A VISIT TO THE PLACES WHERE MOUNTAIN ENVIRONMENTS ARE STUDIED

There are two sites in the Torgnon area that anybody can visit to learn how **scientific research** is carried out to **collect data that is useful** to interpret the extent of climate change in the mountains.

Important observational and monitoring activities are conducted here to assess the impact of climate change on alpine ecosystems. The monitoring stations are located in specific areas that present suitable physical and vegetation-related conditions for the various types of measuring techniques. In each of them the Regional Agency for Environmental Protection of Valle d'Aosta (ARPA Vda) has placed **highly technological** scientific monitoring instruments that record the various physical parameters required to understand the vegetation's response to variations in climatic conditions in the course of time. Data collected can, therefore, be processed through specific analysis procedures, even through remote transmission systems.

The visit to the two sites, the one in Tellinod and the one in Tronchaney, is particularly interesting to see the special set of technological instruments dedicated to ongoing collection of climatic data (temperature, humidity, rainfall, wind speed and direction, snow height) and of particular scientific data (sun radiation, plant coverage, soil temperature, values of CO_2 absorbed and released by the vegetation and by the soil, etc.).

Monitoring sites can be visited on foot or by bicycle, with easy access from Champtorné as a result of the network of trails present along the deep valleys that partly feature woodland and pasture, which characterise the northern area of the Torgnon area. Accompanied by a guide, you will learn about the implications of such research and monitoring activities, and better understand how mountain environments respond to climate change.

DETAILED INFORMATION

PHENOLOGY, A WAY TO GAUGE THE EFFECTS OF CLIMATE CHANGE

Plants and animals develop and grow every year, depending on the season.
This development can be divided into well defined stages.
For instance, plants start germinating at the end of winter. They develop leaves, flowers and fruits, and finally either die or start resting before the forthcoming winter.
Hence, the life of plants and animals is marked by regular events that occur around the same period every year. The sequence of these events is called **phenology**, and every development stage of plants and animals is a **phenological stage**.
These events are repeated every year but their precise date can vary year by year because they are strongly affected by environmental conditions, particularly by climatic factors.
For instance, we expect a larch to change colour and shed its needles in autumn but we cannot precisely predict the date when this change will occur every year.
Hence, phenology is the study of annual variations of regular events of plant and animal life, depending on the climate.

CLIMATE CHANGE

We often hear the term climate change. But why do we say that the climate is changing? What are the grounds for this statement?
The collection of historical data of temperatures has allowed to analyse the global progress of this data.

Starting from the early 20th century, the climate on Earth has recorded a mean **warming** of 0.8°C. Quite an abnormal change in temperature, considering its extent and rate of manifestation, since it widely exceeds all temperature variations that have been traced over the past 1,000 years.
However, this warming is not homogeneous throughout the world. In Europe, the mean temperature has increased by 0.95°C in the 20th century, while the Alps have warmed by 1°-3°C over the past 60 years, depending on the sites.
The phenomenon is so extensive that natural cycles alone (variation in solar activity, earth's orbit, volcanism, etc.) cannot be deemed the sole cause.
Indeed, after the start of the industrial age, the massive combustion of oil, natural gases and carbon in industrialised countries, and intensive cattle breeding have contributed to change the composition of the atmosphere. This combustion introduces large quantities of gas (mainly carbon dioxide and methane) into the atmosphere, and scientific studies have proven that these compounds are at the origin of the enhanced greenhouse effect.
The **quantity of CO2** in the atmosphere today is 30% higher than the amount observed before the industrial age.

It is now an ascertained fact that this climate change concerns a large number of living beings in the whole world. An increasing number of scientific studies underscores the link between the temperature increase over the past 30 years and changes in the biological cycle, in population dynamics, and in the abundance and distribution of animal and plant species.
Among the changes observed, those regarding the phenology of plants and animals, are crucial.

CHARACTERISTICS OF ARPA MONITORING SITES IN THE TORGNON AREA

The monitoring sites of ARPA Valle d'Aosta present in the Torgnon area focus on remote collection of scientific data and phenological observations that are useful for the long-term study of climate change and of its impact on mountain ecosystems.

They are located in two different representative sites of two typical high altitude mountain settings, namely:

- **Tellinod - alpine prairie, instruments at ground level - altitude 2,164 m a.s.l.**
- **Tronchaney - larch woods, instruments at ground level and data collection tower (height: 20 m) - altitude 2,160 m a.s.l.**

The reasons for the creation of two different monitoring sites can also be traced to the different response to climate change of the vegetation present in these two environments.

Particularly, the plant species present in the alpine prairie (prevalently graminaceous species) have a faster response to climate change and their phenological phases are either anticipated or delayed in a more evident manner as seasonal climate conditions vary, compared to events recorded for tree species that are present in the woods (larch woods).

For the Tronchaney station, which is located in the larch woods, a monitoring tower had to be created to place some dedicated instruments above the vegetation coverage formed by trees. The instruments present at the two sites can continuously collect data and send them remotely to the collection station of ARPA Valle d'Aosta, where the data is processed and shared on various scientific cooperation platforms that are common to other European and non-European research centres.

Measuring instruments record two data categories:

- **climatic data:** temperature, humidity, rainfall, wind velocity and direction, snow height, presence of snow on the ground;
- **chemical-physical data:** solar radiation, plant coverage, temperature at ground level, levels of CO_2 absorbed and released by the vegetation and by the soil, lymphatic flow.

Both sites have a webcam and a digital camera for ongoing detection of conditions of plant coverage and of the presence of snow on the ground.

The colour images collected by webcams and digital cameras are also useful to calibrate images taken by the satellite and to ensure they are correctly interpreted. It is particularly useful to associate false colour images taken by the satellite using non-optical technologies (e.g., infra-red) to gauge the colour that prevails on the crown of larch trees in spring (increased green component given by the foliage) and in autumn (gradual variation from green to orange and yellow, reaching the brown/grey of the bare branches). This allows to consider, alongside the precise data of the soil, the more extensive information resulting from the analysis of satellite images, broadening and extending the analysis of annual series also to areas that are not directly involved by data monitoring campaigns at ground level.

For those who want more detailed information, we recommend visiting the monitoring sites with a guide.

PHENOLOGICAL MONITORING WITH QUALITATIVE AND QUANTITATIVE PROCEDURES

Remote data collection is accompanied by a series of phenological monitoring field operations by choosing and marking appropriate monitoring areas. These operations are carried out with common monitoring procedures and measure well defined stages of growth levels and the observation of the appearance of the plant species monitored.

In the case in question, the monitoring procedures have envisaged:

- for **herbaceous plants**: measurement of the growth in mm of specific wood types, at regular intervals, always on the same individuals (measurement of the physical information);
- for **trees**: empirical observations based on the aspect related to the manifestation of specific phenological phases, such as budding/foliation/flowering or yellowing of larch trees, observed always on the same individuals (date of event).

The processing and correlation of climatic, physical and phenological data have allowed to establish trends and underscore certain interesting aspects related to the vegetative cycle of plants at high altitudes.

Indeed, every species has its own phenology resulting from its genetic make-up. But it also depends on external factors, such as the photoperiod and factors, such as temperature, rainfall, sunshine. Hence the importance of collecting continuous series of climatic, chemical and physical data that span several years.

To better perceive the importance of this data, we must understand the underlying mechanisms of the development of phenological phases and the role of the various parameters monitored by analysing what occurs in spring.

The photoperiod (relative duration of day and night) differs depending on the latitude but remains unchanged for the same area year in and year out. Hence, this factor allows the organism to evaluate the period of the year in a reliable manner. The decisive climatic factor in the temperate alpine region is temperature. Most of the plants are based on the temperatures of the previous weeks (2-12 weeks) to evaluate the seasonal change and start phenological responses.

At the end of winter, plants need to accumulate a certain amount of heat to develop. This accumulation of heat occurs above a threshold temperature that corresponds to the temperature starting from which the plant can commence its activity (generally in the range of 0°-5°C). The plant daily "accumulates" degrees above the threshold temperature until it reaches the suitable amount for its development. The sum of heat is expressed in degree days (0DD).

For instance, in spring the larch needs a very scarce quantity of heat for its buds to sprout, less than 40DD, which means that larch needles develop very rapidly starting from the moment in which the temperature returns to positive values in spring. Hence the larch is an early species. Conversely, the spruce needs 316DD for its buds to sprout. This means that spruce needles develop very late in spring. This late development of sprouts is an adaptation that prevents young needles, which are very sensitive to the cold, from being damaged by a late freeze.

A summary of data collected can be found on https://goo.gl/NUEwjp

PHENOLOGICAL RESEARCH AND MONITORING PROCEDURES

Phenology is the study of climate-related variations of regular events of plant and animal life. Phenology is a climate indicator but it is especially a key element for the adaptation of living beings to climate changes. The study of phenology is growing in importance in the current context of climate change, since it allows to evaluate the effects of this change and the response to it from other living beings.

As with all scientific research, even the efficacy of phenological studies is based on quality, quantity and geographical distribution of data collected. To do this it is essential to establish data collection rules for every person assigned to the monitoring process to collect them in the same way, according to methods described in the **monitoring procedures**. This allows research centres to compare them and analyse them without fearing that they might not have been correctly collected.

In the case of phenological observation, these procedures envisage the detection of two different data types, namely physical and sensory.

Physical data require dedicated equipment for their detection that can be more or less technological depending on the data collected and on the measuring methods. For instance, data on temperature, wind speed, snowfall and amount of sunshine that need quite simple measuring instruments are important. Besides these data, research can be expanded by collecting very particular information, such as carbon flow, colour spectrum of the vegetation, and infra-red data collected by the satellite. Obviously, these findings are solely the property of the scientific community.

But sensory data that requires simpler visual observation of specific characteristics of plant and animal species can also be collected. Hence, these monitoring procedures allow even enthusiasts to participate in scientific research as they do not require particular instruments.

In the case of observations on plant phenology, for instance, records generally focus on the periods of greatest change of plants, namely spring and autumn, and only on particular species in which these variations are more easily detected.

For instance, the programme **Phénoclim** is particularly interesting. It makes use of a network of observers distributed throughout the Alps, situated between 200 m and 2,200 m a.s.l.
The detection procedure of this programme envisages for the vegetation the weekly observation of chosen plants (they must never change in the course of the years) and the statement of the dates on which the various phenological phases occur. Budding, foliation and flowering are observed in spring, while yellowing of leaves and shedding of the crown are studied in autumn.

The easy observation method allows **everybody to participate** in scientific research, from private individuals to schools and associations, parks and highly specialised research centres.

Data collected by **phenological observers** in the Alps are sent, season after season, to the reference scientific site, the CREA in Chamonix, which can thus collect and process a large amount of significant data that are comparable because they have been recorded by all contributors with the same method.