Phénoclim, a research project on phenology in the Alps

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Résumé

Le Centre de Recherches sur les Ecosystèmes d'Altitude a lancé et coordonne depuis l'automne 2004 le programme de recherche "Phénoclim". Phénoclim a pour objectif la mise en place d'un réseau de suivi à long terme de la phénologie de la végétation dans les Alpes, en lien avec les changements climatiques. Une des particularités de Phénoclim est de s'intéresser à l'effet des conditions locales (situation géographique, altitude, exposition) sur l'impact du changement climatique sur la végétation.
Les observations phénologiques sont menées par un réseau d'observateurs – professionnels et amateurs – dans les Alpes françaises et le Valais suisse. Huit espèces d'arbres et 2 espèces herbacées sont inclues dans le suivi, avec 7 stades phénologiques notés, du début à la fin de la période de végétation. Soixante-cinq sites d'étude de la végétation, situés entre 250 et 2150 m d'altitude, ont été suivis en 2006. Sur ces 65 sites, 35 ont été équipés d'une station de mesure de température, spécialement conçue pour le projet, afin de pouvoir corréler température et date d'occurrence des événement phénologiques.
En complément de l'étude scientifique, Phénoclim comporte un important volet pédagogique, de sensibilisation et d'éducation à l'environnement, qui s'adresse aux particuliers et écoles des Alpes françaises et du Valais suisse. Plusieurs espaces protégés, dont le Jardin Alpin du Lautaret et le Jardin Alpin de Champex, prennent part au programme. Pour permettre les échanges entre le public, les observateurs et le CREA, une partie du site Internet du CREA est dédiée à Phénoclim (www.crea.hautesavoie.net), avec une visualisation des données et une analyse des résultats accessibles à tous.
Une extension du programme dans le futur, à d'autres espaces protégés et jardins botaniques sur l'arc alpin est envisagée.

Introduction

The Research Centre of Alpine Ecosystems (CREA) has launched in 2004 a research programme called "Phénoclim". Phénoclim focuses on vegetation phenology as an indicator of climate change in the Alps.
The interest in phenology, the study of the timing of life-cycle events of organisms[1], has grown quickly in the last decade. Recent studies have extensively demonstrated the importance of phenological studies to describe and understand the effects of climate change on ecosystems. A meta-analysis conducted by C. Parmesan and G. Yohe (2003) on 677 species from a large range of taxa (woody plants, herbaceous plants, birds, insects, amphibians and fishes) showed a significant mean advancement of spring events by 2.3 days per decade for 62% of the species during the last century, and this change is related to an increase in temperature[2]. The most important message is that the observed changes in climate have already significantly impacted natural systems[3,4]. It gives a first indication and warning of the potential large changes that might occur if mean temperature continues to increase by 1.4 to 5.8°C globally this century or 2 to 6.3°C as predicted for Europe[5-7].

Phenological changes have the potential to contribute to the climate change impact debate because many historic observations exist (gathered by numerous phenological monitoring networks)[8-9]. There is actually a need to ensure the continuation of existing networks and to invest in the expansion and creation of new networks to provide better global coverage and cover areas where few observations are available. The latter is the case of mountainous regions.

The objective of Phénoclim was therefore to correct for the lack of phenological observations in the French Alps by setting up a new monitoring programme. The main research objective of Phénoclim was to measure phenological changes as indicator of climate change in the Alps, and more specifically to understand better how vegetation responds to local conditions such as geographic exposition, altitude and climate and ultimately to assess the long-term impacts of climatic variations on vegetation.

The Phénoclim network

Vegetation observations are carried out by a network of observers, coordinated by the CREA. The network was launched in autumn 2004, and covers a large part of the French Alps and a small part of the Wallis canton in Switzerland. It aims at including other alpine regions in the near future. In 2006, Phénoclim had 86 participants (83 in the French Alps, 3 in Wallis canton).

Two types of observers are involved in Phénoclim : professionals working in different types of protected areas (botanical gardens, national parks, regional parks) and participants from the general public (environmental organizations, individuals and primary and secondary schools) (Fig. 1). The CREA is still expanding the Phénoclim network, e.g. by increasing the number of protected areas in the network.

The Phénoclim protocol

The participation of the general public implies a relatively simple field protocol, easy to understand and in particular doable by children.

Study area

The study area is the Alps. In 2006, 65 study sites of vegetation were monitored, all over the French Alps and a small part of the Wallis canton – Switzerland, between 250 m and 2150 m a.s.l. The study sites are relatively well distributed with respect to altitude with 34 sites located between 250 and 1000 m and 31 sites located between 1000 and 2150 m (Fig. 2). However, the latitudinal gradient is not yet well represented with more study sites located in the Northern Alps (47 sites) than in the Southern Alps (18 sites). The objective is to sample all the alpine ranges, with a better representation of Northern vs. Southern Alps, inner vs. external Alps, which have different climatic influences (e.g. Mediterranean, oceanic, continental). We plan furthermore to monitor vegetation phenology along altitudinal gradients of about 1000 m at 6 locations throughout the region (this is already done in the Bauges and the Mont-Blanc massif in France).

Species

Phenoclim monitors the phenology of 10 species (Table 1). They represent different plant functional types:

- 5 tree species : *Picea abies*, *Larix decidua*, *Betula pendula*, *Betula pubescens*, *Sorbus aucuparia*, *Fraxinus exelsior*
- 2 shrub species : *Corylus avellana*, *Syringa vulgaris*
- 2 herbaceous species : *Primula veris*, *Tussilago farfara*

Three species are monitored per study site, with 3 marked individuals per site. Monitoring is done on the same individuals during several years as the species studied are all perennial. These species are common in the Alps, easily recognizable by non-specialists, present on a large range of altitude and studied as climate change indicators in other phenology research programmes[9-11].

Phenological observations
Seven phenophases are monitored (3 in spring and 4 in autumn) (Table 2). Observations are carried out every 8 days by the same group of persons. These phenophases provide a measure of the beginning of the vegetation activity and senescence in relation with temperature variations[10-13].

Meteorological data
In mountainous areas, weather conditions often vary at small temporal and spatial scales. The existing network of weather stations is then too fragmented to be used when studying detailed relationships between phenology and climatic factors at a small scale[14-15]. Meteorological data for Phénoclim will be provided through the implementation of a temperature stations network, designed for this project (Fig. 3). These stations are composed of a 2 m high pole on which 4 temperature sensors are fixed vertically at different heights (5 cm in the ground, right on the earth, 30 cm and 2 m above the ground). A second 1 m high pole is connected to the station and contains an electronic card and batteries for energy supply. Temperature of the air and the ground are registered every 15 min and stocked on a memory card, that can be changed manually. The card’s memory can store data up to a period of 40 days. Thirty three stations are installed in vegetation study sites of Phénoclim and we plan to install 100 temperature stations in total.
These stations will provide temperature data which are closely related to the temperature experienced by the plants, depending on local conditions (altitude, slope, geographical situation) and will allow correlating phenology to climatic factors. They will also provide information on snow depth and duration (Fig. 4).

Results
First, Phénoclim should allow us to better understand the relationships between phenology and local variables such as altitude, slope, exposure to the sun and geographic localisation. Figure 5 and 6 show the altitudinal dependence of flowering (45 individuals) and leaf unfolding (55 individuals) for Hazel and of budburst for Ash (78 individuals) and Larch (48 individuals) in spring 2006. In both cases there is a clear delay of the timing of the phenophases with altitude. The importance of the delay depends on the species (Hazel flowering : 4.3 days per 100 m, Hazel leaf unfolding : 3.6 days per 100 m, Ash budburst : 3.3 days per 100 m, Larch budburst : 3.3 days per 100 m). Further analyses will lead to a better understanding of the responses of species to climatic factors and to evaluate the differences of response between species.
Second, the relationship between phenology and climate variation and changes can be assessed when time series are longer. Figures 7 and 8 show the interannual variability of the timing of budburst for Silver Birch (21 individuals) and Larch (29 individuals) between spring 2005 and spring 2006 (comparison based on the same individuals monitored during these 2 years). There is a general delay in 2006 compared with 2005, due to the difference in temperature with a cold spring in 2006. Note that the differences observed for Birch are the same for all the individuals (2.5 days per 100 m in 2005 and 2006), whereas for Larch, the delay in the timing of budburst increases with altitude (7 days of difference between 2005 and 2006 at 1000 m asl, but 16 days of difference between the same individuals at 1900 m asl,

which correspond to 2.3 days per 100 m in 2005 and 3.6 days per 100 m in 2006). It will be interesting to make the same comparison over several years and then examine the general patterns towards delay or advance, to have an indication of climate change impact. As the programme started only two years ago, the results presented here give just a general indication of the results expected from Phénoclim.

Conclusion

The preliminary results show the interest of a project involving actively the general public. With a simple protocol, we could obtain valuable data. The quantity of data collected and the size of the area covered by the monitoring scheme could compensate for the relatively low precision of some of the data collected (e.g., once a week). Moreover, Phénoclim is a good medium of education for the general public. The CREA is developing a strong educational component for schools in addition to the scientific study. Phénoclim aims at raising the public awareness of environmental and climatic change, in particular through the use of the website www.crea.hautesavoie.net. We also explain the role of research organization and the way they are working.

In addition to the public participation, we want to include in Phénoclim more professional organisms working on vegetation in the Alps and in particular botanical gardens. Phenological observations are easy to carry out for this type of organisms where permanent staff is working in the field every day during the vegetation period. This could be a mean to develop research activities in the gardens without too much investment, to add to the values of existing historical phenological data made in different gardens, to share information concerning phenology and to ensure a long-term monitoring scheme of vegetation. Phénoclim could also be used in the gardens for public awareness and education and to built educational programmes with neighbouring schools.

Acknowledgements

This program had received financial support from Région Rhône-Alpes, FEDER, Région PACA, Fondation Somfy, Fondation Nicolas Hulot, Patagonia.

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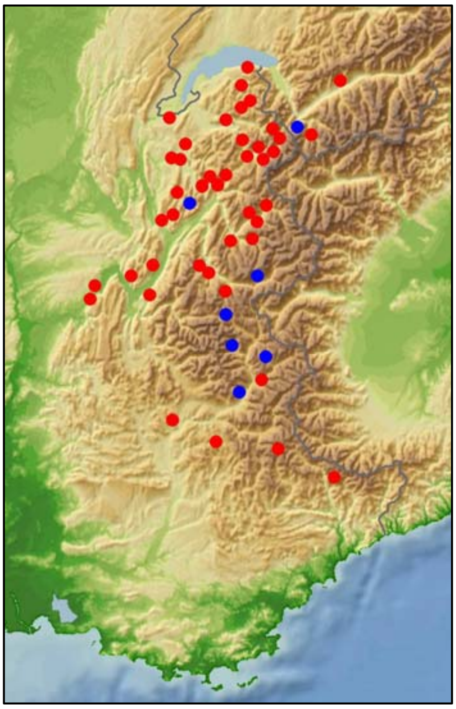

Figure 1: Phénoclim network in 2006 - Map of the observers (*in blue : professionals and protected areas, in red : schools and private individuals*)

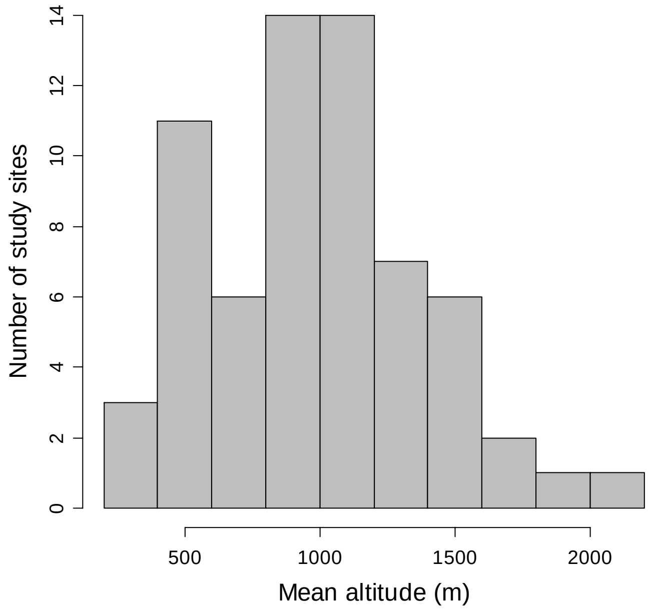

Figure 2: Distribution of altitude of study sites in 2006

Table 1: Studied species, with number of individuals studied per species

Type of plants	Species	Scientific name	Nb of individuals	Altitudinal range
Trees	Spruce	*Picea abies*	127	448 m – 2136 m
	European Larch	*Larix decidua*	66	485 m – 2136 m
	Silver Birch	*Betula pendula*	119	278 m – 1790 m
	Downy Birch	*Betula pubescens*	8	485 m – 2136 m
	Ash	*Fraxinus exelsior*	134	250 m – 1600 m
	Rowan	*Sorbus aucuparia*	29	690 m – 2136 m
Shrubs	Hazel	*Corylus avellana*	101	250 m – 1330 m
	Common Lilac	*Syringa vulgaris*	35	300 m – 1400 m
Herbaceous	Primerose	*Primula veris*	22	250 m – 1370 m
	Colt's foot	*Tussilago farfara*	37	485 m – 2136 m

Table 2: Studied phenophases, with BBCH scale codification equivalent

Species	Autumn phenophases				Spring phenophases		
	Leaf colouring		Leaf fall		Budburst	Leaf unfolding	Flowering
	Beginning (92)	50% (94)	50% (95)	Bare (97)	Beginning (07)	Beginning (11)	Beginning (61)
Picea abies							
Larix decidua							
Betula pendula							
Betula pubescens							
Sorbus aucuparia							
Fraxinus exelsior							
Corylus avellana							
Syringa vulgaris							
Primula veris							
Tussilago farfara							

Figure 3: Phénoclim temperature station

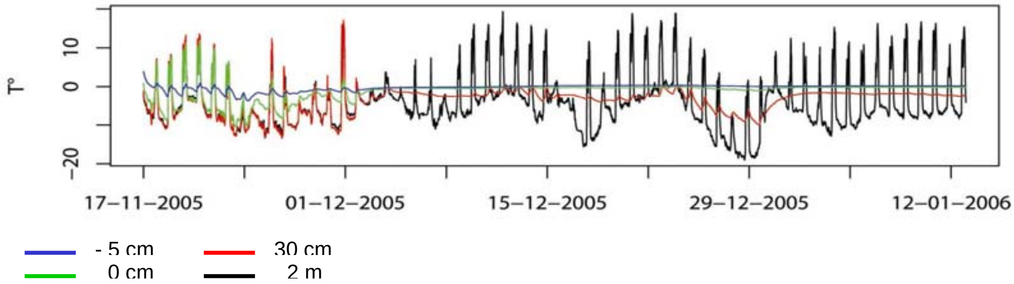

Figure 4: Temperature data provided by a Phénoclim temperature station *(Vallorcine – France, 1920 m a.s.l)*

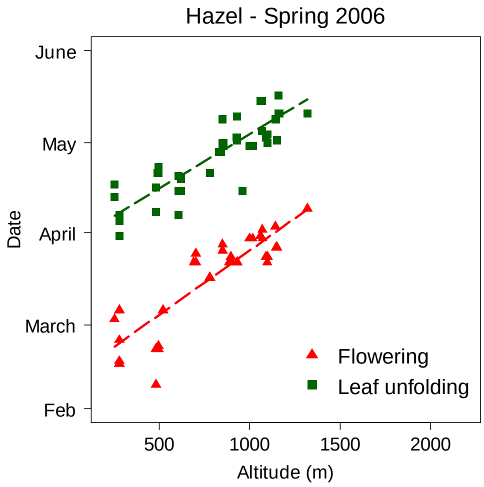

Figure 5: Altitudinal dependence of spring phenophases for *Corylus avellana* - flowering and leaf unfolding

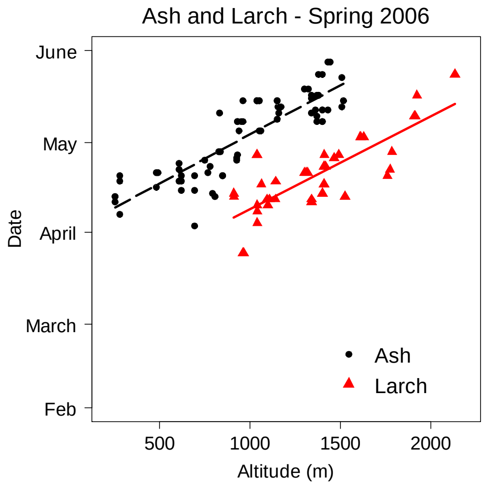

Figure 6: Altitudinal dependence of budburst for *Fraxinus excelsior* and *Larix decidua*

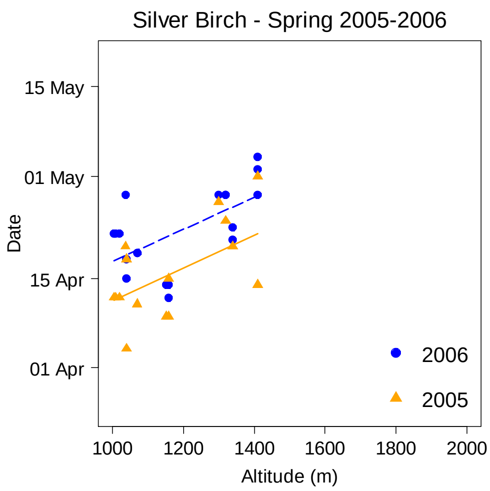

Figure 7: Altitudinal dependence of budburst - Interannual variability of *Betula pendula*

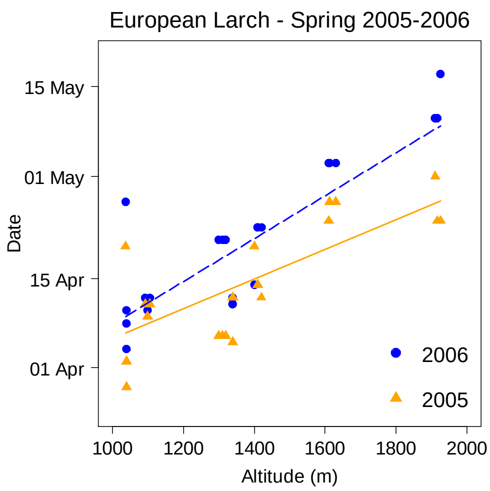

Figure 8: Altitudinal dependence of budburst - Interannual variability of *Larix decidua*