Past and future developments in plant populations in the Alps linked to climate change

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Set up in 2002, the Spatial Ecology (ECOSPAT) group at the University of Lausanne (http://www.unil.ch/ecospat) has been studying how climate change influences developments in plant populations in the Swiss Alps. The research has focussed on two separate issues : using permanent observation plots, Dr Pascal Vittoz has been studying observed changes in plant populations, whilst Professor Antoine Guisan is developing forecasting models to predict the changes that might occur during the 21st century.

The PERMANENT.PLOT.CH project

In 2003, Dr Pascal Vittoz (Vittoz & Guisan 2003) set up the PERMANENT.PLOT.CH project to create a centralised database containing information about permanent plots used to study plants in Switzerland (clearly marked areas of ground used to carry out regular surveys over a period of time). The project's primary aim is to create a record of this valuable historical data and ensure that it is available for researchers to use in studying past and future plant life developments in Switzerland.

The information has been used to study the impact of climate change to date. The researchers initially examined changes in plant diversity on different peaks in the alpine zone and above the snow line (2800 - 3400 m; ***Fig. 1a***) during the 20th century (Vittoz et al. 2008; Vittoz et al. 2009a). The results showed an average increase of 86% in the variety of plant life found on the summits between 1900 and 2000, which confirmed previous findings (see for example Grabherr et al. 1994 and Walther et al. 2005). However, the research also revealed that the majority of new species came from lower zones, thereby proving that the warmer climate is conducive to species migrating upwards. What is more, the species that had colonised a range of new summits tended to have seeds with appendages designed to facilitate effective wind dispersal (silky hairs or narrow wings).

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Figure 1a-1b
(a) Piz Languard, a peak above the snow line (3262 m) for which we have detailed records dating back to 1905
(b) Botanical survey in subalpine grassland (Vallon de Nant)

As human activities have put a lot of pressure on low and mid-altitude areas, there is limited information available on the impact of climate change on meadow plants below the tree line. Most of the grassy areas surveyed in the past have seen dramatic changes in terms of usage and management. Nevertheless, we have been able to use two sets of data for subalpine meadows (Vittoz et al. 2009b) : permanent plots have been monitored since 1954 in the Bernese Alps (Schynige Platte) and plant populations have been surveyed since 1970 in the Vaud Alps (Vallon de Nant ; ***Fig. 1b***). When analysing the data, we have tried to distinguish between climate-related changes and those linked to land management.

At both sites, our analysis has shown that the changes were much less significant than those previously recorded at higher elevation. What is more, most of the developments observed in the plant cover were probably caused by changes in land management. At the first site, grazing had been replaced by mowing, which favoured some species over others (for example, grazing animals did not feed on poisonous plants but these did not survive mowing). The second location was grazed by goats in the past – in their absence, taller and denser grasses have gained ground which in turn means that some small alpine species are no longer able to compete. However, global warming does also seem to have inf uenced the vegetation. At Schynige Platte, a hemiparasite from the premontane to subalpine zones (*Rhinanthus alectorolophus*) has replaced a hemiparasite from the alpine zone (*Euphrasia minima*), whilst some species in the Vallon de Nant have thrived in the absence of the goats and are now found at unusually high altitudes for the region.

These studies, along with others carried out in the Alps, have demonstrated that climate change has already had a significant inf uence on plant life, with species migrating towards the summits, although the effects are currently much more modest at lower altitudes. However, we cannot draw any firm conclusions as yet about vegetation below the tree line as there is not sufficient research data.

Tools for predicting future species distribution

Statistical models known as predictive distribution models can be used to forecast potential current and future species distribution (Guisan & Zimmermann 2000). These models identify links between the observed presence and absence of species and environmental factors such as climate, topography, substrates and land use (***Fig. 2***). By modifying the climatic variables to allow for different scenarios and socio-economic projections (IPCC 2007), the models can forecast potential future species distributions and thereby assess how climate change might affect biodiversity.

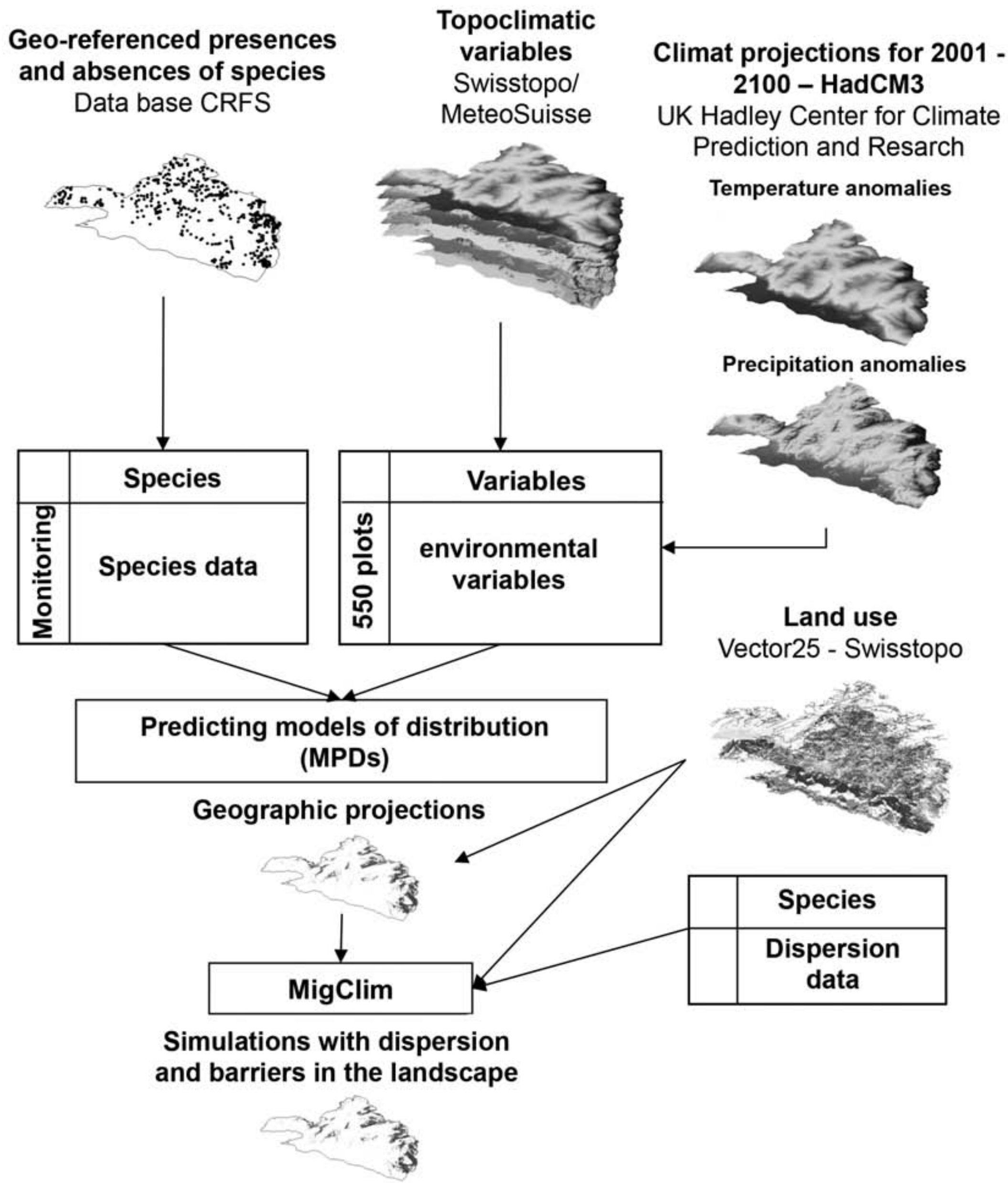

Figure 2
Conceptual model showing the different stages of predictive distribution modelling and the cell-based MigClim simulation tool.

Large-scale studies using coarse-resolution models (16 x 16 km plots in the Alps) have predicted that up to 60% of species could disappear from sites in the European mountain range by the end of the 21st century (Thuiller et al. 2005). However, these large-scale models are not really appropriate for the complex topography of the Alps. Using higher-resolution models (25 x 25 m), we have evaluated the impact of climate change at the end of the 21st century in terms of the distribution of 78 plant species in two regions of the Swiss Alps (Swiss Prealps and Zermatt region; Randin et al. 2009a). As these higher-resolution models are better able to ref ect the microhabitats that allow plants to survive in localised areas, the findings are far less pessimistic, although still worrying, suggesting that between 26% and 43% of these 78 species could disappear from the Swiss Prealps as opposed to none in the Zermatt area. However, many plant species will be far less widely distributed in future, particularly in the Swiss Prealps (38-45% will lose coverage compared with 24-25% in the Zermatt area). These results indicate that species in mountain regions with a wide range of altitudes will have a better chance of surviving as they will be able to migrate more easily to higher elevation sites.

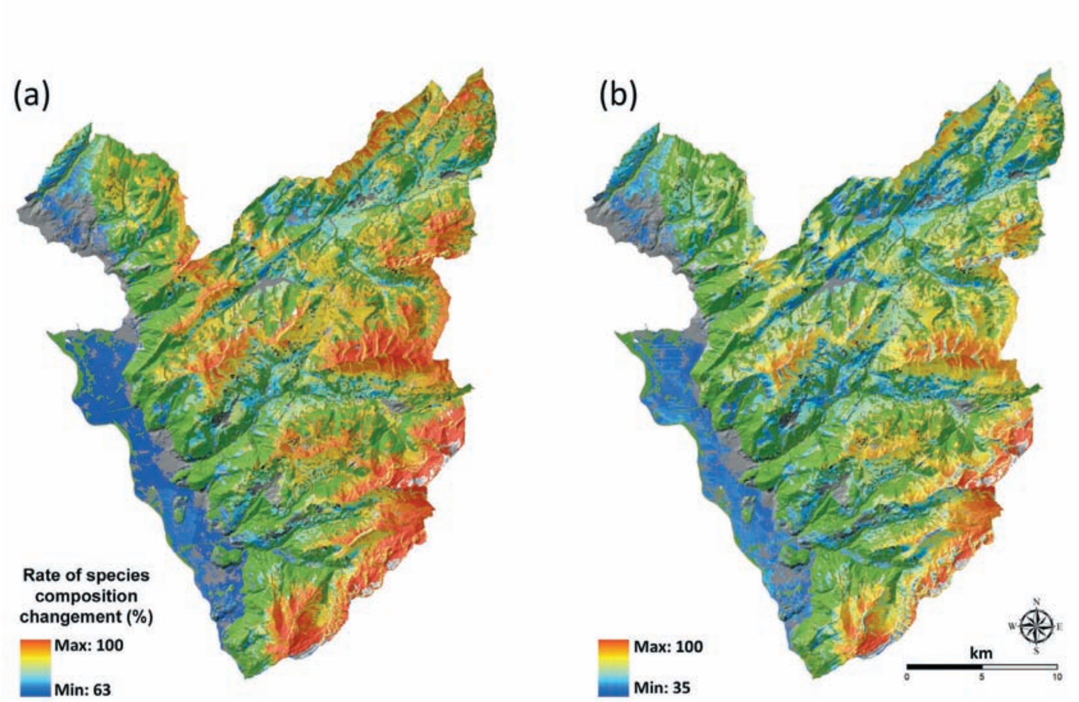

Figure 3a-3b

Predicted rate of species composition change (%)"at the end of the 21st century for (a) IPCC scenario A1FI and (b) scenario B1. The forested zones (shown in green) and land which is not suitable for plants (in grey) have not been included in the projections. The rate of change of composition is calculated for each cell in the landscape (25 x 25 m) using the following formula : T = 100 x (No. of species lost + No. of new species) / (Predicted no. of species now + No. of new species).

Another limiting factor in projects to simulate the potential impact of climate change on plant distribution is that they tend not to include data on seed dispersal. Most studies either assume unlimited dispersal or no dispersal. Yet, depending on the speed of climate change, the fragmentation of the landscape, and each species' capacity for seed dispersal, these assumptions either exaggerate or massively underestimate the changes in plant distribution, and consequently considerably increase the level of uncertainly associated with the projections.

In order to reduce these uncertainties, we have developed the MigClim model (***Fig. 2*** ; Engler & Guisan 2009), which is able to simulate seed dispersal within the future distribution projections. The model also includes parameters such as landscape fragmentation and the time that elapses between two generations. Using the MigClim simulation model for 287 species found in the Swiss Prealps (Engler et al. 2009), we found that when including dispersal and depending on the selected scenario, between 30% and 70% of the species could lose up to 90% of their current potential surface coverage by the end of the 21st century. Taking the most pessimistic IPCC forecast (A1FI, 7.6°C increase in 2100), between 63% and 100% of the species in each plot (25 x 25 m) would be replaced by new species (***Fig. 3a*** : rate of change in species composition). Land above the tree line would be more affected, with all the summits studied likely to have an almost completely new set of species. Consequently the majority of alpine plants could have disappeared by 2100. Under the most optimistic IPCC scenario (+3.9°C in 2100), the forecasts are slightly different : mid-altitude summits would see fewer changes in the variety of species (***Fig. 3b***). However, the higher peaks would still experience massive changes. As these models include species dispersal, this is a significant finding in terms of biodiversity. The models also allow us to estimate when the first wave of extinctions will occur. In the region under examination, plants could begin to become extinct from 2040 onwards in the most extreme scenario, or around 2090 in the most optimistic scenario.

In order to further improve the quality of the projections obtained from the predictive models, other key factors such as inter-specific / biotic interactions, geomorphology and land use could also be incorporated (Randin et al. 2009b ; Randin et al. 2009c). Some land-use categories may actually function as facilitators or inhibit the movements of other species within mountain ecosystems (Randin et al. 2009b ; Randin et al. 2009c). Unfortunately it is very difficult to obtain information about these variables from high-resolution maps covering large areas. ●

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