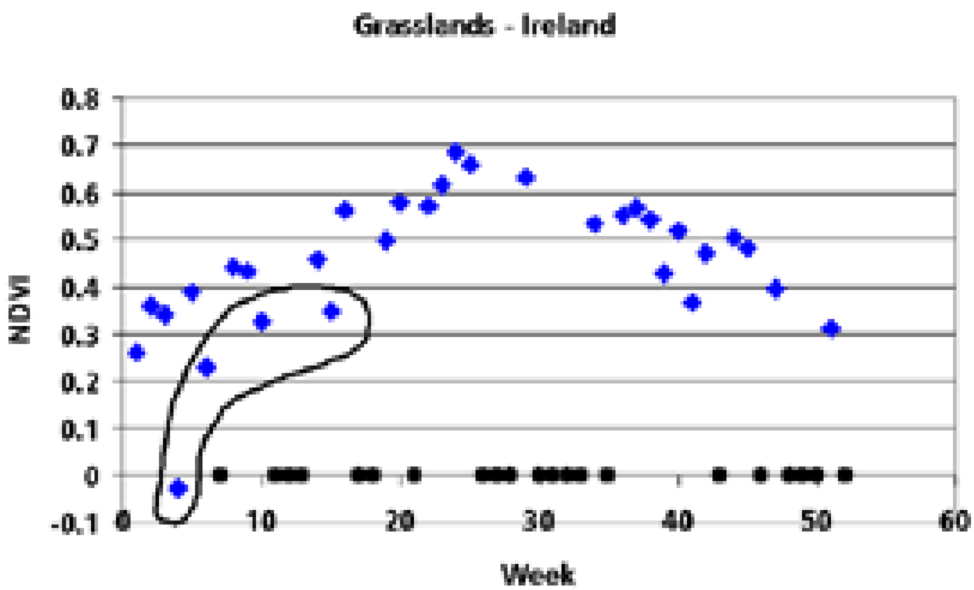

Figure 3: Example of NDVI time series with missing data points and spurious noise

In order to fill in blank data areas and to remove noise from the time series – to, in essence, identify the "true" cycles within the NDVI time series - a technique called harmonic analysis (HA) is currently being implemented within the processing chain. HA is a type of Fourier analysis but one which is able to handle data gaps by using a least-squares method of finding the sinusoids to fit the data.

The following two figures offer examples of the application of HA to NDVI time series which were shown at the EPN conference. Again, the diamond symbols represent the maximum value NDVIs for a single pixel over a week, and the black circles represent the weeks for which no data was available. The black line is the estimate NDVI time series using HA. In both figures 4 and 5, a good fit can be noted, with spurious high frequency data points ignored. However, the missing data at the end of the year (weeks 45+) do not allow the HA to provide a good estimate at the end(s) of the series'.

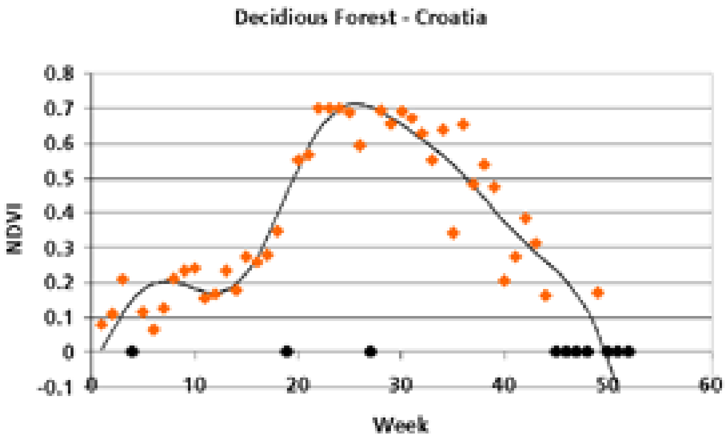

Figure 4: Example of HA applied to an NDVI time series.

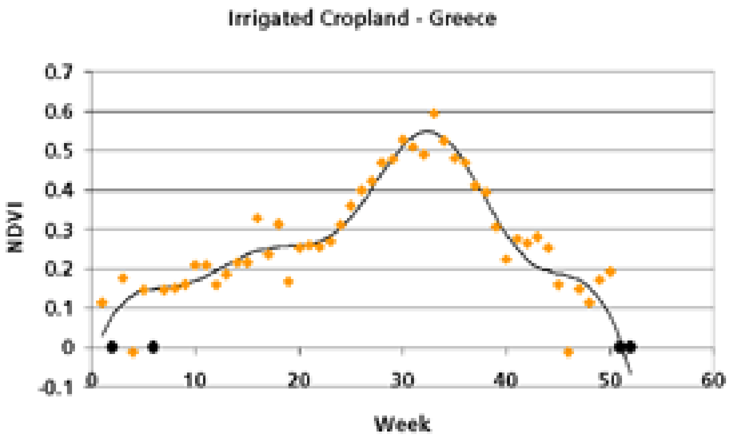

Figure 5: Example of HA applied to an NDVI time series

In summary, the use of remote sensing imagery coupled with plant growth models is a very promising method to estimate the terrestrial carbon sink. Problems related to missing data points and spurious high frequencies can be minimised using HA. An operational processing chain, incorporating satellite data corrected by HA and the NPP model BETHY is in the final developmental stages at DLR. The processing chain could be adapted to other higher resolution satellite data, such as MODIS and MERIS.

Since this research was presented at the EPN conference, the implementation of the HA technique has been altered to avoid the problems at the ends of the time series.
Please contact the corresponding author for more information on the NPP product or our implementation of the HA technique.

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Plant and animal phenological changes linked to recent and predicted climate change in Catalonia (North western Mediterranean basin)

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The available data on the climate over the past century has indicated that the Earth indeed is warming (IPCC 2001). Important biological effects including changes in plant and animal life cycles were already reported (e.g. Schwartz 1998; Ahas 1999; Menzel and Fabian 1999; Hughes 2000; Both and Visser 2001; IPCC 2001; Menzel and Estrella 2001; Peñuelas and Filella 2001; Peñuelas et al. 2002; Walther et al. 2002; Parmesan and Yohe 2003; Root et al. 2003). However, evidence of such effects was mostly limited to Northern latitudes and to the last few years and decades. Here we try to gain further knowledge on the effects of climate change on plant and animal phenology 1) by providing data on the Mediterranean basin, which is particularly interesting because it is one of the biologically richest regions in the world and one on which studies on the effects of climate change on wildlife are much needed, and 2) by providing experimental data on what phenological responses can be expected for the next years and decades on the basis of predictions on climate change drawn up by IPCC.

Previous decades

Here we present long-term (1952-2000) overwhelming evidence of drastically changed life cycles for a whole set of the most abundant plants and birds, and one butterfly species of a Mediterranean area (Central Catalonia). Average annual temperatures in the study area (Cardedeu) have increased by 1.4 °C over the observation period while the precipitation remained unchanged. A conservative linear treatment of the data shows that leaves unfold on average 16 days earlier, leaves fall on average 13 days later, and plants flower on average 6 days earlier than in 1952. Fruiting occurs on average 9 days earlier than in 1974 (Fig. 1). Butterflies appear 11 days earlier, but spring migratory birds arrive 15 days later than in 1952. Greater changes both in temperature and phenophases timing occurred in the last 25 years. There is no significant relationship between changes in phenophases and the average date for each phenophase and species. Neither are there any significant differences among species with different Raunkiaer life-forms or different origin (native, exotic or agricultural).

Focusing on butterfly phenological responses, we also present data from the Catalan Butterfly Monitoring System (CBMS). We analysed the phenological trends observed in the period 1988-2002 by butterflies inhabiting Aiguamolls de l'Empordà a Mediterranean site in NE Catalonia. We found strong evidence of phenological change as a consequence of recent climatic warming. Between 1988-2002, there was a tendency towards earlier first appearance dates in all 17 butterfly species tested (Fig. 2), and significant advances in mean flight dates in 8 out of 19 species, coinciding with an increase of 1-1.5ºC in mean February, March and June temperatures. In addition, there was some indication that phenological responses may differ between taxonomic lineages or species with similar diets.

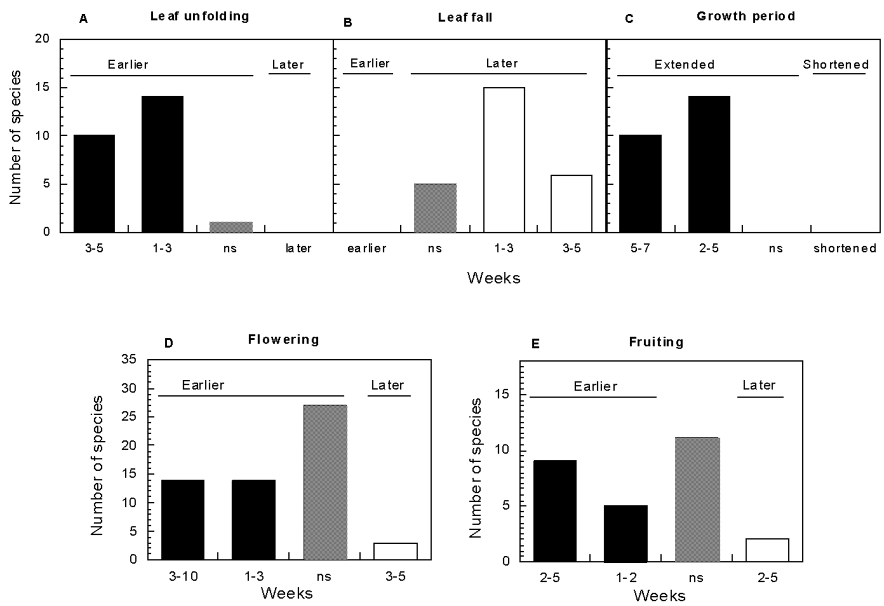

Figure 1. Phenological changes in plant species of Cardedeu field station from 1952 to 2000. Frequency distribution of the species with advancing and delaying trends in phenophases. (A) Leaf unfolding dates for 25 species, (B) leaf fall dates for 26 species, (C) leaf life for 24 species, (D) flowering date for 57 species, and (E) fruiting date for 27 species. Significant trends (p<0.05) are shown in black for advances in white for delays; for non-significant in grey.

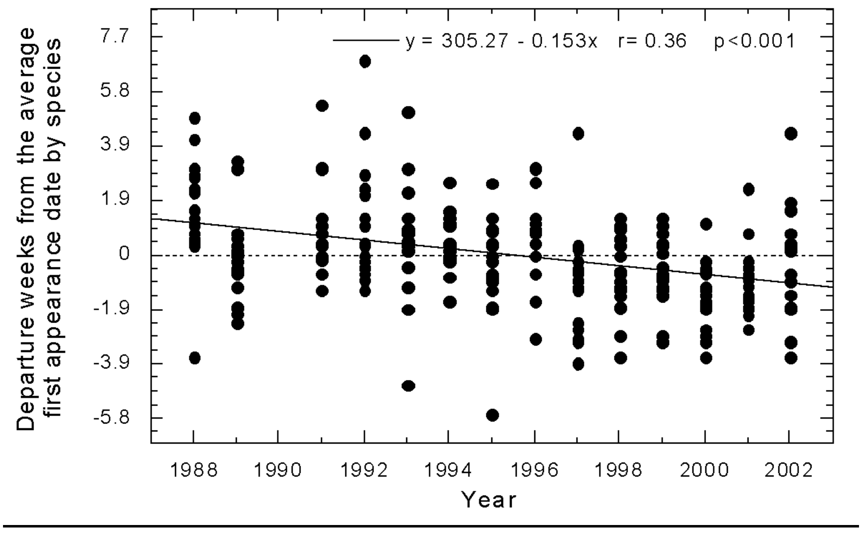

Figure 2. Temporal trends of first appearance date for all the butterfly species studied (14) in Aiguamolls de l'Empordà during the last 15 years (1988-2002). Phenology is expressed as the departure from the average date by species to avoid discrepancies owing to species specificity.

Next decades

Regarding phenological responses that can be expected under the climate scenarios predicted for the few next, decades we conducted manipulative field experimentation in a Mediterranean shrubland and in a Mediterranean forest that simulated conditions forecasted for this region for the next decades by most GCM (IPCC 2001). We conducted an experimental manipulation of a Mediterranean forest in Prades (southern Catalonia) by submitting 10 x 15 m forest plots to a reduction in the availability of soil water of about 15% by using plastic strips and funnels that partially excluded rain throughfall and by ditch exclusion of water runoff (Ogaya and Peñuelas 2003). We studied the phenology of two dominant species and found that whereas *Arbutus unedo* was affected (decreased number of flowers and delayed flowering), *Phillyrea latifolia* was unaffected by rainfall exclusion (Fig. 3). The annual variation was also encountered in the number of flowers (lower in the second year of study in *Phillyrea latifolia*), in the timing of flowering (delayed in the second year of study in *Arbutus unedo*), and also in the effects of the drought treatment (stronger in the second year in *Arbutus unedo*) showing the complexity of responses to rainfall.

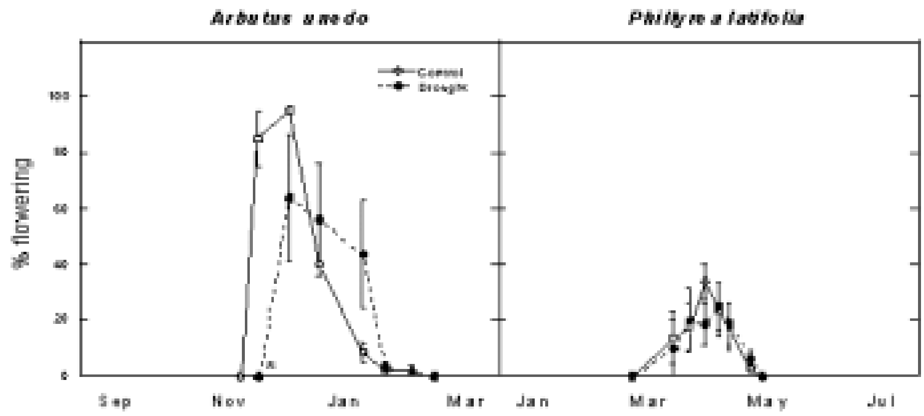

Figure 3. Percentage of flowering plants in two dominant species of Prades Mediterranean forest in control and rainfall exclusion (15% average decrease in soil moisture) plots.

Finally, in our field experimental system in Garraf shrublands (central coastal Catalonia) simulating the warming and drought predicted for the next decades in the Mediterranean shrublands, we took a new non-intrusive methodological approach that increased the temperature and prolonged the drought period by using roofs that automatically covered the vegetation after sunset or when it rains. In those experiments we found that warming (1°C) and drought (20% decrease in soil moisture) produced advances or delays in leaf unfolding, flowering and fruiting depending on the species and on the season of the year. For example, we found flowering advances by warming in the colder seasons, winter and spring, whereas on the other hand we observed flowering delays by warming in the warmer seasons, summer and autumn (Fig. 4).

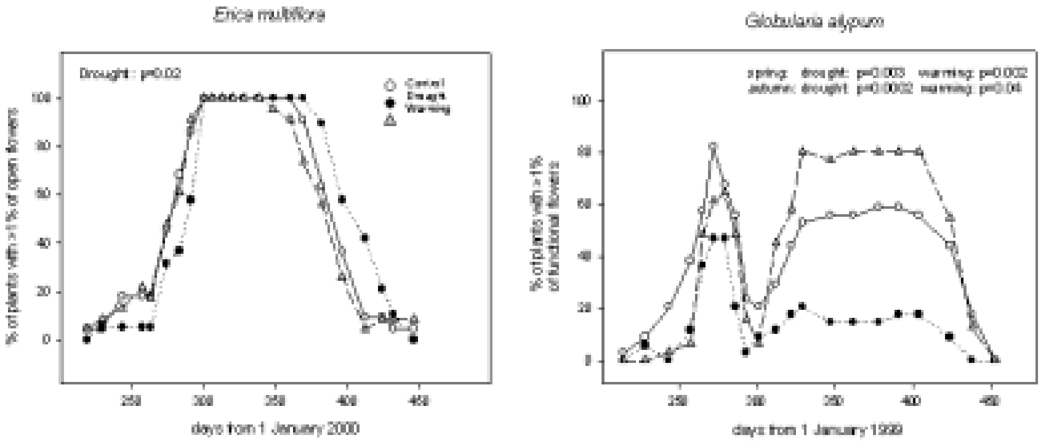

Figure 4. Percentage of flowering plants in the two dominant species of Garraf coastal Mediterranean shrublands in control, warming (1°C) and rainfall exclusion (20% average decrease of soil moisture) plots. Significant differences were assessed by log-rank statistics for the comparisons between survival probability curves for control and drought plants

The wide range of phenological alterations among the different species may have altered and may alter their competitive ability even more in the next decades, and thus, their ecology and conservation, and the structure and functioning of ecosystems. Moreover, the lengthening of the plant growing season is likely to contribute to the current global increase in biospheric activity (Peñuelas, Filella 2001; Nemani et al., 2003). The limit will come from other limiting factors such as the availability of other resources like water, nutrients, or light, among others things.

Acknowledgements: This research was supported by the EU projects CLIMOOR (UE-DG XII ENV4-CT97-0694) and VULCAN (EVK2- CT-2000-00094) and by MCYT-REN2000-0278/CLI and MCYT-REN2001-0003/GLO grants from the Spanish Government.

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The INPA long-term phenology project monitoring Amazon forest trees: tracking the effects of climate changes on tree phenology

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Introduction

INPA is the National Institute for Amazon Research, located at Manaus city, Amazon State, North Brazil. Before the description of the INPA long term phenology project monitoring Amazon forest trees, we present a short overview of phenology studies in Brazil.

Brazil is the largest South American country. The main vegetation types are: tropical evergreen moist forest including the Amazon forest, the Atlantic rain forest, and Atlantic seasonal forest or semi-deciduous forest, cerrado or woody savannah, and open grassy savannah, pantanal – seasonally inundated vegetation, caatinga – semi-desert vegetation, sub-tropical Araucaria forest, and natural fields. Some vegetation types are among the most diverse in the world (Amazon forest and Atlantic forest) and have been recognized as biodiversity hotspots for conservation priorities. All this diversity of species and vegetation types has not been completely studied in respect to its floristic diversity. Consequently, just a small percentage of its species and vegetation have been examined as to their seasonal changes.

A survey of phenological works performed on Brazilian native vegetation, considering just community studies including information on flowering and fruiting patterns, points out that tropical forest is the best studied ecosystem, and the Amazon (terra-firma) forest, and the Atlantic forest of Southern Brazil are the best studied vegetation (Morellato 2003). Cerrado or woody savannah is the second most studied vegetation type. Trees (forest) and woody plants (cerrado) are the life-forms observed in almost all papers surveyed. Most papers cover a short time span, usually about 1 to 3 years of observation, and just a few long-term phenology databases were surveyed (Morellato 2003). Besides the INPA project presented here, a similar programme of long-term phenological data collection was established by Companhia Vale do Rio Doce (CVRD), a mine company, at Espirito Santo State, Northeast Brazil. They have been observing lowland evergreen forest trees employing the same methodology proposed by the INPA project. The project started in 1982 and seems to be going on until today. Another long-term observation of Amazon trees was carried out by EMBRAPA (Brazilian enterprise for Agricultural and Cattle Breeding Research), but no data is available. According to Morellato (2003), the number of phenology papers published has increased over the last 20 years. The last five years show that more vegetation types have been studied. However, long-term phenological observations are uncommon.

The INPA project represents the first and oldest and possibly unique long-term phenological data collection for South American tropical forest trees. The phenological work started in 1962 at Reserva Florestal Ducke, (Manaus, Amazonas State, Brazil), with regular, phenological observations since 1965 until today. A second study site was established in 1974 at the Silviculture Experimental Station. The original goals of the project were: to know more about the biology of tree species of great or potentially economic importance and to determine the best time for seed or fruit collection to support silviculture procedures such as, planting and fruit harvesting. Now we want to add some more research goals: to investigate the effects of natural climatic changes on plant phenology over the 35 years of observations; to compare the phenological patterns of the species that are common between the two research stations; to explore the potential applications of this long-term phenological data in order to understand the effects of climatic cycles and climatic changes on tropical forest trees.

Methods

The phenological work started in 1962, at Reserva Florestal Ducke, (Manaus, Amazonas State, Brazil). Trees were selected from 1962 until 1965, up to a total number of 300 trees (about three per species) and 100 species marked over an area of 140.5 hectares of native Amazon lowland tropical forest (terra-firme forest). The regular observations started in 1965. In 1970 the sample size was extended to 500 trees (five per species), which are still being monitored today. In 1974, INPA replicated the phenology study. They marked 500 trees of another 100 species from an Amazon lowland forest at INPA Experimental Station about 30 km from Reserva Ducke.

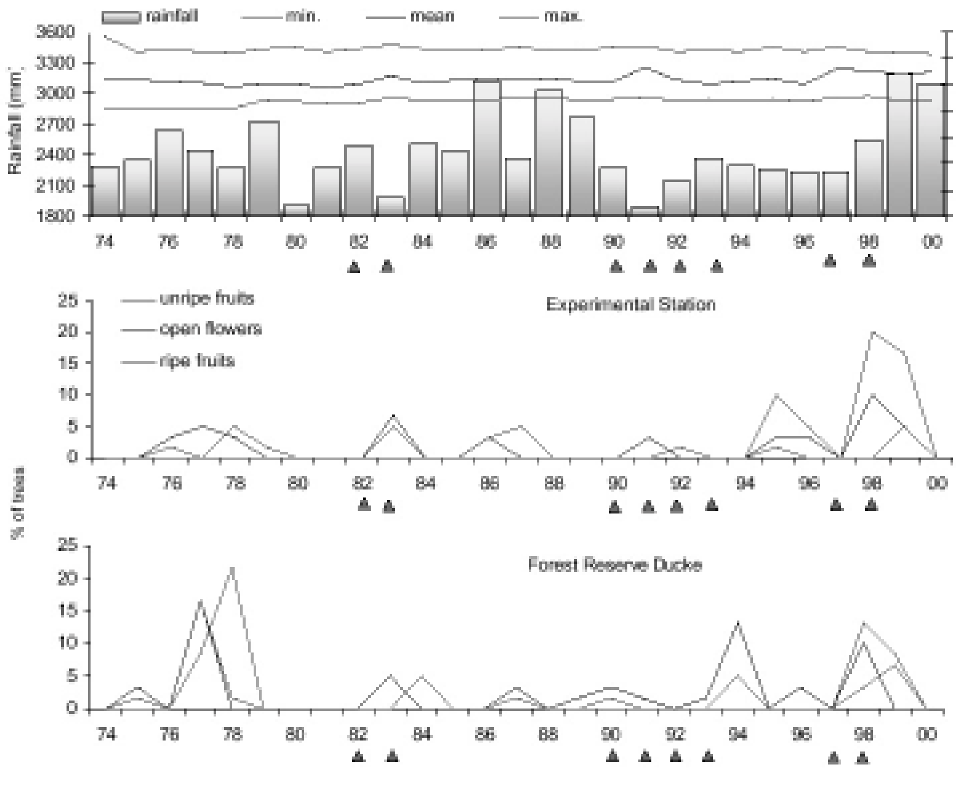

Figure 1. Percentage of trees of Aniba canelilla in flower and in fruit at two sites of Amazon forest, Brazil (triangle symbol: year of occurrence of El niño).

The species were chosen according to some basic forestry rules: actual or potential economic value of timber, potential source of gum, resin and oil (wood or seed). Both studies performed monthly observations on changes in reproductive and vegetative phenology.

They defined 10 phases:

1. flower buds, 2. flowering (open flowers), 3. end of flowering, 4. beginning of fruiting (new fruits starting development), 5. ripe fruits, 6. end of fruiting, 7. leaf fall, 8. beginning of leaf flushing, 9. new leaves, 10. old leaves.
The database is a Dbase –DOS database. The output is the mean of phenology data over a specific period. It does not produce a year by year output.

Research results
The Phenology Project has produced a good number of papers over the last 30 years. All papers deal with data from the Reserva Ducke. No paper with data from the Experimental Station has been published. Most papers focused on one species or family (e.g. Alencar 1994), and just two papers analysed community phenological changes (Araujo 1970 who set up this project, Alencar et al., 1979 who succeeded Araujo in this project). The papers analyse the mean phenological data over 6 to 12 years. A few papers have analysed the time series. The most significant correlation was found between flowering phenology and temperature (Alencar 1994). The papers never took into account the effects of climatic change and their evaluation using plant phenology.

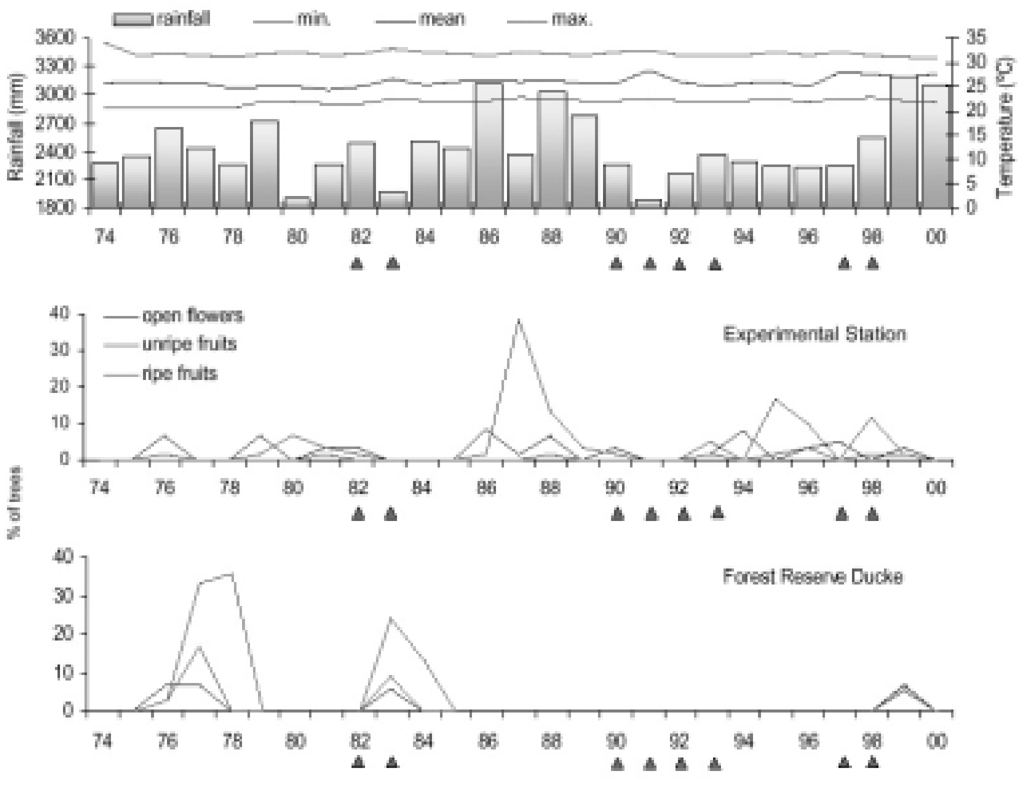

Figure 2: Percentage of trees of Aniba rosaeodora in flower and in fruit at two sites of Amazon forest, Brazil (triangle symbol: year of occurrence of El niño).

Preliminary results

After transferring the data from the dbase database to an excel spread sheet, we compared the phenological patterns of some species present at both study sites and tried to track the effects of natural climatic changes.

The first species observed, *Aniba roseodora*, showed a flower and fruit pattern irregular with a one-to-four-year gap between events at the Experimental Station (Figure 1). Patterns were more frequent but irregular at the Reserva Ducke, with one to three year gaps. No apparent relation with the occurrence of el niño events (triangles) was found.

The second species, *Aniba canelilla*, presented very different patterns between the two sites (Figure 2). At the ES there was one flowering episode every two or three years, while at RD just three flowering events were registered during the 27 years of observations. The period between events ranged from 4 to 14 years.

Some considerations

Our preliminary analyses showed that the long-term phenology observations revealed the irregularity of the reproductive patterns of tropical forest trees. They highlighted the importance of taking into account phenology data when planning the management of forest trees, especially fruit and tree harvesting, and that the influence of natural climatic change on tropical tree phenology is difficult to detect.

Our next steps will include setting up a new, more friendly data base, to store and analyse phenology and community data from different perspectives.

Acknowledgements

Participation in the Challenging Times Conference was supported by FAPESP. The research is supported by CNPq – Brazilian National Council for Science – grant (473415/2003-8). AMP and LPCM receive, respectively, a doctoral and research fellowship from CNPq.

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Integrating Historical Phenological Observations into a 280-Year Long Series

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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 (Vestrheim 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 representiveness 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^{th} 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^{th} 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 thefindings 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.

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Table and Figures:

Period	Place	Altitude [m a.s.l.]	Observer	Source
1721-1738	Winterthur	442	Rieter	Pfister 1984
1739-1764	*substituted*	*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	*substituted*	*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.*

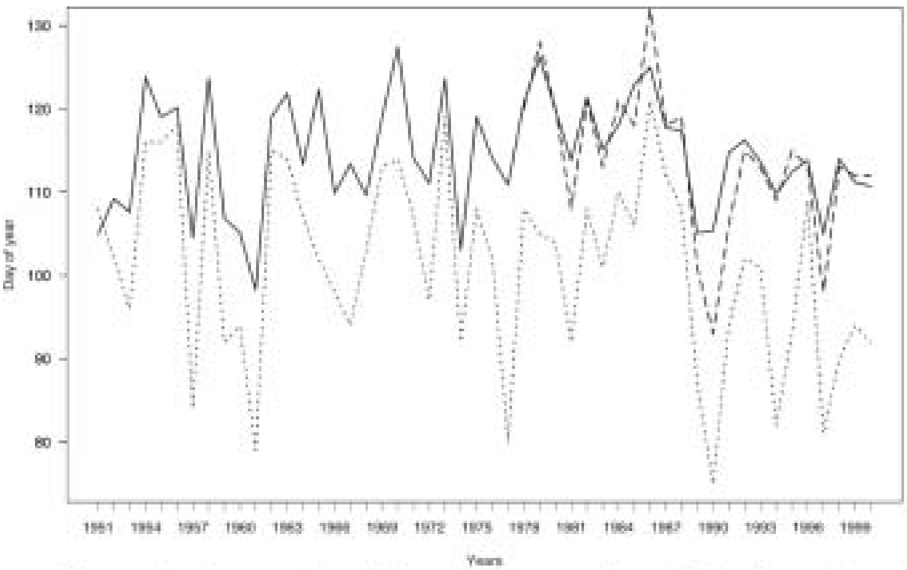

Figure 1: *Comparison of network mean date of the flowering of cherry trees (solid line) with single observations at Liestal (dotted line) and Grossaffoltern (dashed line) for 1951 to 2000.*

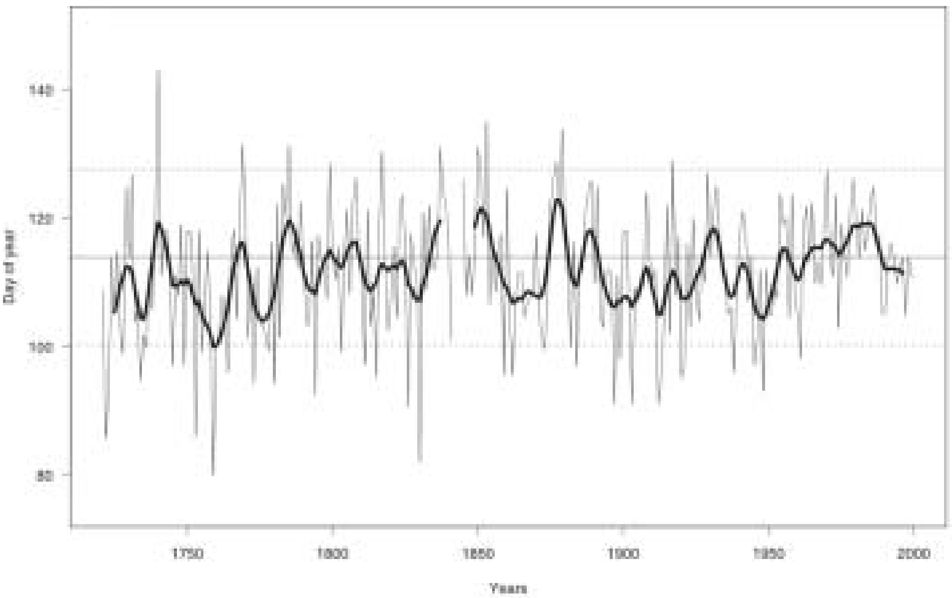

***Figure 2**: Phenological records of the flowering of the cherry trees for the Swiss Plateau Region and Liestal (alt. 320-620 m a.s.l.) 1721 to 2000; bold line: 9-year triangular filter; mean (solid line): 1951 to 2000; dashed lines represent 2-standard deviation range based on the period 1951 to 2000.*

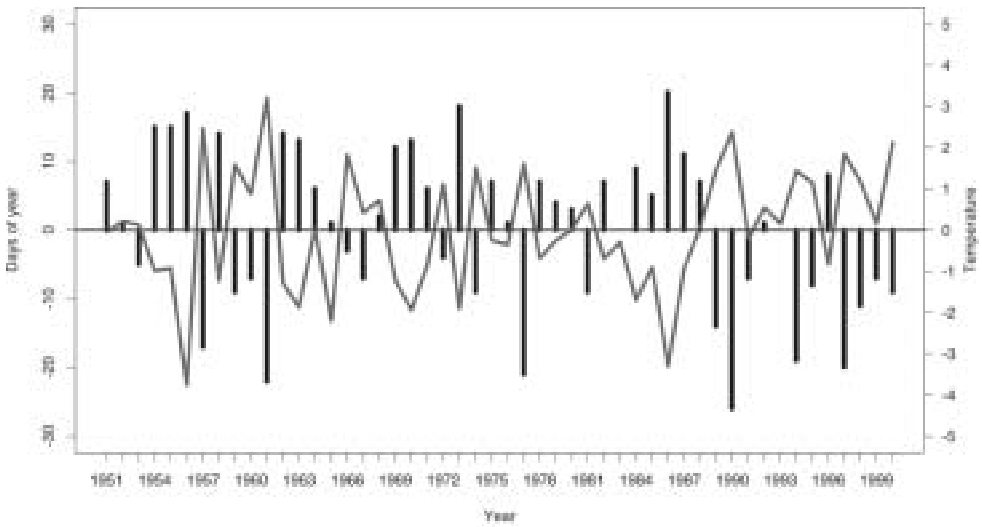

***Figure 3**: Anomalies of the flowering date of cherry tree at Liestal (columns) and monthly mean temperatures February to April at Zürich-SMA (line) to the reference period 1951-2000. Negative correlation (r=-0.88).*

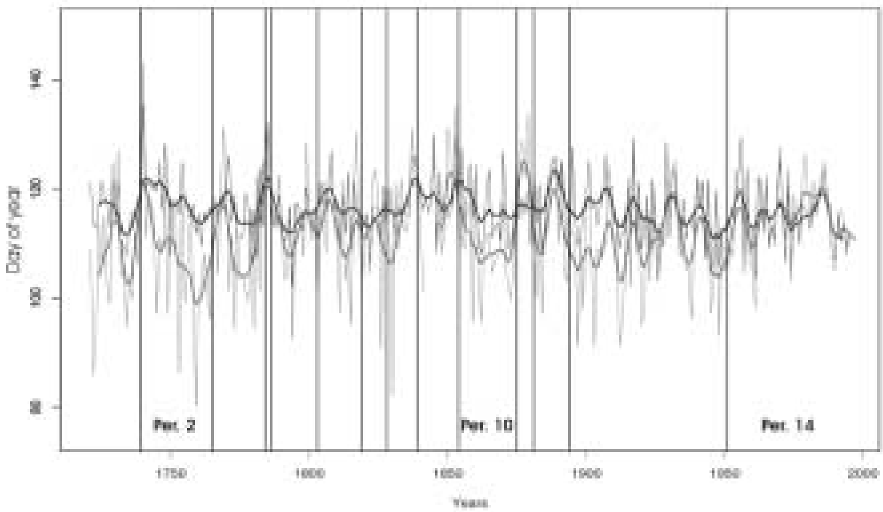

***Figure 4**: Comparison of the observed (red) and statistically reconstructed (black) flowering of the cherry tree for 1721-1995. 9-year triangular mean. 14 periods of independent data from Table 1 (vertical lines). $r_{1721-2000}$ = 0.55. $r_{calibration}$ = 0.84 (Period 14).*

The Phenoclim database for fruit trees and vine in France

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The perspectives of climate evolution lead to questions about possible consequences for agricultural production (IPCC 2001, Perarnaud et al., 2003). The main lines have already been known for about ten years, as mentioned in reports about research results in the case of France, especially for annual crops (mainly wheat and corn) and pastures (Delecolle et al., 1999, Soussana, 2001). Within the physiological processes affected, the development has to be considered first as the driving process of crop cycle duration known to be highly correlated to temperature. So far, only few studies have been devoted to perennial cultures like fruit trees and vine, until recent observations concerning noticeable advances in phenological stages over the last two decades have led to more research in this area.

Some phenological evolutions already observed

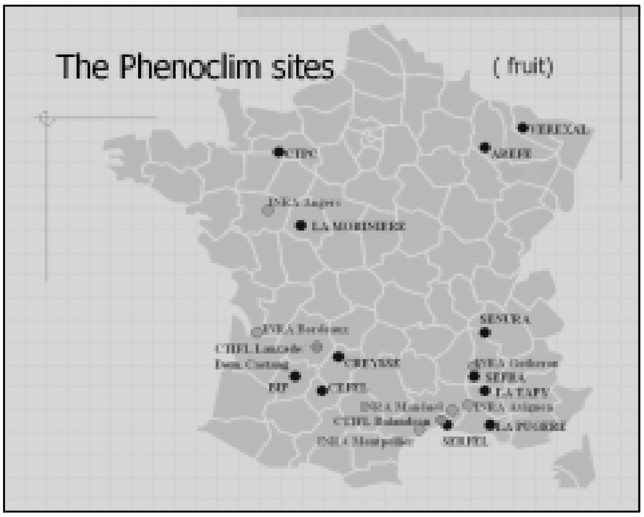
The effects of climatic change may already be apparent resulting from a change temperature, and they are evidently central in the context of global warming as predicted in climate change scenarios. It has been identified in the climatic context in France, with an increase in temperature of 0.9° C during the last century (Moisselin et al., 2002), and with a recent increase of between 0.4 and 0.6 ° C during the last decade. In relation to this warming, observations from farmers and professional advisers have recently shown a trend in advanced crop calendars. It is still difficult to document such an evolution for annual crops because of changing farming practices, but it seems feasible and useful for the phenology of perennial crops, as described in the presentation concerning fruit trees by Brisson and Domergue (see page 121).

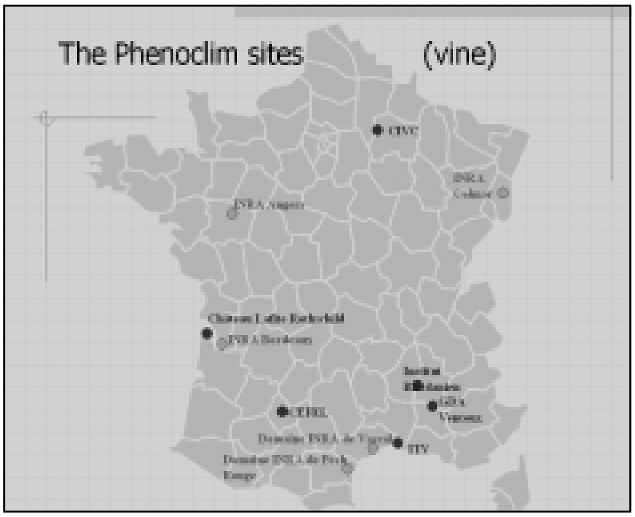
The Phenoclim database

A consortium of agricultural institutions (among them technical institutes like CTIFL for fruit-trees and ITV for vine, as well as experimental stations) have positively reacted to the initiative taken by INRA at the end of 2001 to propose a cooperative action for collecting phenological data for fruit trees and vine .

This project started in 2002, and resulted in the setting-up of the so-called 'Phenoclim' data base, located in the Agroclim unit of INRA Avignon. It allows a connection with meteorological data also collected by the same unit (about 80 locations in France).

Fig 1 and 2 : geographical location of sites of fruit trees and vine





Up to now, historical series, mainly for 20 to 30 years, have been collected for fruit trees (apple, pear, cherry, peach, apricot, plum, wallnut, blackcurrant, olive) and vine in 28 locations (see fig 1 and 2). These series will be extended in the future by collecting the data every year.

First results and perspectives

As depicted in fig 3, the first results confirm the general character (for all species/ varieties as well as for all sites) of a noticeable advance of the various phenological stages. It also concerns the flowering of fruit trees (two to three weeks, as noted by Domergue (2001) in the lower Rhône valley) as harvesting dates for vine(by almost one month, as noted by Ganichot (2002) for the Chateauneuf-du-Pape vineyard).

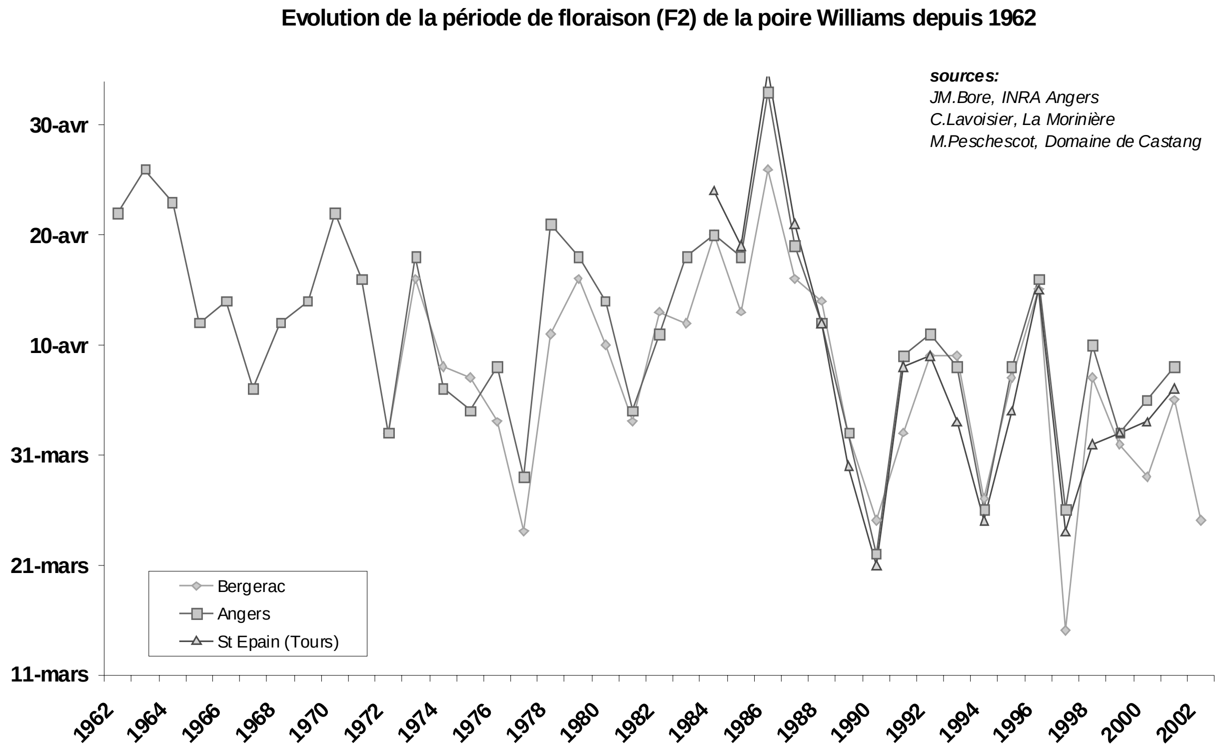


Fig 3. An example of Phenoclim data: F2 dates for William pear.

Apart from a precise characterisation of these evolutions and the analysis of recent trends, this database will allow to improve the modelling of the phenological dates compared with the existing knowledge only based on temperature sums. These improved models will be useful for a real time monitoring and will also contribute to the development of mechanistic models like STICS presently underway for vine (Brisson et al., 2003) allowing to simulate crop functioning in the context of future climate scenarios. A first example of computations by a phenological model is given in fig 4.

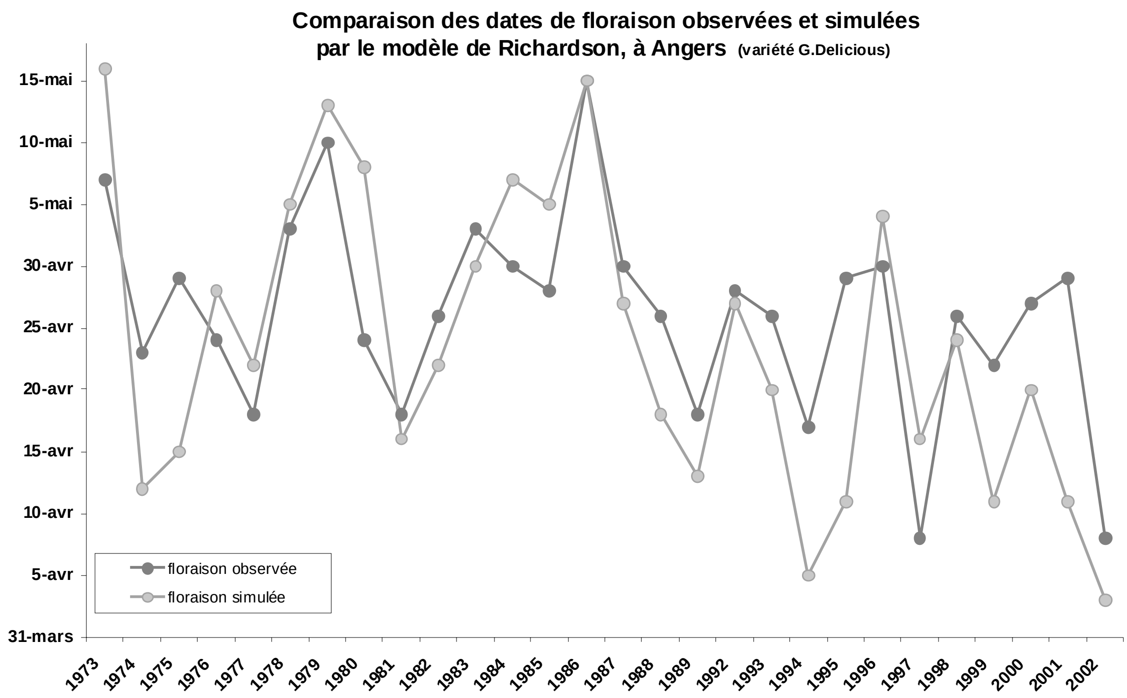


Fig 4. Comparison between observed and simulated (Richardson model) mid-flowering dates for Golden apple in Angers.

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Inter-annual variability and decadal trends in Alpine spring phenology: A multivariate analysis approach

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Introduction and methods

An increasing number of studies show evidence for a shift in phenological processes towards an earlier onset of spring. These studies were mostly based on individual species and on local individual station data. For example for the Swiss Alpine region roughly 64% of the time series exhibited a trend toward earlier appearance, whereas 36% showed trends towards later appearance. In this work a more general analysis of the inter-annual and decadal trends in Alpine phenology is presented. First large scale multispecies patterns of the phenological development were established by means of multivariate EOF (Empirical Orthogonal Functions) analysis. Second the co-variability of these patterns with meteorological parameters was explored using a SVD (Singular Value Decomposition) approach. The parameters of interest were temperature (cumulative temperature sum from January 1st to long-term mean appearance date) and precipitation (no. of days with > 3mm precipitation). The time evolution of the dominant patterns was finally used to determine a robust trend estimate. The data source was the Swiss phenological observation network consisting of a total of 69 time series. Since there are fewer observations for earlier time periods, only time series from 1965 to 1997 were included in the analysis to provide a sufficient sample size. Before the analysis each time series was normalised in order to eliminate the mean height dependence as well as to standardise the inter-annual variability.

Results and discussion

Leading EOF patterns

To assess a general inter-annual pattern 15 phenological spring phases were combined into one single multispecies data set and analysed by an EOF analysis. The first mode of the EOF analysis of the combined phenological data explained about 40% of the total covariance and revealed a mean trend in spring appearance in Switzerland of -1.8 days/10 years for the period 1965 - 1997. This pattern suggests a general forcing for the observed inter-annual variability independent of single phases.

The phenological development in time shows a mean trend of -1.8 days per decade (Fig.1). This trend is mainly due to the series of years with very early appearance dates since 1987. There is no trend in the first 20 years of the investigated period.

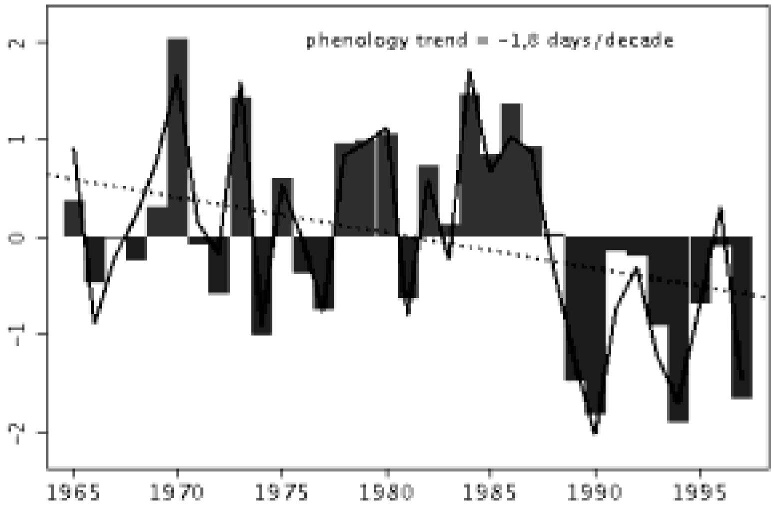

Figure 1: Development of the standardised first principal components of the EOF analyses for phenology (bars) and temperature (line). The dotted line represents the linear trend in the phenological data.

The main temperature pattern is highly correlated to the phenological time series with a correlation coefficient of 0.96 (Fig.1), leaving no doubt on the importance of temperature as the driving force in phenological development.

Multispecies and single phases SVD analyses

SVD analysis of the combined phenological and temperature data showed a strong covariance between the two fields (Normalised Root Mean Squared Covariance = 0.52) and indicated that the trend in phenology towards earlier appearance dates was largely driven by the temperature. There was a much weaker but still considerable covariance between phenology and precipitation (RMSC = 0.22), but there was no trend in this pattern.

Table 1. Temperature driven trend and covariability (normalised root mean squared covariance) between phenology and temperature for single phases and for the multispecies phase based on SVD analyses.

Analysis	**Total RMSC%**	**Trend d/10y**
Multispecies	0.52	-1.8
Hazel full flowering	0.48	-3.4
Larch needle appearance	0.58	-2.1
Beech leaf unfolding	0.44	-1.3
Dandelion full flowering	0.59	-1.9
Daisy full flowering	0.51	-1.6

Similar to the combined data all individually analysed phenological phases showed a very strong co-variability of phenology and temperature (Table 1). The temperature driven trend was most pronounced for hazel (*Corylus avellana*) full flowering, the earliest observed phase in the year (-3.4 days/10 years). For the other individually analysed phases - beech (*Fagus sylvatica*) leaf unfolding, larch (*Larix decidua*) leaf unfolding, daisy (*Leucanthemum vulgare*) full flowering and dandelion (*Taraxacum officinale*) full flowering - the temperature driven trends were in the same range as for the combined data (-1.3 to -2.1 days/10 years).

Second order patterns

The first pattern explains 97% of the covariance between phenology and temperature, but only 40% of the total variance within the phenological data. So there must be other structures not explained by the first mode. The second EOF mode explains 10% of the variance in the phenological data and exhibits a slight trend.

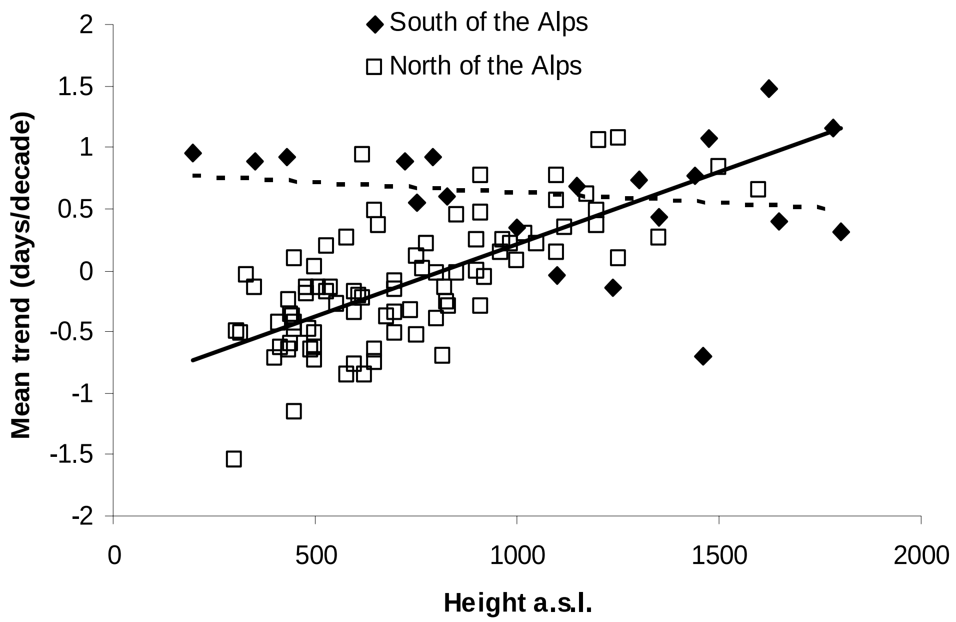

Figure2. Mean trend in days per decade explained by the second order EOF pattern in relation to the elevation of the observation station.

This trend was found to depend very much on the elevation of the stations (Fig. 2). As a mean over all stations the trend is close to zero (0.0035d/decade), but it is varying strongly among stations. Stations in the lowlands tend to show negative values whereas stations in the highlands rather show positive trends.

This stands in contrast to the pattern we found on the first mode, where the identified trend was completely independent of the geographical position of the stations. Additionally, stations on the southern side of the Alps generally tend to later appearance dates but do not show any height dependence.

The results of the second order effects lead to the conclusion, that the trend in the leading pattern is rather underestimated for the lowland stations, whereas it is slightly overestimated at higher elevations and in the southern parts of Switzerland.

Conclusions

The application of multivariate methods seems to be a good tool to asses a general view of large scale inter-annual variability and trends of phenological development. The multispecies patterns can also serve as a reference to validate results for individual phases as well as Satellite derived products. There are plans to apply these methods to European-scale data in a future study.

The Dutch Phenological Network De Natuurkalender; Results of the first two years.

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Background of De Natuurkalender

De Natuurkalender is the phenological monitoring scheme in The Netherlands, which started in 2001. The founder of phenological research in the Netherlands was Carl Linnaeus. In 1751 he described in his journal "Philosophia Botanica" the objectives and methods for recording what was later called "phenology". Systematic phenological observations were made for the first time at the end of the 19th century. The phenological networks were operational from 1894 till 1968. These networks concentrated on wild plants, butterflies, trees, and agricultural plants.
The start of the European Phenology Network in January 2001 was the reason for the Dutch VARA radio program "Vroege Vogels" (Early Birds) to record an issue on phenology. This communication resulted in the joint initiative of Wageningen University and Vroege Vogels to restart the Dutch phenological recording scheme in the Netherlands. De Natuurkalender consortium now also includes Dutch Butterfly Conservation, the Foundation for Sustainable Development, SOVON Dutch Centre for Field Ornithology, the FLORON Foundation, Institute for Environmental Communication, Royal Dutch Meteorological Organisation, World Wildelife Fund, Vogelbescherming Nederland, VOFF and Topshare.
Via the weekly broadcasts on Sunday morning we asked people to participate. As 500 000 people listen to the radio programme we quickly had a few thousand registered observers. They all received an observation manual with instructions on how to participate (Van Vliet et al, 2002). Via an interactive website we offered the observers to submit their observations to the central database from which they also could see all the observations. Since the start of De Natuurkalender Vroege Vogels broadcasts a short overview of the most recent observers submitted to the phenoline. The phenoline is an answering machine on which the observers can record their own observations.

Objectives of De Natuurkalender

The objectives of De Natuurkalender are:

- To collect phenological data from selected plant-, bird- and butterfly species.
- To study the effects of climate on timing of life cycle events;
- To study the ecological and socio-economic impacts of climate induced phenological changes;
- To raise public awareness on climate change impacts in order to increase public support for climate policy.

In order to do this, good communication between scientists and public is necessary. We developed interactive ecological educational programs for children and the general public, and provide observers with information on our website.

Evidence for significant phenological changes in the Netherlands

From 2001 until 2003 we collected thousands of observations of the 57 plant, 25 butterfly and 26 bird species that are included in De Natuurkalender programme. The species were selected because they are relatively easy to recognise or because they have been included in the phenological programmes in the 20th century (Groenendijk, 2001). During the first years it also became clear that a lot of people appeared to have collected phenological data privately for many years in a row. We integrate this data with the new observations.

By linking the new and historic observations with climate data we were able to determine the relation between temperature and timing of life cycle events of many species. The most significant correlations were found between flowering of several plant species and spring temperature. The start flowering for, for example, Ground ivy (*Glechoma hederacea)* and King-cub (*Caltha palustris*) depends on the average temperature in February and March (Figure 1).

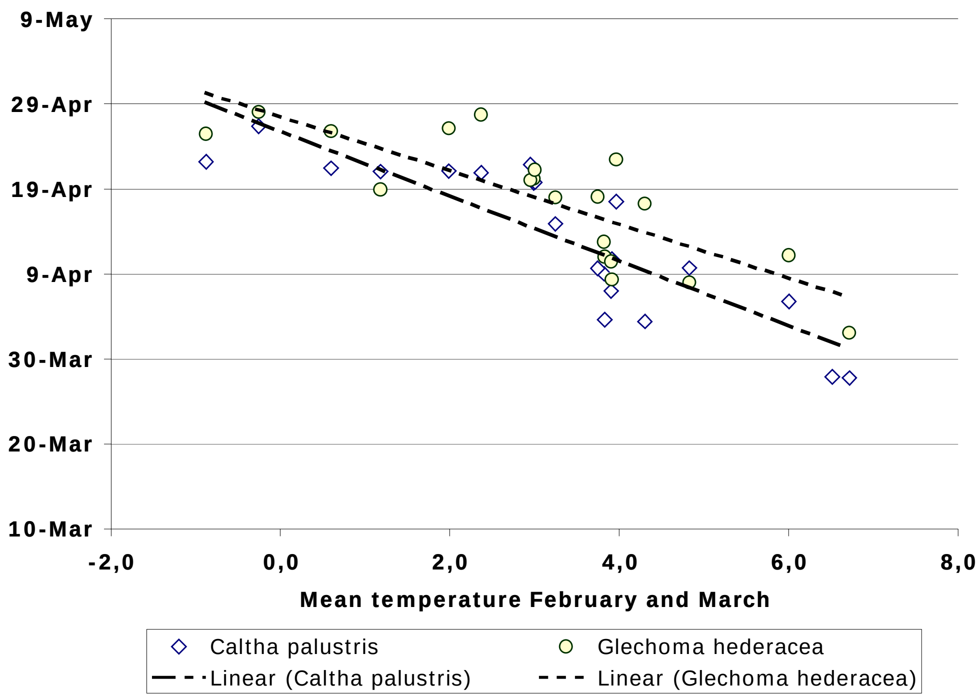

Figure 1: Start of flowering of Glechoma hederacea and Caltha palustris in relation with the average temperature in February and March.

In the Netherlands spring temperature has risen since the end of the 1980's. Especially the temperature in early spring has increased. Because of this increase, in recent years, plants showed a significant advance in flowering in the period after 1990 in comparison with the period 1940 till 1968. In comparison with the mean flowering date in the period 1940-1968 the flowering of Ground ivy (*Glechoma hederacea*) and Sweet violet (*Viola odorata*) showed an advance of 14 and 20 days respectively. There was also a clear difference in flowering date between 2001 and 2002. Especially in 2002 plants flowered early which was mainly caused by the very high temperatures in the end of January and in February. The average temperature for February 2002 was for example 7.1°C while 3.0 °C is normal. In 2001, only early spring flowering species showed advance in flowering date while mid-spring flowering species showed no or little advance. While there was a significant difference between the flowering dates of spring flowers between 2001 and 2002, the arrival dates of migratory birds like for example Chiffchaff (*Phylloscopus collybita*) showed little difference. As the migratory birds spend the winter in Southern Europea and in Africa, it is very likely that weather conditions in these areas caused this difference. As we currently lack historic phenological observations of bird species, we are not able to determine the changes in timing of phenological events like migration for the species included in De Natuurkalender. Other data, however, suggest a continuous advancing trend of breeding date in The Netherlands during the 1990s for several species (see e.g. Majoor et al. 2001, Pilzecker, 1998).

In 2002, the first generations of butterflies flew earlier than in 2001. Butterflies that hibernate as butterflies appeared on the first days with high temperature. Brimstone (*Gonepteryx rhamni*), Peacock (*Inachis io*) and Comma (*Polygonia c-album*) are examples of those butterflies. Butterflies that hibernate as pupae like for example Small Copper (*Lycaena phlaeas*) were also early in 2002. Migratory butterflies like the Red Admiral (*Vanessa atalanta*) and Painted Lady (*Vanessa cardui*) were early in both years. Normally we would have expected the first observation of these species at the end of April and in May but in both years these species were already observed in February and March.

The difference in phenological responses to the increased temperature in the Netherlands will undoubtedly have an impact on species interactions. The impacts are however difficult to quantify and our research will focus on this issue in the coming years.

Improved communication: Interactive website

Communication is an important issue within De Natuurkalender project. It is our opinion that observers should be well informed about what is going on in nature, what they can expect to see outside at a certain time of the year and how they have to make their observations. Furthermore, observers are interested to know what we are doing with the data that they collect. By providing this type of information we increase the motivation of observers to continue to participate in the monitoring network. Not only the observers are interested in the results of De Natuurkalender. Especially the media are an important customer for this type of information.

The weekly broadcast of Vroege Vogels played a central role in this communication during the first years of De Natuurkalender. However, to further facilitate the dissemination of information to the observers, to the media and to other interested persons we are continuously developing our website (http://www.natuurkalender.nl/). In 2003 we launched a new version of our website. The most important new features of the website were the forms to submit observations and the tool to visualise all observations from the current year and all previous years in maps and graphs (see Figure 2).

The maps give a spatial representation of the locations where the observations have been made in The Netherlands. The colour of the dots represent the week of the year when the observation have been made. The graphs give an overview of the number of observations made per week and the maximum temperature from day to day. The maps and graphs always give a live update as all new observations submitted via the website are directly added to the maps and the graphs. With this tool on the website people can clearly see the change of the seasons during the year. This part of the site will be further developed in the future.

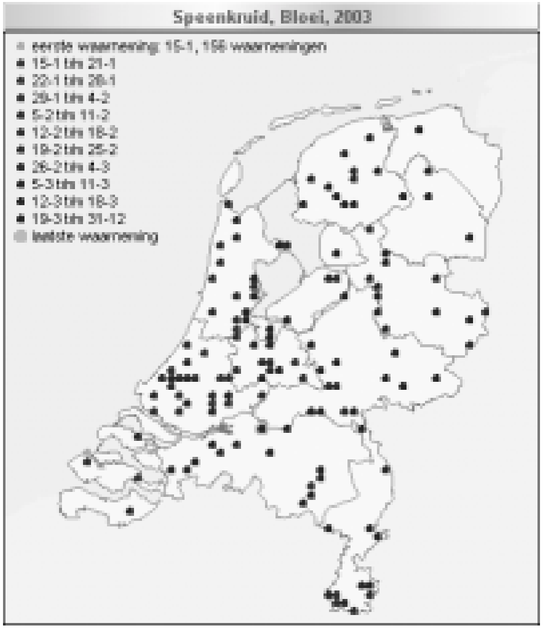

Figure 2: Start of flowering of Small selandine (Ranunculus ficaria) in The Netherlands in 2003.The colour of the dots on the website give an indication of the week of the year in which the observation has been made.

Attention in the media

De Natuurkalender has been very successful in generating media attention during the first years of its existence. Over 50 news paper articles in national and regional newspapers addressed the network and its results. Sometimes the articles made it to the headlines or covered almost an entire page in newspapers. In addition to the newspaper articles, several television and radio programmes paid attention to De Natuurkalender. With all the publicity we were able to inform an equivalent of over 50 million people during the first two years.

Conclusions

Because of the thousands of observations gathered, the analyses made, the improvement of the website, the attention in the media, and the good cooperation between a large number of institutes we consider De Natuurkalender as a successful project. We have been able to demonstrate that cooperation between, scientific organisations, Non Governmental Organisations, the media and the public can result in a valuable contribution to the monitoring and analysis of climate change impacts.

Acknowledgements

We would like to thank the organisations that financially supported De Natuurkalender in 2002 and 2003: Stichting Weten and the Prins Bernhard Cultuur Fonds. Furthermore, we would like to thank the European Phenology Network for their institutional support. Finally, we thank all the participating organisations for their contribution given during the build-up of De Natuurkalender and all the observers of De Natuurkalender.

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Plant phenology in Norway related to climate change and latitude

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Increased temperature, probably mainly due to climate change, has caused spring to be earlier along the coast of Norway for decades, maybe particularly in the south. However, it is observed that the time of spring in the mountains and in the north-east of the country has been stable or even delayed over the last 20 years. A possible explanation is that although the temperature has increased, an increased precipitation during autumn and winter in the same period has often fallen as snow, often resulting in later melt in spring. In some years in elevated oceanic western districts of Norway early and strong snowfall partly before the ground was frozen has even caused trees particularly of birch and *Prunus padus* to start leafing before snow melting in spring.

Along the coast climatic change is suggested to be one possible reason for earlier flowering of many plant species for a period of about 100 years from the mid-1800, both along the coast of northern Norway (71°N) and in the southern lowland area (58-60°N). On the other hand, no clear differences have been found for a similar period in an elevated district of southern Norway, maybe partly due to slower snow melting.

North of the Polar Circle there is a day length of 24 hours in summer, and even at 58-60°N there is still a day length of 18 hours in the last part of June. Plants have different ecotypes when originating from various day lengths. Normally, the leaf bud break is later in southern and particularly oceanic district provenances when further north, while the end of their growth is later in the autumn, which may cause less hardened shoots and frost damages. Climate change with longer autumns may also result in changes e.g. in the hardening and thus a change in the adaptation to different provenances in various districts.

Plant phenology

Most scenarios for climate change predict such changes to advance towards Arctic regions at least through the next 50 years. Temperatures in northern Norway are supposed to increase by 0.3-0.4ºC per decade (Fig. 1) on average for the whole year, but more during winter and spring than during autumn and summer and more in the relatively continental inland regions than along the coast (Förland et al., 2002). The amount of precipitation is also supposed to increase in the next 50 years, particularly in the autumn and along the coast (Fig. 2), and advancing to the coastal North-west (up to 6% per decade). During spring, however, there may be a higher increment in the more continental parts of northern Norway and smaller changes in other regions (Hanssen-Bauer et al., 2001).

In many oceanic and lowland districts, an increased winter temperature may also cause increase in precipitation in this period to fall as rain and less as snow. Periodically this may also happen in inland and higher elevated areas causing layers of wet, packed snow or ice. But an increased precipitation in winter will also in the future fall as snow in spite of higher temperatures, according to modelled temperatures for the period 2020-2049 in the inner part of northern Norway (Table 1).

In spring, however, the strongly increased precipitation in the North-Norwegian inland (Fig.2) may fall as very wet snow and form ice crusts, which are difficult to penetrate for the large herds of reindeer digging for their main winter diet, the reindeer lichens.

In the lowland of southern Norway and along most of the coast of the country spring seemed to be earlier over the period 1982-1999 (e.g. Högda et al., 2001). However, in spite of higher temperatures, it is observed by satellite images that in mountain districts of Norway and in the more continental parts of northern Fennoscandia as well as in parts of the Kola Peninsula in Russia, spring has been delayed over the last 20 years by up to one week (Högda et al. 2001). This may have been caused partly by the increased snowfall in winter and early spring. In some cases even fresh snow in the autumn occurred earlier, resulting in a shorter growing season (Fig. 3). This was also observed in field observations at the Kola Peninsula over a 60-year period 1930-90 (Kozlov and Berlina 2002). On average the fresh permanent snow appeared 13 days earlier in autumn during that period, while the snow melted 16 days later. The temperature was slightly lower in August-September late in the period, but not low enough to explain the shorter growing season. However, the winter snowfall increased by 44% during the study period and influenced the snow-free period.

There have been strong variations in Fennoscandia at the time of onset of the birch pollen season; from before April 20 in the South and along the south-western coast of Norway to after June 10 in the sub-alpine and sub-arctic regions over the last 20 years. In the same regions in which there was a delay in snow melt, there was also a delay in the pollen season, longest in the most continental parts of northern Fennoscandia, approximately one week (Högda et al., 2002). In southern parts of the region, on the other hand, the first recorded birch pollen advanced by 9 days (Oslo). Along the south-western coast of Norway, the pollen season has also started 1-2 weeks earlier over the last 20 years. The start of the pollen season, of course, follows the timing of the vegetation of the birch and will be early when the bud break is early. Therefore, it is very surprising that the pollen season is found to have been delayed over the last 20 years in Tromsö near the coast at 69^{o}N. We will try to find the reasons for this and other correlations between satellite images and ground phenological studies and climate observations in a new phenological network in Norway.
At higher elevations, e.g. 700-800m a. s. l. in the south of Norway close to the N-S mountain range, precipitation is very high (up to 7000-8000 mm are registered). Autumns often last very long in the region before the temperature suddenly drops below zero and the precipitation falls as snow on an unfrozen ground (even after a climate change to milder climate). Easily at least 1 m of snow can fall in a short period, which may increase to several metres during the winter. This snow pack insulates the ground which remains unfrozen or is only slightly frozen. In spring, when the temperatures in the air increase, early sprouting trees in the sub-alpine zone (Fig. 4) start to vegetate and transport water and nutrients from the unfrozen soil long before the snow melts. This is very common in many areas more inland areas in the southwest to the far north of Norway.

Along the coast and in lowland areas of Norway the climate change with increased temperature and precipitation, the positive North Atlantic Oscillation (NAO) through February-April over at least 20 years may have been greatly responsible for the earlier spring and earlier plant phenophases which are generally also observed in Central Europe. This may change the present vegetation zones. By comparisons of the first flowering dates from about the mid 1800s with similar observations from the same places nearly 100 years later, earlier first flowering was found even near the bottom of the fjord in north-easternmost Norway (Klaveness and Wielgolaski 1996). A scatter plot shows that this is particularly true for the later flowering species, and more so later in the 1900s than in the earlier part of the century. This indicates more favourable growing seasons in the 1900s than in the century before. However, the earliest flowering plant *(Tussilago farfara)* was somewhat later in the more recent periods. This may be due to later snow melting or low temperatures. Another early flowering species, the hydrophilic *Saxifraga oppositifolia*, on the other hand, was clearly earlier by flowering in the first part of May throughout the 1900s, but late in May in the middle of the 1800s.

From observations in Oslo or Christiania, more historical data are available than from northernmost Norway (Klaveness and Wielgolaski 1996). This data also generally show earlier first flowering in the later part of the last century (1900s) and also particularly later in the season (while this cannot be concluded for the period 1928-1952). However, there are also here great differences between the species in their response to the climate ("phenological interception"), which was also found by the author in other studies (Wielgolaski and Inouye 2003). During the period 1870-1970 the mean annual temperature increased by 0.6-0.8°C.

A third area where it has been possible to compare older and newer first flowering data in Norway is a mountainous area in more continental southern parts of the country (Fig. 5). Here, there is no significant difference between the data from the third quarter of the 1800s and the second quarter of the 1900s. However, there may be a slight tendency to later flowering in the second half of May in the 1900s (Klaveness and Wielgolaski 1996). This may in part be due to the higher precipitation observed in spring during that period, falling as snow, at least in the mountains. This causes cold water and air masses running down also in the upper parts of the valleys. Thus, the delayed or stable flowering in these mountainous areas may be explained partly in the same way as the delayed arrival of spring in the Norwegian mountains and in continental, northern regions of Fennoscandia and the Kola Peninsula.

Norway is a long country latitudinally, from 58°N to more than 71°N, but only north of the Arctic Circle (66°33'N) is the day length 24 hours in summer. At about 70°N, this means approximately 2 months of midnight sun, while the sun shines "only" about 18 hours at the summer solstice in Oslo at about 60°N (Wielgolaski and Inouye 2003). The variation in photoperiod may strongly influence the phenology of many plants growing in Norway, particularly long-day plants, which have lower temperature sums or use fewer days between phenophases when growing in long days (Skjelvåg 1998). Normally the temperature decreases to the North, which means that many agricultural plants can be grown further north than otherwise would have been possible. This is the case e.g. for cultivars of grain species used in Norway (Bleken and Skjelvåg 1986). This is also important in forestry by transplanting trees of different origin, genetically adapted to a climate by various ecotypes or so-called provenances (Myking 1999). Northern provenances showed earlier bud-burst than more southern provenances. On the other hand, southern provenances showed a prolonged growth in the autumn compared with northern ones. These results are found both in conifers and in mountain birch. For the southernmost ecotype of Norway spruce the highest degree-day sums are needed for bud burst, 193°days at 50.5°N, compared to 152°days at 67.5°N (Beuker 1994).

Conclusion

1. Along the coast and in lowland areas of Norway climate change shows the "normal" results, earlier spring and later autumn, and earlier phenophases.
2. In mountainous regions and in cold continental northern Fennoscandia the increased winter snow cover in spite of higher temperature may explain a later snow melting and to some degree also a shorter growing season.

3. The high snow fall in western mountainous regions of Norway insulates the ground against strong frost. Vegetation may then start under the snow, and green birches may be found in the snow.
4. Increased day length during summer causes lower degree day sums to reach various phenophases in many plants in the North than further South.

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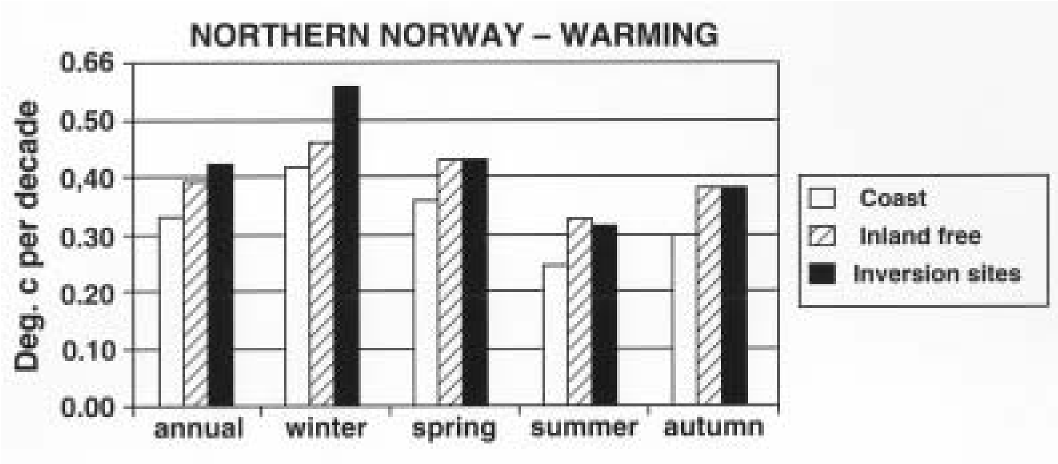

Figure 1: Downscaled annual temperature scenarios up to 2050 in northern Norway and in various parts of the year in coastal areas (coast), freely exposed more continental areas (inland free) and at sites exposed to inversion. From Förland et al., 2002.

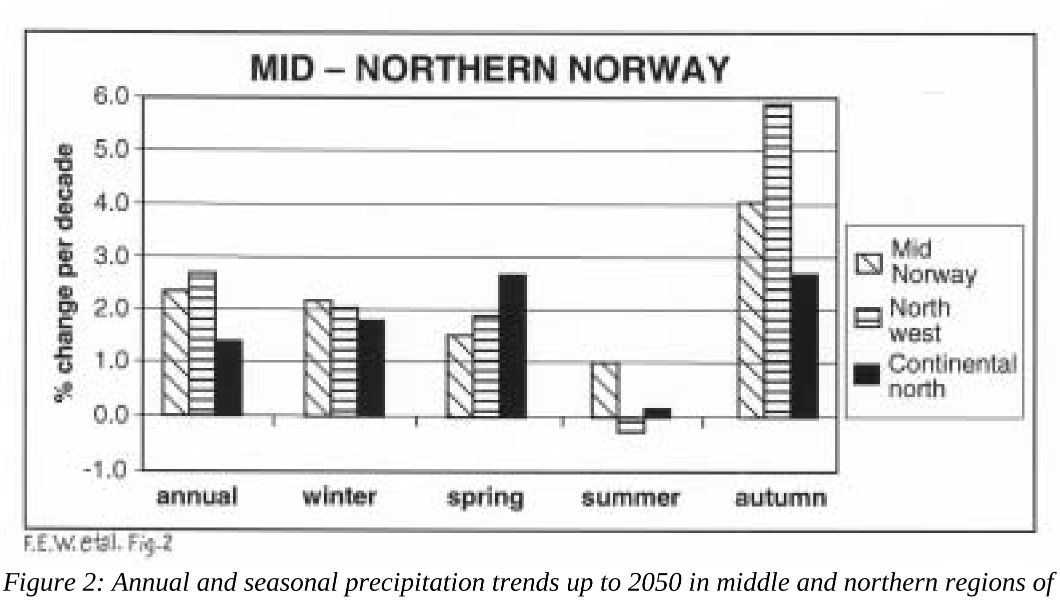

Figure 2: Annual and seasonal precipitation trends up to 2050 in middle and northern regions of Norway. From Hanssen-Bauer et al., 2001.

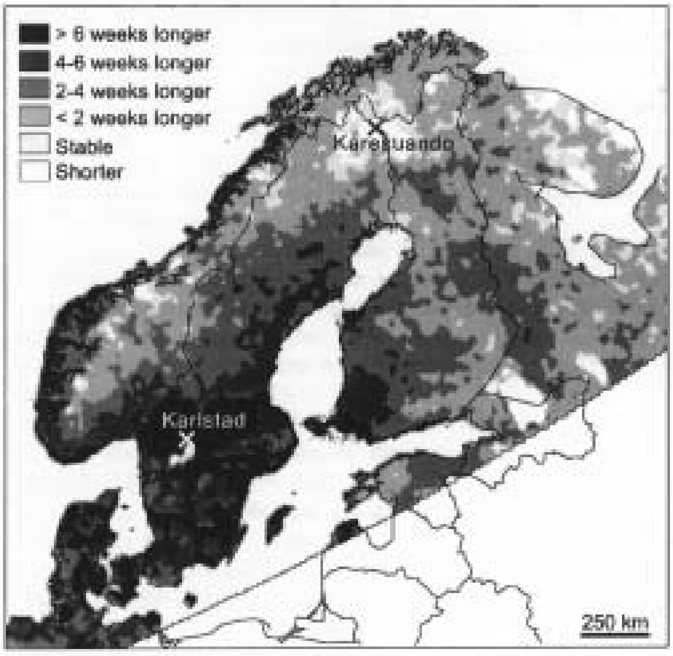

Figure 3: Change in length of the growing season through the period 1982-1998. From Högda et al., 2001.

Figure 4: Green mountain birch in old snow and unfrozen ground in mountainous western Norway. Photo: Leif Ryvarden.

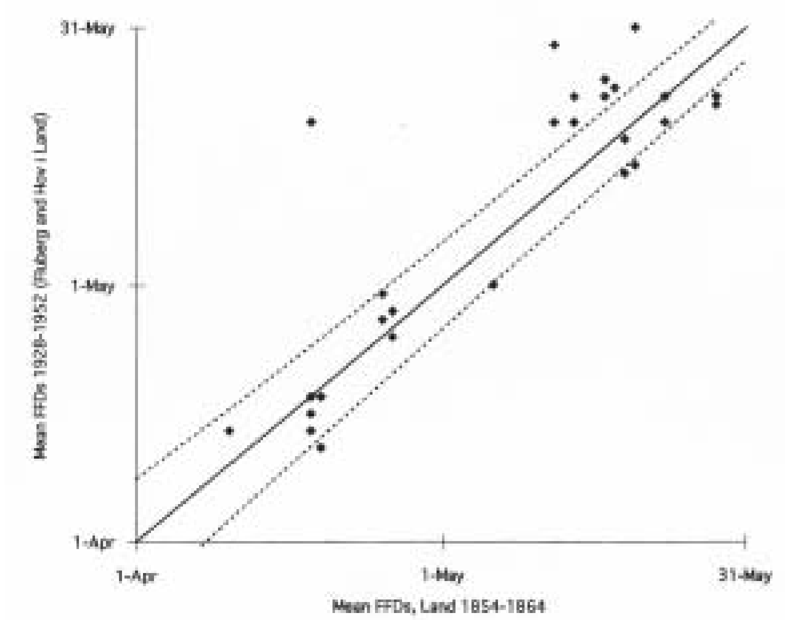

Figure 5: Scatter plot of mean first flowering dates of various species from two mountainous sites in southern Norway (about 61^{o}N) in the second quarter of the 1900s (y-axis) compared with flowering of the same species at one site in the third quarter of the 1800s (x-axis). Line equals the equivalent response, with 95% C.I. calculated for 11 years. From Klaveness and Wielgolaski 1996.

Table 1: Modelled (2020-2049) and observed mean values (selected periods 1876-1990) of monthly mean temperatures (^{o}C) at Karasjok, north-eastern, relatively continental Norway. From Hanssen-Bauer et al. 2000.

Monthly mean temperature (^{o}C), Karasjok, Norway

	Period	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
O	1876-1900	-15.5	-14.6	-11.3	-3.9	3.2	9.3	12.4	10.4	5.0	-2.2	-9.6	-14.9
B	1901-1930	-14.3	-14.7	-10.0	-3.3	3.2	9.5	13.2	10.5	5.6	-2.1	-9.6	-13.2
S	1931-1960	-14.9	-14.6	-10.1	-3.2	3.6	9.9	13.7	11.3	5.9	-1.3	-7.3	-11.9
	1961-1990	-17.1	-15.4	-10.3	-3.1	3.8	10.1	13.1	10.7	5.3	-1.3	-9.4	-15.3
MOD	*2020-2049*	*-11.9*	*-10.5*	*-7.5*	*-1.6*	*7.4*	*13.0*	*14.9*	*11.9*	*6.8*	*1.5*	*-5.0*	*-11.3*

A phenological data bank in Northern Italy

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In this paper we present a phenological data bank - an ACCESS® database - in which phenological observations referring to the last twenty years are stored (Puppi, 1993; Puppi et al., 1983, 1985,1989, 1991, 1993, 1994; Zanotti et al., 1994, 1997, 2000).
The data were collected in the province of Bologna (Italy) in 239 stations sited in various natural environments from the plain (at an altitude of 10 m) to the mountain (at an altitude of about 1800 m) between 11°42' and 10°49' E longitude and between 44°07' and 44°39' N latitude.
Collected data (about 28.000 records) refer to 255 species, mostly spontaneous, both woody and herbaceous and concern both vegetative and reproductive phases.
This data bank is an important reference tool to compare the phenological behaviour of species in different years and to check the influences of global change on the flowering and leafing of plants.
Observation were conducted every week in winter and spring, adopting the following phenological keys, where the symbols + and 0 refer to the classic Marcello's key (1954)

REPRODUCTIVE PHASES OF WOODY AND HERBACEOUS SPECIES - Official key adopted by Phenological Gardens National Working Group (Gruppo di Lavoro Nazionale per i Giardini Fenologici) (Puppi, 1993)
1.Flower buds or aments present, but not developed ((+)00)
2.Flower buds ready to open, with visible petals; developed but immature aments (+00)
3.Flower buds and opened flowers; immature and pollinating aments (++0)
4.Full flowering (+++, 0+0): buds, opened flowers and faded flowers; pollinating aments
5.Beginning of fading: opened flowers and faded flowers; pollinating and faded aments (0++)
6.Full fading: faded flowers and aments (00+)
7.Beginning of fructification (000)

VEGETATIVE PHASES OF WOODY SPECIES - Official key adopted by the Phenological Gardens National Working Group (Gruppo di Lavoro Nazionale per i Giardini Fenologici) (Puppi, 1993)
1.Dormant buds
2.Swollen buds
3.Swollen and opening buds, with folded leaves
4.Opened buds and young leaves with extended blade
5.Young leaves with extended blade
6.Young and adult leaves
7.Adult leaves

REPRODUCTIVE PHASES OF GRAMINACEAE (according to Puppi et al., 1993)
1.Inflorescence still hidden in the leaf sheath ((+)00)
2.Visible, but immature inflorescence: in part or fully pouring out of the sheath, not visible stamens (+00)
3.Stamens appearing from a part of the inflorescence (++0)
4.Stamens appearing from the whole inflorescence, pollen emitting anthers (+++)

5.Inflorescence with pollen emitting and withered stamens (0++)
6.Inflorescence with only withered stamens (00+)
7.Beginning of caryopsis formation (000)

Phenological data were expressed in the database as weighted average of the observed species, for every day and every observation station. Topographic data of single stations were also reported.
By means of the database we can compare the phenological trends of single species or groups of species at different stations in the same year or at the same station in different years, and estimate the range of fluctuations.

Below we report some examples from a data base concerning woody species.
In single species, sited in location at different altitudes, we can observe a phenological gradient. For example, the full flowering of *Ostrya carpinifolia* (fig.1) presents a gradient of about 4 days of difference every 100 m of altitude.

In many sites phenological observations were conducted during many years, as in the station "Botanical Garden", situated in the centre of the town of Bologna, where we have been observing the flowering and leafing of several species since 1977.
An example regards the spring leaf emergence (phase 4) of 5 species (Ostrya carpinifolia, Cornus mas, Viburnum lantana, Sambucus nigra, Prunus avium). We observed that (fig.2):

- the earliest leaf emergence occurred in 1983 and in 1999 (9 days in advance as regards an average year)
- the latest leaf emergence occurred in 1987 (7 days of delay as regards an average year)
- Another example concerns the full flowering of Fraxinus ornus (fig.3). We noted that:
- the earliest flowering of Fraxinus ornus occurred in 1981 (9 days in advance)
- the latest flowering of Fraxinus ornus occurred in 1984 (6 days of delay)

At the above mentioned station we observed that:

- Phenological trends of leaf emergence and flowering are significantly correlated
- 16 days is the difference between the earliest and the latest spring
- In the recent observed years 1999 and 2002, flowering and leafing occurred in advance in comparison with an average year, but this still remains within the range of fluctuation, any anomalous advance being observed.

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*research financed by Ministero Politiche Agricole " Progetto Finalizzato Phenagri"

Figure 1

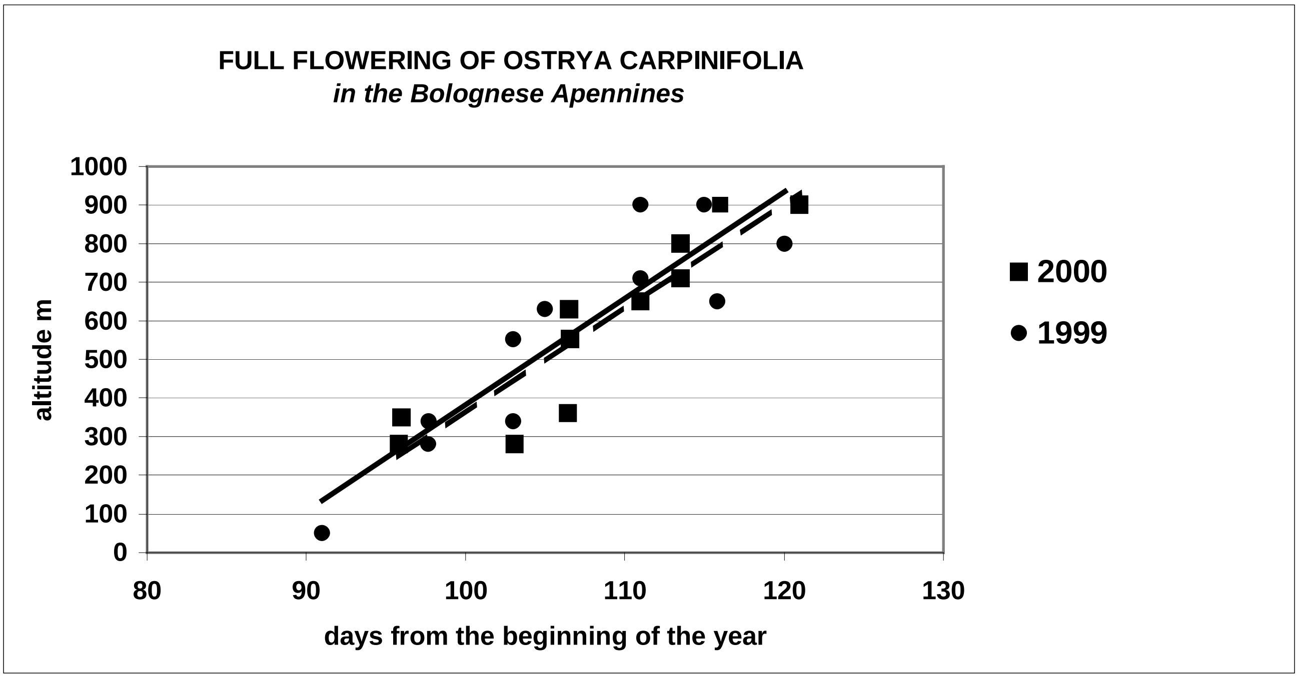


Figure 2

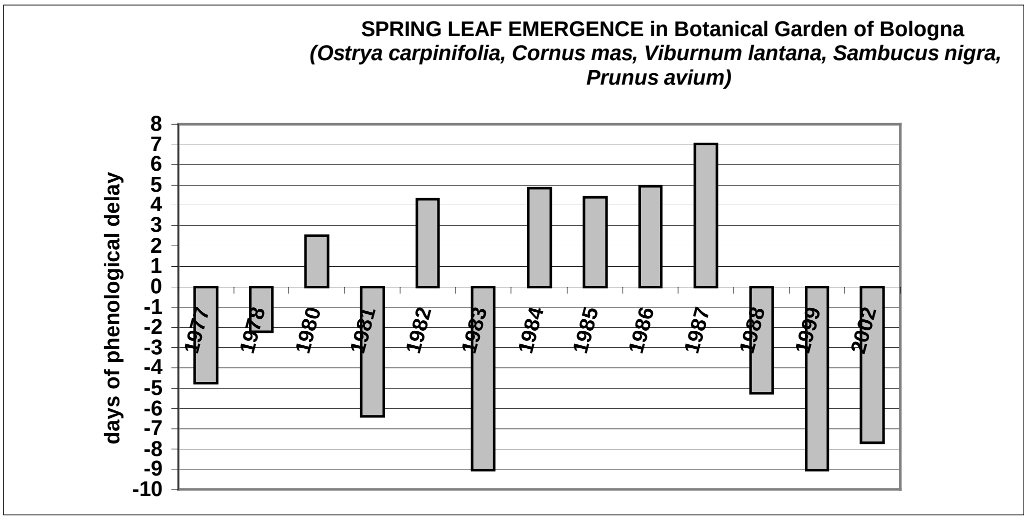
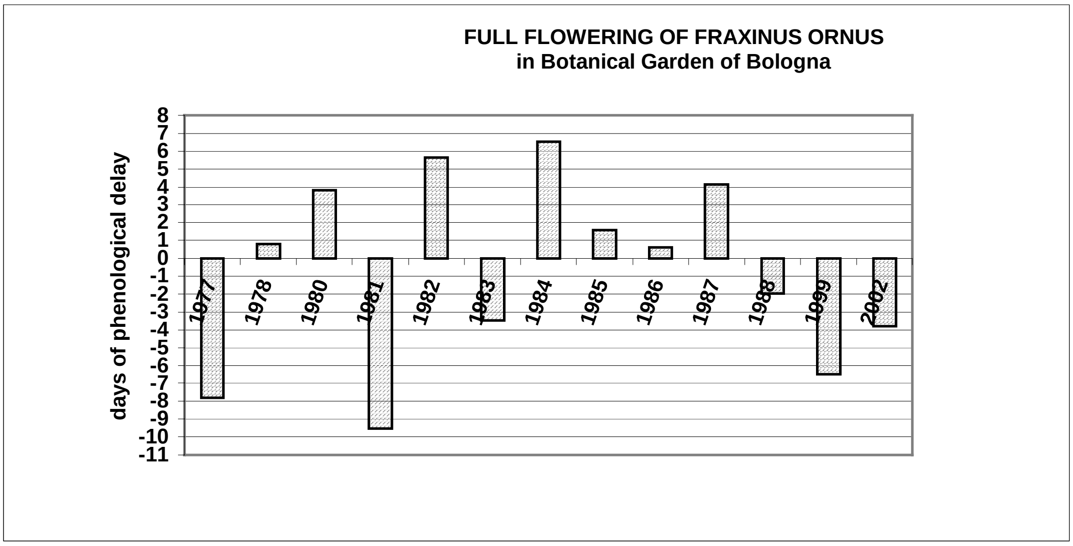


Figure 3



Presentations on the activities of the European Phenology Network

EPN

Why a phenological bibliographical database?

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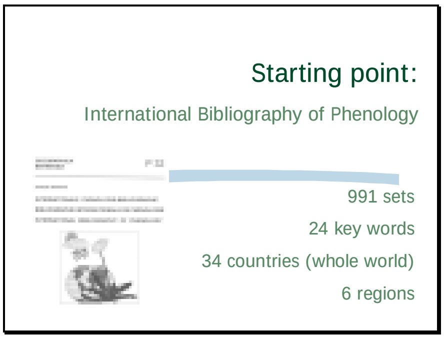
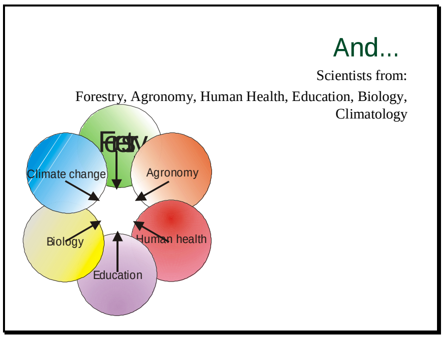
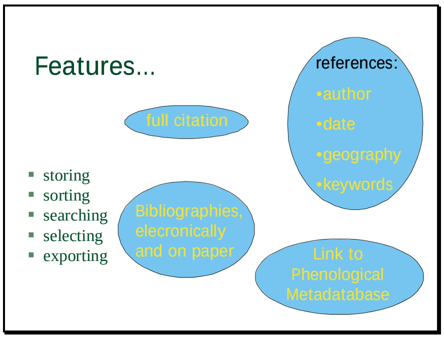


The basics, part 1:
The bibliographical database on phenology is based on one of the existing international bibliographies of phenology, which is developed by the workpackage manager. It includes 991 sets and 24 key words.

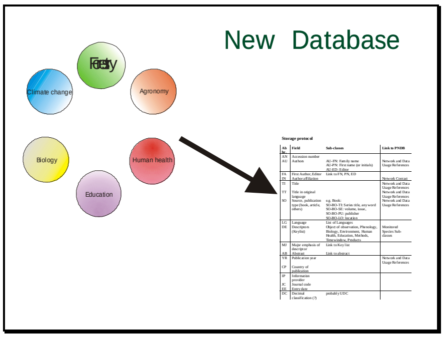


The basics, part 2:
Phenology interests scholars of different fields: botany, zoology, ornithology, entomology, geography and history, but also agronomy, forestry, environment, and medical sciences. Therefore, publications are difficult to find as they are scattered throughout numerous publications, periodicals, reports and books. Furthermore, much fundamental work was done long ago and is no longer accessible. Contacts amongst researchers, who usually work in both phenology and other fields, are often rare. Therefore, access to this information is very much required

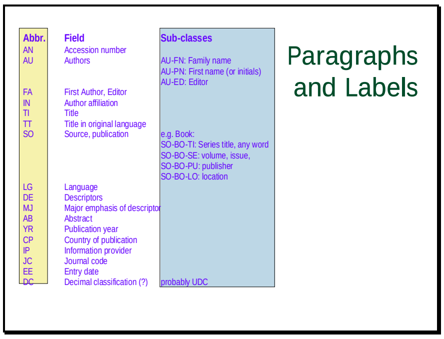


Database features:

- **Storing:** Store references in formats that allow access to all information needed for a full citation.
- **Sorting:** Sort references by author, date, etc..
- **Searching:** Search on specific data fields (author, journal, etc.).
- **Selecting:** Select the references needed for a particular project or passage.
- **Exporting:** Print formatted bibliographies and citations electronically and on paper.

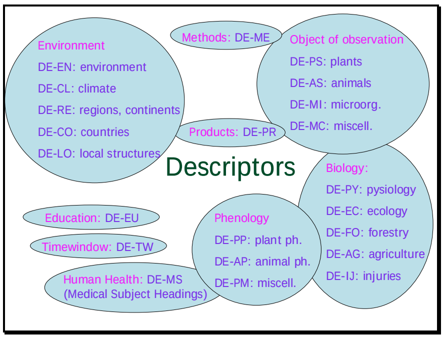


From the basics to the new database:
First, the structure will be defined, and the bibliography entries formatted according to the preliminary results. All entries must be checked and completed with keywords and links. The electronic publication will be coordinated with the meta-databank, leading to an online database which will include a maximum of links to information on phenology in Europe. A big issue will be the search and the negotiation of a structure and financing of the regular update of the bibliography, and to hand over the structure and the bibliography to a operational documentation centre for routine collection and management.



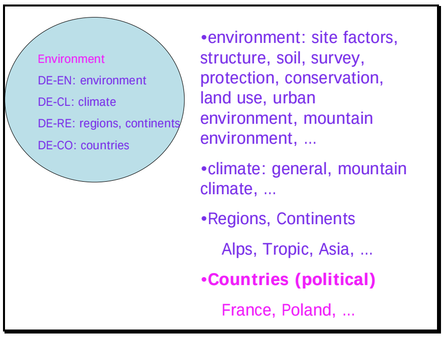
Open Questions:
1. what format?
2. What techniques can be used to bring this bibliography online?
3. What will be the features of this database (what can be done with it)?
4. Where will we store the database?

First answers:
MySQL, PHP
55 paragraphs in 3 layers
Labels from MEDLINE (if available)



Descriptors:
The bibliographic entries can be described from different points of view. Main categories (view-points) are:

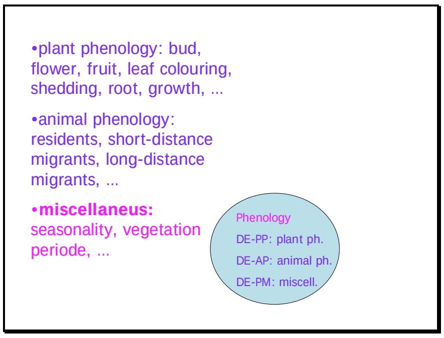
1. Environment
2. Methods
3. Object of observation
4. Products
5. Biology
6. Phenology
7. Human health
8. Time window
9. Education



First example: Environment:
We can describe the bibliographic entry from an environmental point of view. Sub categories for the keywords are:

1. environment
2. climate
3. regions, continents
4. countries

Some of the possible keywords are mentioned on the list beside.



Second example: Phenology:
Here we describe the phenological focus.
Sub categories for the key-words are:

5. plant phenology
6. animal phenology
7. miscellaneous

The bibliographic database is just under construction. Its structure has slightly changed since April 03 (see Fig. 1).In July, a first version will be accessible online. A final discussion of the keywords will follow in August. The database will then be completed (searching of new entries, subject heading,…) successively.

Description of the Tables of the Phenological Bibliographical Database (see Fig 1):
bib_db Main database with information on a publication
sub_lang Language of the publication; used for HTML output
sub_pubtype Type of publication (Book, Article, ...)
sub_author Name of autor/editor
meta_authors Meta table for multiple authors/editors
sub_countries List of countries in different languages
meta_countries countries where the publication was published
sub_pubref Title of publication where this entry was issued
sub_publisher Publisher of this publication
sub_1stkey top level of key list: "Object of observation", "phenology" etc.
sub_2ndkey 2nd level of key list: "DE-PS, DE-AS"; "DE-PP, DE-AP" etc.
sub_3rdkey 3rd level of key list: "plants, grassland, ..."; "plant phenology, animal phenology, ..." etc.
sub_4thkey 4th level of key list: "latin, english, ..."; "bud, flower, ..." etc.

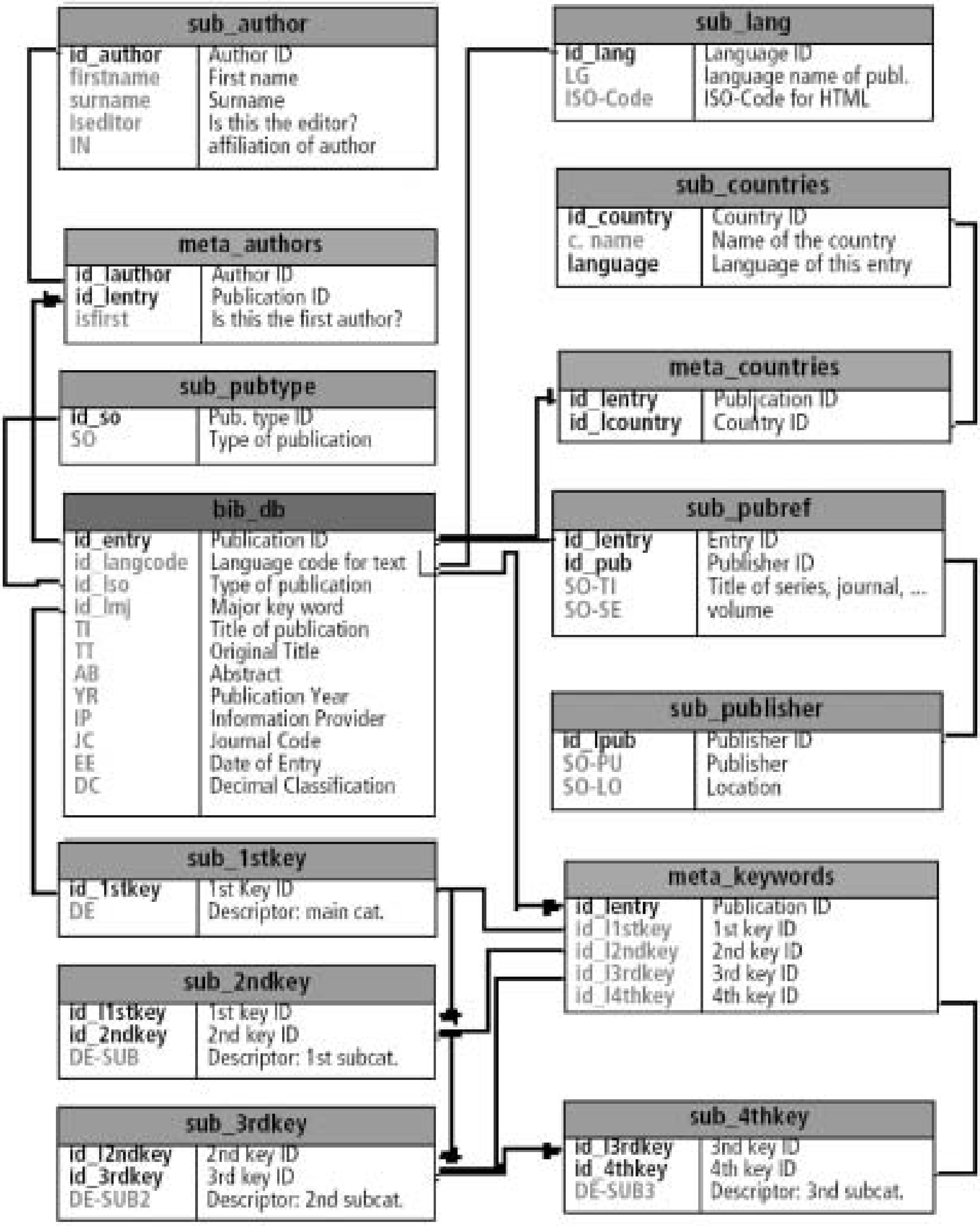


Figure 1: Structure of the Phenological Bibliographical Database. Text in gray: Fields appearing in both admin GUI and search GUI.

An on-line accessible metadatabase on phenological networks

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Within the framework of the European Phenology Network EPN a metadatabase on phenological networks was developed to store basic information about active and historical monitoring networks on phenology. In parallel two frontends to this database were made accessible to the scientific community and the general public on the Internet: A digital questionnaire to gather information on phenological networks and a corresponding retrieval tool to browse this information.

The overall aim of EPN is to improve monitoring, assessment, and prediction of climate induced phenological changes and their effects in Europe. It has been financed as a thematic network by the Fifth Framework Programme of the European Union. One of the objectives of EPN is to improve integration of, and access to phenological data in a systematic, structured and user-friendly way and to exchange knowledge and information between phenologists from different scientific disciplines.

In the past there was a lack of well-structured and online accessible information on phenology network data in Europe and the whole world. This situation has hampered research as well as the exploitation and application of data by potential users. The metadatabase is a first step to fill this gap.

About 1.400 addresses from institutions and persons related in any kind to phenology were gathered from different sources and these were informed about the digital questionnaire in late September 2002. As from mid-March 2003 about 50 returns from Europe and outside Europe have been collected and stored in the metadatabase.

The authors had expected to get information from more networks. In general there seems to be a low sensitivity of the phenological community and especially of the data providers to the necessity to share basic information with the scientific community and the general public. Recent papers on the impacts of climate change on natural systems address the demand for a common view on phenological data across scales and networks, which should make the phenological community more sensitive to sharing information.

The digital questionnaire and the retrieval interface for the phenological metadatabase will also be available from the EPN Homepage in future.

EPN Homepage:	http://www.dow.wau.nl/msa/epn/
Metadatabase Questionnaire Website:	http://epn.pik-potsdam.de/cgi-bin/epn/readepn.py
Metadatabase Retrieval Interface Website:	http://www.pik-potsdam.de/~rachimow/epn/html

Workshop on Bird Migration

Tim H. Sparks

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The timing of migrant birds has already been affected by rising temperatures and there is an urgent need to explore this in greater depth, to identify potential problems and to understand the consequences of changed timings and migration routes on bird populations.

This workpackage aimed to build links between prospective partners from across Europe. It will encourage free exchange of information and ideas and identify potential areas for pan-European research.

Eighteen people from across Europe met in Cambridge, UK in April 2002. They represented locations as diverse as Gibraltar and the Arctic Circle. In broad terms the workshop divided into three areas i) presentations of existing and planned research, ii) a discussion to identify where new research is most needed and iii) an identification of collaborative work possible within existing resources or dependent on new funding.

Workshop on Modelling

Annette Menzel

Lehrstuhl für Bioklimatologie und Immissionsforschung, Technische Universität München, Germany

Modelling is one of the most useful techniques available for impact assessment based on historic observations. The workshop on Modelling Seasonality and Phenology aimed to improve co-operation between ecological, agricultural, human health and phenological research by exchanging knowledge on phenological model development and common tools and techniques used in impact studies.

The overall objectives of this workpackage were to:

- Present the latest results of phenological research on modelling
- Obtain a survey of commonly used phenological models and parameterisation techniques
- Illustrate the use of phenological models for forest growth models, agricultural yield models and pollen shedding models as well as climate impact studies
- Discuss the problem of parameterisation and validation techniques
- Illustrate how Earth Observation data can be used with phenological models
- Strengthen the network between modellers and phenological monitoring teams

Workshop on Human Health

Bettina Menne, Pim Martens

World Health Organisation, European Centre for Environment and Health

Despite significant improvements in our understanding of health impacts of climate change in the last decades, it is still difficult to understand the complete range of effects of climate change. Within the European Phenology Network project, the WHO European Centre for Environment and Health and the International Centre for Integrative Studies (ICIS), Maastricht University, organised a workshop with the general objective of bringing together experts from medical disciplines with phenologists to improve the exchange of data and research and increase cooperation in the field of hay fever and vector borne diseases.

Specific objectives:

- Explore the influences of climate change and phenology on plants
- Explore changes in prevalence of allergic rhinitis and other disorders or diseases resulting from the changing climate and phenology
- Explore available information, data-sets and the need of future developments
- Explore available preventive measures
- Improve interdisciplinary collaboration.

Workshop on Agriculture

Peter Braun

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The main problem in combining climate research with the respective socio-economic consequences is the interface between the different disciplines. Relevant climate as well as economical information contained in phenological records can provide this link. Historical phenological records have been collected in the agricultural and horticultural sectors in many sites throughout Europe for long periods of time and are thus ideal to link the different disciplines. The workshop identified currently missing links and gaps between climate, plant based and economical research and developed strategies for future cooperation by:

- Describing the current way of linking climate research to climate information in phenological records or models;
- Describing current ways of linking climate research to economical consequences;
- Defining shortcomings in current practices in linking climate, phenology and economics and the needs (quantity and quality) for information from others for each discipline;
- Defining ways of effectively using the climate information in historical phenological records for a refined GCM development to forecast economic consequences

Use of Earth Observation data for phenological monitoring: Outcome of the EPN Workshop

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Introduction

Phenology is the study of recurring natural phenomena mainly related to climate. Since in the past century changes in climate were observed which seem to have an effect on plants and wildlife responses, it is expected that the timing of phenological processes will continue to change under a changing climate. This will have considerable consequences for forestry, agriculture, biodiversity and human health.

Phenological records provide an integrative indication of the sensitivity of natural systems to climate change (see e.g IPCC Third Assessment Report) and they have a clear added value to climate impact assessment. Phenological monitoring has a long tradition in European countries and many long-term (50-100 years) data sets exist. Actually, phenological processes are mostly observed in the field by individuals. Remote sensing techniques and data provide relevant and useful information for phenological studies where field observations have limitations. Earth Observation data can also help in upscaling the field observations to regional and continental scales and can be used to validate phenological data and models.

Within this context, the European Phenology Network (EPN), funded by the European Commission within the Fifth Framework Programme[1], aims to increase the efficiency, added value and use of phenological monitoring and research and to stimulate the practical use of phenological data in the context of global (climate) change (EPN website: www.dow.wau.nl/msa/epn).

In the framework of EPN, the Joint Research Centre and Wageningen University have co-organised an International Workshop on the 12th-13th December 2002 to address the use of Earth Observation (EO) data for phenological monitoring. The workshop was held in Ispra (VA), Italy, on the 12th-13th December 2002. The principal aims of the workshop were:

- to clarify and to illustrate the state of the art and the usefulness of Earth Observation for phenological studies with particular relevance for ecology, forestry and agriculture related topics;
- to demonstrate the importance and added value of EO techniques and data for phenological monitoring and to address issues of scale;
- to assess process requirements of EO data before use within phenological models and to discuss methodologies to translate reflectance values into biophysical variables related to vegetation state and dynamic;
- to identify potential future advantages offered by new EO sensors and data for phenological research;

[1] Fifth Framework Programme, Energy Environment and Sustainable Development, Key-action 2.4.1: Better exploitation of existing data and adaptation of existing observing systems

- to strengthen cooperation, networking and exchange of information between phenologists, EO experts and other users.

In order to meet these objectives and to provide a forum at which experts could discuss the issue of the added value of EO techniques and data for phenological monitoring, the workshop was divided into 3 sessions and the presentations were restricted to thematic applications for agriculture and forestry: (1) EO tools and techniques, (2) Forest phenology: Observed phenological processes and EO value added, (3) Agriculture phenology: Observed phenological processes and EO added value. In each session time was provided for discussions and questions. However, the amount of information given in the presentations was so large that two days were not enough to answer all the questions of the attendees.

The outcomes of the workshop with respect to the main issues discussed during the 2 days and recommendations for the way forward on research related to the use of EO for phenological monitoring are summarised in the next section.

Main outcome of the workshop

Vegetation phenology is traditionally observed in the field. This approach implies some limitations related to the lack of temporal consistency and the limited geographical coverage of observations. Moreover, when areas to be surveyed are very large, target surfaces may change significantly before the field work has been completed. Remote sensing techniques do not directly provide information on phenological stages, but rather on parameters which are directly related to plant physiology changes, therefore to phenology. One of the principal advantages of remote sensing data compared with traditional observations in the field is the possibility they offer to gather synoptic information at regular time intervals over large areas. Repeated observations from satellite-borne sensors can be used to move from plant-specific to the regional level. In addition, remote sensing data can be used for model validation and fine-tuning over large areas. Despite the many advantages of remote sensing data for phenological studies, there are also several limitations to the data that can partly be solved by in situ observations. Therefore, a combination of the two sources of information should be aimed for.

Various sensors on different platforms provide a large sampling in terms of spatial, temporal, spectral and radiometric resolutions, and it was acknowledged that a trade-off is necessary between data cost and the required spatial, temporal and spectral resolutions in the phenological studies of interest. Recent developments offer the possibility to acquire data from low (1 km) to very high spatial resolution (< 1m) with swath width ranging from tens to thousands of kilometers, with a few large or hundreds of narrow spectral bands, and temporal resolution from approximately 30 days down to daily. Satellites and their associated data sets should be seen as complementary to field data rather than competitive, and clear choices need to be made by the user depending on the phenological study of interest.

Satellite data used for phenological studies are mainly provided by optical sensors which collect data in the visible range (mainly in the red and near-infrared bands) of the solar spectrum. These data can be used to derive vegetation indices or other parameters to monitor the physiological state and spatial distribution of vegetation. Thermal data give complementary information on the land surface temperature which can be related to phenology, as demonstrated by the study of vegetation in semi-arid environments. Microwave data may be useful to study variations in the vegetation structure and also to remove the contribution of soil moisture in the remote sensing of vegetation phenology. Research into the use of ERS Scatterometer and ENVISAT ASAR wideswath or global mode for such purposes is currently going on. The revisit time interval of approximately 35 days of radar data is in any case considered a drawback for phenological studies.

The spatial resolution of data selected depends on the scale of analysis. The need to run carbon cycle or large-scale global processes models for understanding the Earth system requires the assessment of the global distribution and spatial/temporal variations of vegetation types, as well as their biophysical and structural properties. Phenological data used in large-scale global process models are typically based on coarse resolution remote sensing data (1 km). Crop growth monitoring or precision of farming management require higher spatial resolution observations.

The scaling problem and the heterogeneity within the pixel, irrespective of the spatial resolution of the sensor, was often raised in terms of "what does EO measure?" For example, time series over a kilometre pixel selected over a homogeneous forest stand does not measure the green-up of a single leaf or a single plant, but rather the green-up of the forest canopy and, depending on the canopy density, it would also integrate the under-storey green-up. Therefore, EO derived measurements characterise the phenology of a mosaic of several vegetation types and would never provide the timing of first leaf or bud burst but rather general statements like canopy duration. A necessary condition to overcome such problems when validating remote sensing phenology would be to select the most homogeneous ecosystem sites. In addition, more detailed field information on the vegetation types and the level of development per species groups can provide relevant assistance in validating remote sensing phenology.

Long term data records exist and are now sufficient to study seasonal and inter-annual characteristics. Global datasets of old sensors like the NOAA-AVHRR were available for nearly 20 years (1981 - 1999). However, it was underlined that the merging of data from various sensors and of different level of accuracy is mandatory to obtain continuous time series. Indeed, data from previous sensors need to be integrated with data from newer sensors such as SPOT Vegetation, TERRA-MODIS or ENVISAT-MERIS to provide long term time series for use in operational monitoring studies.

One common workshop recommendation is the availability of ready-available and easy-to-use EO derived products for supporting the non-EO user. These products would permit the user to focus on phenological issues rather than being concerned with specific processing and sensor-specific engineering issues. The current situation was judged rather confusing for a non-EO expert and a single, optimal phenological product is currently not available. Indeed, the number of possible vegetation variables computed using EO data is rather high. Various vegetation or greenness indices exist in the literature (NDVI, SAVI, SARVI, GEMI, EVI, etc). Despite the fact that alternative vegetation indices decontaminated of atmospheric, angular and soil effects have been proposed during the last 10 years, the NDVI (Normalized Difference Vegetation Index) remains the most popular and commonly used parameter. The NDVI is correlated to the plants' photosynthetic efficiency and parametrically associates to biomass and vegetation properties which can be linked to plant phenology. The number of periods when the NDVI exceeds a threshold may indicate the number of growing seasons. The NDVI integrated over time, the gross primary production, and the length of the period when NDVI exceeds a threshold may indicate the length of the growing season. Contrary, biophysical vegetation parameters like the Leaf Area Index (LAI) and the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) were acknowledged to be more relevant to phenological studies - promising results were shown but more research is needed to generate validated products. These parameters can be empirically

estimated from NDVI based on statistical relationships between ground measured biophysical parameters and vegetation indexes: the robustness of these site-specific relationships depends on different factors, such as the background contribution, the structural and biochemical characteristics of the canopy and the viewing geometry. A valid alternative to these semi-empirical models to derive parameters such as LAI and FAPAR, is offered by the inversion of vegetation radiative transfer models, which represent the interactions of the incoming solar radiation within the vegetation and simulate the spectral reflectances emerging at the top of the canopy.
One of the main issues in using remote sensing for phenology is the need to define key features to be detected and measured. Remote sensing data are used to estimate phenological variables such as the start (SOS), the end (EOS) and the length (GSL) of the growing season. Remote sensing of spring phenology by identifying the SOS was reported to be easier than remote sensing for autumn (leaf fall, leaf colouring). However, remote sensing phenology urgently requires clear and precise definition of variables needed for the phenologist which can be effectively provided by the EO community. For instance, the ecophisiologist community defines the growing season length as the carbon uptake period and the phenologists as the canopy duration (leaf duration), which is much longer than the former. Phenology may also have different characteristics according to the biogeographic region of interest. The GSL for instance is related to the snow cover duration in boreal environments. Obviously different definitions imply different variables to be measured. In addition, a variety of techniques are being utilised to derive phenology from satellite data (threshold based, inflection points, curve derivatives) but none of them has yet been universally accepted. As an example, a shift of 6 weeks from applying one method or another to identify the SOS was demonstrated: this error factor is obviously not satisfactory, considering a reported shift of season between 2 and 4 weeks in the literature. Finally, no common agreement on best practices for the time composite algorithm *i.e.* to grab the temporal profile of the vegetation signal over a year, has been reached. Indeed, remote sensing derived products are normally composited over a set period of time, typically 10 days or monthly; however some studies use daily data or select the most representative day according to various criteria (higher value of NDVI, minimum variation of FAPAR from average value, etc…) over a set period of time.
All the above reported factors increase the possibility to obtain different results: consequently, future research must focus on the need of common definitions and methodologies.

The relation between remote sensing derived products and ground data represents another important issue. The availability of long term surface observations in both phenology and climate over continental Europe makes it possible to conduct statistical intercomparisons with the satellite derived product and this offers the opportunity to further validate the soundness and usefulness of these land surface products. The fact that field sampling schemes should also take into account the environmental heterogeneity was particularly stressed during the workshop.

The collections of field phenological data are available thanks to National and European programmes. For instance, in the framework of the International Cooperative Programme on the Assessment and Monitoring of air Pollution Effects on Forests (ICP Forest), surveys conducted at the Level II monitoring scheme plots include as an optional - on some plots only and according to events- observations of forest phenology. In this context, the relevance of Earth Observation relies on the forestry community in the aspect of up-scaling the results from the Level II plots. National networks like the ones in Germany, United Kingdom and The Netherlands show the possibility to realise a high density of observations, which can be valuable for validation activities.

Records of agricultural phenological data seem to be more detailed and numerous than those on forest to allow EO data validation and up-scaling studies: a regional phenological databank collected in a systematic way over three years for herbaceous and woody species and analysed together with meteorological data and the European Agrometeorological Questionnaire related to Phenological Observations and Network since the 1920s, were presented. Potential developments of interest that were mentioned for the near future are (1) to relate the consistent archive of CNDVI (NDVI crossed with Corine Land Cover) starting in 1989 to agricultural phenology; (2) to amend the existing LUCAS (Land Use/Cover Area Survey) survey and (3) to retrieve yearly some basic information related to crop phenology.

There is no doubt about the current role of remote sensing and its potential uses in phenological regional scale studies. However, the generation of harmonised vegetation products and validation of EO derived phenology estimates are requested.
A gap between the Earth Observation and the phenological communities in terms of expectations, definitions and scale of analysis was highlighted during the workshop. Moreover, remote sensing products can be useful if potential end users are clearly identified with their needs in terms of spatial and temporal scales.

Educational programme: Global Learning and Observations to Benefit the Environment

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One of the objectives of EPN was to:
Provide a basis for integration of an international educational monitoring programme with phenological networks.

To achieve this EPN wanted to:
- Make an inventory of requirements and problems that may arise when involving schools in phenological networks;
- Adjust phenological observation protocols and education materials to the European situation;
- Recruit European schools to participate in the EPN network;
- Establish links between schools and scientists.

The objective for the first year was to:
Make an inventory of requirements to integrate the different networks and of the potential problems that might arise.
The results of year 1 have been drawn up in Deliverable 5. It gives an overview of the main international educational phenology programmes, their different added values, the main European educational networks and the keys for success in drawing up a European educational phenology network. This has resulted in *guidelines* for EPN to adjust phenological observation protocols and education materials to the European situation, to involve the stakeholders on phenology education, and to implement such a programme at national and school level.

The objective of the second year was to:
Adjust phenological observation protocols and education materials.

Other objectives of this sub-project were:
- *Finding potential participating schools; and*
- *Establishing links with scientists.*

Abstracts of other presentations

Sunspot cycle and phenology: case study of European database

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The 11-year quasi-cycle of the solar activity and its impact on the climate conditions and the phenomena of physical environment have been studied and discussed by many authors. In brief it can be said that there is either a direct or indirect link between the sunspot activity and different climate parameters. The impact of the sun activity on living nature has often been studied in relation to the studies about dynamics of the population and climate relations. Certain links between the development of living nature and the sun activity can be detected, but trustworthy relations are rather insufficient. Statistically, these relations are hard to detect, as the time series are too short and the direct effect of energy resulting from the sun activity is too low. We discovered an interesting connection between the sun activity and regular pattern of spatial distribution of spring phenophases in Europe using database of POSITIVE programme. The regular pattern of spatial distribution in case of birch leaf unfolding.

Breeding season phenology and sustainable forestry: case study of FSC certification of Estonian State Forest

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Considering seasonal and temporal aspects while making forest management decisions in boreal and sub boreal forest regions is critical for maintaining both economically productive, well managed and viable stands and ecologically sustainable and healthy forest ecosystems. This is due to the fact that forest operations such as logging and skidding in spring and early summer as a rule have many negative impacts to virtually all aspects of forest ecosystem. Although the cumulative effect is a complex result of many factors deeply integrated and interplaying with each other, the impacts could be divided into four major categories: soil and vegetation; avifauna and fauna; spreading of fungi and pests, wood quality.

Main goal of this paper is to conceptualise principle of "quiet season in forestry": how to plan forest management with minimal disturbance during spring breeding and reproduction season. Quiet season includes also measures to protect soil during and after melting in spring; protection trees from root pests during logging and need to harvest wood in best time.

Mass participation in phenological recording; Recent development and lessons learnt in the UK Phenology Network (key-note)

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The UK Phenology Network was revived in 1998 and is a partnership between the Woodland Trust and the Centre for Ecology and Hydrology. In two years the number of people registered as recorders has risen from 350 to 18,650. Phenology has shown itself capable of reconnecting people with nature and has proved to be extremely inclusive. The UKPN is run as an on and offline recording programme, with the database held on the website where the public can directly contribute data and interact with over 250 years of data. The system used is deliberately designed to be scaleable and replicable for use by other organisations. Interest in the data is growing and it is starting to be used at a regional and national level in monitoring climate change. Biannual media campaigns (often with other expert partners) have been a very successful way of promoting the project and raising awareness of climate change. Media interest and coverage has increased each season, helped by record temperatures in autumn 2001 and spring 2002.

In common with some other organisations in the UK successfully engaging the public in monitoring and recording the natural world, we have found that though interest in and enthusiasm for the project is very high, we have as yet been unable to attract funding, other than that currently being provided by the Woodland Trust.

The rapid growth of the project has resulted in many lessons being learnt, experience the UKPN is keen to share with others engaged in phenology.

Quality control and mapping of phenological data

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Phenological observations provide valuable climate information by linking the physical part of the climate system to its effects on the biosphere. Variations in phenological stages are therefore important information to quantify the impact of climate variability and/ or climate change

However, a number of points need to be addressed. Current phenological models all are statistical models, that is, they are not based on a sound mechanistic understanding of the processes leading up to a particular phenological stage. They are mainly based on some form of correlation techniques. They are all aspatial, that is, developed on a given site and probably tested and readjusted over a limited number of additional sites. They also geared towards the determination of the mean without specified accounting of existing variability. Therefore some of the conditions for and challenges in up-scaling of model information to regional or even larger scales are to start with rigorous statistical sampling procedures, introduce stochastic elements into input variables and parameter values and, consequently, develop a probability distribution rather than a single value to arrive at phenological models valid over larger areas. Observations covering an area as a basis for such a development are, however, sparse and stem mainly from volunteer networks with a number of inherent problems. The records available may only cover a short period of time, the species or even cultivars to be observed may not be well defined, problems may exist in the definition of phenological stages, local observations may not be representative for the region around the observation site and observations may not be carried out frequently enough to define the correct date of a given phenological stage. All this calls for a homogenization of observations in space and time together with a quality control scheme.

We present a method to quality control and analyse a series of phenological observations and, from there, construct a spatial map for a given phenological stage or phase. In this case, data stemming from a volunteer network managed by the German weather service, were used as an example. The data span the period from 1951-2000 and cover northern Germany. First, the method itself is presented. It includes quality control of raw data, construction of a field for the mean date over all years of a given phenological stage and construction of the respective anomaly fields for each year. The approach ensures that the density of observations defines the achievable spatial resolution of the maps, that is sufficient data are available for the definition of mean and variability of each grid point. After the first simple test like correct order in relation to the sequence of phenological events (for example, begin of flowering is before end of flowering), they are tested for being within a chosen range of the mean terrain height above sea. The approach then includes a test for each observation where distortion of the field by extreme values is identified. Such values are tagged and excluded from further analysis. The final result is the mean map over the whole time period and the region in question together with the deviation of each year from the mean map. A simple addition of mean and anomaly map for a particular year results in a map of absolute values for that year.

The data are gridded data which can be combined directly with other data sets of whatever variable of interest. The data include the mean as well as the observed variability for each grid point. Furthermore, the method allows for a valid statistical test of main influencing variables. For example, we tested the influence of population density, that is the city effect, on phenology. Not astonishingly, it was significant, but the main point is that it is now proven objectively which was not possible before. Similarly, it is now possible to systematically test for example for soil effects or effects of particular climate variables. Hypotheses can be built and tested systematically. The anomaly maps also allow for the definition of areas where a high sensitivity to climate variability exists and for areas where it does not exist. Therefore, it is for the first time possible to interpret climate variability/ climate change effects correctly in space.

Phenological modelling and climate change impacts in orchards: examples of apple, peach and apricot trees in the Rhone Valley (France)

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The last decade was characterised by warmer winters than the average, resulting in symptoms due to lack of chilling and earlier flowering dates in orchards. The predicted increase of temperatures, due to global climate change, is likely to amplify those phenomena, and justifies the renewal of interest for phenological modelling.

The Southern Rhone Valley is a typical fruit region, in which farmer organisations enabled us to gather a significant data set of observed flowering date series for three species (apple, peach and apricot) and three genotypes for each, in order to cover a large range of earliness. Those data were used to fit the genetic parameters of the Richardson's phenological model, which estimates the date of dormancy break by chilling requirements and the subsequent date of flowering by heat requirements or growing degree days. The model was applied, in combination with calculation of frost damages, to various climatic series of the studied region : past series (until 1989) without global warming, present series (past decade) assuming the warming has started and fictitious series simulated by a climate generator on the basis of temperature calculations provided by a large scale climate model.

The accuracy of flowering estimated with the parameterisation of the phenological model varies from 5 to 8 days depending on genotypes, while the inter-annual variability is correctly described. The implementation of the model, on various meteorological stations of the Rhone Valley, shows that climate change would results in an earlier flowering, increasing frost damages in spring (even in spite of average temperature increase), all the more for the southern zones of the region. The genotypes with high chilling requirements would have difficulties to satisfy their needs in the same zones. The trend to earliness observed in the last decade gives us to think that this evolution has already started, pointing out the need for breeders and farmers to reconsider the geographical adaptation of genotypes.

Global Phenological Monitoring (GPM) in Relationship to other networks and to other efforts of standardisation

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Attempts at standardisation in phenology did not start with the founding of Global Phenological Monitoring (GPM); indeed, it was partly these that led to the global network in 1995.
The basic idea at the time was "to breathe life into the ideas by means of an active network", and this has succeeded.
The first GPM stations were planted in Germany in 1998. Since then, several gardens **-** or at least one garden **-** have been added each year. Meanwhile GPM has taken root in three continents.
However, in order for it to have a chance of survival, it is time to institutionalize GPM.

The poster intends to present the ideas of the GPM observation programme, as well as the international interconnections that have materialised in recent years. It can be seen that the interconnections are on the increase and that standards have been formulated and have made their appearance in first European networks, which are rich in tradition.

Let us hope that GPM will be given the attention it urgently requires at this conference, that in future phenologists will be aware of its existence, and that it will establish for itself solid roots in all continents.

Phenological assessment at the permanent plots of the CON.ECO.FOR. programme in Italy

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The CON.ECO.FOR. (CONtrollo ECOsistemi FORestali) programme includes 28 permanent monitoring plots in woodland areas throughout the whole Italy. The main forest ecosystems are represented: *Picea abies* (in the Alps); *Fagus sylvatica* (across the mountains of the whole Italy, both Alps and Apennines); *Quercus cerris* (in Central and Southern Italy); *Quercus ilex* (in Mediterranean areas) and mixed broadleaves. Currently, observations about crown conditions, biotic and abiotic damage, foliar nutritional status, meteorology, deposition and gaseous pollutants and ozone symptoms are done according to the ICP-Forests manual (www.ICP-Forests.org). Starting since 2001, phenological observations are carrying out in the majority of the permanent plots, with special attention to the period of unfolding of the leaves and to the autumnal turning and falling. The purposes are:

- to evaluate the risks of climatic stress, with special attention to early and/or late frost;
- to evaluate the period of exposition to air pollutants, to calculate the Critical levels" for ozone;
- to evaluate the interactions with biotic damage (insects and pest diseases);
- to individuate the possible shift of the phenological phases in consequence of climatic variations and/or fluctuation.

That presentation shows the first results and the problems met in the implementation of the programme.

This programme is coordinated by the Fifth Division of the Ministry of Agricultural and Forestry Policies - National Forestry Corps (National Focal Centre), Dr. Davide De Laurentis, Dr. Bruno Petriccione and Dr. Enrico Pompei.

UK Phenology Network- 2002 analysis of results

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Recent data from the UKPN have shown some interesting results. The first three months of 2001 were, on average, only 0.03ºC warmer than the 30-year average (1961-1990 Central England Temperature). This near-average temperature allows us to presume that phenological timing in 2001 was also close to average. We believe, therefore, that 2001 results gave us a useful phenological benchmark with which we will be able to compare other results.

Spring 2002, by contrast, was very warm; on average the first three months were 2.6ºC (CET) above the 30-year average. The data (on average, 1052 records per event) indicate that the rate of response to warmer temperatures is different amongst different taxa. As expected in a warmer spring all events were earlier in 2002. However it is the degree to which phenological timing differed between taxa that is interesting. Bird activity was on average 6 days earlier than 2001, while plant activity (flowering, leafing) and insect activity (first seen) were on average 13 days and 18 days earlier respectively. These different response rates across different taxa lead to questions about synchrony between species, ecosystem functioning and the need for further research.

Latitudinal variation was shown across all taxa.

Autumn 2002 results are just emerging. The number of records per event ranged from 250-1500. All events were earlier across the UK, but interpretation of results is complex.. Events were influenced by a cooler than average late summer, which induced earlier first tint than 2001. Warmer than average temperatures in September would be expected to slow the progress of autumn, relative to 2001 results, however this month had approximately half the average rainfall. This suggests that rainfall has an important impact on autumn phenology. Colder weather in October meant that full tint and leaf fall dates were even earlier, both 9 days earlier on average than in 2001.

The Global Monitoring of Environment and Security (GMES) programme of the European Commission and the potential contribution of phenological networks (Key-note)

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GMES is an initiative set up jointly by the European Commission and the European Space Agency to establish by 2008 a European capacity of Global Monitoring for Environment and Security. It is an integral part of the European Strategy for Sustainable Development approved at the Göteborg Summit in June 2001 by the Heads of State and Government of the countries of the European Union [1]

The commitment to sustainable development, now embedded in all Community policies, requires a much enhanced information basis and one of a different nature. The need for policy decisions to address the environmental, social and economic issues simultaneously, in their interactions and in a long term perspective necessitates tailored indicators backed by wide-ranging high quality observations and validated models. The European Union needs independent information to play its part on the global scene, either as a party to international conventions or to implement and develop European policies. Rapidly developing policies, such as these related to security, present new information requirements. The interplay between human activities and the environment needs to be assessed at different territorial levels, from the local to the global, which means that information can "zoom" in and out. The increasing influence of human activities on the Earth System as well as the exposure to natural or technological hazards require rapid reactions. The mission and challenge of **GMES** thus is to contribute to the timely provision of such information necessary to enable all society agents, each in their own capacity, to take the decisions and actions which will make sustain-able development become a reality. the causes of this mismatch between the policy

demand and the technological offer are multiple and interrelated

By and large, the many organisations involved in the production of information tend to work side by side rather than jointly. Programmes tend to be temporary with an ad hoc character, rather than long term oriented. Data policies are rarely set to encourage the use of data. Little effort is made to foster the use of information compared to the investments for the acquisition of primary data. There are important gaps in observation and data collection systems. Moreover these systems are rarely compatible and data cannot be assembled in a routine fashion to produce policy relevant information. And, despite progress made, our understanding of the functioning of the environment and its relation to human activities is still in its infancy in a series of domains, which limits our capacity to interpret the observed data and to perform the correct observations in the first place. The combination of these causes results in a rather low efficiency of the current European capacity to produce policy relevant information. The **GMES** initiative thus has to address these issues and to propose solutions for a European capacity for Global Monitoring of Environment and Security to be operational and efficient by 2008. Clearly it will not do so by duplicating existing activities, but by offering a frame which will bring about synergies between the activities of the European actors and that will constitute a basis for complementing these where gaps exist. The expected benefits are better information for users and a more active economy in Europe in the sectors related to information production.

Phenology Shifts of Butterflies and Dragonflies in the Netherlands

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Climate change is one of the major factors which might explain the 30-40% decline on butterfly population numbers in The Netherlands. On the other hand dragonfly populations are apparently stable in the last decades in this country. Possible reasons for this difference between these insect groups are: 1) improvement of dragonfly habitats in recent years due to a better water management and 2) good ability of dragonflies to reach new habitats by flight. Changes in phenological processes have been identified as an important indicator for climate change impacts.

During the last 20 years the Dutch Butterfly Conservation has developed a database with records on presence and distribution of butterfly species in the Netherlands: The Dutch Butterfly Database. At present the database comprises 1,2 million records of 104 species collected since the start of the 19th century. In cooperation with the European Invertebrate Survey-Netherlands and the Dutch Society for Dragonfly studies, records of dragonfly observations are collected for a dragonfly database now containing 250.000 records. Also, for both species groups a monitoring scheme is maintained with, yearly, 300 routes for dragonflies and 500 routes for butterflies. In addition, within the project Nature's Calender (supported by a large number of organisations in The Netherlands) phenological data of butterflies, among other species groups, are collected. All these databases make it possible to detect shifts in phenology of butterflies and dragonflies and to select insect species within these groups that are particula

In conclusion, butterflies and dragonflies both show large phenological shifts in the Netherlands. In spite of that, butterflies population numbers are declining during recent years, whereas dragonflies are more or less stable. Further research is necessary to understand these differences.

The role of phenology in the MARS crop yield forecasting system and the land use/cover area frame statistical survey program (LUCAS). Phenology activities within the MARS-STAT project (Key-note)

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According to its institutional role (Parliament-Council co-decision n 1445/2000) MARS STAT provides independent analysis and forecasts on crop yield at European and National levels, in near real time to DG-Agriculture and EUROSTAT. The forecasts are produced running an agro-meteorological system (MARS Crop Yield Forecasting System - MCYFS) which has been conceived and is continuously improved by MARS-Stat. Agro-phenological information are being used intensively within the Crop Growth Monitoring System - simulation model (CGMS; Supit et al. 2001) adopted in the MCYFS. Based on the WOFOST model (Van Diepen et al. 1989), CGMS produces biomass estimates for ten different crops at a 50x50 km grid, covering the whole Continent and Maghreb Countries. The MARS crop forecasting system uses observations or estimates of the phenology during the season in order to improve agro-meteorological analyses and crop yield forecasts (Genovese, 2001). In the past MARS gathered with different actions Pan-European agro-phenology data:

- A ground survey made in three consecutive years on a sample of 60 sites in Europe within the Rapid Estimates Project (MARS ground surveys Activity C 1994/1996).
- Estimated data as a results from a study made by the KUniversity of Leuven. This data constitutes the main input for the CGMS model. This information is used within the model for plant physiology description and specific analysis of climate impact.

To systematically collect and have available for its analysis and models data on phenology, MARS-Stat is committed to contribute a Pan-European Data Base on Agro-Phenology. The main contribution will be base at the moment on

- An existing European ground survey called LUCAS (Land Use/Land Cover Area frame Survey)
- Exploitation of the low resolution satellite data archive (Spot-Vegetation since 1999 and NOAA-AVHRR based indicators since 1992)

The contribution presents the way the phenology information is exploited within the MARS system and the way the future agro-phenology data will be collected.

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Design of a European coastal operational system for monitoring, modelling, and forecasting of phenological changes and their socio-economic impacts (Key-note)

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The organisms of marine ecosystems are of great socio-economic importance in e.g. fisheries, tourism and water quality control. They respond to environmental forcing similar to terrestrial organisms with seasonal and latitudinal modifications. Global warming has caused many such changes, some of which could be documented.

In order to monitor such future changes a European marine biometeorological network (EMBN) is being prepared in the framework of the international council for the exploration of the sea (ICES). This framework is based on the activation of marine research stations along the European coasts for observing some selected biota for seasonal and taxonomic biodiversity and for the training of volunteer observers for phenological monitoring. The recruitment of these volunteer observers from environmental organisations, hatcheries, diving activists and others shall be enabled by a non-profit organisation on the basis of public funds. Government organisations are intended to run the databanks for the control of in-coming phenological observations, continual access of science and administration of these data.

The scientific treatment of marine biometeorology is almost pristine. Besides detailed physiological investigation of macroalgae and selected studies on zooplankton few statistical and numeric simulation models have been developed which consider biometeorology. Seasonal and latitudinal shifts could be analysed on this basis and the forecasting of phenological events has reached the state of a temporary operational prognostic service for the seasonality of marine meso- and makrozooplankton.

An investigation into the relationship between Wood anemone (*Anemone nemorosa*) flowering and temperature at the regional scale

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The Wood Anemone (Anemone nemorosa) is a flower of early spring found throughout the United Kingdom and much of northern Europe. First flowering events for this species were recorded for the Royal Meteorological Society's phenological recording scheme from 1891 - 1947. Previous analysis of this data showed a significant relationship between first flowering date and temperature at the national level (Sparks, Jeffree and Jeffree, 2000). However, it may be useful to understand temperature response at the regional level as species' response is likely to be location-dependent and there must be upper and lower limits to flowering dates.

This study examines the relationship between first flowering date of Wood Anemone and temperature in four latitudinal bands from the south to the north of Great Britain. Analysis of the Royal Meteorological Society historical time series showed that first flowering date was significantly related to temperature ($p<0.001$) in all four regions and predicted that flowering date would advance by between 3 and 6 days per 1oC increase in temperature. To examine the reliability of this prediction, the historical data were compared with first flowering records for the last 5 years (1998 - 2002) collected by the UK Phenology Network. Analysis showed that, despite a 1oC increase in temperature between the two time periods, there was no significant difference between historical and recent first flowering dates for any region. We are examining a number of possible explanations for this finding, but may have to accept that some species do not or cannot respond to climate warming as we expect.

A study of local climate fluctuations in a tick habitated hilly microregion Klatovy (Southwest Bohemia)

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The aim of this study is to analyze long time series (1923-2000) of both climatological and phenological characteristics of micro-region Klatovy. It is a hilly, partly forested, partly agricultural country with relatively strong occurrence of the tick borne encephalitis, where some shift of the disease to sites of higher altitude has been indicated, similarly as in other areas of southern and south western Bohemia.

On level of yearly temperatures, tests of periodicity brought not very useful, rather problematic result that a period of roughly 4 and 9 are involved in the series. The row is to short for serious considerations on its possible cyclic features. Nevertheless, five alternating, unequal, differently structured periods have been distinguished on the series:

- warm period 1931-39
- cold period 1940-42
- warm period 1943-53
- cold period 1954-1965
- current warm period since 1974.

The recent warm period takes practically one third of the whole series and exhibits the positive trend of about 0.4^{o}C per 10 years. However, it has higher fluctuation variability than previous warm period 1943-53, which is partly caused by an incidental occurrence of a relatively cold year 1996.

Generally, similar situation has been found on level of monthly temperatures, with exception of the November, where a clear decrease of temperatures since 1974 is reported, and September (decrease since 1986). In detail, structure of 12 monthly temperature time series differ with each other, in evident dependence on position in season – the “neighbouring” months are usually most similar.

As for severity of winter, time distribution of least 10-fractile values for winter monthly temperatures as a criterion has been used. It has been found, that only January and February are frequented and carry responsibility in this sense. The most severe winters came only in older half of the series: it brought 19 critically severe months falling to the least 10-fractile, with total minimum value –12,4 °C in February 1929 and sub-total –12,3 in January 1940 and second sub-maximum –11.8 in January 1942. Figures for the recent half of the series are only 5 with values between –4.2 in December 1996 and –7.0 in February 1986. In other words, the second half of the series tends strongly to milder winters.

On the level of yearly precipitation sums, it is possible to observe an increase during prevailingly moist periods 1935–1941 and 1953–1958, and downward tendency in rather dry period from 1941 to 1953. The absolute extremes of yearly precipitation sums are 400,6 in 1943 and 824,7 in 1986. To some extent, the situation in precipitation is indirectly proportional to situation in temperatures, but the individual periods aren't so distinctive.

Analogous phenological data from neighbouring site RUDOLTICE by Klatovy (e.g., flowering of hazel, first leaves of golden elder, flowering of linden, ripeness of fruits of red currant and another

20 phenological phases) lead mostly to the time series, structure of which confirms main features of the temperature series. The grade of similarity between phenological and meteorological rows is good (reached values of correlation coefficients vary in range from 0,46 to 0,74). It is an indication that seasonal biological phenomena change in accordance with climate fluctuations, namely in the recent warming period. In phenological terms, the recent period starts with the year 1988 vigorously, but, in some later phases, a slight acceleration is observable since early seventies.
The recent warm period with both its climatic and phenological parameters (in particular length of periods and increased frequency both of high temperatures and earliest data of the onset of many phenological phases) has no parallel in the history of the 70-year time series studied, suggesting the possibility of the change of the climate.

Abrupt climate change affects flowering phenology and abundance of *Mertensia ciliata* (*Boraginaceae*) in the Colorado Rocky Mountains

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We conducted a long-term study of variation in the timing and abundance of flowering by Mertensia ciliata (Boraginaceae), a common long-lived herbaceous perennial at 2,900m in the Colorado Rocky Mountains. From 1973 - 2002 flowers and inflorescences were counted every other day during the flowering period in ten 2x2m plots at the Rocky Mountain Biological Laboratory. Flowering typically began in late June or early July and continued for about a month. Bumblebees are the most common flower visitors.

We used all possible model comparisons with 72 weather-based variables (precipitation and temperature) to determine the best models for predicting flower abundance and phenology. Snowpack depth on 22 May was the best single predictor of the onset of flowering ($r2 = 0.635$, $p < .0001$). Snowpack on 30 April was the best single predictor of flower abundance ($r2 = 0.607$, $p = .0001$), however flower production was best explained by a two-variable model that included July mean temperature and snowpack depth on 30 April ($r2 = 0.62$, $p < .0001$). Abundance of flowering plants was best explained by a two-variable model including June mean temperature and snowpack on 15 May ($r2 = 0.36$, $p < .05$).

There is evidence of an abrupt climate change in the Colorado Rocky Mountains starting about 1998, when the North Pacific Oscillation changed phase. The NPO is an interdecadal mode of variability of the north Pacific atmosphere system (driven largely by sea surface temperature) that resulted in a couple of decades of above-normal precipitation following the change in 1976 to the warm phase. Since 1998, when the NPO switched to its cool phase, snowfall has declined significantly. This decline appears to be the proximate cue resulting in a change to earlier flowering by all of the 70+ species we have studied, and the reduced abundance of flowering by some of them. We predict that the Rocky Mountains are at the beginning of a decades-long change in precipitation patterns that will reinforce the effects of global climate change on high-altitude phenology, much of which is determined by the timing of snowmelt. This change may also affect the frequency of late-spring frosts, which can kill flower buds of many species.

Pheno-, weather- and NDVI-data comparison for selected Czech pheno-stations

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The study named Meteo-, pheno- and NDVI-data comparison for Czech wild plants which was presented by authors in Wageningen conference ('The times they are a-changin', 5-7 December 2001) is extended for fruit trees and field crops just as for weather and NDVI-data to the year 2001. The aim is to find or determine not only the interactive relations between weather, NDVI and phenological data during the period 1995/2001, but also the more common conformity among wild and cultural plants phenological data.

Phenological data of the wild plants, fruit trees and field crops in the Czech Republic are compared to meteorological and NDVI satellite data. For several selected stations from the Czech phenological network trends are calculated for the 1995/2001 period. The Czech NDVI scenes are cut out from the European NOAA/AVHRR NDVI maps processed by the German Remote Sensing Data Center (Deutsches Fernerkundungsdatenzentrum - DFD) of the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt - DLR). For the analysis weekly maximum value composites of the NDVI (Normalized Difference Vegetation Index) from Feb 20, 1995 to Sep 9, 2001 are used.

Meteorological data, such as daily average temperature, daily maximum and minimum temperature, as well as precipitation and total sunshine energy, is used. Phenological data of wild plants are computed according to Czech control & correction programme in order to get biotime curve for every station and vegetation season, selected data of wild plants, fruit trees and field crops are added.

Some numbers of the MCYFS system are: 94 printed bulletins from 1993 (7 bulletins in 2002); 35 countries covered; 28 years of meteo and agrometeo reference data base; 10 years of NOAA and SPOT VEGETATION satellite reference image; time series on 20 agro-meteorological crops indicators; 10 crops covered with area estimates (up to 1998) and yield estimates; real time agriculture monitoring web interface; CGMS (Crop Growth Monitoring System) software for spatial yield prediction over all of the territory

Phenological synchrony in the prediction of insect; Herbivore impacts on native plant populations

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Synchrony between populations is hypothesized to be an important parameter of biological interactions, critical both for persistence of co-evolved species and for prediction of invasive species impacts in novel environments. In spite of the acknowledged importance of phenological synchrony, however, few field studies have quantified the phenological variation in both consumer and resource populations. The data are weakest for the effect of variation in synchrony on the resource species' population. Using the interaction between an invasive biocontrol weevil (*Rhinocyllus conicus*) and its acquired native host (*Cirsium canescens*), we asked if the magnitude of spatial and temporal variation in phenological synchrony could explain the differing rates of herbivory on *C. canescens* populations between years and sites in the Sand Hills prairie of the central Great Plains. We quantified temporal and spatial variation in phenologies of both *R. conicus* and *C. canescens* populations at four sites in two geographic areas over four years. Using these data, we evaluated the ability of population synchrony between herbivore and plant to explain the number of *R. conicus* eggs laid on *C. canescens* flower heads. We found that quantitative variation in the timing of peak *R. conicus* activity was large, greater than that of *C. canescens* floral development, and that it drove the temporal and spatial variation in synchrony between the two species. The variation in synchrony was highly significant in predicting the mean number of *R. conicus* eggs per flower head. Further, we found no evidence that priority, the identity of the species that is more phenologically advanced, influenced the rate of floral herbivory. Given the experimental evidence that *C. canescens* population growth is limited by floral and seed herbivory, we infer that phenological synchrony increases the demographic consequences of this interaction. We conclude that quantification of herbivore-host plant population synchrony is critical in predicting interaction outcomes of insect herbivory for host plant populations and thus highly informative in anticipating invasive species effects.

Shifts of Insect Pests on Trees

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In The Netherlands, insect pests on trees and shrubs, in forests and in cities, are being monitored annually since 1946. During last decades, peculiar shifts in insect pests are observed. Some pests from 1950-1960 such as *Diprion pini* are not occurring anymore, while other low level species such as *Agrilus biguttatus* have become a serious problem. *Haematoloma dorsatum* originates from the Mediterranean region, but it is now widely distributed in Europe, causing severe needle browning in The Netherlands. We are also facing problems with other exotic insects such as *Thaumetopoea processionea*, *Pulvinaria regalis* and *Cameraria ohridella*.

Flowering and fruiting phenology in Brazilian Atlantic rain forest Myrtaceae: climatic and phylogenetic constraints

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Phenological studies on tropical forests have traditionally focused on diverse taxonomic groups of species, trying to investigate biotic and abiotic factors affecting the phenological patterns observed. The Myrtaceae is one of the most important families in Brazil, and often the dominant family in the Atlantic forest.

Few studies have examined the evolutionary and ecological constraints on phenological patterns of species within a single family or genus. The phenology of Myrtaceae species from two Atlantic forests were analyzed in the light of the current hypothesis proposed to explain flowering and fruiting patterns of taxonomically-related species.

We explore these hypotheses as explanations for flowering and fruiting phenology of Myrtaceae species from Atlantic rain forest, where climatic constraints would not seem to impose restrictions to their phenological behavior. However, recent research has demonstrated the influence of light and temperature in the phenology of Atlantic rain forest trees. [Financial Support by FAPESP - CNPq Research fellowship].

Power to the people

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Phenology plays an important part in great number of peoples lives; these people work independently and remotely but share one common vision, that climate change is affecting their local biodiversity.

The UK Phenology Network are proposing to build an online community for our recorders to interact with one another and share their thoughts, views, questions and concerns **-** we will develop one single technology that will be able to be implemented on any number of websites to allow Phenological issues to be discussed not only in subject groups specific to one website but globally throughout a wider phenological community spanning species, academic knowledge and language differences.

Users would need to log in and can add personal profile information to identify themselves to other users as either: beginner, enthusiastic amateur or expert, to allow interaction to be appropriate to the users level of understanding.

I would be like to see how many other phenological recording schemes would be interested in our technology to allow their recorders to interact with recorders in other schemes.

We also want to look at ways to use an online community to educate and advise the growing number of amateur phenology recorders to ensure the accuracy of observations and promote better understanding of individual species reactions to change. Using the different levels of users (detailed above), allowing the most experienced passing their knowledge down to others who then pass on their knowledge and so on.

I would also like to look at ways to link the individual recorders, to centralise their common voice and to bring a new force to the argument that climate change is increasing its effects on individual species and global action is required if the predicted trends are to be changed. This could be through online petitions, viral emails of thought provoking material of key results and findings, and maybe even emailing world leaders or possible advocates to apply pressure for global action to effect change.

I remember at the last conference people were more concerned about the actual data and not people that recorded it, also they preferred recorders to be trained and a specialist so they were sure the data was good, but it struck me that with the UK phenology network being so large, it is our unique selling point, the way we engage the general public and the issues.

The best way to gain value from these individual recorders, whose data may not be of the highest quality, is by adding their collective voice together with the data. This will then become more important and may get noticed.

Trends in the phenology of the Orange tip butterfly (*Anthocharis cardamines*) across Europe

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Butterflies are excellent organisms for studying the effects of climate change and their abundance and distribution have responded to global warming over a relatively short time-scale. Phenological changes have also been demonstrated for this group of insects, contributing to the globally coherent fingerprint of climate change impacts demonstrated across natural systems (Parmesan and Yohe, 2003). Analyses of the UK Butterfly Monitoring Scheme have shown that the first and peak appearance of most species has advanced over two decades in response to increased temperature (Roy and Sparks, 2000). In this paper, we extend these analyses to other parts of Europe using data from Butterfly Monitoring Schemes in Finland, the Netherlands, Belgium, Spain and the UK. We examine the phenology of a spring-butterfly, *Anthocharis cardamines* (Orange tip) that has a single generation per year throughout Europe and has responded markedly to warming in the UK – appearance dates 2 weeks earlier over two decades.

Examining global changes in the onset of mid-latitude spring

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Understanding atmosphere-biosphere interactions is essential in order to improve global change simulation models, monitor variations in the growing season, and calculate the carbon budget. One kind of phenological observation, the first appearance of spring foliage, is crucial for accurate assessment of many processes, and is among the most sensitive plant-response measures of climate change. Since satellite data are available for only several decades, and may not provide the details needed for many studies, and a global phenology network is not yet functional, alternatives must be employed to measure changes in the onset of spring at the global spatial-scale and century timescale. The Spring Indices (SI) phenology models have been developed to simulate the spring phenology of representative understory shrubs, using only daily maximum-minimum temperature data as input. They have been rigorously tested in a variety of regions and continents. While not capable of reproducing all the detailed information that would be obtained from multi-species phenology data, they can process weather data into a form where it can be applied as a baseline assessment of some aspects of a location=s phenological response over time.

Daily temperature data have been obtained for all mid-latitude locations during available periods of the 20th century, and comprehensive analyses are underway. Initial efforts have concentrated on station-by-station linear trend assessment in North America, China, Germany, and the former Soviet Union during the 1961-2000 time period. Results in North America show SI first leaf (an early spring event) getting much earlier in many areas across the continent, but especially in the northeast. SI first bloom (a late spring event) displays regional patterns, getting earlier in the east and west, but with little change or even a tendency toward lateness in central areas. Last –2.2°C freeze dates are also getting earlier in many areas. China has shown little change in SI first leaf or first bloom dates over most of the period, except for several very early years at the end. However, last –2.2°C freeze dates in China are getting earlier over large areas, especially in the northeast. In Germany, first leaf and first bloom are both getting earlier, but with considerable year-to-year and spatial variability. In the former Soviet Union, SI first leaf is generally unchanged, while SI first bloom displays some tendency towards getting earlier in the west. The pattern of last –2.2°C freeze dates is mixed with some areas getting earlier and few others later. Results from other global regions will be added and compared as they become available.

The Agrophenological Network and the Phenological Garden in the North West Italy

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During the last years, the importance of phenological observations for agriculture is surely increased. Several aspects of crop cultivation need the knowledge of the behaviour of the cultivations and in particular the date of appearance of the phenological stages and the characteristics of productions are indispensable information to apply crop production forecast's models, phytopathological models, irrigation models. Also remote sensing use the phenological information as input data.

In the Piedmont region (North West Italy) a new agrophenological network was established during the spring of 2002. It's a new-born network that includes 9 main and typical cultivations (corn, wheat, barley, rice, vine, hazelnut, apple, peach, kiwi). The phenological stages are recorded in total 45 experimental fields following the BBCH scale. All the phenological fields are located near a meteorological station.

Phenological and agrophenological observations have also a great importance for ecological aspects, so in parallel with the agrophenological network, in the River Po Park of Turin in 1999 was established the Phenological Garden "C.Allioni" (m 218 s.l.m., coord. U.T.M. Est 395761,16.; U.T.M. Nord 4984927,41) in which are included the great part of the botanical species considered by the European Phenological Network for the Phenological Gardens.

Recently a meteorological station was installed in the Garden and moreover in the neighbourhood, only few kilometers far from the garden is located the meteorological Observatory of Moncalieri - Real Collegio Carlo Alberto, m 267,5 s.l.m. that possess a precious climatic series that starts from 1860.

The observations has been taken weekly starting from May 10th 2001 considering the arboreal--shrubby species and the main species of spontanous Gramineae of the area (*Lolium multiflorum* Lam., *Holcus lanatus* L., *Poa pratensis* L., *Arrhenatherum elatior* (L.) Presl., *Dactylis glomerata* L., *Agropyron repens* (L.) Beauv.).

Comparing the phenological dates of the years 2001 and 2002 of the arboreo-arbustive species we observed an anticipation of the vegetative stages in 2002. For the reproductive stages we have only the observation recorded in the 2002 because during the first year the great part of species didn't flower.

Considering the Gramineae, and in comparison with the 2001 we observed in 2002 a delay of about 10 days in the appearance of the stage 3 (Total emission of the inflorescence with not-visible stamens).

Also, it is useful to carry out phenological observation on these herbaceous entities because of their pollen grains cause respiratory allergy: the knowledge of the appearance of stages 3 and 4 is important to program prophylaxis and therapy.

Study on climatic adaptability of six peach varieties

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Peach culture in Piemonte (Northwest Italy latitude 45°) was developed in flat areas that are frequently exposed to spring frosts, particularly during blooming.
Vegetative and productive traits of the cultivars are usually well described, as well as fruit quality, but informations about tree phenology, chilling and heat requirements are generally poor. For this reason, introducing new varieties in regions with different climatic conditions, with respect to the native ones, may be subject to risks.
The aim of this research is to select varieties that fit Piemonte's plain area climatic conditions and to determine chilling and heat requirements using local varieties (adapted to these climatic conditions) as a reference. Six peach varieties, two local (Franca and Michelini) and four American cultivars (Elegant Lady(r), Stark Red Gold, Nectaross and Big Top(r)) were used for the trial located in Lagnasco (Cuneo province) at 336 m a.s.l..
Hourly temperature data were recorded in the orchard by a thermograph from the end of summer till full-bloom during seasons 1999-2000, 2000-2001, 2001-2002, 2002-2003. Phenological data were determined in the orchard by weekly observations following Baggiolini stages (1952).
The Utah model was used to determine the starting date of chilling units accumulation. To determine the real moment when the chilling requirement was satisfied, in order to assume it as the starting point for accumulation of the heat, ten twigs of each variety, 40-60 cm long, were collected weekly from November to February. Twigs were kept at 18-22°C partially dipped in water, in order to determine the date of dormancy breaking. Data on bud development were observed every three days until full-bloom. Dormancy was considered broken when 70% of the twigs and 50% of the flower buds in each twig began to flower. To calculate chilling units requirement (WCR), several methods were compared (< 7.2 °C, 0 - 7.2 °C, Utah, North Carolina), while to assess heat requirement, growing degree hours accumulation (GDH), and growing degree days accumulation (GDD) were calculated using base temperature equal to 4.4°C.
The date of dormancy breaking presented variation among varieties: from the middle of December to the middle of January. The CU requirement, in fact, vary from 806 for Elegant Lady to 925 for Nectaross. In the same way, peach cultivar showed a consistent difference in the amount of GDH to reach full bloom, from 4692 to 5333. The local variety Michelini, had the highest heat requirement (5333).
Moreover, the research wants to evaluate and compare the applicability of different chilling requirement models to the environmental conditions of Northwest Italy. Some difference among the methods to determine CU requirement were found. GDH and GDD both seemed to be reliable methods for calculating heat requirements.

Examining the total arrival distribution of migratory birds

T.H. Sparks, F. Bairlein, J. Bojarinova, O. Hüppop, E. Lehikoinen, K. Rainio, L.V. Sokolov and D. Walker

In 2002 a workshop on bird migration phenology was held in Cambridge, UK. At that meeting a number of research projects were suggested. One of these involved an examination of the whole arrival distribution rather than looking at the first bird only. In this talk we present some preliminary results of an examination of the arrival time distributions of chiffchaff, willow warbler and pied flycatcher from Dungeness (UK), Helgoland (Germany), Rybachy (Russia), Ladoga (Russia) and Jurmo (Finland).

Changes in the phenology of Snowdrop (*Galanthus nivalis*) in experiment and survey

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Snowdrop is being grown in a series of temperature and CO2 modified chambers at CEH Bangor in North Wales. Aspects of the phenology and growth of the plants are being measured and results will be presented in this talk. Comparisons with phenological time series recorded in the natural environment will be made and discussed.

Implementation of Phenological Models throughout Geographic Information System (GIS) Technology

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This paper illustrates the elaboration and interpretation of insect and agricultural crop phenology forecasts using GIS technology in Republic of Moldova . Our objectives were to: 1) analyse patterns of pest occurrence in relation to geographic weather patterns, using to predict insect phenology; 2) create weather forecasts for given geographic location by downscaling mesoscale outputs to a higher spatial scale and extrapolating data values to digital terrain data.

Modelling approach included:

- Collection and analysis of data 30 year weather data from all country network of weather stations;
- Calculation of daily average temperature for each weather station (17 stations, 30 year average) ;
- Calculation of historically daily average temperature deviation from reference (Chisinau) station;
- Elaboration of all country digital maps (elevation, slope, aspect), 600x600 m resolution;
- Regression analysis of temperature and precipitation vs. altitude, slope and aspect;
- Degree-days and precipitation interpolation (kriging, inverse distance in power);
- Developing Degree-days and precipitation digital maps (600x600 m resolution), using regression equations and results of interpolation.

Approaches include validation of mesoscale weather models with automated weather stations data, mapping and modelling using Geographic Information System (GIS) technology and logistic regression analysis. A database in Microsoft ACCESS format for data storage and processing was elaborated. The database contains: climatic data, pest models, crop phenology, management processes. The DdayGIS decision oriented software was elaborated to analyse and interpret the spatial weather information. The pest development models were integrated in the GIS environment to produce the final pest and crop prediction maps. Insect and crop forecasts are based on air temperature and precipitation interpolated from nearby weather stations, adjusted to digital terrain data.

The models use real time and historical temperature information to calculate Degree days and determine which life stage the population should be entering at a location. It also uses projected temperature to give 7-day forecasts for short-term prediction. The GIS maps produced with computer model are used as a guide for directing, where pest sampling should be conducted, anticipate life stages, provide information on the life stage and key events for a given geographic location. We have tested a nonlinear method of Degree-day calculations, based on logistic S-curve of rate of development. This method have shown more precise forecasts in the spring time, when the temperature is near minimum threshold of crop and pest development.

The site-specific weather data for phenological models were validated, comparing with on-field automated ADCON weather station data. The predicted generation time for an insect was compared with the actual Degree-days using sampling and combining the weather and sampling data to compute the Degree-days and start dates. Mean absolute error was 4.3 days for Colorado Potato Beetle in potato fields and 3.1 days for Codling Moth in apple orchards. Maximum expected errors at a 95% probability level ranged from 5 to 7 days.

Phenology in communications on climate change (Key-note)

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The science of phenology has gained added value to society, since climate change due to global warming became a problem for human and nature. Both science and society together with the people who are making an effort to curb climate change, can benefit from this; we should make optimal use of this mutual interest.

In our effort to curb climate change awareness of the problem and the impacts are crucial to raise the urgency of the issue. Bringing the message to the public is not an easy target: the problem is abstract and far away from daily life to most of us. Phenology though is about events in nature everybody knows: first leafs on the trees, flowering of plants in our garden, return of birds in spring, etcetera. These events are already shifting in date due to climate change. Being very much related to the most discussed issue in large parts of Europe - the weather -, life cycle events draw the attention easily. The changes can be noticed by everybody, and occur in our every day lives. Therefore the science in itself provides for an important rule of communications: it fits in a well-known perception of the environment. A broad range of media will be interested in this kind of information; even for example a gardening magazine can bring the message to the public.

Next to spreading the results as mentioned above TIMING adds two more values to communications. It makes people part of the issue by asking their contribution in monitoring. Moreover, it opens up the possibility to keep people involved: people who are engaged in the process will certainly be interested in feedback on the results.

Organizations like WWF trying to curb climate change can build on this knowledge by contributing in spreading the information, providing a broader perspective of the issue and most importantly, adding solutions to the problem.

Phenology as a climate change indicator in the EEA indicator program (Key-note)

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In the EU, climate change has been given high priority over the coming decades. Because of this interest, the need for appropriate indicators has been identified. Such indicators are needed (e.g. by policy makers) to measure trends in greenhouse gas emissions, to identify susceptible sectors and to evaluate the effectiveness of policies aimed at reducing these emissions. Therefore climate change state and impact indicators (e.g. on biodiversity) are needed to provide early warning signals and subsequently deliver arguments for emission reduction and/or adaptation measures.

To fulfil the mentioned need, the European Topic Centre on Air and Climate Change selected a set of 49 state and impact indicators, divided in 9 different categories covering ecological as well as socio-economical impacts. Growing season length, plant phenology and animal behaviour are some of these indicators that have been defined to assess climate change impacts on ecosystems and biodiversity. In the presentation I will show the current state in the design of these indicators. Recent trends in climate have resulted in an extension of the average growing season length in Europe of about 10 days. Projects like EPN could be a major source of information for a more comprehensive and spatially differentiated assessment of ecological changes. Such projects could, for example, provide a picture of observed changes in phenological stages (incl. start and end of growing season), which then could be used to assess past, current and future trends of climate change impacts throughout Europe.

Variation in the response to climate change of laying dates of Great and Blue Tits

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Climate change is expected to affect laying dates in birds. However, on a European scale there is clear variation among 14 populations of Great and Blue Tits in the changes in laying dates over the period 1979-1998. In the 3 populations from Finland and Russia, there has been no warming of the relevant spring temperatures and hence no change in laying dates. In the population from Corsica there has been no change as here the phenology of the whole food chain Oak - caterpillar - Blue Tit is temperature insensitive. For the mainland France, UK, Belgium and Dutch populations there is variation in how the birds have responded. In some populations the laying date has advanced, while in others not but in these population there has been a strong decline in the proportion of birds that make two broods per year. Thus, meta-analysis on the observed changes in phenology might be misleading as some of the non-responding populations should also not respond, while others do respond, but in a different life-history character. Another serious problem in such analysis is that even for the populations that do change their phenology it remains to be shown that this response is sufficiently strong to match the changes in the underlying levels of the food chain.

The garden of San Pietro Capofiume: 10 years of phenological observations

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A phenological garden was established in the eighties by the regional government of Emilia-Romagna. It is located in the Po valley plain, at San Pietro Capofiume, 40 km north of Bologna, at the "Giorgio Fea" regional meteorological base (44° 39' 17" N, 11° 37' 25" E, 10 m asl). The garden is managed now by the regional meteorological service of ARPA (the regional environmental protection agency)and observations are collected every week on 27 different plant species on more than 60 specimens. Data are taken according to the standards established by the Italian Phenological Garden Working Group. Most of the plants are clones coming from Germany. We present here for the first time the data collected over the last ten years in our garden, which belongs to the International Phenological Gardens.

Data are analysed from the statistical point of view in order to establish a tentative phenological calendar, to check for the existence of trends and of correlations with weather data measured nearby. Pollen data measured in the city of Ferrara, some 20 km away from San Pietro Capofiume, are also presented and compared with the phenological data as an independent check for data quality assessment.

Global Warming Impact on Phenology of Annual Cycles in Birds

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Investigations carried out in the Eastern Baltic region allow us to draw certain conclusions on the impact of global climate change on timing of annual cycles in birds. The article presents material attesting to differences in the impact of global warming on bird spring arrival, migration timing, population state, and numbers of different breeding bird species - short- and long-distance migrants and residents. The paper considers the impact of global warming upon spring arrival phenology of 128 bird species registered in Zuvintas State Strict Reserve and 48 species near Vilnius, basing on registration since 1961 until 2002. The arrival dates of birds under the effect of global warming became markedly earlier both for short- and long-distance migrants. No essential differences were found in the impact of global warming on the spring arrival of short- and long-distance migrants. It was established that the breeding populations of southern (south-western) bird species are increasing.

Global Observation of Vegetation Phenology from MODIS Data

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There is growing scientific interest in the measurements of vegetation phenology since it is a crucial parameter to model terrestrial ecosystems, calculate carbon budget and monitor climate change. Remote sensing plays a leading role in monitoring phenological activity of vegetation communities at large spatial scales. However there is difficulty in the direct linkage between phenology of individual species measured in field and that of vegetation communities observed from satellite since they may represent different ecological meaning.

By utilizing Moderate-Resolution Imaging Spectroradiometer (MODIS) data at the global extent, we calculated four key phenological transition dates in each cycle, which are the onsets of greenup, maturity, senescence, and dormancy respectively. For monitoring vegetation variation, we selected an enhanced vegetation index (EVI) calculated from MODIS product of Nadir Bidirectional Reflectance Distribution Function (BRDF) Adjusted Reflectance (NBAR) with a spatial resolution of 1 km from 1 January to 31 December 2001. An annual trajectory of EVI in each pixel was fitted using a sigmoidal model of vegetation growth. Extreme values in the curvature-change rate were derived from the correspondingly fitted growth models to automatically determine both phenological transition dates and cycle modality.

For understanding the MODIS observations of phenology, phenological transition dates calculated from NBAR EVI were compared with field measurements of bud break and leaf development in spring, and coloration and leaf drop in autumn during 2001 in both Harvard forests and Hbrook forests of North America. In these comprehensive sites, more than 30 native woody species were measured along a 2 km loop transect. In order to fill the gap between field and satellite observations of phenology for various ecosystems, however, a field phenology network is essential to measure annual vegetation leaf development of vegetation communities at the global scale.

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