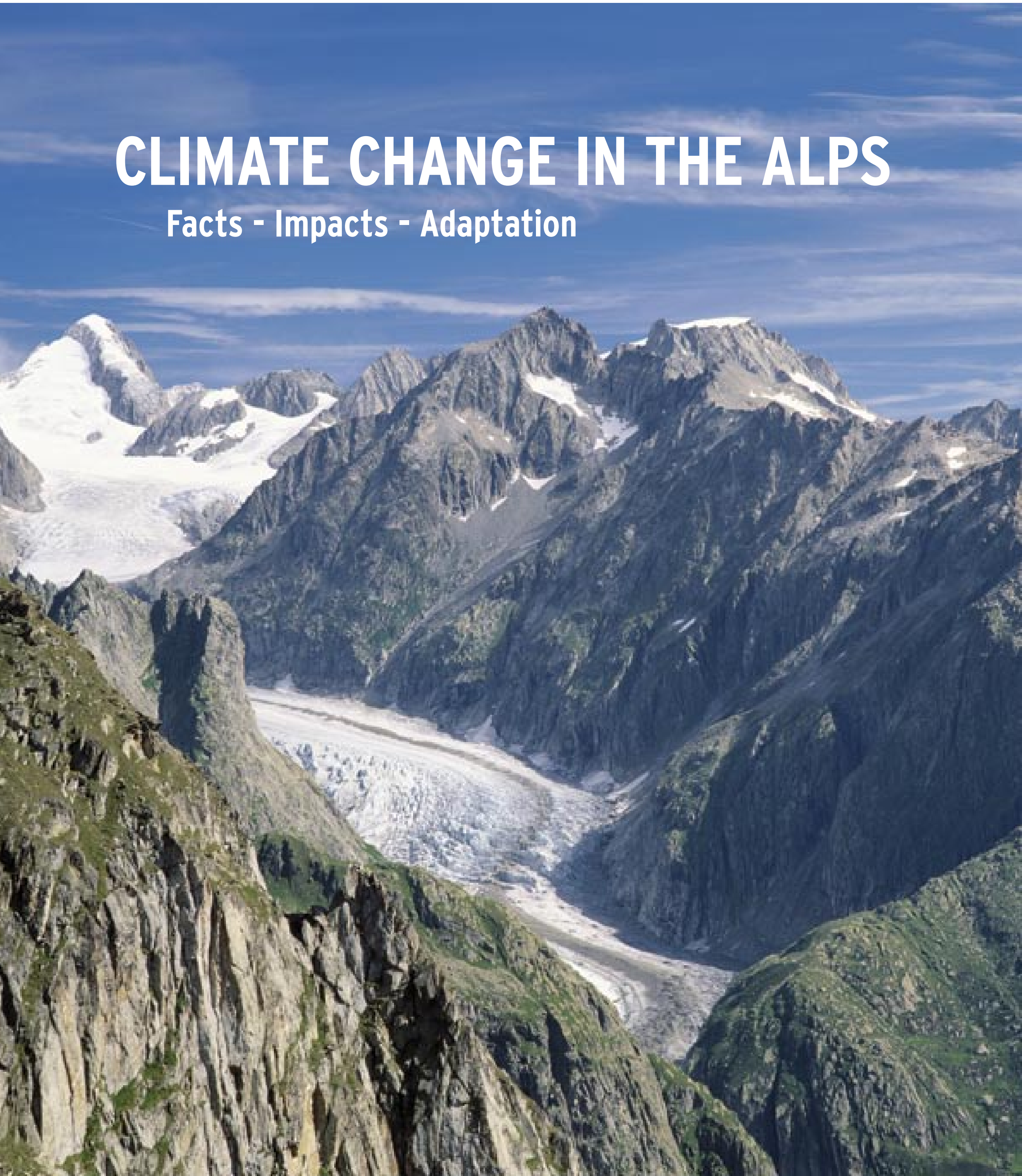
Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

CLIMATE CHANGE IN THE ALPS

Facts - Impacts - Adaptation



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FOREWORD

by **Michael Müller and Dr. Otmar Bernhard**

Dear Readers,

Michael Müller

Dr. Otmar Bernhard

Everyone is talking about climate change, but what does it mean for the Alpine environment? Which changes can be expected? And which adaptations are necessary and realistic?

The impacts of climate change pose some of the greatest threats to the Alpine mountain ecosystem. Nature reacts particularly sensitively here, because nowhere else in Europe will you find so many sensitive areas of natural landscape within such a relatively small region. In addition, in the Alps it is becoming very clear that some negative impacts of climate change can no longer be avoided.

According to the latest model calculations, the Alps must anticipate a warming twice as high as the general German average. The risk of extreme weather events will increase. The Alps will be particularly affected by the impacts of climate change:

- an increase in the probability of heat waves, as in summer 2003
- an increasing trend towards heavy precipitation and floods
- an upward shift of biological zones, with many Alpine flora at risk
- glacier retreat on a massive scale
- changed risk potential of natural hazards such as rock falls
- strong decrease in the snow reliability of many winter sport regions

In view of these developments, the Alpine countries have identified climate policy and the development of adaptation strategies for the Alpine region as the key focus of their cooperation in the coming years. On the occasion of the IXth Alpine Conference in November 2006, their environment ministers adopted a Declaration on climate change in the Alps and, to promote implementation of the Declaration, requested the Alpine Convention‘s Standing Committee to produce an action plan containing recommendations for activities specific to the Alpine region in time for the Xth Alpine Conference in 2009.

The climate protection concepts of the Federal Government and the federal state of Bavaria are centred around a preventive two-track strategy: mitigation and adaptation, i.e. reducing greenhouse gas emissions on the one hand while researching regional climate change and the implementation of adaptation strategies on the other. The local level will play a key role in solving future problems in mountain regions.

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Bavarian State Ministry of the Environment, Public Health and Consumer Protection (StMUGV) therefore extend a cordial invitation to the municipalities in Bavaria‘s Alpine region to address these complex and increasingly acute issues together.

This Background Paper presents the most up-to-date information on anticipated climatic changes and appropriate adaptation strategies with direct relevance to the Alpine region. It also highlights the opportunities available to the Alpine Convention to strengthen transboundary cooperation on these issues at municipal level, especially an exchange of experience through the Alliance in the Alps local authority network.

The Alpine region has immense potential to position itself as a best-practice region for climate protection in future.

We want to make this our joint concern.

Michael Müller

Parliamentary State Secretary,
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

Dr. Otmar Bernhard

Bavarian State Minister,
Bavarian State Ministry of the Environment, Public Health and Consumer Protection (StMUGV)

FOREWORD

by **Dr. Marco Onida**

Dr. Marco Onida

Dear Readers,

Climate change is now widely recognized among the scientific and political communities to be accelerated by human activities. Awareness is widespread, and possible actions for the prevention and adaptation to climate change are on the agenda of several decision making bodies, at international, national and local level.

However, the effects of climate change are not equally spread over the different parts of the planet. Some areas are more vulnerable than others, and among the most vulnerable ones, the mountain areas are certainly to be mentioned. The effects of climate change on mountain regions, including the Alps, are far more significant and visible than in many other areas. At the same time, practically any activity in the Alps is more closely linked to their territory than in other areas: in the sectors of winter tourism, transport, energy production, water availability, agriculture, forests, biodiversity (and this list in certainly not exhaustive) the impact of climate change is felt strongly, and its costs are on the rise.

The Alpine Convention, as a multilateral framework Treaty between the eight States of the Alpine bow, can play a fundamental role in this context. Its main objective is to protect the Alpine territory and to safeguard the interests of people inhabiting it, embracing their environmental, social and economic dimensions in the broadest sense. In order to achieve its objectives, over the years the framework Treaty has been equipped with a large number of thematic Protocols on spatial planning, nature protection, mountain agriculture and forests, energy, transports, tourism and soil protection. Two of these Protocols, the ones on mountain forests (adopted in 1996) and energy (adopted in 1998), directly address the issue of climate change. Other Protocols, such as the one on transport adopted in 2000, although not mentioning climate change directly, pursue objectives which also help decreasing the emissions of greenhouse gas.

The multi-annual 2005-2010 Work Programme of the Alpine Conference made climate change one of the key issues for tourism, nature-related hazard management, housing development, agriculture and forestry as well as water management. In order to make these political commitments a reality, and to give climate change an even wider recognition in the framework of all policies of the Alpine Convention, the IXth Alpine Conference which was held in Alpbach in November 2006 adopted a declaration on climate change. It was decided that an Action Plan recommending alpine-specific measures as well as long-term initiatives against a precise schedule must be prepared by the next Alpine Conference in January 2009. The preparation of the Action Plan is therefore one of the current tasks of the Permanent Secretariat of the Alpine Convention, together with the French Presidency and the other Contracting Parties. Indeed, the adoption of such an Action Plan represents not only a great challenge, but also an opportunity to make the Alpine Convention impact concretely, in view of preserving (and, as appropriate) improving both the Alpine natural territory and the quality of life of the people inhabiting the Alps.

Focus is also being put on the contribution that regional and local authorities can give to prevent and adapt to climate change, primarily by identifying and disseminating the existing best practices.

Finally, the 2008 Report on the State of the Alps, currently under preparation, addresses the subject of water in the Alps and dedicates a specific chapter to climate change and water management. Key issues lie ahead of us, in particular regarding the use of water resources, with an eye to the needs of Alpine and surrounding areas, and regarding the impact of further investments in hydropower plants on the natural environment.

The success of the Alpine Convention in the area of climate change is not an end in itself, but would also contribute to complying with the international commitments under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. The Permanent Secretariat of the Alpine Convention is therefore cooperating closely with the European Instutions. The EC Commission has recently issued a Green Paper on adaptation to climate change. The European Parliament has set up a Committee on climate change. The Alpine Convention is cooperating with these Institutions in order to press the point that the Alpine areas are, in light of their specific experience, a natural early warning system for negative changes as well as a laboratory for the implementation of adaptation strategies. It is also hoped that this will help steering the European Policies in the direction of an even greater recognition of the role of mountain areas, be it in regional, transport, water or any other European policy.

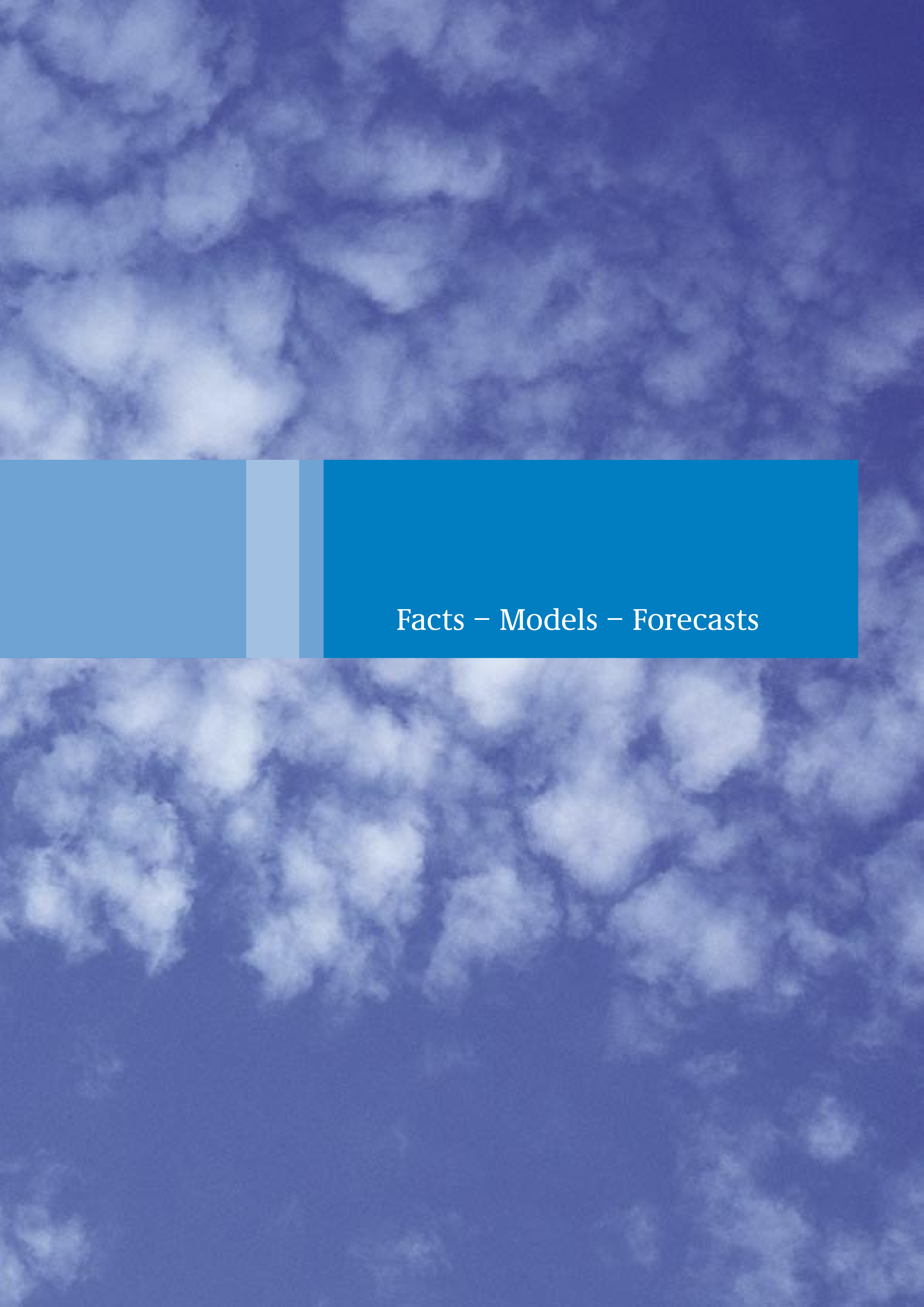
Germany is one of the world-leading countries on the climate change debate. I am personally very pleased that the subject of climate change has been chosen for the 2007 Nationale Alpentagung and I am convinced that this will give an important positive contribution to the ongoing work towards the adoption of the Action Plan of the Alpine Convention on climate change.

Marco Onida

Dr. Marco Onida

Secretary General of the Alpine Convention

THE SCIENTIFIC BASES



Facts – Models – Forecasts

The Facts in Brief

- The atmospheric concentration of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) etc. has increased substantially since around 1850.
- This increase is human-induced. In the case of CO_2, it is mainly caused by the burning of fossil fuels, with the clearing of forests being a secondary factor. In the case of methane, the main causes are rice cultivation and cattle farming.
- The climate warmed significantly during the 20th century: the global surface air temperature rose on average by around 0.6°C. Eleven out of the last 12 years (1995-2006) are among the 12 warmest years on record.
- Most of this warming is caused by the increased atmospheric concentration of CO_2 and other anthropogenic greenhouse gases.
- It therefore follows that continued emission of greenhouse gases on the present or on an increased scale would very probably lead to climatic changes beyond those which occurred in the 20th century.
- The scenarios modelled by the Intergovernmental Panel on Climate Change (IPCC) for global temperature rise to the end of this century vary between 1.8°C and 4°C, depending on future greenhouse gas emissions trends.
- According to current research, Europe's future climate will show a significant rise in interyear variability, which may result in an increased probability of flooding and drought.
- In Germany, a trend towards greater warming in winter than in summer can be observed. Precipitation will also shift to autumn and winter, but will remain relatively constant when calculated over the year.

The monitoring and evaluation of trends and the expected impacts are naturally beset with uncertainties; long-term measurement series are often simply not available and cannot be evaluated easily due to inaccuracies and location changes. Nor can a highly complex system such as the Earth‘s climate be modelled with absolute accuracy. Nonetheless, state-of-the-art computer systems come close to describing and modelling the climate and can thus make predictions about possible future trends. In recent years, there has therefore been more and more clarity within the scientific community that climatic changes are taking place. There is now a scientific consensus that climate change can be observed and that it is mainly caused by human activity. Regrettably, extreme positions are often cited in the media, such as absurd disaster scenarios or massive downplaying of the situation, which bear no relation to their weight in academic circles.

The phenomenon of emerging climate change will not be discussed in every detail in this paper; interested readers are referred to the extensive specialist literature listed in the Appendix.

Already, also in Europe, the far-reaching consequences of climate change can be observed. The trend towards warming and the altered spatial variability of precipitation are already having numerous impacts, such as the retreat of glaciers and permafrost distribution, the lengthening of the vegetation period, and changes in species composition and distribution. In the Alps in particular, these impacts can already be seen very clearly today.

Climate Change in the Alps

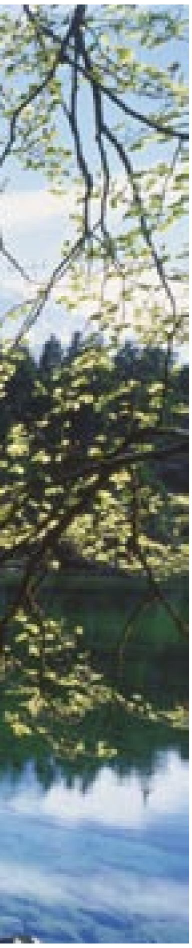
No one notices a change in global median temperature or the average frequency of hurricanes. What people do notice is the local manifestations of the global climate and its impacts. Climate is a global system, but its impacts are local. Thus it is the local climate which is a key factor for flora, fauna and humans. Mountain regions, which account for 20-24% of total land area, have highly diverse and species-rich ecosystems. The Alps in particular, in the heart of Europe, are showing above-average sensitivity to climatic changes. In Germany, the annual median temperature has increased by 0.9°C since 1901, but in the Alps, the temperature increase is almost twice this figure, at 1.5°C. This is likely to result in reduced snow cover and other feedback effects. Changes in macroscale current conditions would also result in long-term changes in the distribution of precipitation in the Alps.

Which predictions can scientists now venture to make for the Alps' climatic future? Which changes are expected to occur?

As the Alps are very small when viewed in a global context, they are depicted very poorly in global climate models. The complex topography and various microclimates disappear over a 250 km grid. With the development of regional climate models, such as REMO at the Max Planck Institute for Meteorology in Hamburg, attempts are being made to achieve more precise climate simulations using higher resolutions. However, climate models are generally beset with uncertainties, with the result that different climate models produce sometimes highly divergent behaviour, especially in difficult topography such as the Alps.

Badersee lake near Grainau, Upper Bavaria

Dufour Peak in the Pennine Alps,
the highest peak in Switzerland (4,634 m)



Morteratsch Glacier in Switzerland,
the largest glacier by area in the Eastern Alps

There is a consensus on findings which reveal the following picture:

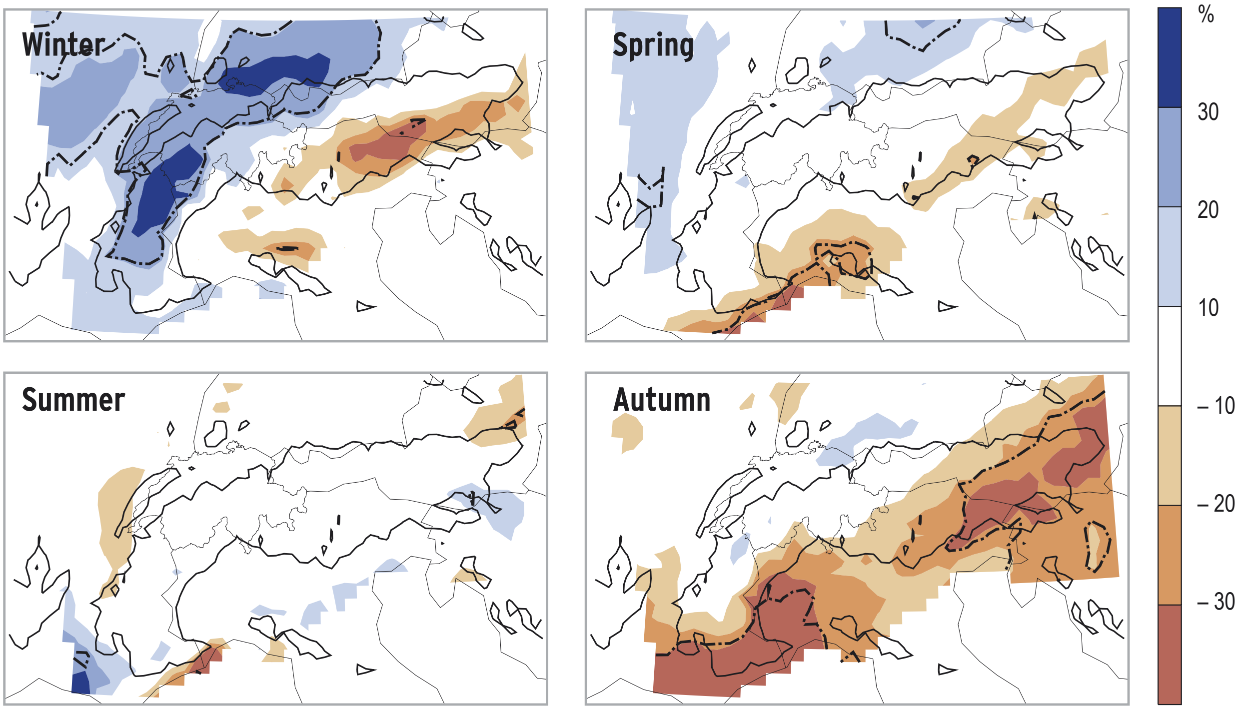
- Decrease in the number of ice and frost days; greater warming of winter than summer temperatures; precipitation falls as rain rather than snow.
- Less summer and more winter precipitation; earlier onset of snowmelt, with a resultant shift in maximum runoff from spring to winter.
- Greater variability of both temperature and precipitation, with an increased risk of extreme weather conditions.

Precipitation

Compared with the statements on temperature trends, the results of modelling precipitation trends for the past and the future are still beset with considerable uncertainties. The differences between these models are often greater than between various future greenhouse gas emissions scenarios. However, a shift away from summer precipitation towards more autumn and winter precipitation is viewed as likely.

Models for the future development of global circulation predict that further temperature rise will result in an increase in atmospheric water content, leading to more water vapour in the atmosphere. As water vapour is also a greenhouse gas, this will then cause further warming and could also result in changes in the intensity and distribution of precipitation. In mid- and high latitudes, a higher relative increase in total precipitation is anticipated, particularly in winter. It is also assumed that there will be a greater increase in precipitation over the mountain slopes than elsewhere. In the mountains, the moist air is forced to rise up. It then cools, condenses and precipitates to rain. This process removes water vapour very effectively from the atmosphere, which is why the amounts of precipitation in mountain regions could increase more significantly – or, to put it another way, they could experience less drought than elsewhere.

Linear trend of seasonal mean precipitation in the Alps (1901–1990)

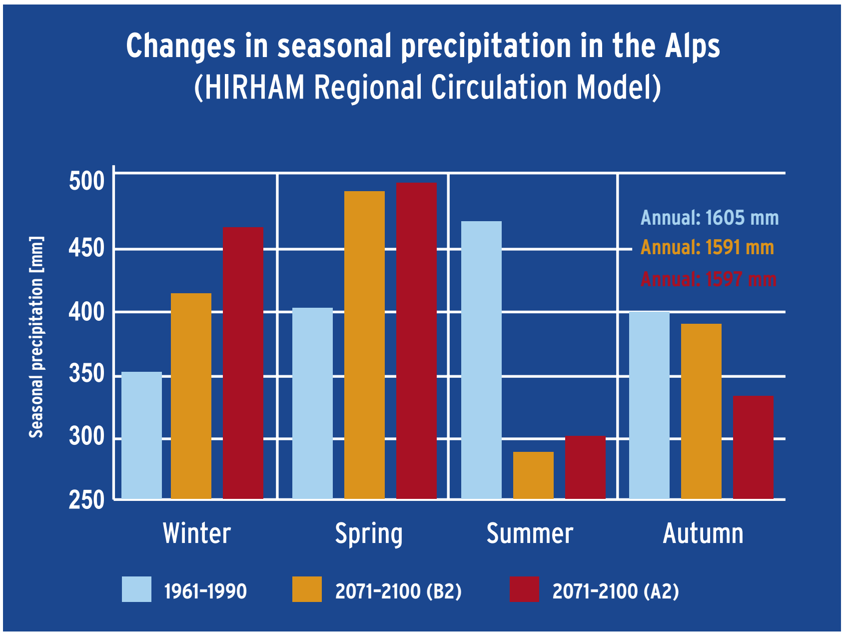


Colours: Trend magnitude in % change per 100 years
Bold contours: 850 m topographic contours
Thick dash-dotted contours: Statistical significance at the 10% level

Source: Schaer, C. and Frei, C. (2005)

In the north-western Alpine areas in particular, an increase in winter precipitation was observed in the 20th century, accompanied by a decrease in autumn precipitation in the southern and eastern areas. In the Swiss Alps, there was a decrease in the number of days with rainfall in some cases, but an increase in its intensity. The results of the cooperation project "Climate change and consequences for water management" (KLIWA) for Bavaria and Baden-Württemberg also show a redistribution of the precipitation within the seasonal course since 1931: drier in summer, more precipitation in winter.

Changes in seasonal precipitation in the Alps, 2071-2100, in various emissions scenarios (A2, B2)

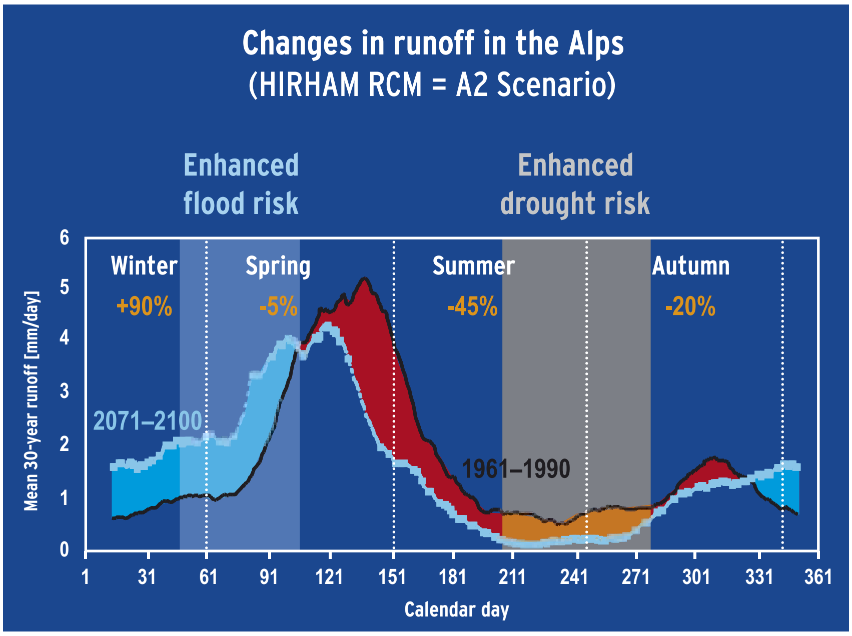


Source: Beniston, M. (2006)

Furthermore, studies show not only an increase in winter precipitation while annual precipitation shows virtually no change, but also point to an increase in the intensity of precipitation events with a return period of one year for Europe. Trends for Switzerland during the 20th century reveal a significant increase – in both strength and occurrence – of winter precipitation. In autumn too, a significant increase in heavy precipitation can be observed.

The changed precipitation patterns are not without implications for water resources management. The IPCC, for example, has already identified growing signs of increased and earlier runoff in spring from rivers that derive their water from glaciers and snow cover as well as a warming of lakes and rivers in many regions, with effects on thermal structure and water quality. Simulations point to a higher peak runoff, due among other things to earlier snowmelt onset, and very low levels of runoff in the summer months.

Changes in runoff in the Alps



Source: Beniston, M. (2006)

Snow causes chaos in the Ausseerland region of Styria (Austria)

Snow

Snowfall in the Alps is heavily dependent on climate fluctuations in the North Atlantic (North Atlantic Oscillation) and thus shows strong decadal variability. This means that not only local but also macroscale factors play the dominant role in determining the quantity and distribution of snowfall. In the Swiss Alps, the duration and amount of snow cover have decreased significantly since the mid 1980s. Trends for altitudes below 650 m show a noticeable decrease in snow cover, indicating that winter precipitation is increasingly occurring as rain rather than snow. The sensitivity to these climate fluctuations, mentioned above, disappears at altitudes above 1,750 m, however. Swiss monitoring stations at altitudes below 1,300 m also observed a decrease in the number of days with snowfall in the late 20th century, which is mainly due to an increase in seasonal median temperature. However, the decrease in snowfall at lower altitudes is greater than would be anticipated from global temperature rise alone.

The KLIWA project also looked at long-term behaviour of snow cover in Bavaria and Baden-Württemberg. For the second half of the 20th century, a decrease was observed in the mean number of days with snow cover (snow cover duration) by approx. 30-40% in lower lying areas (< approx. 300 m above sea level). In the higher regions, values of under 10% are observed on average, and even an increase in the winter cover. Thus a reduction in the negative trend can be observed with increased height of the terrain, and occasionally even a trend reversal on mountain ridges and peaks.

Oberstdorf in Allgäu, Bavaria, in January 2007: ski championships cancelled due to lack of snow

Proof of the statistical significance for the found trend values is possible only in isolated cases. Nevertheless, climatological changes can certainly be concluded from the area-wide concurrent trend behaviour of the quantities studied. The trend is doubtless towards milder winters with less snow and with a shorter duration of snow cover.

These studies of trends over the last one hundred years reveal the changes which have occurred; however, these changes are minor compared with the predicted scenarios for the next decades:

A snow cannon in use at a ski resort in South Tyrol

- As a result of temperature increases, the snowline will rise by about 150 m for every 1°C of warming; the seasonal distribution of snow may well change as well. (IPCC, 1997)
- For every 1°C of warming, the duration of snow cover will decrease by several weeks. (IPCC, 2007b)
- A warming scenario of 4° C as projected for the period 1971–2100 compared with current climatic conditions suggests that snow volume in the Alps may respond by reductions of at least 90% at altitudes close to 1,000 m, by 50% at 2,000 m, and 35% at 3,000 m. In addition, the duration of snow cover is sharply reduced in the warmer climate, with a termination of the season 50–60 days earlier at high elevations above 2,000–2,500 m and a full 100 or more days earlier at sites close to the 1,000 m altitude. The shortening of the snow season concerns more the end (spring) rather than the beginning (autumn). The results of this study are of relevance to the estimations of the impacts that the projected warming may have on the start of the vegetation season and on meltwater levels, whose peak will shift to the winter. (Beniston et al., 2003)

Extreme events

The predictions for precipitation and wind speeds react very sensitively to the choice of model and to minor changes in criteria, whereas heat wave trends for the future are regarded as robust. Extremely warm seasons – especially very hot summers – are occurring with increasing frequency in Germany, while extremely cold days are now rarer. The 2003 heat wave across Europe, which had dramatic impacts on nature and society, is statistically very unlikely to occur in a climate such as that of the 20th century. However, it does tally with a combined increase in average temperature and temperature variability. But in a warmer climate in the 21st century, as simulated in climate models, this type of summer will be a fairly frequent occurrence. It is predicted that in future, countries in central Europe will experience the same number of hot days as are currently experienced in southern Europe.

Dried-out bed of the Sylvenstein Reservoir in the upper Isar valley, Bavaria, during the prolonged drought in April 2007

As far as precipitation is concerned, strong seasonal differences occur, as a study commissioned by the Federal Environment Agency shows. In winter, a trend towards greater variability and quantity of precipitation can be observed, which could lead to a noticeable increase in extremely heavy precipitation on a widespread basis. The German Meteorological Service has recorded an increase in heavy precipitation (more than 30 l/sq. m) during the summer months since 1901, at the expense of ordinary summer rainfall. For Bavaria and Baden-Württemberg, too, a clear increase in the levels of heavy precipitation was noted during the winter half-year in the 20th century in the period 1931–2000, but there was also an increase in the number of days with little or no precipitation. It should be noted, however, that trends and forecasts for natural extremes are more uncertain than estimates of median values.

- There is a high probability of more frequent heat waves, such as that which occurred in summer 2003. By the end of the 21st century, large areas of central Europe will experience the same number of hot days as are currently experienced in southern Europe. (Beniston, 2003)
- A warmer atmosphere leads to an increased frequency of heavy precipitation events (> 30 mm/day): by more than 20% with warming of 2° C, leading to substantial reductions in the return period of strong events. (Frei et al., 1998)
- The probability of extremely high seasonal precipitation will increase by a factor of 2-5 over the next 50 to 100 years, with flooding likely to occur more frequently in most regions of Europe. Here, variations in climatic extremes are more likely than changes in median values to have greater impacts on society. (Eisenreich et al., 2005)

Storm over Spitzingsee, Bavaria

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Possible Climatic Changes in the Alpine Region

by Dr. Daniela Jacob, Holger Göttel, Sven Kotlarski and Philip Lorenz

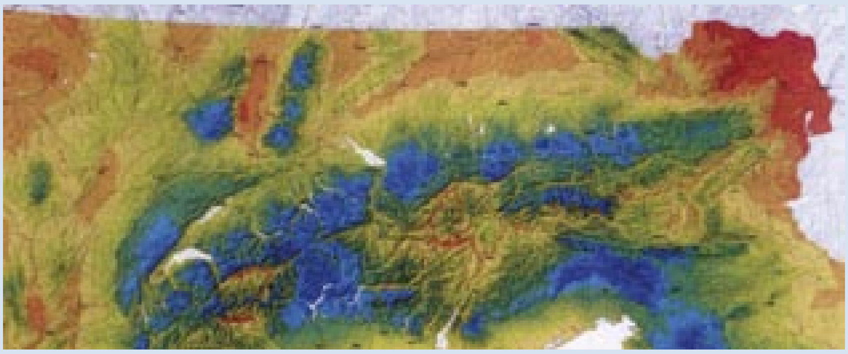
Introduction

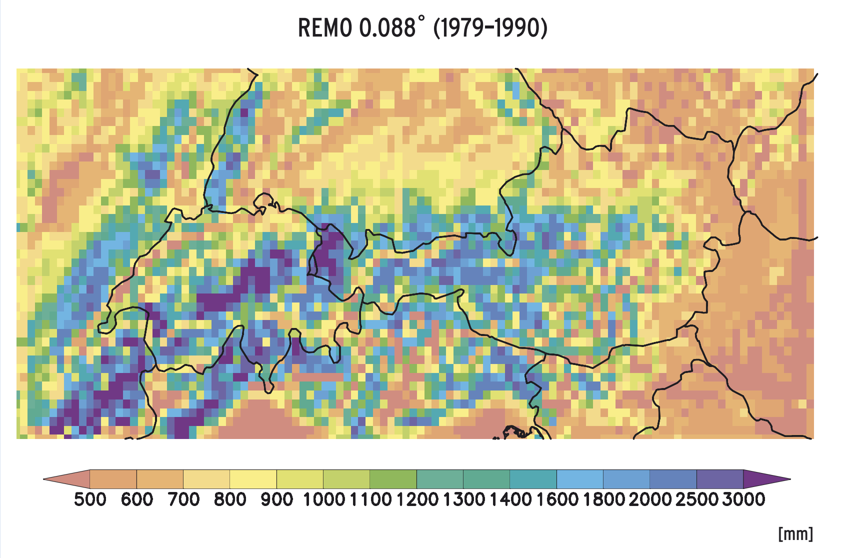
The debate is over: the Earth's climate has changed over recent decades, as a wealth of data collected by meteorological and hydrological services worldwide show. The Alpine region is also affected, and it seems that the impacts of future changes could be particularly serious here.

In order to analyse possible future climatic changes, global climate models have been developed which, together with various assumptions about greenhouse gas emissions in the atmosphere, enable climate scenarios to be calculated for the next 100 years. These computer models can be regarded as mathematical images of the Earth system, as they describe its physical processes in numerical terms and calculate them as realistically as possible. To determine the quality of the climate models, they are initially used to model periods in the past. A time period for which extensive monitoring data are available worldwide should preferably be selected here.

If predictions are also to be made about possible regional or local climatic changes and their impacts, a bridge must be built between global climate change calculations and the regional effects. To this end, regional climate models with a range of detailed information from the region and its environment are embedded in the global models, thus allowing the regional climate to be studied in detail.

Figure 1: Annual precipitation over the Alpine region from observations for the period 1971-1990 (top: Frei et al. 2003) and a REMO simulation with a horizontal resolution of approx.10 km (bottom)





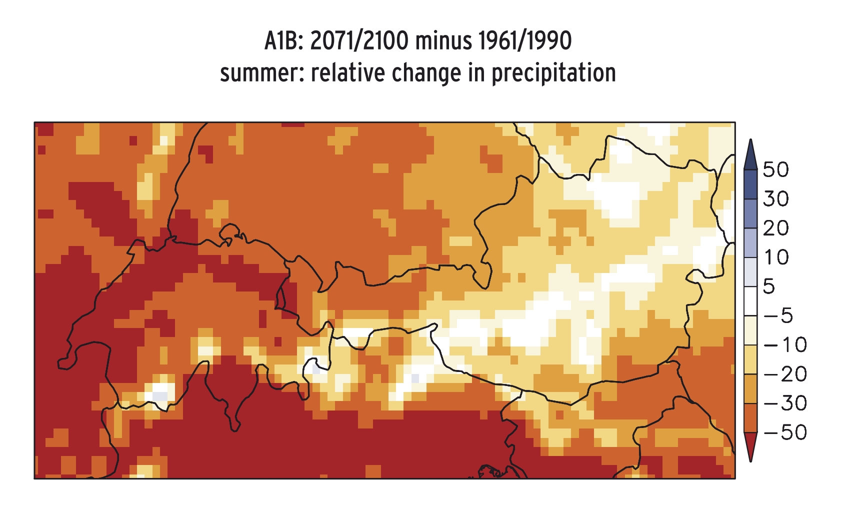
A mountain stream
in spate in the French Alps

Regional Climatic Changes

On behalf of the Federal Environment Agency, the Max Planck Institute for Meteorology (MPI-M) developed scenarios for possible climatic changes in Germany, Austria and Switzerland to the year 2100, which broadly conform with the IPCC's SRES scenarios, i.e. low-emissions (B1), mid-range (A1B) and high emissions (A2) scenarios. The MPI-M received support from the German Climate Computing Centre in Hamburg here. The Regional Model REMO [2,3], which was used for this purpose, presents a very realistic picture of climate trends over the past one hundred years (Fig. 1), as is apparent from the comparison of observations, also in highly structured terrain such as the Alps [1]. This verification process is necessary in order to evaluate the quality of the modelling results. The climate simulations undertaken using REMO were carried out with a spatial resolution of 10 km. As a result, these simulations provide information which was previously unavailable in this level of detail.

The results in detail: more greenhouse gases could lead to moderate warming in the Alpine region, amounting to between 3° C and 4.5° C – depending on the level of future greenhouse gas emissions – in 2100. The amount of annual precipitation appears unlikely to change significantly, however, but there may be a decrease in the amount of precipitation in the summer months (up to approx. 30%). For winter months, an increase of 5–10% is forecast (Fig. 2).

Figure 2: Possible changes in precipitation amounts in the Alpine region for the summer months (top) and the winter months (bottom), calculated in the A1B scenario for the period 2071-2100 compared with 1961-1990



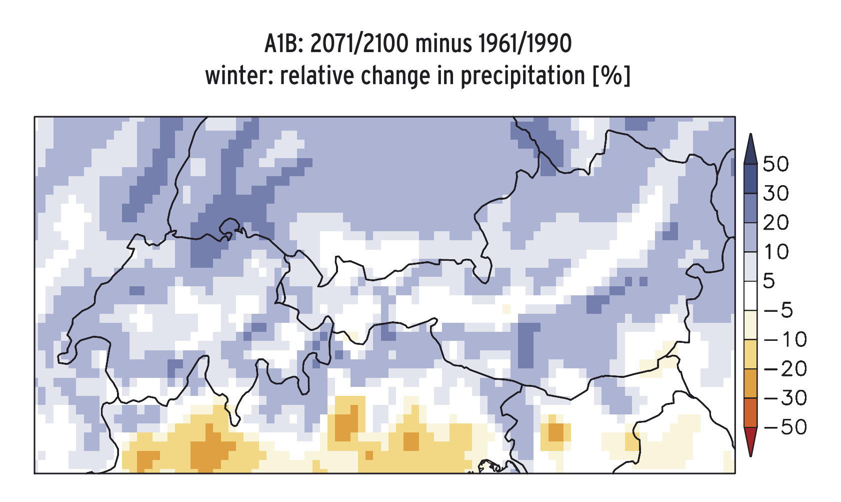
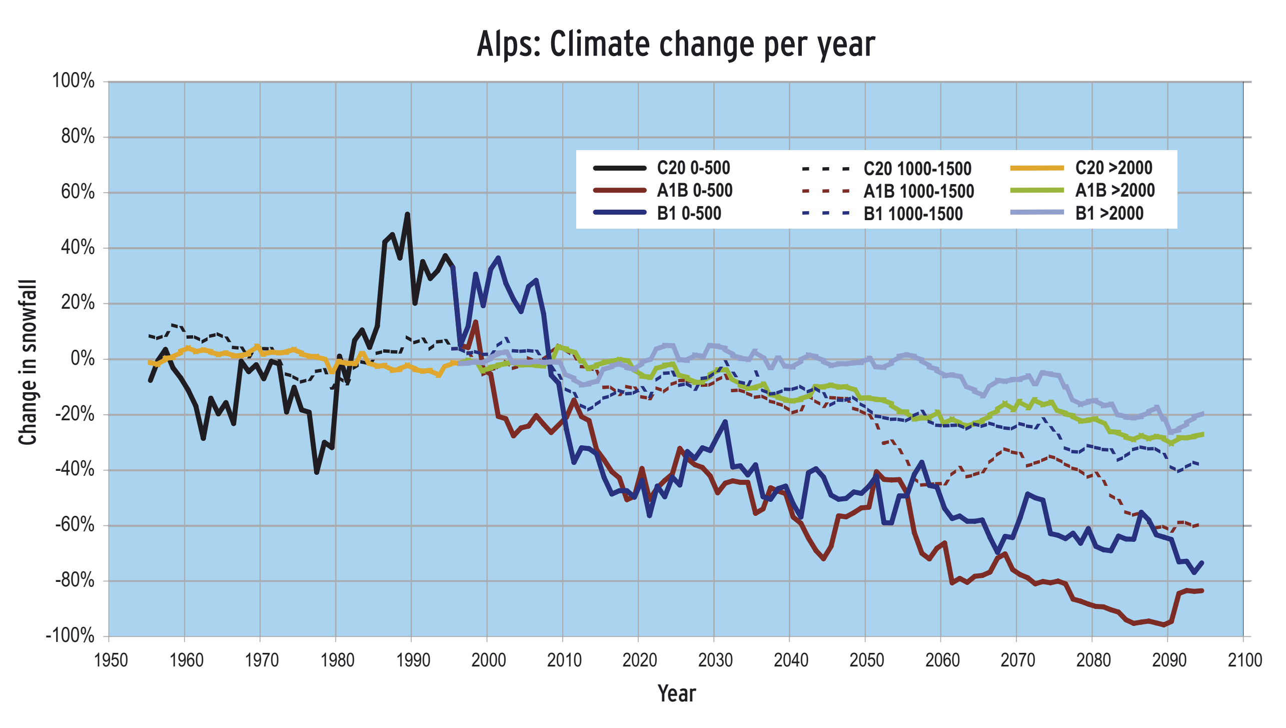


Figure 3: Change in snowfall amount per year for various altitudes (0–500 m, 1,000–1,500 m, > 2,000 m) and the climate scenarios A1B (red) and B1 (blue)



Due to rising winter temperatures in the Alps at the same time – possibly amounting to more than 4° C by the end of the century (A2, A1B) — precipitation will fall more frequently as rain rather than snow. Over the next decades, far less snow could fall at lower altitudes and from the mid 21st century onwards, a decrease in snowfall is predicted even for altitudes above 2,000 m (Fig. 3).

An analysis of temperatures show that in the winter months, a mean rise of 155 m in the altitude of the zero degree line could occur for every 1°C of warming; in other words, by the end of this century, the altitude of the zero degree line could shift upwards by around 650 m if air temperatures at 2 m above ground increase by around 4.2°C compared with the period from 1961 to 1990.

As a result of these changes, the number of days with more than 3 cm of snow per year could be reduced; this would occur to a greater extent in lower lying regions such as Garmisch-Partenkirchen and Mittenwald, for which decreases well in excess of 50% could occur (Fig. 4).

For higher-altitude regions, however, a reduction of only around one-third is calculated. By the end of the 21st century, therefore, snow-covered areas in the Alpine region could shrink very considerably if warming increases substantially (e.g. > 4°C). But even with a temperature increase of 3°C, as simulated to the mid 21st century, very large snow-covered areas that are currently considered to be snow-reliable could disappear (Fig. 5).

Garmisch-Partenkirchen in Upper Bavaria

Figure 4: Possible change in the number of days with snow (> 3 cm) per year in the A1B scenario for the regions Mittenwald and Garmisch-Partenkirchen

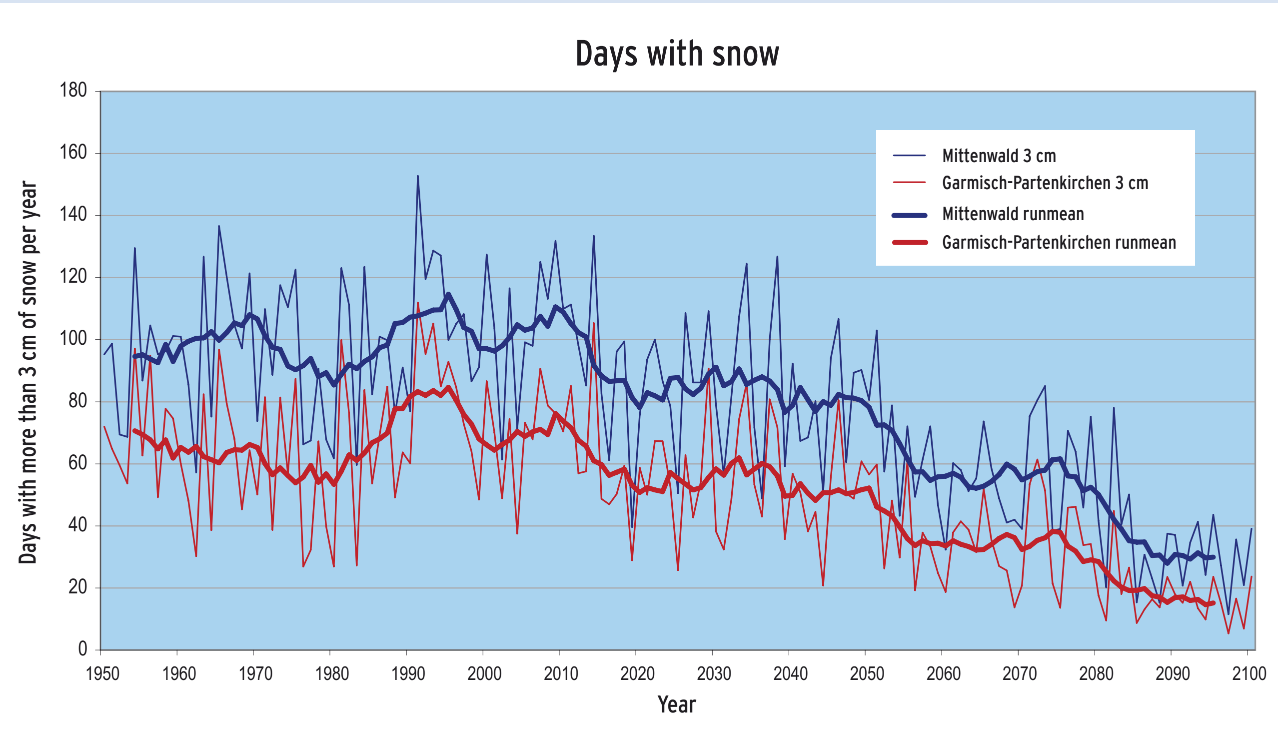
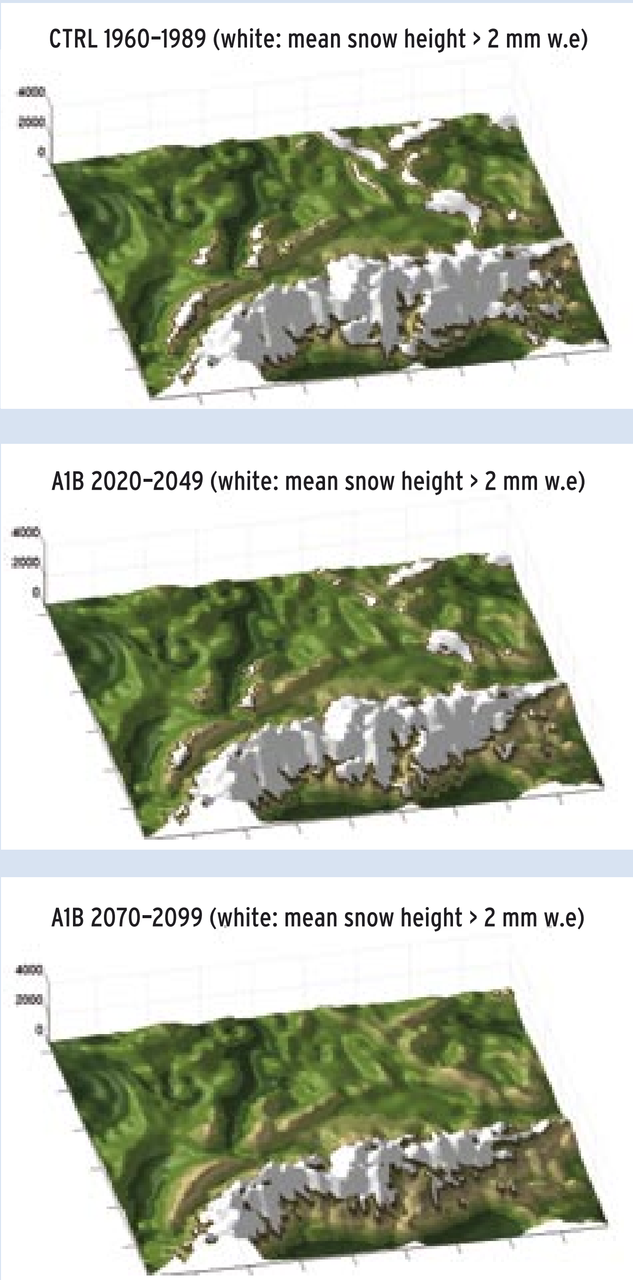


Figure 5: Mean snow heights > 2 mm water equivalent (white) as a 30-year mean based on the A1B scenario



These rapid and far-reaching climatic changes could have grave impacts on human communities and the environment. The potential damage caused by extreme weather events such as heat waves, heavy precipitation and storms is often far greater than that caused by gradual climatic change. For that reason, the Max Planck Institute for Meteorology is currently carrying out detailed analyses of the climate scenarios in order to make predictions about the frequency and force of future extreme events.

Hochkalter (2,607 m) in the Berchtesgaden Alps, Bavaria

Conclusion

All the above findings result from one simulation per emissions scenario. In order to take account of natural variability, many of these possible manifestations of an emissions scenario would have to be calculated. This is being planned and will be carried out in order to analyse the robustness of climate change models.

Furthermore, linkage must now also be established with the environmental and socioeconomic aspects of the Earth system. Regional climate models must be expanded into regional system models which take account of the numerous biogeochemical interactions as well as the influence of human activity.

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KomPass
The KomPass Competence Centre on Climate Change Impacts and Adaptation at the Federal Environment Agency

In the National Climate Protection Programme 2005, the German Government pledged to start work on a strategy for adaptation to climate change in Germany. To facilitate the development of this strategy – including the provision of expert and environmental policy support for its implementation – the Federal Environment Ministry commissioned the Federal Environment Agency (UBA) to establish a Competence Centre on Climate Change Impacts and Adaptation (KomPass).

Remit:

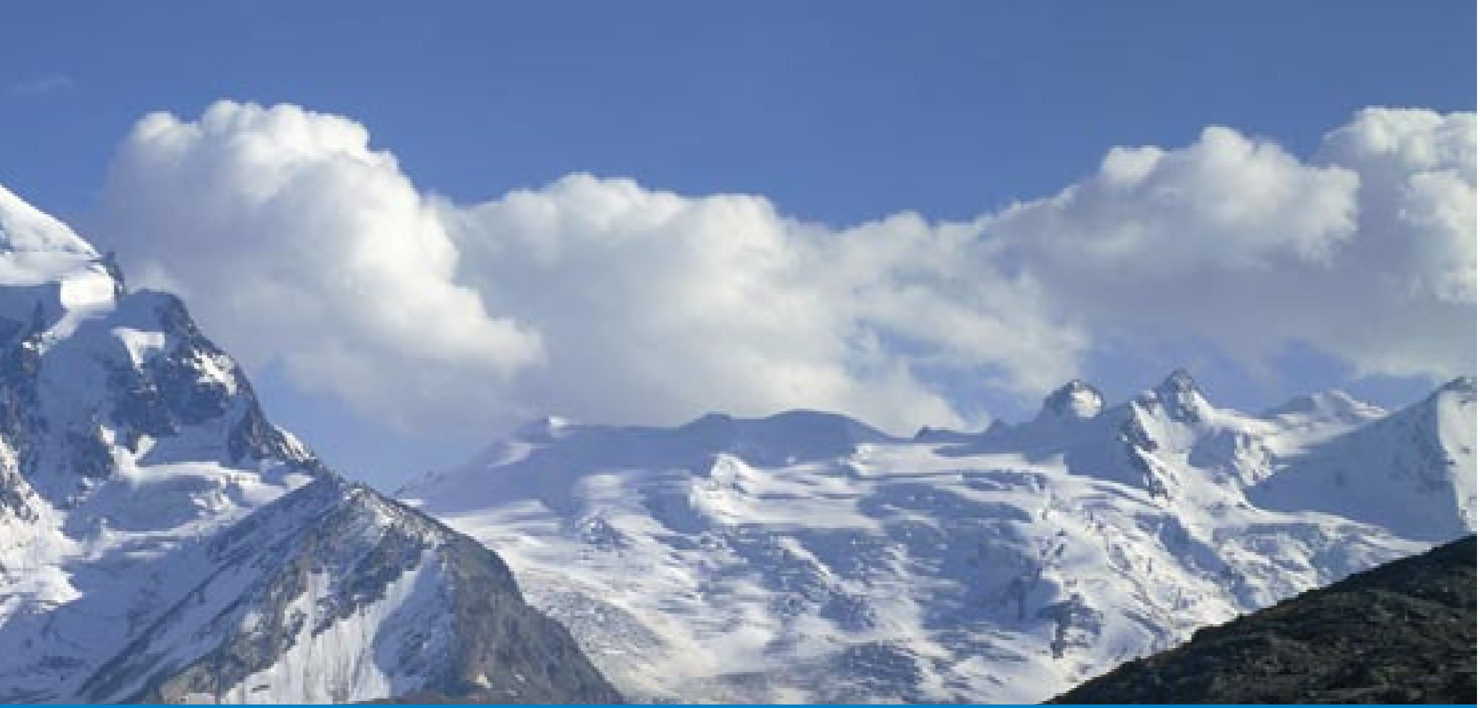
KomPass aims to link fields of expertise on climate impacts and adaptation and to educate decision-makers and the public at large. In this way, the Federal Environment Agency (UBA) is seeking to facilitate the work being undertaken by all the bodies and organisations – in the corporate sector, administration, and business and environmental associations – which must address the issue of adaptation to climate change. KomPass will make available its own climate scenarios, based on various models, and draw together existing knowledge on adaptation to climate change.

KomPass will supply specialist conceptual bases for the identification and implementation of a German adaptation strategy. In this context, a key role is played by issues such as the following: how can vulnerable sectors of our society be identified, along with possible adaptation measures? What will adaptation cost, where do its limits lie, and which political parameters are required for the implementation of adaptation strategies?

Services:

The KomPass Competence Centre on Climate Change Impacts and Adaptation at the Federal Environment Agency will provide the following services on a progressive basis to 2011:

- KomPass – with broad participation by other political actors at federal and *Land* level



– will provide scientific support for the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in the development of the National Adaptation Strategy.

- KomPass will supply data on regional climate change and thus intensify regional climate impact research relating to Germany.
- KomPass will evaluate information on regional climate change and climate impacts and summarise the findings of climate research projects for decision-makers in a clear and understandable way. The summarised findings will be published by KomPass via a searchable information catalogue with reports, brochures, themed papers and background documents.
- KomPass will offer an Internet platform which in future will be supplemented by a specialist information system. The Platform will offer not only Kompass products such as the information catalogue but also projects from cooperating networks, studies, background papers, newsletters and specialist information, as well as a mapping service on regional climate change and impacts in future.
- KomPass will promote networking with actors from the research community, business, administration and non-governmental organisations in order to drive the exchange of experience on adaptation and to address actors' expectations as regards strategy formulation and KomPass itself. KomPass will run workshops and seminars for this purpose.
- KomPass will contribute to the development of a European and an international framework on adaptation.

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THE IMPACTS

So what are the impacts of the climatic changes described above? According to the Intergovernmental Panel on Climate Change (IPCC), mountain regions will experience glacier retreat, reduced snow cover and extensive species extinction. These aspects are discussed in detail below.

Ecosystems

Mountain ecosystems are among the most species-rich sites on the planet and are particularly sensitive to climatic changes. On the one hand, life in the Alps is well-adapted to the cold, but temperatures are noticeably warming. The Alps are characterised by a large number of endemic species of flora and fauna, which have few avoidance opportunities in the face of ongoing climate change. Alpine ecosystems are influenced by a number of factors which are insignificant elsewhere, such as slope angle, the role of root systems in slope stabilisation, a high degree of topographic heterogeneity and the protective function of forests in relation to natural hazards such as avalanches and rock falls. Furthermore, the abundance of unique microclimatic locations and azonal biotopes increases the vulnerability of this unique natural landscape area. On the other hand, vulnerability to global change is heavily dependent on the starting conditions. For example, large areas of the Alpine ecosystem, especially settlement areas and the high mountain meadow zones (alms), are already under pressure from human influence and have undergone profound changes during recent centuries. Projections based on a better understanding of the global climate systems and their

Alpine marmot

associated regional aspects show that future changes will exceed past risks. Moreover, in all probability, the more frequent occurrence of extremes will be at least as decisive, if not even more significant, than gradual climatic change per se.

Although the Alps are certainly the best-studied mountain region in the world, long-term studies of vegetation and species distribution are still hard to find. In particular, there are no comparative studies covering the Alpine region as a whole. Nonetheless, it is almost certain that European mountain flora will be exposed to far-reaching changes as a result of climate change. The IPCC's scientists are very sure that the current level of warming is strongly influencing terrestrial ecosystems. General trends show a longer vegetation period, earlier budding, and an upward shift of some species of flora and fauna. In Europe, for example, the average annual vegetation period has extended by 10.8 days since 1960. Warming could thus be an advantage for late-blooming species. Changes in the duration of snow cover and the vegetation phase will probably also have stronger effects on plant growth than will the impacts of temperature changes alone.

In essence, there are three ways in which mountain flora can respond to climate change: through persistence in the changed climate, migration to suitable climates, or extinction. It is considered likely that plants' primary response will be migration rather than adaptation. On average, most Alpine and nival species could tolerate the direct and indirect impacts of a temperature increase of 1-2°C, but are unlikely to tolerate a much greater change, which could result in many Alpine species losing large areas of their habitat. The fact is that every upward areal shift means a net loss of area because the surface area available at higher altitudes is smaller. Assuming a temperature increase of 3.3°C, which amounts to an altitude change of 600 m, Switzerland is predicted to lose 63% of its Alpine vegetation zone.

In addition, more habitat fragmentation could occur as species of flora and fauna seek colder climes by migrating upwards to isolated mountain peaks. What's more, the microclimatic and geomorphological conditions prevailing at these higher altitudes do not replicate those found at the original lower lying sites.

Furthermore, the displacement of nival species, i.e. species growing in or under snow, could occur as these species cannot migrate upwards. Recent studies carried out as part of the Global Observation Research Initiative in Alpine Environments (GLORIA) project show – in conformity with expectations and models – a withdrawal of nival and subnival species to their lower distribution limit and, at the same time, an upward shift of Alpine species. There is also an increased growth of trees and saplings above the existing tree line in the sub-Alpine zone. As a result, comparisons with historical records show that the species-richness of plants on 30 peaks in the Alps has increased by a maximum of 70%, probably as a result of their spread at higher altitudes. However, this is achieved at a cost, namely the displacement of the species previously existing here. Furthermore, there are also signs that strong selection such as that caused by climate change can lead to rapid genetic differentiation within the plant populations. In parallel, endemic species in mountain regions could also be at risk from the immigration of alien species, which may well speed up with climate change. The extinction of species at geographical barriers, such as high altitudes, will become increasingly visible with the progressive establishment of new species on an increasing scale. Moors in particular are at risk from higher temperatures and longer dry periods, as species which are atypical of high moors could penetrate into these habitats. Many of these trends point to an accelerated change in recent decades.

It is often argued that plants will benefit from the stimulating effect of increased CO_2 concentrations. However, this argument can be refuted for Alpine plants, which are unlikely to benefit from a CO_2-enriched atmosphere. On the contrary, the warming which will occur during the coming decades could lead to a weakening of dominant species regionally or locally, caused by outbreaks of disease. Not only flora but also fauna will have to adapt to the climatic changes. For example, insects seem to be even more sensitive to climatic changes than plants since

Gentian

Ibex

their distribution is generally temperature-limited, which is why they are also faster to react.

Recent studies – albeit based on rough spatial analyses – point to a potential species loss of up to 60%. The same applies to fauna, making mountain regions the most at-risk regions in Europe.

- Empirical studies and model simulations indicate that mountain vegetation responds particularly sensitively to anthropogenic climate change. (Bugmann et al., 2005)
- Climate change could hardly happen at a worse time, as ecosystems have already been heavily modified and destroyed as a result of human activity such as land use, fertiliser application, etc. (Theurillat and Guisan, 2001)
- There is virtually no doubt that even moderate warming triggers a migration process and that this has already begun. (Grabherr et al., 1994)
- Rising temperatures could trigger an upward shift of adaptable and rapidly growing pioneer species and, on the other hand, put slow-reacting plants at a disadvantage or isolate populations on mountain tops. (Körner, 2005)
- In many cases, the indirect impacts will have a far greater effect than temperature rise per se. Above all, the effects of changes in the amount and duration of snowfall will have an impact on Alpine vegetation. (Körner, 2005)
- Species of alpine flora in mountains with restricted habitats above the tree line will suffer biotope loss and severe fragmentation in the event of a temperature increase of 2°C or more. The fact is that a shift to cooler areas is almost impossible for species which inhabit the cold and isolated zones close to mountain peaks. (Dirnböck et al., 2003)

Alpine species therefore appear to react with above-average sensitivity to climatic changes. Climate change is overlaid by land use, however. In recent centuries, for example, many mountain hay meadows have been abandoned, or intensive farming of meadows and pastures has occurred, thereby causing changes in the mountain landscape and forestry which have even more drastic impacts on Alpine biodiversity, potentially reinforcing or weakening the effects of climate change.

Forests and woodland

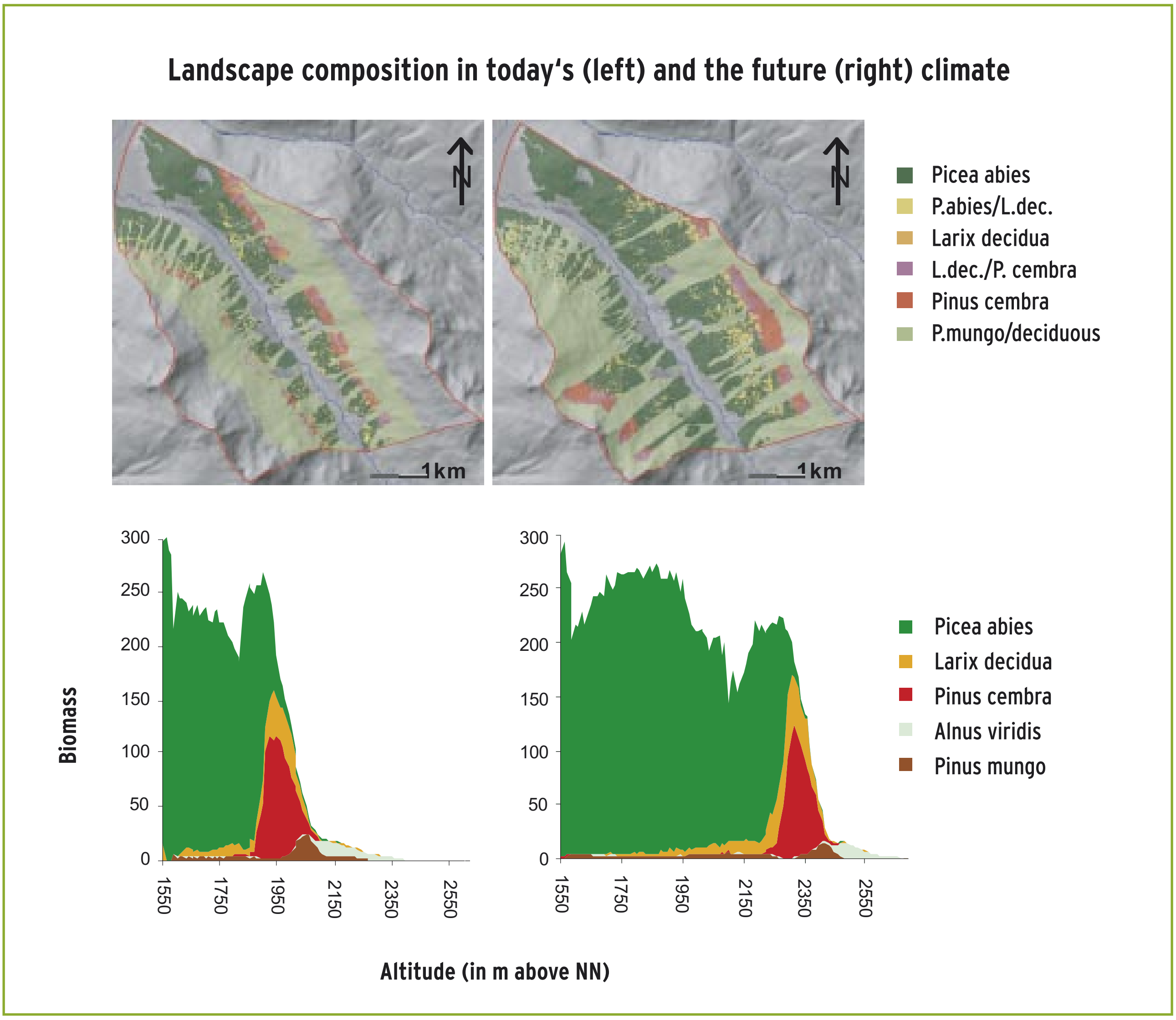
Thanks to the forestry sector, information has been collated on how climatic changes could impact on species distribution and diversity as well as on the timber industry. Climate change will affect forests and woodland too, on the one hand through direct impacts such as changes in temperature and precipitation, and on the other, through indirect effects such as the increased risk of forest fires.

It is not only the warmer temperatures which may pose a problem for some species; biodiversity is also crucially determined by the distribution of precipitation. Model studies show that a temperature increase of 1-1.4°C would alter the classification type of the Swiss forest by 30-55%, and by as much as 55-89% with warming of 2-2.8°C. According to statistical models, beech-dominated forest in hilly to sub-montane zones may well be replaced by oak and hornbeam. It is therefore assumed that forest biodiversity is more likely to increase than decrease in a warmer climate.

Experts disagree, however, about the extent to which the tree line will shift upwards with a general increase in temperature. A shift of several hundred metres seems likely. However, this new potential tree line is unlikely to be achieved everywhere. The Alpine region is densely populated and the majority of forests and woodland is managed, which is why the current tree line is already lower than the natural tree line in some places. Land use is a very important factor which could either reinforce or, if managed appropriately, delay the impacts of climate change. Nonetheless, it is doubtful whether, given future emissions scenarios, there is any prospect of maintaining the current species composition by means of judicious planting, as other effects will prevail.

From a long-term perspective, however, the more frequent occurrence of hot and dry years could impair the composition and diversity of forests and woodland. As a result, fire could probably become as crucial a factor in shaping the landscape as the direct effects of climate change. In addition, an increase in the frequency of storms could reduce the productiveness of forests, with conifers appearing to be more susceptible than mixed forest here.

Impacts of climate change on landscape structure in Dischmatal (Graubünden, Switzerland) in an ecosystem model



Source: Körner, C. et al. (2005)

Furthermore, some studies show that extreme conditions could, over the long term, transform ecosystems from being a net C sink to being a net C source. The forests would therefore no longer absorb CO_2 from the atmosphere, but would instead release it through the process of decay and extinction.

- The direct and indirect effects of climate change will have far-reaching consequences for mountain forests in the European Alps, including their protective function against natural hazards. (Schumacher and Bugmann, 2006)
- A rise in temperature of 1-2°C is unlikely to shift the current tree line by more than 100-200 m. (Theurillat and Guisan, 2001)
- Even a slight rise in the probability of storms occurring could have substantial impacts of economic relevance, comparable with the Lothar storm. (Fuhrer et al., 2006)

Agriculture

Possible impacts on agriculture are very difficult to predict. However, agriculture is likely to be adversely affected, first and foremost, by increasing weather extremes. The 2003 heat wave temporarily reduced the net income of farmers in Switzerland by 11%, amounting to SFr 500 million. Harvest losses of this kind may occur more frequently, for projections show that the probability of droughts occurring in the Alps will increase from the current 10-15% to around 50% by the end of the century. However, the predicted increase in the frequency and intensity of rainfall could heighten the risk of erosion of nutrient-rich surface soils in some areas, unless countermeasures are taken.

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Alpine Ecosystems and Climate Change: Facts and Forecasts

by Georg Grabherr[1], Michael Gottfried[1] and Harald Pauli[2]

The scientific community is currently being called upon to make clear and unequivocal statements about the impacts of climate change. This applies to the tropics and the Arctic and, equally, to the world's mountain regions and therefore also to the Alps. High mountains are "hot spots" of biodiversity. Some 5,000 flowering plants per 100 x 100 km can be found in the Eastern Himalayas or the equatorial Andes, for example, and the Alps – with their 1,500-3,000 species – are not far behind. Alpine flora in the narrower sense – i.e. species which mainly grow on and/or above the tree line – make a key contribution here. Taken together, the Alpine species present in Europe's high mountains account for some 20-25% of Europe's total plant diversity – a remarkably high figure if we consider that the Alpine zone encompasses just 3% of Europe's territory. According to the "logic" of climate change research, it is widely assumed – and this assumption appears to be borne out by macroscale computer models – that such cold-adapted flora will suffer major losses under the postulated climate change scenarios; these losses could range from a decrease in population density to the disappearance of entire populations and, ultimately, species extinction. The latter applies especially to Alpine endemic species, i.e. species with a narrow geographical range, and mountain regions with a narrow Alpine zone. Candidates for this type of species disaster worldwide include, for example, the Australian Alps, the Hokkaido Mountains and in Europe, the Sierra Nevada in Spain, Lefka Ori or White Mountains in Crete, and some parts of the Alps (e.g. the northern-most parts of the Limestone Alps).

So will such catastrophes really happen? In fact, comparisons with records of the flora found in the past (e.g. dating back 150 years) on a number of 3,000 m peaks in Switzerland and Austria appear to confirm that Alpine flora are currently in a state of flux. A clear indicator is the higher number of species on most peaks today. This trend appears to have accelerated recently, correlating with the extremely warm years over the past decade. Precise comparisons undertaken on the Schrankogel (3,497 m) in Tyrol between 1994 and 2004 on more than 300 1x1 m plots clearly show increased population density at altitudes between 2,800 and 3,200 m of species which need more warmth, whereas high-altitude species which need cold decreased in area cover. However, this was not due to invasion of species from lower altitudes. High-resolution computer models for the Schrankogel also confirm, however, that due to the rough relief of the mountain, a few relic populations of the cold-loving flora may be able to survive even in extreme scenarios (e.g. + 5°C in 100 years). It can be assumed that generalised models based on a zonal altitude increase depict the situation in overly extreme terms. Nonetheless, direct observation of the biota is the basic prerequisite for reliable statements to be made. Due to their diversity, Alpine flora – rather than Alpine fauna – are an excellent indicator of the ecological relevance of climate change. In a cultivated landscape – but also in woodland which, with very few exceptions, is affected by forestry and in some cases changed – similar studies provide little information, as other factors such as fertiliser application, timber felling etc. exert far greater influence than climatic changes, other than in extreme events. But even in a heavily used mountain region such as the Alps, there are areas which have never, or only rarely, been directly influenced by human activity.

The Alpine biota has reacted to the climate change that has occurred over recent decades, and its diversity is at risk, at least over the long term and on a regional basis. On the other hand, it offers

Gentian

a unique field for direct monitoring of the ecological impacts of climate change. The Global Observation Research Initiative in Alpine Environments (GLORIA) makes use of this opportunity. Based on standardised methodologies, more than 40 working groups from the Andes to the polar Urals have established permanent monitoring stations in selected mountain regions as a starting point for a comprehensive ecological monitoring network.

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Climate Change Projects in Berchtesgaden National Park

Berchtesgaden National Park

Berchtesgaden National Park is located in the south-eastern tip of Bavaria. It is Germany's only Alpine national park. Ranging in altitude from 600 to 2,700 m, the National Park encompasses spruce monocultures in the development areas of the buffer zone as well as the grassland of the high Alpine zone, which is untouched or hardly touched by human activity. Experts agree that climate change will have a dramatic impact on these sites. Therefore in the National Park's management plan of 2001, the National Park Administration was tasked to monitor global environmental changes in the National Park and to document them using up-to-date tools, especially at altitudes of the core zone which are not influenced, or are barely influenced, by human activity. The following projects are intended to record the impacts of climate change:

Climate monitoring network

Climate monitoring stations are the backbone of the projects being run in Berchtesgaden National Park to document and evaluate global climate change and its impacts on Alpine ecosystems over the long term. Data quality is ensured with the assistance of the German Meteorological Service. The climate data are evaluated with particular reference to extreme weather events and climatic water balance. Last year, some 15 years after the start of monitoring, an evaluation of the climate monitoring network took place, after which the climate monitoring stations at lower and mid-altitude sites were reduced to around 20 stations. However, climate monitoring stations will now be established at higher altitudes above the tree line.

Water springs

Water springs are special habitats with quite specific characteristics. In many water springs, the water temperatures vary by only a few degrees Celsius over the year, with virtually no daily variation. The same applies to many other environmental parameters as well. Highly specialised species of fauna have adapted to these conditions and can also act as indicators of changes. The springs are currently being subjected to zoological and chemical-physical analysis in a five-year cycle in order to document and interpret future changes in fauna. To date,

more than 700 species of fauna have been found in the National Park's springs, including eight species which were new to science; several species are being newly described. Last year saw the publication of Research Report 51, "*Quellen im Nationalpark Berchtesgaden. Lebensgemeinschaften als Indikatoren des Klimawandels*" [Water Springs in Berchtesgaden National Park: Communities as Indicators of Climate Change], which deals with this topic.

Phenology

Phenology is the study of the times of recurring natural phenomena and can encompass observations of both flora and fauna. In plants, phenology observes and records the date of emergence of characteristic vegetation stages (phases). Such phenomena are very sensitive to weather and climate, so they can be used in many different types of application and fields of research. It seems likely that in future, phenological data will be used increasingly in the analysis of climate trends as the dates of emergence of many phenological phases correlate very neatly with temperature trends. In Berchtesgaden National Park, two International Phenological Gardens have been established, one on Schapbach and the other on Kühroint. In addition, phenological observations are under way at around 30 sites in the altitude profile from the area above Wimbachbrücke via Schapbach to Kühroint. This corresponds to a height above NN of around 700-1,400 m. The project was initiated, at the proposal of the National Park Administration, by the Institute of Botany at the University of Salzburg in 1994–1997 and since then has been pursued by the national service. The entire data series will be evaluated scientifically in the near future once funding has been secured.

View from Archenkanzel over Königssee lake

Peak vegetation

This project, led by the Institute of Ecology and Conservation Biology at the University of Vienna, looks at the influence of climate warming on the altitudinal distribution of alpine plants. The Department of Ecology, Geobotany Unit, at the Center of Life and Food Sciences Weihenstephan and the Administration of Berchtesgaden National Park set up a third sampling site on the Graskopf (2,500 m NN) in 2006. Other sites had previously been set up on Schlunghorn peak (2,200 m NN) and Hochscheibe (2,400 m NN). The data are integrated into the National Park Administration‘s central botanical database and shared with the headquarters of the Global Observation Research Initiative in Alpine Environments (GLORIA) in Vienna.

Alpine vegetation

The Department of Ecology, Geobotany Unit, at the Center of Life and Food Sciences Weihenstephan studied the influence of climate warming on the altitudinal distribution of Alpine plants. The long-term studies are intended to act as an early warning system for global climatic changes. Phase II of the project, which is funded by the *Deutsche Forschungsgemeinschaft* (German Research Foundation), revisited around 40 sites at Horstseggen-Rasen and Polsterseggen-Rasen, which had initially been the subject of phyto-sociological studies as part of a project part-funded by the Federal Environment Agency in the Hoher Göll – Schneibstein – Kahlersberg area in 1984–1988. The National Park Administration supported the project through preselection using its own GIS and database data and by surveying in the sample sites using the National Park‘s GPS. The data were transferred to the National Park Administration‘s botanical information system. The study showed that certain species reacted more strongly to warming and can be found in increased numbers at the sampling sites. Diversity in the Alpine grassland has increased. In Berchtesgaden National Park, the comparison of historical and current vegetation records showed clear indications of changed species composition in these habitats. In the last 20 years, many species have shown noticeable population growth and species richness has increased. The increase in temperature has encouraged the growth and reproduction of many species, with the result that they now occur more frequently, with typical “filling” processes taking place. The findings were published in Research Report 52, “*Auswirkungen des Klimawandels auf alpine Pflanzengemeinschaften im Nationalpark Berchtesgaden*” [Impacts of Climate Change on Alpine Plant Communities in Berchtesgaden National Park].

Snow cover project

As part of the GLOWA-Danube Project, which is sponsored by the Federal Ministry of Education and Research (BMBF), a snow cover modelling project is currently being carried out in Berchtesgaden National Park by Munich University‘s Institute of Geography. The project is intended to determine the variability of snow cover and therefore models the amount of snowfall, snow distribution and snowmelt in the National Park. Current climate data are essential for this purpose, so the Avalanche Warning Centre provides data from the automatic monitoring stations at Kühroint/Funtenseetauern, Kühroint and Jenner, and Schönau Climate Station, which is run by the special purpose association of tourist region Berchtesgaden-Königssee *(Zweckverband Tourismusregion Berchtesgaden-Königssee)*. The automatic climate monitoring stations which are planned for the Alpine zone of the National Park in future will be utilised for this purpose once their funding and long-term operation are secure. The project makes a contribution to the GLOWA-Danube Project, in which Berchtesgaden National Park was selected as a "super test site". It provides an entry point into the hydrological and substance flow model which is to become a key element of long-term environmental monitoring in the National Park. It also plays an important role in developing an understanding and therefore providing protection from natural hazards such as flooding and avalanches outside the National Park.

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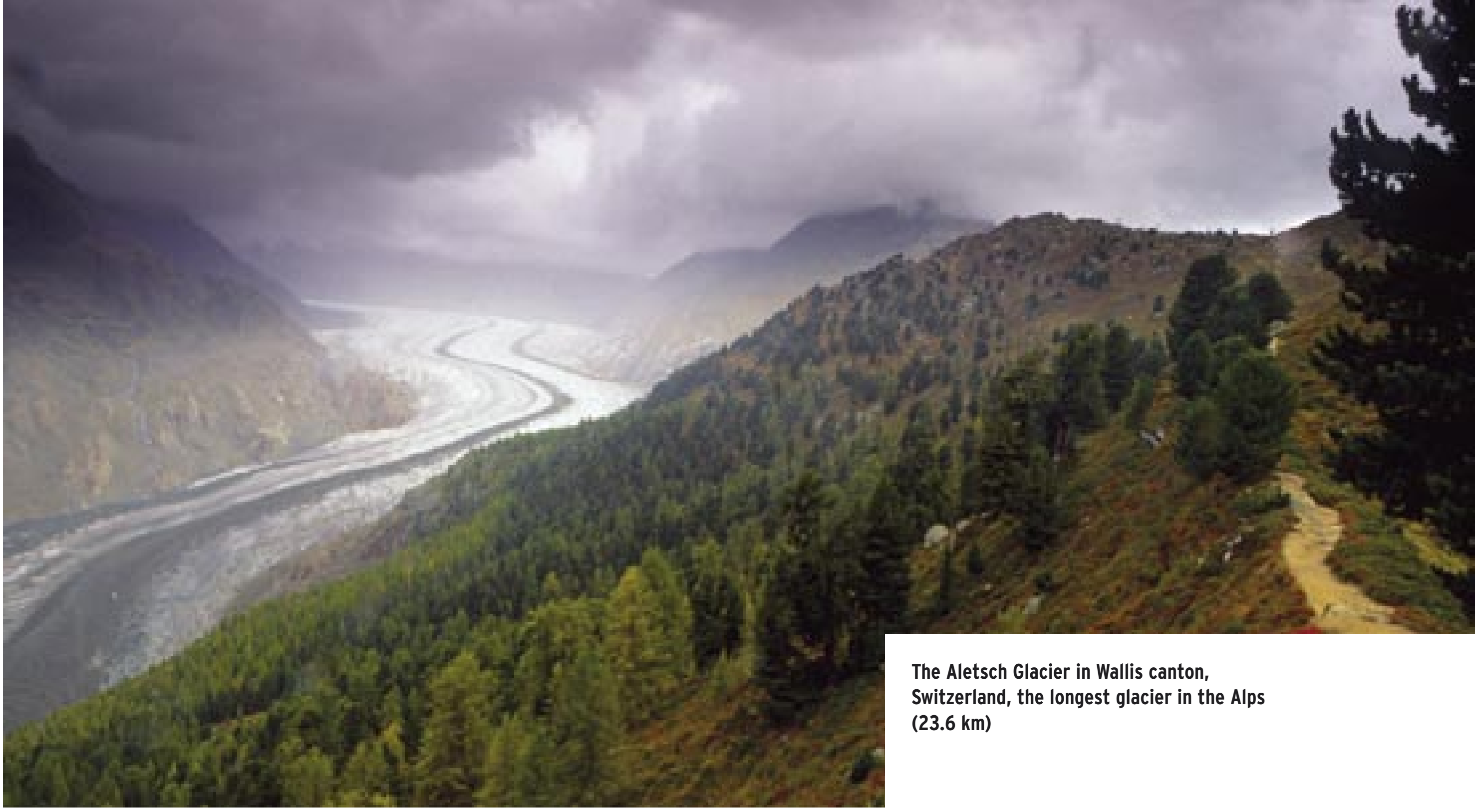


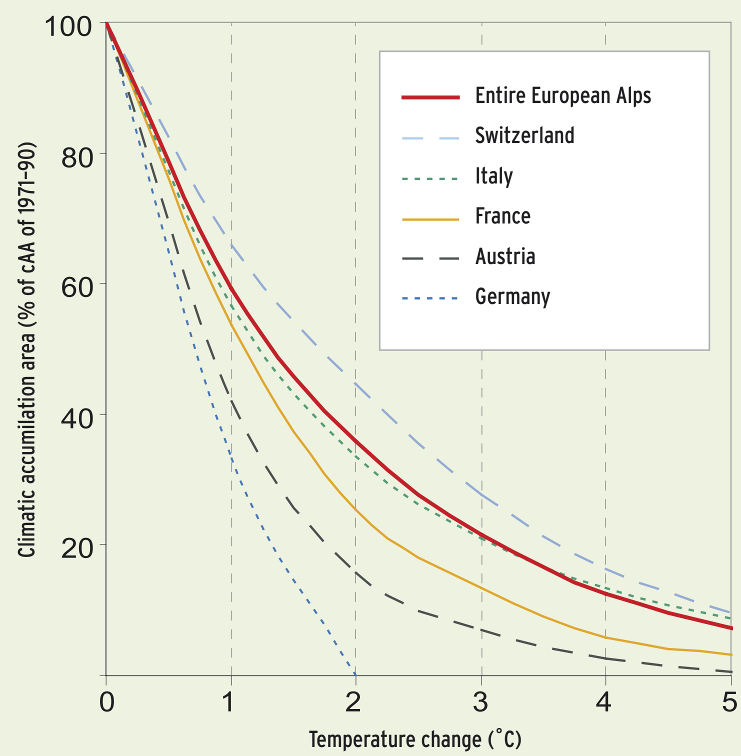
The Aletsch Glacier in Wallis canton, Switzerland, the longest glacier in the Alps (23.6 km)

Glaciers

The glaciers – with few exceptions – are retreating, not only in the Alps but worldwide. This strong retreat is one of the clearest indicators that climate change is taking place and having profound impacts on our environment. In melt conditions, the glacier surface temperature reaches 0°C, which is why glaciers react very sensitively to temperature fluctuations. In addition, the temperature increase in mountain regions was well above average during the 20th century. As a result, for the Alps as a whole, the glacial area has been reduced by 50% since the mid 19th century.

Under climatic conditions such as those modelled in regional simulations – i.e. a greater increase in temperature at higher altitudes, heavier and more intensive precipitation in winter, and dry summers – the European Alps will lose major parts of their glacier cover within the next few decades. Smaller glaciers will disappear, and larger ones will suffer a 30-70% decrease in volume by 2050. The glacier equilibrium line is likely to shift upwards by 60-140 m for every 1° C of warming. In addition, the lower permafrost boundary will probably shift upwards by several hundred metres, which in conjunction with glacier retreat could lead to slope instability.

Modelled remains of the Alpine glacierisation according to an increase in summer air temperature of +1 to +5°C

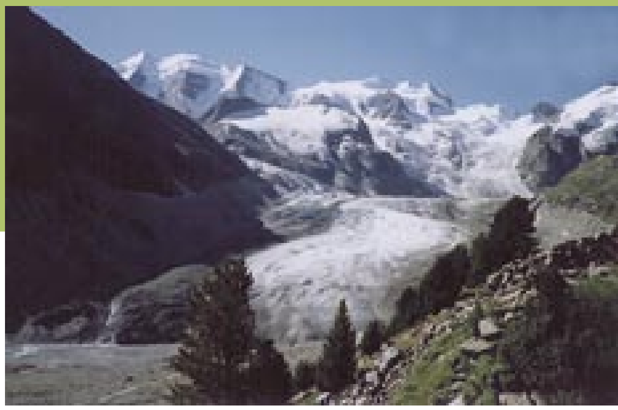


The total of 100% refers to the ice cover of the reference period (1971–90) and corresponds to 1,950 km² for the entire Alps.

Source: Zemp (2006)

Not only glacier cover but also glacial mass and the volume of ice are decreasing. The Alpine glaciers, for example, could lose as much as one-quarter of their mass by the mid 21st century. Indeed, with warming as predicted, up to 95% of Alpine glacier mass could disappear by the end of the century. This would result in substantial losses of glacier runoff in dry periods in summer and early autumn, with major impacts on water resources management in glacier-fed lakes and rivers.

To sum up, it may be argued that glacial regions in mountain areas could be among the regions worst affected by accelerated warming. Unfortunately, due to the complex interaction of numerous variables within the energy balance in these regions, the actual impacts can only be estimated approximately. Research findings indicate, however, that a large proportion of the mountain glaciers existing around the world today could disappear within the next 100 years.



A) Morteratsch Glacier (Switzerland) in 1992

B) The simulated photograph shows how the glacier might look in the year 2035 as a result of a temperature increase of 1.4°C and a corresponding shift of +200 m in the equilibrium line altitude (ELA).

- Alpine glaciers lost 50% in area from 1850 to 2000. A 3°C warming of summer air temperature would reduce the currently existing Alpine glacier cover by a further 80%, leaving just 10% of the glacier extent of 1850. (Zemp, 2006)
- As 90% of the Alpine glaciers are less than one square kilometre in area, the probability that most glaciers will disappear in the coming decades is not inconsiderable. (Zemp, 2006)
- Changes in the cryosphere (ice) of the Alps would have major consequences for the water flow regime of rivers and would also affect shipping. (IPCC, 1997)

Glaciers, the Water Cycle and Water Yield

by **Dr. Ludwig Braun and Dr. Markus Weber**

The Reichenspitz Group on the Gerlossee lake in Hohe Tauern National Park (Austria)

Introduction

The Alpine glaciers play an important role as "water towers" in the hydrological cycle and have a regulating effect on water flow from the high mountain regions. As a result of the warming which has occurred since the mid 19th century, at least 50% of the water stored in the form of ice has flowed off, and if the trend which can be observed over the last 150 years continues, the majority of glaciers could disappear before the end of the century. What would be the consequences for channel flow in Alpine rivers? Are there opportunities to slow down the melting through human intervention?

The Alps: Europe's water tower

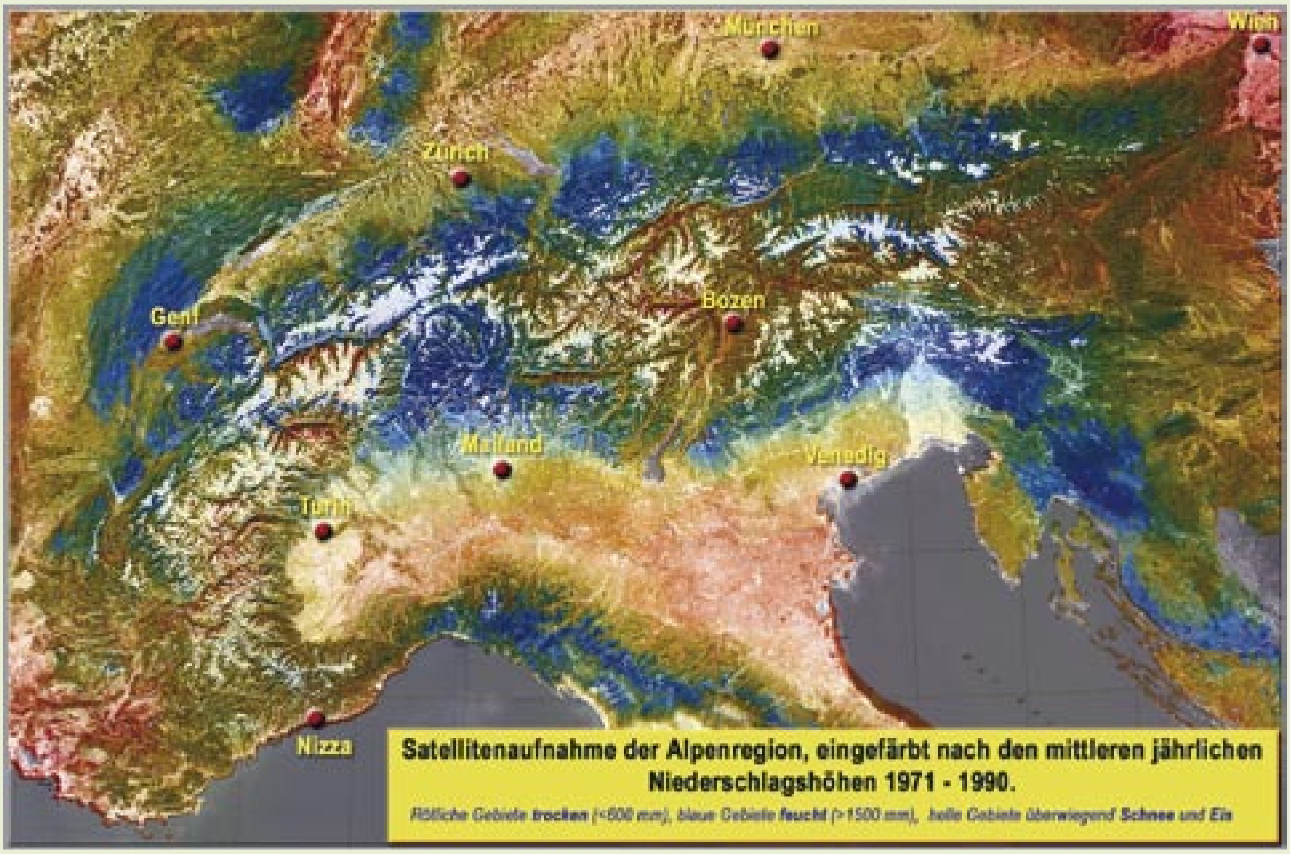
One of the most serious impacts of climate change could be large-scale water scarcity. The summer of 2003 in Central Europe provided a mild foretaste of the problems which Europe could face in future, as do the extremely dry periods currently (i.e. early summer 2007) being experienced in Spain, Portugal and southern Italy. By contrast, Alpine communities and those living directly adjacent to rivers (with the exception of the Po) are obviously less at risk from drought despite the particularly strong increase in median temperatures.

The Alpine countries currently benefit from the particular characteristics of the Alpine climate. The mountains form a considerable obstacle to air currents, forcing the air masses to rise and thus greatly encouraging the formation of precipitation. As a rule, the amount of precipitation on peaks on the weather side of mountains is a good three times higher than in the surrounding area. Precipitation begins to increase noticeably as soon as the air masses approach the mountains.

In the mountains, a large proportion of this precipitation in the annual seasonal cycle initially falls as snow, most of which melts during spring and early summer. The rivers then receive an injection of water, in the form of meltwater, in addition to current precipitation. In unfavourable conditions, this meltwater can be so abundant that it causes the flooding events that are notorious in the Alpine foothills in spring. In general, the reserves of snow in the mountains continue to feed the mountain streams and rivers well into summer, even during dry episodes.

Glaciers and their hydrological significance

Even if no precipitation occurs for a longer period in summer due to fine weather conditions, most of the major Alpine rivers still contain substantial amounts of water. This is primarily due to the glaciers, which formed and were maintained under the climatic conditions prevailing in recent centuries. Rather like the puddles which always appear in the same place after rain or snow, glacial ice was formed at those sites where the balance between the accumulated snow and snowmelt shifted in favour of the former. These sites generally include high-altitude basins and plateaus, or areas of ridges (see Figure, “Satellite image of the Alpine Arc”). This gave rise to the image of the ice-bound Alps, which is borne out by historical records dating from the mid 19th century.



Satellite image of the Alpine Arc

Coloured according to the depiction of mean annual precipitation levels 1971-1990, based on Schwarb et al. (2001, Hydrologischer Atlas der Schweiz, Blatt 2.6), with dry areas (N < 600 mm) shown in red, wet areas (N > 1,500 mm) shown in blue and glacier/snow areas in white. This shows that the majority of glaciers are found in high altitudes in the Central Alps and in the precipitation-rich northern periphery of the Alps. Image processing: M. Weber

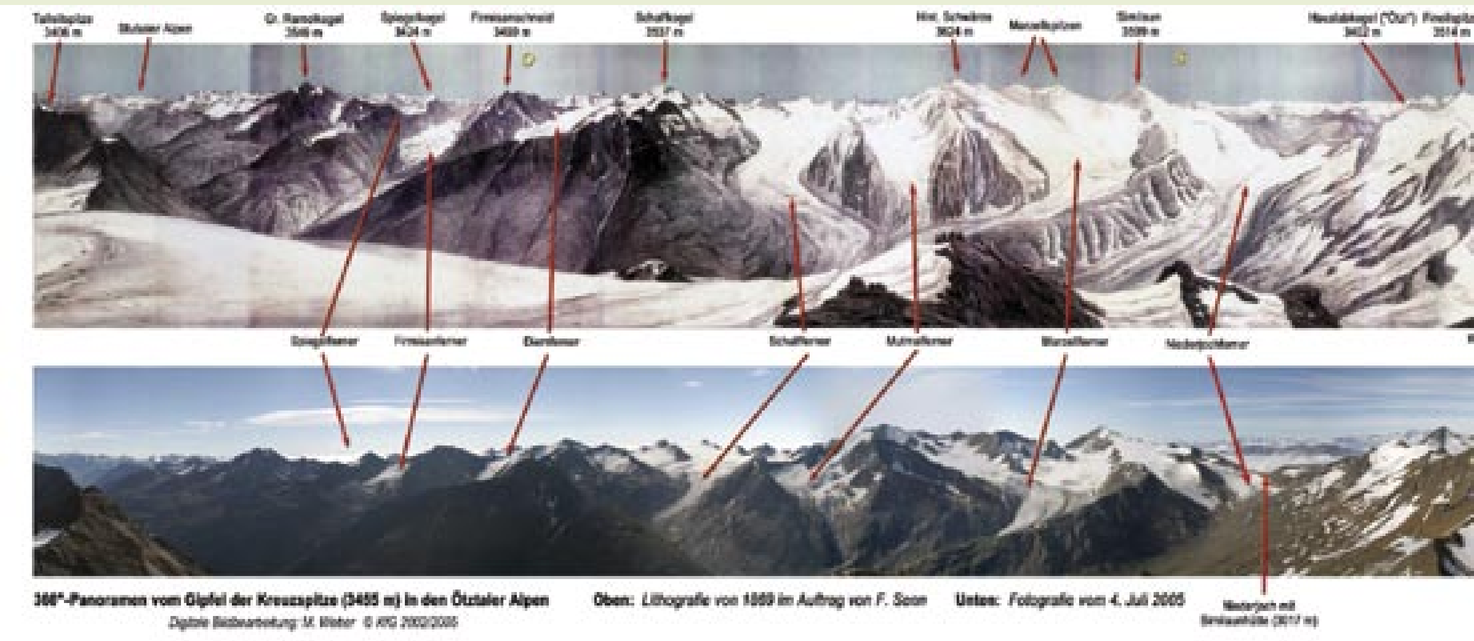
It was then that the glaciers reached their most recent maximum positions. Today's Alpine glaciers are therefore not relics of the last Ice Age but have been continually renewed by the interaction between the processes of snow accumulation and melting.

Since the glaciers reached their most recent maximum position around 1850, glacier equilibrium – which maintains a balance between the accumulation zone, where snowpack is retained to the end of summer, and the ablation zone, where all accumulated snow from the winter is lost – has clearly shifted towards ablation, due to the gradual warming of the air temperature near the ground. The glaciers are no longer increasing in size; on the contrary, they are losing much of their substance accumulated prior to 1850.

At the end of the 20th century, there were still around 5,000 glaciers with a total area of 2,500 km^2 and an estimated ice volume of 125 km^2 in the European Alps. Around 1850, however, the figures would have been at least twice as high. Detailed observations of changes in the mass of selected glaciers also show that losses in glacial mass have been especially high in the last 25 years, amounting to at least one-third of the original total mass. Rather like a bank account whose balance constantly changes as a result of incoming payments and outgoing expenditure, the shrinking of the glaciers could be attributed both to a decrease in snowfall and to stronger snowmelt. Studies on this issue, e.g. at the Vernagtfern-

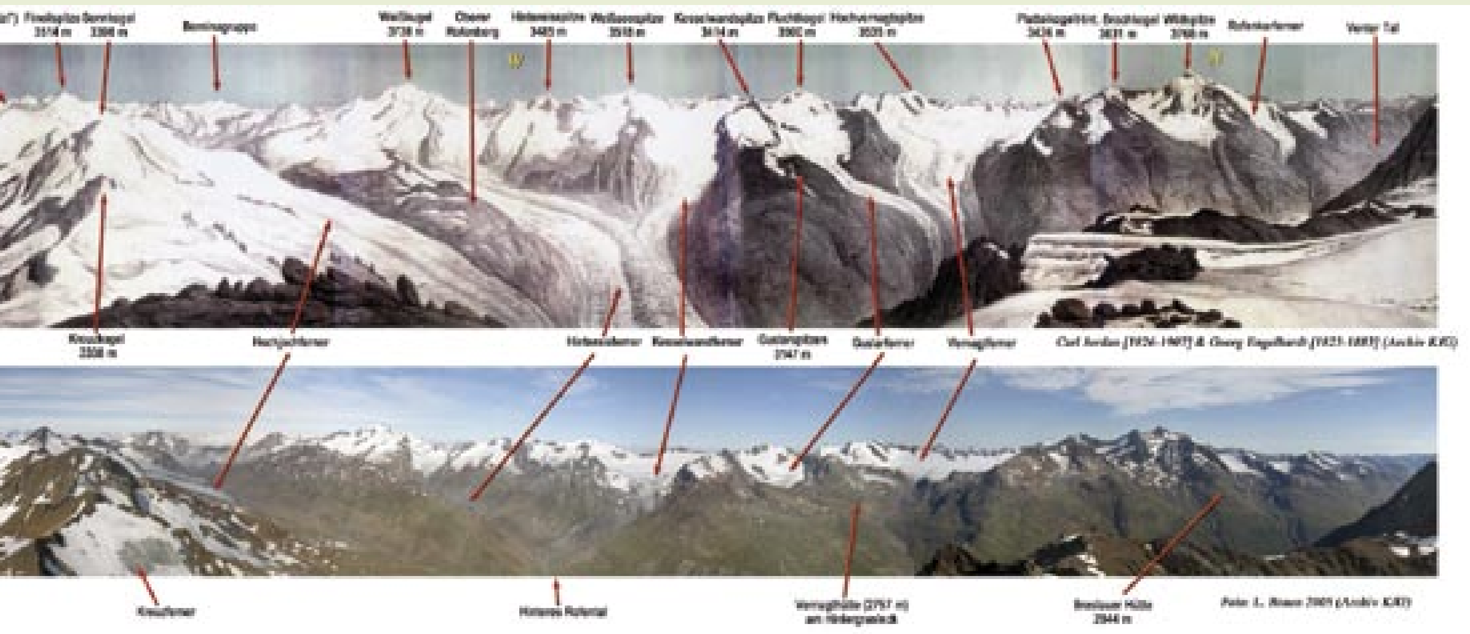
360° panoramic view of the glaciers in the rear Ötztal from Kreuzspitze, 3,455 m

The top picture is based on a drawing by Engelhard and Jordan done in 1869; at the bottom is a photograph from July 2005. A comparison shows the detail and accuracy of the older picture, but also the extent of deglaciation within the last 136 years in this region. Image processing: M. Weber

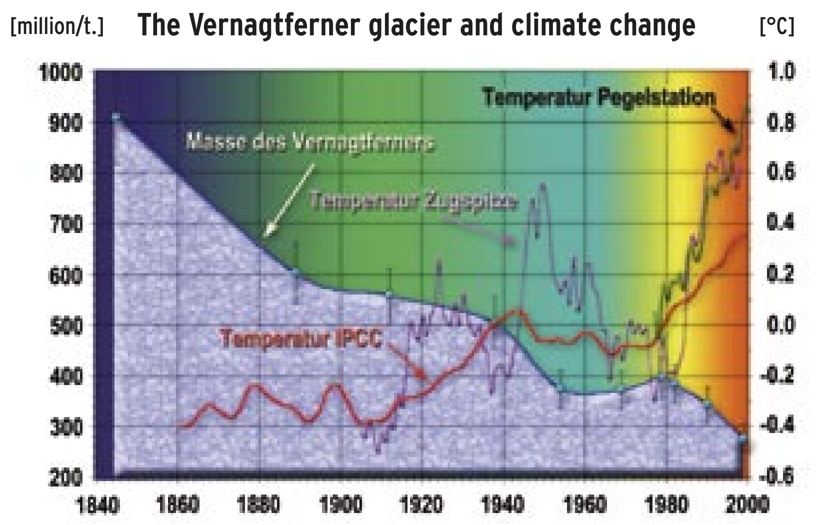


er glacier in the Ötztal Alps, show that the amount of snow falling in winter has not changed significantly, whereas the amounts of meltwater produced in summer have virtually doubled since the start of monitoring – even though the area of the glacier has steadily decreased to around two-thirds of its original size. Returning briefly to the bank account metaphor, the outgoings exceed incoming payments to such an extent that in the near future, there is a real risk of insolvency: in other words, the disappearance of most of the Alpine glaciers.

Vernagtferner Glacier in 1844 and 2001



Decrease in mass of the Vernagtferner glacier since 1846 in relation to the rise in mean temperature in the Northern Hemisphere (IPCC) on the Zugspitze peak since 1990 and at Vernagtbach gauging station since 1974



When and where glacier discharge begins

So what makes glaciation so sensitive to climatic changes and causes glacial streams to swell to such extent? The solution to this conundrum can be found in summer. To the layperson, glaciers are only visible in summer when they are quite distinct from their snow-free surroundings. This is also when the many glacier streams are noticed, which carry glacial meltwater quickly and efficiently into the valley. It can be observed that the water flows are most abundant on hot and cloudless sunny days, for it is incoming solar radiation which supplies most of the energy needed to melt ice and snow.

It would be logical, then, to expect the highest quantities of meltwater to be produced around noon during the days of early summer, when the position and intensity of the sun reach their peak. In fact, the highest discharges do not occur until high summer, generally during the first half of August. The reason is that meltwater formation does not depend solely on the supply of energy (solar radiation) but also on the proportion of this energy that is absorbed and utilised.

A snow-free glacier produces far more meltwater

In essence, a glacier melts in the same way as an ice cube in a bowl. On its surface, energy is absorbed from the environment and is used for phase conversion as soon as the surface temperature reaches freezing point. Heat exchange between the atmosphere and the glacier is a complex process which depends not only on the radiation and temperature conditions but especially on air movement and humidity as well. In simple terms, the lighter and smoother the snow and ice surface, the less energy it absorbs. A dark crevassed ice surface absorbs at least 4–5 times more solar radiation and heat energy than fresh smooth snow.

As long as the glacier is snow-covered, melting occurs slowly as most of the incoming solar radiation is reflected and is therefore not available to the melting process. However, if the dark ice of the glacier appears from under the snow, as much as 10 cm of ice can melt on a warm summer's day. This process is known as "ablation".

The meltwater that is formed flows along crevasses and fractures in the glacier's surface (meltwater streams; see photo of a surface ice channel on p. 54, left) and englacial channels (glacier mills – channels and tunnels; see photo of an ice cave on p. 54, right) and finally through a network of channels, comparable with a municipal drainage system, along the base of the glacier, where it merges and flows out at the glacier mouth, causing strong diurnal variations in the channel flow of the glacial stream. The quality of the accumulation zone is important in this context. If

Vernagtferner Glacier in 1898, 1992 and 2005

more than two-thirds of the entire surface area of the glacier is covered with snow that has been left over from past seasons (firn), the water is retained, rather like a sponge, for days at a time and then discharges slowly. This was the case in the second half of the 1960s and in the 1970s, when mass budget conditions were favourable to glaciation. Following the years of heavy loss of glacial mass, observed since 1980, the firn-covered surfaces have become greatly reduced, resulting in stronger and swifter meltwater runoff and far greater diurnal variations in the glacier stream (see photos on p. 55, top). Accelerated loss of mass, on the other hand, results primarily from an increase in the number of days with strong glacial melt compared with "before". An extreme scenario was observed in 2003, when instead of the usual 10–20 days with strong melting, 100 such days suddenly occurred. This observation tallies with climate models, which do not necessarily predict warmer days at all times, but forecast an increase in the number of hot and above-average warm days.

Glaciers as the source of flooding

Climate researchers predict that in future, precipitation in the summer months will be limited to a few very heavy short-term events. Due to the continued upward shift of the frost limit, precipitation will fall as rain, even up to high altitudes; this removes the earlier and effective self-protection mechanism against flooding, for the short-term storage of precipitation in the form of snow delayed the discharge of water and protected the Alpine valleys from more serious disasters. Under current conditions, the far more abundant meltwater produced on hot days may merge and become overlaid with runoff from thunderstorms, as occurred on 4 August 1998 in the Vernagtbach catchment in the Ötztal Alps.

Accelerated glacial melt and shrinking glaciers

Some glacial melt processes have a self-reinforcing effect, with the result that despite their decrease in area, the glaciers are losing more mass year on year. For example, released sediment is increasingly working its way to the ice surface, making it appear even darker and further increasing the absorption of solar radiation. Furthermore, the decrease in the snow and ice surface is causing a further rise in the frost limit, for the reduced warming of the near-ground layer of air caused by melt in glaciated areas produced somewhat lower median temperatures in the Alps compared with lowland.

The increasingly unfavourable relationship between glaciated and snow- and ice-free area is thus resulting in accelerated warming in the Alpine region and therefore to even more intensive glacial melt. A stronger increase in the local temperature in the Alps compared with the global median temperature can already be observed.

Glacier farming?

The management of glaciers, e.g. through ski tourism, becomes a problem if pollution and mechanical stress reduce the snow's reflective capacity and changes the surface properties. Due to increased absorption of solar radiation and therefore melting heat at local level, this may increase glacial melt. In general, however, this can be regarded as a subordinate problem. By contrast, operators of ski lift systems are attempting, at local level, to slow down the melting process through "snow farming" by adding additional snow under the apparatus or piling it up for the halfpipe and covering it with light reflective material.

However, these measures are only intended to protect the installed systems, not preserve the glacier in its entirety, for they are localised in scope and have a very limited effect.

Drainage channels on the surface (left) and in the ice body (right) of the Vernagtferner Glacier

Summary

The changes occurring in the Alpine glaciers are clear evidence of climate change and are visible to everyone. General glacial melting has been under way for around 150 years, with a brief period of recovery and glacial advance in the 1960s and 1970s. At present, during hot dry summers, the consumption of the ice reserves is causing above-average water flow from the high mountains, thus preventing serious drying out of mountain rivers. If the glaciers disappear, however, no such input during dry periods would occur. Channel flow in the rivers would then depend solely on precipitation, which varies considerably. Not least, deglaciation would alter the appearance of the mountain regions in a negative way, so these regions would lose some of their appeal for tourists. In the mid 1970s, mean increases of 30 cm per year could be observed in the Vernagtferner glacier, and in order to offset the loss which occurred in 2003, seven wet and cold years of the type seen in summers in the 1970s are required.

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Peak values of runoff at Vernagtbach Gauging Station have more than doubled since the start of continuous monitoring in 1973

Comparative views of the Platt with the Schneeferner from Zugspitze peak in 1890 (top) and 2003 (below). The protective sheeting laid out by ski operators are visible in the bottom photograph.
Photos of 10.8.2003 and image processing of archive photo: M. Weber

GLACIERS IN THE GREENHOUSE and GLACIER ARCHIVE

A Project by the Society for Ecological Research

The most visible sign of climate change is the melting of the glaciers. Therefore, in 1999 the Society for Ecological Research *(Gesellschaft für ökologische Forschung e.V.)* set up the Glacier Archive, a photographic documentation comparing glaciers throughout the Alps.

The archive is based on a collection of 7,000 historical photographs of Alpine glaciers. Postcards and photographs from the beginning of the last century are contrasted with recent pictures of the same site taken from the same vantage point. New photographs of these comparisons are currently being taken.

The pictorial comparisons document the rapid melting of the Alpine glaciers. This comprehensive work is extremely important, for the very subject of the development it records is progressively disappearing.

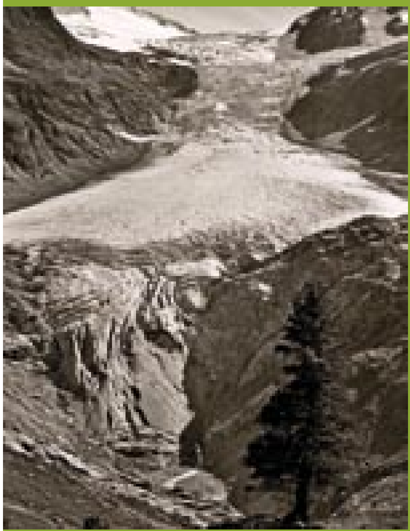
The *Society for Ecological Research* focuses on ecological relations in major photographic exhibitions, for example the exhibition "Beautiful New Alps" (1998–2003), which toured the entire Alps region.

The project Glaciers in the Greenhouse has been on exhibition since 2004 and is continually updated. It has met with a positive response both at home and abroad. The exhibition not only illustrates the disappearance of the glaciers, it also provides information on global climate change: the greenhouse effect caused by industry is considered the main cause.

The projects Glaciers in the Greenhouse and the Glacier Archive (for more information see www.gletscherarchiv.de English site in preparation) have thus become an important source of information about climate change and its consequences for the Alpine region.

The book "Glaciers in the Greenhouse", containing over 100 glacier comparisons and numerous articles by experts was published to accompany the exhibition.

The glacier project is supported by Greenpeace.



Trift glaciers, Gadmental, Switzerland, 1948, 2002 and 2006

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Natural hazards

Alongside the above-mentioned weather extremes such as heavy precipitation or drought, natural hazards are especially relevant in connection with glaciers and permafrost in Alpine terrain. Changes in glaciers, snow cover and permafrost and especially the resulting natural hazards can be regarded as some of the most visible sides of climate warming and have a major impact on human communities. Human and environmental vulnerability in Alpine communities therefore appears to be increasing rapidly.

The Swiss National Platform for Natural Hazards (PLANAT) warns that the general warming and more intensive precipitation that is predicted will facilitate the formation of debris flows and slope failure, while slope stability is reduced as a result of permafrost melt. There is a concern that hotter summers, as forecast in the climate models, will lead to increased instability of rock faces and cause rock falls in the coming decades, putting valleys at risk. During the last century, Alpine permafrost warmed by 0.5-0.8°C. Fitting in with this picture, during the very hot summer of 2003, an unusually high number of rock falls occurred in the Alps. This could be regarded as an early and unexpected sign of climate change. Furthermore, the development and growth of glacial lakes, caused by the melting of the glaciers, increase the risk of debris flows and devastating outbreak floods. Scientists predict that both the number and the size of these glacial lakes will increase. However, according to current scientific knowledge, the occurrence of avalanches does not appear to be influenced by climate change to any measurable extent. Thus the potential hazards associated with glacial and permafrost melt include:

- outbreaks from glacial lakes, causing flooding and debris flows
- ice falls and ice avalanches
- stable and unstable (abrupt) glacier changes
- destabilisation of rock faces
- combinations of, and chain reactions between, these events (Kääb, 2005)

Cars are buried in debris after a scree avalanche in a Swiss Alpine village

The examples of adaptation in the Monte Rosa massif on the Italian-Swiss border, where a potentially dangerous glacial lake was artificially drained, and the construction of barriers in Pontresina (Engadin, Switzerland) to protect the community from the threat of debris flows resulting from permafrost melt, are niche examples compared with the scale of the anticipated changes in the Alpine region. There is an urgent need for efficient natural hazard assessment and mitigation methods which must go beyond short-term project financing, so that climate change can be incorporated more effectively into risk assessment and policy-making on natural hazards.

Adaptation to climate change also requires more flexible and forward-looking natural hazard management. Traditionally, natural hazard management has been based on empirical experience and past events, but this no longer appears appropriate in light of climate change. Preventive measures should therefore take account of more frequent and stronger weather extremes.

Furthermore, risk maps should be updated more frequently and the quality of their data on future risks should be improved. Cost-effective methods are required to take account, on a regular basis, of the rapid changes occurring in high Alpine regions and identify the most vulnerable areas.

Eschenlohe municipality during the flood disaster in the Bavarian Alps in summer 2005

Satellite-based remote sensing and good modelling can support the evaluation of natural hazards resulting from accelerated change in the Alpine region. The macroscale influence of the climate will far exceed any human-induced environmental impacts at local level. The major challenge, therefore, is to adapt to these impacts of climate change.

Porous rock in the Dolomites, Italy

- The great potential of natural hazard assessment using numerical models and remote sensing should be fully exploited.
- Risk maps should take account of the changed risks.
- Objective scientific criteria should be developed to assess the risk potential of natural hazards, and should be applied internationally.
- More intensive information exchange on natural hazards between the scientific community and policy-makers is essential in order to raise awareness and increase the willingness of local authorities to utilise and build on existing knowledge.

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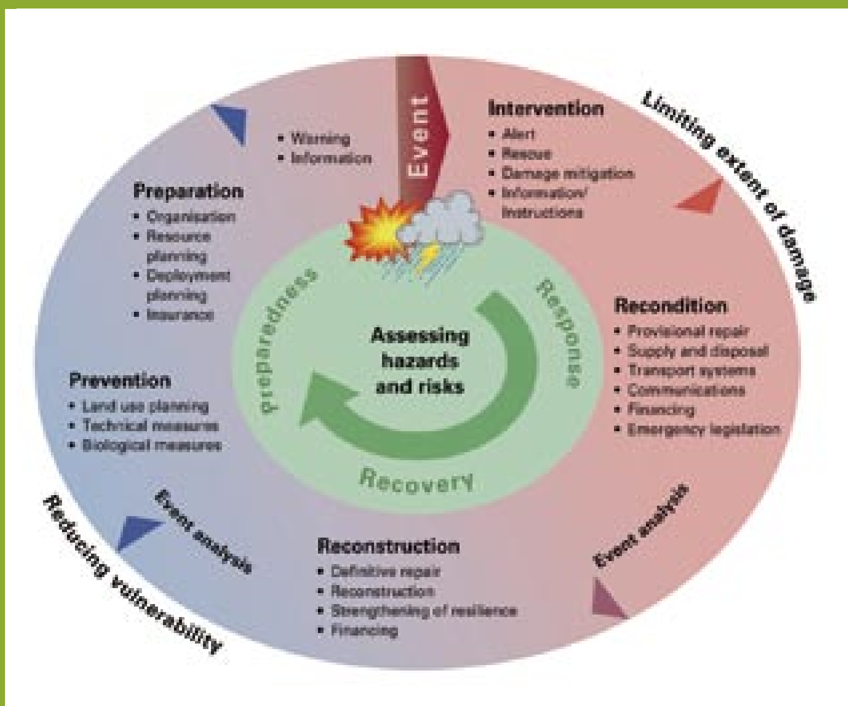
The Platform on Natural Hazards of the Alpine Convention (PLANALP)

The extent of the damage caused by natural hazards is constantly increasing. The main reasons for this include the concentration and increase of value, more vulnerable infrastructures, and increasing requirements with regard to mobility. Climate change in the Alpine region exacerbates these impacts. Strategies and measures that are agreed across the Alpine region as a whole are therefore urgently needed. The Platform on Natural Hazards of the Alpine Convention (PLANALP) was established by the VIIIth Alpine Conference in November 2004. It develops joint strategies for the mitigation of natural hazards and advises on appropriate adaptation strategies.

Debris flow after heavy rain in September 2005 in Schoppernau/Vorarlberg (Austria)

After the devastating avalanches and floods of 1999, the Alpine Conference appointed a working group to develop common strategies and activity fields on the level of the parties to the Alpine Convention, with a view to establishing a Platform on Natural Hazards. PLANALP was then appointed by ministers at the VIIIth Alpine Conference in 2004. The mandate of PLANALP covers both the formulation of strategic concepts on integrated risk management against natural hazards and the coordinated implementation of subsequent measures.



Integrated risk management means the entire process in a cycle of preparedness, response and recovery.

Source: Bundesamt für Bevölkerungsschutz, Schweiz

Eschenlohe municipality during the flood disaster in the Bavarian Alps in summer 2005

The contracting parties to the Alpine Convention delegated high-level experts to PLANALP in order to ensure effective networking and coordination of mitigation activities in the Alpine region. Andreas Götz, a Vice-Director of Switzerland's Federal Office for the Environment (FOEN) and President of the Swiss National Platform for Natural Hazards (PLANAT), is the current chair of PLANALP. PLANALP works closely with the relevant professional international and national institutions in the field of natural hazards.

After beginning work, PLANALP focussed primarily on the exchange of knowledge and experience among its member countries. To the end of 2007, PLANAT is undertaking an in-depth analysis of current management tools and practices in the Alpine countries for dealing with natural hazards. This is part of a comprehensive focal point project on climate change funded by the INTERREG III B Alpine Space Programme.

In November 2006, PLANALP's long term working programme was approved by the IXth Alpine Conference. Principal topics include "Integrated Risk Management", "Early Warning Systems" and "Risk Dialogue". In dealing with these issues, the economic, social and environmental aspects of sustainability are a particular focus of attention. There are plans to provide information on selected topics such as "taking account of climate change in the development of protection strategies".

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The "ClimChAlp" project

A scree avalanche close to a Swiss farmhouse

How will climatic changes impact on natural hazards?

The **ClimChAlp** ("**Clim**ate **Ch**ange, Impacts and Adaptation Strategies in the **Alp**ine Space") project is a Bavarian initiative for the Alpine countries to adopt a joint approach to the challenges posed by climate change in the Alpine space and develop adaptation strategies.

ClimChAlp is the foundation stone for an "Action Plan for the Alps" in which adaptation to the unavoidable effects of climate change is addressed as an urgent issue. The project establishes the scientific bases and develops strategies for adaptation to climate change in the Alpine space.

Adaptation to climate change in the Alps is a very important field of activity as the Alps are affected in two ways: firstly, in the Alps, the temperature increase is almost twice the global average, and all the climate models forecast greater temperature increases in future too; and secondly, climate change has particularly severe and in some cases unforeseeable impacts in the Alps, as a highly sensitive ecosystem.

A total of 22 partners from the Alpine countries of Slovenia, Italy, Austria, Switzerland, Liechtenstein, France and Germany are participating in this international project. Ministries and subordinate authorities at individual state and provincial level have joined together to form an intensive project partnership. Universities and other research institutes are involved in the project on a contractual basis.

The project is part of the European Union's INTERREG III B Alpine Space Programme and funding for the period to March 2008 totals € 3.54 million, with around half of this coming from the European Regional Development Fund (ERDF).

Purpose and objectives

The Bavarian State Government adopts a "dual principle" to the issue of climate change: it focusses on CO_2 reduction, on the one hand, and adaptation to the unavoidable impacts of climate change, on the other. The ClimChAlp project is part of this climate protection strategy. Its key focus is to develop appropriate adaptation strategies to mitigate the negative impacts of climate change in the Alpine region. The task of defining these strategies requires a thorough understanding of the Alps as a holistic ecosystem which reacts very sensitively to global and regional changes. However, there are still considerable gaps in the knowledge, which can only be reduced through large-scale Alpine-wide cooperation on an interdisciplinary and transnational basis. INTERREG III B offers the ideal platform from which to initiate and facilitate this type of project.

Description

The ClimChAlp project was launched at a working meeting of the project partners in the Bavarian State Ministry of the Environment, Public Health and Consumer Protection (StMUGV) on 22 March 2006. The comprehensive work programme has included the analysis of historical climate data, along with climate modelling to assist in the development of future scenarios aimed at gaining a better understanding of the current and future impacts of climate change on natural hazards in the Alps. Flooding, slope failure and the increased threat posed by scree flows and debris flows as a consequence of melting permafrost are a particular focus of attention. With the development of a "Flexible Response Network", the strategies to combat natural hazards will be coordinated and aligned on a transnational basis. Detailed strategies for crisis management and risk avoidance are also being developed jointly. Other work deals with the impacts of climate change on key economic sectors such as tourism, or addresses regional planning issues.

Outlook

As one outcome of the project, which – after two years of intensive work – is due to end in March 2008, forecasting of the anticipated impacts of climate change has been improved and recommendations for administrative and policy action developed.

The work, which is structured around work packages (WPs), is currently being undertaken through numerous individual projects and is well under way. Information about the project and its work can be accessed on the project's website: www.climchalp.org. One example of the current work is the compilation of information and references on the natural hazards associated with climate change, which can be accessed at: http://risknat.obs.ujf-grenoble.fr/projets/climchalp_wp5/pages_eng/base_eng.htm.

The synthesis of outcomes will begin in the second half of 2007. In this context, an "Extended Scientific Report" (in English) is planned, which will present the scientific findings in detail, as well as a "Common Strategic Paper" which will outline policy recommendations and adaptation strategies on the basis of a short summary of the relevant results. The Common Strategic Paper will be published in English and in the languages of the Alpine countries.

A lack of snow in January 2007 in Riezlern in the Kleinwalser Valley, Vorarlberg (Austria)

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Health

Climate change can impact on human health in very many different ways, e.g. by increasing the frequency and intensity of heat waves, or heightening the risk of natural disasters and transmitted diseases, etc. As yet, very little research has been undertaken on the links between climatic changes and factors influencing human health, and very few useful results exist. A distinction must also be made between weather-related and climate-based risks. For example, climate change may change the risk of specific weather conditions occurring, but an individual event cannot be ascribed conclusively to climate change.

Communities have always been, and will continue to be, exposed to natural meteorological hazards such as storms, flooding and drought, but these could increase as a result of climate change.

According to climatologists, it is very likely that human influence on the global climate has doubled the risk of heat waves occurring, as in summer 2003. During the heat wave in August 2003, the death rate was 60% higher than normal in France, with more than 14,000 deaths. And although fewer deaths are known to have occurred in Alpine countries such as Switzerland, the mortality rate nonetheless increased here too. Higher air pollution during heat waves can also increase the number of those suffering health impairment. However, if summers generally become hotter in future, it is likely that adaptation will take place and similar events will not claim so many lives. On the other hand, an increase in the number of hot days could well attract more tourists to the Alps to enjoy the fresh mountain air. In the Alps themselves, hot summers are more likely to lead to problems as a result of melting permafrost and the ensuing instability of slopes rather than posing a direct threat to human health.

With storms, a decrease in frequency is more likely to occur in Central Europe. At the same time, however, very strong storms may become more frequent and could thus pose a risk to more human lives. On the other hand, flooding could become one of the most relevant impacts on health in the Alps. In some cases, floods could also result in the discharge of hazardous chemicals from their normal storage places.

Tick warning

There is still great uncertainty about the indirect impacts of anthropogenic climate change, especially as regards vector-borne diseases whose occurrence is influenced by a range of factors: the survival and reproduction rates of the vectors, their distribution and frequency, and the infection rate in the host. The climate can impact in diverse ways on many of these influences, and is only one of many factors. So it is very difficult to attribute the spread of a pathogen to climatic changes. For the Alps in particular, a key question is whether an increase in the spread of tick-borne diseases is likely. A Czech study has noted that one common species of tick has extended its range to higher altitudes, from 700–800 m to the current 1,250 m, over the last two decades.

For this site too, analysis of climate data clearly reveals a 2.5° C increase in average temperature for the May-August period. Yet in parallel to these climatic changes, many other changes have also occurred: for example, populations of the main host, i.e. deer, have also increased in size, etc. However, the possibility that ticks may in future be found at higher altitudes than before in the Alpine regions cannot be ruled out.

Climatic changes are also likely to have impacts on hay fever and asthma through their effects on pollen and other allergens. Studies show that in some cases, more pollen is produced as a result of higher CO_2 concentrations and/or temperatures. The World Health Organization (WHO) forecasts an earlier start and peak of the pollen season, especially affecting early-blooming species. The duration of the pollen season of some summer- and late-blooming species will also be extended.

Most of the predicted human health problems will not occur in Europe or the Alps, however. A change in the incidence of malaria, yellow and dengue fever and poor drinking water quality will primarily affect the developing countries.

- Some uncertainty exists with regard to the causal relations between climate change impacts and vector-borne diseases. Nevertheless, conditions for the spread and transmission of these diseases improve with rising temperatures, so an increased risk can be assumed. (UBA, 2005)
- Many central regions north of the Alps will experience longer grass pollen seasons. (Emberlin, 1994)
- The health impacts of climate change are most likely to affect people whose health is already vulnerable, e.g. the elderly and children. (UBA, 2005)

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Tourism

The years 1994, 2000, 2002, and 2003 were the warmest on record in the Alps in the last 500 years. Climate projections show even greater impacts for the future, not only as a result of rising temperatures but also in relation to precipitation and snowfall (see above). Besides the natural hazards, the impacts on winter tourism will have long-term consequences for life in the Alps. Tourism is a key pillar of the economy in the Alpine countries, generating around € 50 billion euros per year in the Alpine region and providing 10–12% of the jobs. So how will climate change impact on winter tourism?

The winter of 2006/07 was extreme as far as snow cover was concerned. At lower locations below 1,300 m, snow cover was unusually poor compared with the last 70 years. Nonetheless, a single extreme winter cannot be taken as evidence of climate change; the unusual combination of specific weather conditions is considered to be the cause. Nonetheless, if the researchers' climate models are correct, this could be a foretaste of the conditions which could become the norm in the Alps within a few decades.

As a result of the generally warmer climate, the number of areas with snow reliability will be significantly reduced. With ongoing climate change, according to climate models, southern Germany must expect more precipitation at the end of this century, but this is more likely to fall as rain, not snow. Only at high altitudes – estimates vary between 1,600 and 2,000 m – could precipitation fall as snow, perhaps even in greater amounts than before.

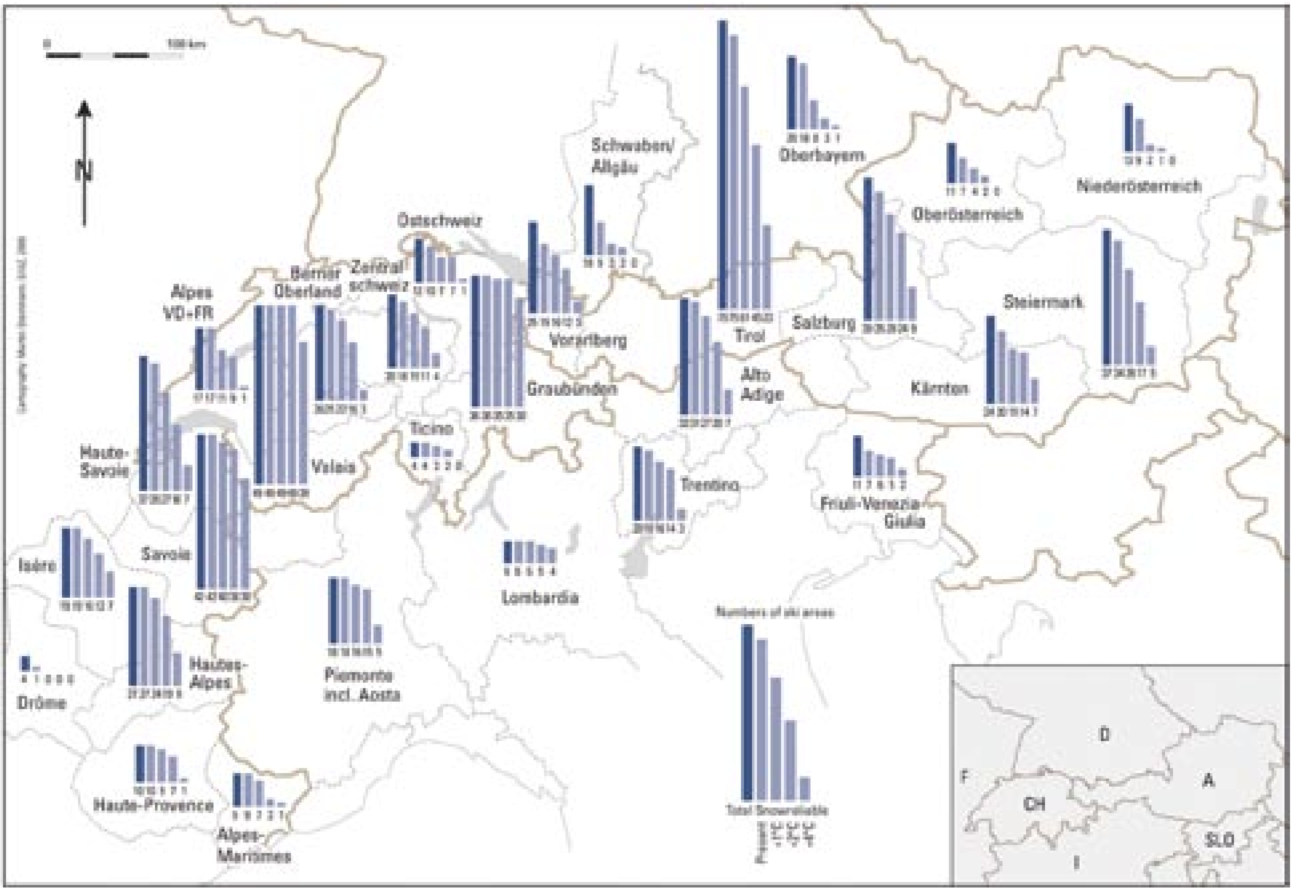
At present, 609 out of the 666 Alpine ski areas – i.e. 91% – are regarded as being snow-reliable. An area is considered to be snow-reliable and economically viable if there is at least 30 cm of snow for at least 100 days per year. In Germany, due to the relatively low altitudes of its winter sports resorts, this currently applies to only 69%. According to an OECD report, Germany is the country most at risk, with even the 1°C warming scenario leading to a 60% decrease in the number of naturally snow-reliable ski areas. Based on these estimates, a global warming scenario of 2°C would reduce these resorts to just 13%, and to 61% Alpine-wide. For winter tourism in Bavaria, these are alarming figures.

View of the Hohe Tauern with the Grossglockner (almost 3,800 m) in the Austrian ski resort of Obertauern

With warming of 4 ˚C, which is not ruled out by climate models if no climate policy measures are taken, Germany will have just one ski resort with naturally guaranteed snow. Although these figures are estimates and therefore beset with uncertainty, they nonetheless show a clear trend:

- The number of snow-reliable winter sport areas will decrease massively as a result of the predicted warming, and Germany could be hardest hit among the Alpine countries.
- The OECD warns that almost all winter sport areas in Germany could face economic risks as a result of climate change.

Snow reliability in the Alpine region under current conditions and under 1°C, 2°C and 4°C warming



Source: Abegg, B. et al. (2007)

One of the most widespread adaptation measures is artificial snow-making. In Bavaria, the area covered by snow-making amounts to approximately 425 hectares (2004). This is about 11.5% of total skiable terrain. However, artificial snow can only partially compensate for the effects of climate change, as most snow cannons can only be operated at temperatures below 2°C. Snow-making also poses environmental externalities in terms of high energy and water consumption and local ecological impacts. From a sustainability perspective, it is doubtful whether artificial snow-making is a sustainable adaptation strategy for climate change. The International Commission for the Protection of the Alps (CIPRA) and researchers from the University of Zurich therefore recommend that in response to climate change, ski resorts reduce their dependency on winter tourism and pursue enhanced engagement in year-round tourism.

In contrast to the situation with winter tourism, summer tourism could increase to a disproportionate extent and gain in importance, for in the event of more frequent heat extremes, the cool mountain air could constitute a very valuable resource. If the scientists‘ climate scenarios become reality, a shift away from winter and towards summer tourism could be expected.

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Hikers in the Spitzingsee region of the Bavarian Alps

Is the new Alpine winter approaching?

by Dr. Dominik Siegrist

1. Climate change and the Alps

Climate change is a reality. Summer heat waves, winter avalanches, flooding, debris flows and glacier retreat – these are the first visible signs, and a foretaste of what might await the Alps in future. Some municipalities are equipping themselves with snow cannons to combat an all-powerful enemy – climate change, the issue which will increasingly dominate the political agenda in the Alps in the coming years.

Climate experts agree that climate protection is the order of the day, at least to keep climate change in check, for the fact is that we have missed the opportunity to stop it altogether. The climate situation in 2050 will show us whether the outcomes of our current policies have been successful. With their biomass, water, solar, wind and geothermal resources, however, the Alps have the potential to become a region of best practice for the use of renewable energies. At present, this potential is certainly not being exploited to the full, and nor are the opportunities for energy-saving.

As well as adopting climate protection measures, the Alpine countries should start thinking very soon about environmentally and socially compatible strategies for adaptation to climate change. This is especially relevant to the Alps, for the specific conditions prevailing here make them highly sensitive to climate change. Indeed, the Alps could be said to have their own "early warning system". In future, we must focus our efforts on two areas: avoiding further climate warming, on the one hand, and developing adaptation strategies, on the other. However, the solutions are not only technical in nature; they are also political and psychological. This is where the municipalities in the Alpine region have a key role to play, for strategies for adaptation to the impacts of climate change must be implemented at local level, within the municipalities themselves.

Cable car on the 1,800 m Wendelstein mountain in the Bavarian Alps

November 2006: snow cannon in use on the Riederalp in Wallis canton, Switzerland

2. The significance of climate change for Alpine tourism

In its most recent study, the OECD concludes that the current changes affecting the global climate will have dramatic impacts on Alpine tourism (Abegg et al. [2007]). Depending on the temperature scenario, climate change will impact especially on the cable car/ski lift industry and the tourist regions which depend on it, putting their economic future at risk. In view of the generally warmer climate, the number of snow-reliable areas will decrease significantly, according to the OECD in its latest report. The decrease in snow reliability will vary according to altitude and regional climatic conditions around the ski stations. In a worst-case scenario, the number of snow-reliable winter sport resorts in some regions of the Alps could fall to zero. But even with a minimal scenario, a number of ski stations will no longer be able to provide their existing offer as a result of climate change. As well as winter tourism, summer tourism will also be strongly affected by climate change. For example, with the melting of the glaciers, the Alps are losing one of their key attractions. Melting permafrost and an increase in natural hazards jeopardise infrastructure, roads and settlements, while hiking and Alpine tourism are also confronted with new risks.

3. Adaptation and its impacts

Adaptation to the impacts of climate change in the tourism industry began long ago. "Ground-independent transport facilities", i.e. chairlifts, are now standard in ski resorts and are a key feature of their basic infrastructure. Year on year, cable car/ski lift companies and the public purse provide millions of euros in funding for artificial snow-making systems; an end of this resource-guzzling artificial snow boom is not yet in sight (www.cipra.org/de/alpmedia/news/1729/?searchterm=dossier%20schneekanonen). At the same time, there is growing pressure for the construction of cable cars and lifts at higher altitudes and on glaciers, offering promoters the hope of snow reliability at least for the time being. A further trend is towards the development of new pistes and facilities on slopes with longer-lasting snow cover.

In sum, it is not only the impacts of climate change per se, but also the impacts of adaptation which threaten to have a negative effect on the environment. However, by means of legal and planning measures, it may be possible to ensure that the implementation of strategies for adaptation to climate change does not take place at the expense of near-natural and previously undeveloped high mountain areas in the Alps. The Alpine Convention provides an appropriate framework for this process. Within this framework, the Alpine countries could develop and establish joint criteria and guidelines for climate change mitigation, thereby ensuring that the protection of the Alpine space does not fall victim to the adaptation process.

January 2007: a lack of snow at Oberjoch, Germany's highest ski resort and mountain village (approx. 1,200 m)

4. A "new Alpine winter"?

The new Alpine winter has not yet begun. Nonetheless, an increasing number of good practice models for climate-sensitive tourism can be found in various tourist regions.

Comprehensive energy project "Clean Energy St. Moritz" (Switzerland)

The comprehensive energy project "Clean Energy St. Moritz" was launched by the smart resort of St. Moritz (Switzerland) in an effort to reduce its consumption of electricity, diesel and heating oil and replace these fuels with renewable, locally generated energy. The impetus for the project came from the International Year of Mountains in 2002, the International Year of Ecotourism in 2002 and the 2003 Alpine Ski World Championships. St. Moritz initiated the project together with partners from the business community and in cooperation with the authorities, environmental associations, other interested agencies and the general public. As part of the process, St. Moritz is implementing a comprehensive energy project with a focus on renewable energies – hydropower, solar, wind and biogas – at altitudes from 1,770 to 3,057 m above sea level. At the same time, property owners are obliged to obtain one-third of their energy from alternative sources or save energy by installing better insulation.

STRATEGE research project, Schladming (Austria)

Winter sport resorts around Schladming (Austria) are taking part in the STRATEGE research project, which looks at the sustainable regional development of tourist regions in light of global warming. As part of this project, a tourism management model is being developed with the aim of enabling winter sport regions to produce a sustainability strategy of their own. The strategies should enable the resorts to deal with changed conditions such as global warming or a change in visitor behaviour. The outcomes of the STRATEGE project, which is being implemented by the University of Natural Resources and Applied Life Sciences, Vienna, provide a basis for discussion and decision-making on future strategies for this tourist region.

Davos (Switzerland) on the way towards Kyoto

The Alpine city and ski resort of Davos (Switzerland) is aiming to achieve more climate-friendly local policies. To this end, the municipality has joined forces with the Swiss Federal Institute for Snow and Avalanche Research (SLF) and the Swiss Federal Research Institute (WSL) and developed a study identifying measures to achieve the Kyoto target at local level. The highest energy-saving potential is afforded by buildings insulation. The researchers are therefore recommending that the municipality promote energy efficiency, renewable energies and the sustainable use of local timber and inform visitors and residents alike how they can make their own contributions to climate protection.

Climate-neutral winter holidays in Arosa (Switzerland)

In order to safeguard climatic conditions in Arosa on a sustainable basis, climate-neutral winter tariffs are being offered for skiing and hiking holidays here. The offer is available for all the various categories of accommodation, both as a weekend package for three nights and for five- or seven-night breaks. The price includes a ski or hiking pass. On departure, the guest receives a personalised certificate about his climate-neutral winter holiday, which also states the amount of CO_2 that has been neutralised. The emissions resulting from the winter holiday are offset through contributions to a biogas project in Germany.

The "Soft Mobility Key" in Werfenweng (Austria)

The "Soft Mobility Key" (SAMO) scheme is run by hotels in Werfenweng, Austria, in order to safeguard tourism in this small mountain resort in the Salzburg region on a long-term basis. Guests who hand in their car keys and leave them locked in the Werfenweng tourist association's safe for the duration of their holiday can claim a wealth of additional benefits which are reserved solely for car-free guests: these benefits include a free transfer from Bischofshofen railway station with the "Werfenweng Shuttle"; a mobile phone for the duration of the holiday, to enable guests to call the private chauffeur and his electric car for journeys within the resort; free use of electric vehicles (electric scooters and mopeds) in Werfenweng; cycle hire, free entry to spas and a wide range of guided walks and cycle tours. This pilot project is now being expanded with the implementation of "mobilito – the Mobility Management Centre in Salzburg".

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THE ALPINE CONVENTION

The Significance of the Alpine Convention for the Bavarian Authorities

by Karlheinz Weißgerber

Introduction

The content of the framework convention and the protocols to the Alpine Convention is the outcome of negotiations between the countries party to the Convention. Germany/Bavaria has regularly put forward proposals here, based on practices in place in Bavaria's Alpine region. It is therefore not surprising that the provisions of the eight Protocols of Implementation have adequate equivalents in national law (federal law, and the Land law of the Free State of Bavaria) – with minor exceptions. This is demonstrated, for example, by the synopses of legislation published in tabular form in early 2007 (see www.stmugv.bayern.de/eu).

The Report for Germany on compliance with the objectives of the Alpine Convention, for the period to the end of August 2005, contains a list of the legal provisions in force at federal and *Land* level which incorporate the various provisions of the framework convention and its protocols (legislation, ordinances, public notices, regional development planning objectives, funding guidelines etc.). This Report shows that in its Alpine region, Bavaria acts in keeping with the spirit of the Alpine Convention as a matter of principle, with minor shortcomings at most.

The Protocols of Implementation entered into force for Germany on 18 December 2002 following ratification. The executive and the courts must on principle apply the provisions of the Alpine Convention and its Protocols as legislation having the rank of federal law. However, only those provisions of the protocols which, in terms of content, purpose and formulation are sufficiently precise and require no further implementing provisions, have direct effect in national law. The provisions of the protocols must therefore be taken into account in approval procedures or environmental impact assessments.

It should be noted that some targets / mandates are longer-term in focus; here, improvements can only be achieved on a progressive basis.

Attlesee, one of the largest lakes in Eastern Allgäu (Bavaria)

Alpine marmots

Objectives

Various objectives are outlined below which will be of relevance to the activities of the authorities in the coming years, both at federal level and in the Free State of Bavaria.

Overarching commitments

- Transboundary cooperation with Austria (e.g. information about planned legal or economic measures or joint programmes for systematic monitoring) (see Article 4 of the Convention). In this context, contacts should be fostered between authorities on the same level; the opportunities afforded by the EuRegios could perhaps be utilised more fully here.

Action to be taken under the individual specialised protocols:

Spatial planning and sustainable development

- liaison with neighbouring regions in Austria on the development of regional plans and building plans (local development plans and all regional plans are now coordinated).

Soil protection

- international cooperation on soil monitoring, data, etc., collaboration in the Platform on Natural Hazards
- mapping of at-risk areas (including information about fragile areas, expansion of the Alpine Natural Hazard Information Service – IAN)
- reduction in land consumption
- reduction of material inputs in soils
- avoidance of damage during ski slope construction
- promotion of soil protection procedures.

Conservation of nature and the countryside

- international cooperation, e.g. on networking protected areas
- production of a list of biotope types which require special measures (in conjunction with biotope mapping) two years after entry into force)
- identification of species which require special protection (after two years; contained in Red List 2003)
- identification of protected species pursuant to Article 15 (after two years)
- submission of a review on conservation of nature and the countryside pursuant to Annex I of the Protocol (after three years) (on wild flora and fauna, protected spaces, organisation, legal bases, activities, PR) (Article 6)
- development of nature conservation strategies and programmes for the Alpine space (after five years; already under way, e.g. Species and Biotope Protection Programme – ABSP) (Article 7).

Mountain farming

- promotion of agriculture in line with different management conditions to maintain use (e.g. equalisation supplement, Cultural Landscape Programme)
- promotion of the marketing of regional produce.

Mountain forests

- development of protected forests
- location-appropriate renewal and development of mixed forests
- regulation of game stocks.

Frauenchiemsee, an island in Upper Bavaria, popular with tourists

Tourism

- development of guidelines and programmes for sustainable tourism
- strengthening sustainable tourism
- improving quality of services, encouraging innovation, balanced regional development
- tourism impact assessments
- environmental awards for companies (hotels/restaurants, camping sites)
- improving public transport for arrivals and during tourists' stay.

Transport

(primary responsibility lies with the Federal Government)

- encouraging rail instead of road use; logistical improvements in rail freight
- improving local public transport; use of low-emissions vehicles in town centres
- reduction of noise and emissions
- shift towards more cost transparency (tolls for heavy goods vehicles are simply the first step); promotion of "green" fuels or biofuels
- close coordination of plans with neighbour countries.

Energy

(primary responsibility lies with the Federal Government)

- ▶ promotion of energy-saving and rational energy use
- ▶ expansion of renewable energies (especially biomass use; avoiding new construction of hydropower plants)
- ▶ more cost transparency in this area too.

Further recommendation:

Local and regional authorities should support an exchange of experience on successful examples of sustainable development in the Alps – as a supplement to the activities of Alpine cities and local authority networks. The Alpine Convention should be viewed as providing impetus for more international cooperation throughout the Alpine region.

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Climate Protection in Bavaria

Climate Programme for Bavaria 2020

The Bavarian State Government adopted a climate protection concept as long ago as October 17, 2000. The aim of this concept was to exploit the potential CO_2 savings to the best possible advantage in terms of the cost/benefit ratio and to close any gaps in research. It was followed in 2003 by the updating of the Bavarian climate protection concept with the "Initiative for a Climate-Friendly Bavaria".

The new "Climate Programme for Bavaria 2020" will effectively complement the measures already in place on national and EU level and further enhance Bavaria's role as a trailblazer when it comes to climate protection. Owing to its geographical conditions, Bavaria, in particular, is especially affected by climate change. In the last 100 years, the mean annual temperature increase in the Bavarian Alpine regions increased by 1.5 degrees, which is twice as high as the global average. In the next four years, current climate protection efforts will therefore be intensified by another Euro 350 million with a package of measures tailored to meet the specific conditions prevailing in Bavaria. The aim is to reduce greenhouse gases, to adapt to the inevitable consequences of climate change and through research to maintain a sound data basis for more far-reaching strategic decisions.

The State Government pursues a rational climate protection policy that relies on market-oriented incentives. Bavarian companies are market leaders in the field of environmental technology; these investment incentives bring the companies additional growth opportunities and new jobs. The energetic refurbishment of buildings generates contracts for domestic skilled crafts enterprises. In Bavaria, facing up to climate change is both a challenge and an opportunity.

The "Climate Programme for Bavaria 2020" was developed jointly with the Bavarian Climate Council, which since April 2007 has been advising the State Government on its climate policy and contributing its scientific experience. Out of a total of 150 measures, 14 focal points have been identified in three central fields of action:

Reduction of greenhouse gases

Euro 223 million has already been provided to reduce greenhouse gas emissions. The Climate Programme 2020 is designed to close the support gaps on federal German level with a catalogue of measures tailored to Bavarian conditions. As an example, Bavaria complements the Federal development programmes for private households with a Euro 186 million programme of its own for the energy-efficient refurbishment of state, municipal and church properties, including schools, child day-care centres and (school) gymnasiums.

When it comes to renewable energies, particularly favourable conditions exist in Bavaria for biomass, hydro-electric power and geothermal energy. Another Euro 28 million is therefore being provided for renewable energies. The aim is to double their share of the energy supply from the current level of 8 percent to 16 percent by the year 2020. Even though Bavaria's share of global greenhouse gas emissions is altogether very low, it intends to further develop its role model function. By the same token, dependence on fossil fuels will then also be reduced.

Adaptation to climate change

Bavaria was also quick to recognise that climate change could not be effectively faced solely by reducing greenhouse gases. A substantial part of Bavaria's climate protection programme therefore focuses on developing and implementing regional strategies in all sectors in order to adjust to the unavoidable effects of climate change within the scope of the national adaptation strategy; Euro 85 million will in addition be provided for this purpose in the next few years.

The Flood Control Action Programme 2020 is being dynamically adapted to climate change with an additional Euro 50 million. It covers in particular flood control systems, increased wide-scale flood-water retention and keeping emergency overflow facilities clear for storage capacities.

Climate change also threatens Bavaria with dry spells and drought. That is why secure supplies of drinking water must be increased on local and regional level. It is essential to draw up low water management plans, to secure alternative water production facilities, especially in those parts of Franconia and the Upper Palatinate Forest and Bavarian Forest that have water shortages, and to protect usable groundwater resources and sensitive surface water bodies in the long term.

Nature conservation is also affected. Care must be taken to stabilise biological diversity and the ecosystems and to preserve and renature marshy ground. An increase in georisks must also be taken into account, especially in the Alps. The adaptation measures in these fields are financed with close on Euro 12 million.

Over 80 percent of land is devoted to agriculture and forestry, so these sectors are among those most affected by climate change. As a result of increasing storms and periods of drought, an annual damage potential of up to Euro 850 million is predicted for Bavaria. Of the total of approx. 260,000 ha of spruce that are acutely endangered in both private and communal forests, about 100,000 ha will be converted into climate-tolerant mixed forest by 2020. A total of Euro 15 million is earmarked for this by 2011. With an additional Euro 7.5 million, mountain forests and their vital protective functions will be sustainably stabilised for the substantial climate changes occurring in the Alpine Region. This will be accomplished through intensive care and redevelopment of forests to be protected, combined with effective regulation of hoofed game.

Research and development

Research and development are the basis for developing sound strategies for adaptation, damage prevention and anticipatory action. In the field of climate research and climate impact assessment, extensive research activities are being conducted in Bavaria, which can also boast a wide range of competences. Nevertheless, in certain areas there is need for specific research. Basic findings gained from climate research must be examined for their impact on Bavaria and be turned into forecasts specific to the region. Research projects planned in Bavaria are supported with funding amounting to Euro 42 million and designed and implemented in close concurrence with EU and Federal German programmes.

Interdisciplinary research networks are being established, addressing among other fields the impact of climate on ecosystems and climatic adaptation strategies, technologies safeguarding resources and power plants for the 21st century.

An agricultural research enterprise should explore questions relating to precision farming, erosion avoidance and investigation of genetic resources under climate stress. In order to redevelop forests, climate-adapted recommendations of tree species are needed. The increased and new incidence of economically significant pests (e.g. bark beetle and oak processionary moth) calls for an improvement in current preventive and control strategies.

In particular for the Alpine region, special strategies will have to be pursued, like for instance dealing with natural Alpine hazards. Due to the impacts to be expected from global warming (higher mortality rate following heat waves in the summer, increase in allergic complaints, spread of infectious diseases, higher risk of skin cancer), research activities and the development of prevention and adaptation strategies must be intensified in the light of the anticipated consequences for public health.

Research & development is the key to a sustainable supply of energy. Only in this way will the necessary technologies be available for more efficient use of today's sources of energy and for opening up new sources. In addition to the production of fuels from renewable energies, the CO_2-neutral production of hydrogen, separation of CO_2 in the power-plant sector and efficient solar power plants, energy efficiency is also to be increased by means of innovative light-weight designs in motor vehicles. Possible savings in the energy required by sewage plants (electricity, heat) are to be revealed in demonstration projects. The opportunities for producing hydrogen in large-scale sewage treatment plants will also be examined and demonstrated in a practice-oriented manner.

Europe's Climate Protection Action Plan

At its spring meeting in Brussels on March 8/9, 2007, the European Council adopted a package of binding measures and targets to be reached by 2020 in its "Action Plan for Climate Protection and Energy Policy":

- To reduce greenhouse gas emissions by 20% (with reference to 1990) or by 30%, if other industrial nations undertake to achieve comparable emission reductions and the economically more advanced developing countries agree to make a contribution commensurate with their responsibilities and their respective capabilities,
- To increase the share of renewable energies in the total energy mix of the EU to 20%,
- To increase the share of biofuels in the total fuel market to 10%,
- To improve energy efficiency by 20% (referred to a development without additional measures).

Bavaria endorses these reduction targets. However, the special prerequisites and framework conditions prevailing in the State of Bavaria must be taken into consideration, and in particular the geographical location that makes Bavaria a transit country with a high volume of traffic passing through it. Account must also be taken of per capita CO_2 emissions that even now are already roughly one third below the German average. They are a positive result of active Bavarian climate protection policy.

Alpine Network of Protected Areas (ALPARC)

Implementing the Protocol on "Conservation of Nature and the Countryside" of the Alpine Convention from the outset

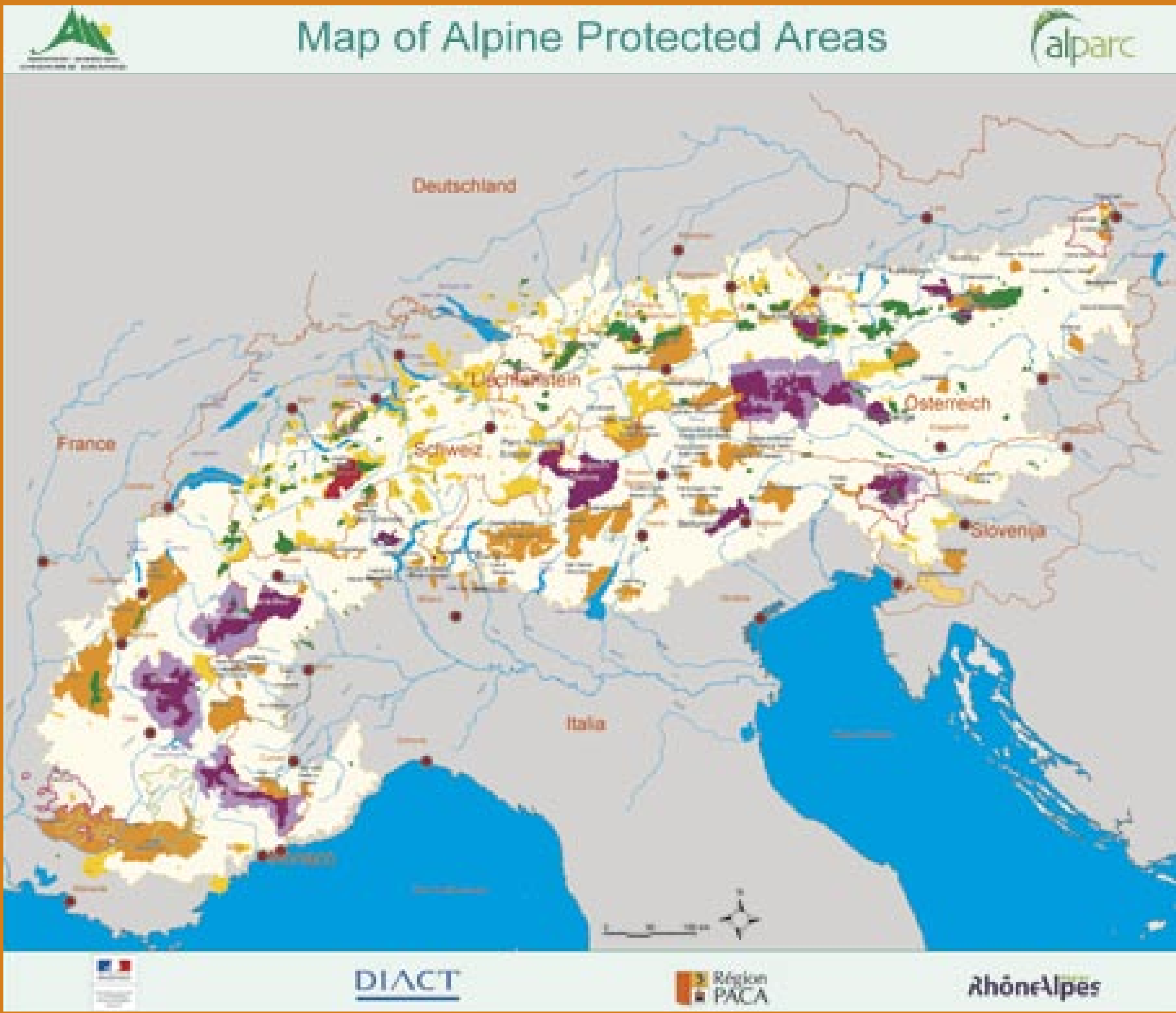
The establishment of an Alpine network of protected areas was proposed by France as early as 1994 in order to improve international cooperation in the field of Alpine nature conservation. The specific implementation of Article 12 of the Protocol on "Conservation of Nature and the Countryside" was the starting point: "The contracting parties take adequate measures to establish a network of existing national and transboundary protected areas, of biotopes and other protected elements or those to be protected. They commit themselves to harmonise the objectives and applicable measures in transboundary protected areas."

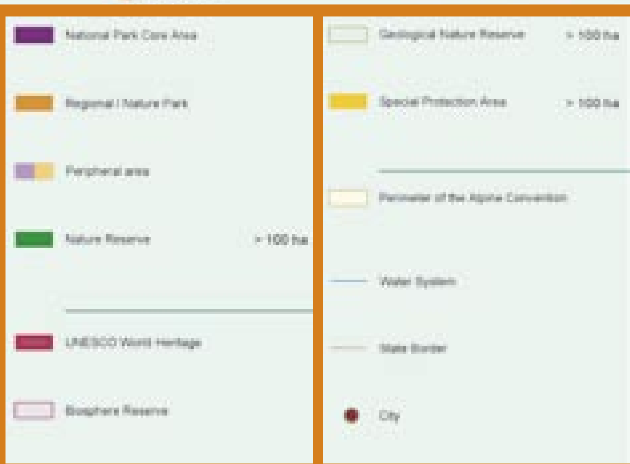
During the first International Conference of Alpine Protected Areas held in Gap in 1995, the participants – protected area managers from all the Alpine countries – agreed to cooperate more closely, with immediate effect, on issues relating to area management, to share their experiences, and to develop and promote joint projects in the protected areas.

During the following years, a number of thematic working groups were established (management of fauna, flora, habitat, tourism, mountain landscape, water resources, public relations ...). In every case, the relevance to the Alpine Convention and its protocols was clear. Numerous publications, exhibitions and other communication tools were produced, joint projects (monitoring, return of wildlife, studies, INTERREG and LIFE programmes) were implemented, conferences, study visits and staff exchanges took place, and Alpine-wide scientific coordination of the protected areas was initiated.

However, as only large and ecologically coherent protected areas can safeguard the lasting and sustainable protection of the biotic and abiotic natural resources of the Alps and guarantee their natural processes, the Alpine Network of Protected Areas was commissioned by the Alpine Conference in 2004 to carry out a feasibility study on transboundary protected areas and ecological corridors in the Alps.

Winter sport in Reit im Winkl, Chiemgau, Upper Bavaria





This was the first practical step towards the establishment of the Network's spatial dimension. The work provides an overview of the existing potential afforded by protected areas and transboundary linking corridors, including existing measures relating to species migration and targeted enhancement of the Alpine Ecological Network.

The Alpine Network of Protected Areas (ALPARC) is now the largest and most comprehensive specialised network for regional nature conservation within the Alpine Convention. The Alpine protected areas are areas of special interest for visitors and local communities. They protect centuries-old natural and cultural assets and can serve as a model of best practice in modern nature conservation.

The protected areas are also spaces for communication, especially through their visitor centres, information policy and the services provided for tourists and hikers. ALPARC promotes joint PR work by the Alpine protected areas, especially on the theme of the Alpine Convention.

The Alpine Network has also been adopted as a model within the framework of the Carpathian Convention. The Carpathian Network of Protected Areas now being established builds upon the experience gained with the Alpine process and has received particular support through the mountain partnerships involving ALPARC and various parties to the Convention (Germany, Monaco, France), which are supported by the Alpine Convention.

With the creation of a Task Force for the protected areas, ALPARC has been incorporated into the Permanent Secretariat of the Alpine Convention since June 2006, and will thus play an even more central role in implementing the Convention‘s Protocol on “Conservation of Nature and the Countryside”.

No snow this winter: Gräner Ödenalp in Tyrol (Austria) in late December 2006

In brief: Alpine Network of Protected Areas (ALPARC)

- Since 2006, ALPARC has been incorporated into the Permanent Secretariat of the Alpine Convention. It has an office in France with five staff members as well as project-related personnel.
- It is supported by the French Government and the Alpine regions of Provence-Alpes-Côte-d'Azur and Rhône-Alpes and, on a project basis, by other parties to the Alpine Convention and by the European Union.
- The Alpine Network currently encompasses around 800 protected areas of all categories, including 14 national and around 70 nature and regional parks.
- It encompasses around 2,000 protected area managers and staff.
- It represents around 23% of the Alpine space and almost all Alpine flora, fauna and habitats.
- It has 15 technical and expert working groups.
- It has arranged more than 250 events, produced numerous publications and run countless exhibitions since 1995.

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ALPARC

CIPRA – Life in the Alps

Aims and activities of CIPRA

The International Commission for the Protection of the Alps, known by its French acronym CIPRA, which stands for “Commission Internationale pour la Protection des Alpes”, has been working for more than half a century in support of sustainable development in the Alps. CIPRA initiated the Alpine Convention and played a key role in its development. It searches for ways and means to reconcile the needs of the natural environment, the business community and social issues.

One way in which it does so is through the dissemination of information: CIPRA is an information platform in five languages for people in and outside the Alps. With its fortnightly alpMedia Newsletter, for example, CIPRA communicates news, publications and events from and into all the countries of the Alps. It also produces its “Alpine Reports”, quarterly information bulletins, dossiers and other publications to round off its information offer.

Putting this knowledge into practice is another goal that CIPRA is working to achieve in various projects and initiatives. For example, CIPRA is one of the initiators of the “Alliance in the Alps” local authority network, in which more than 200 municipalities from all the countries of the Alps are now working together.

With its Climalp project, CIPRA is promoting the construction of energy-efficient houses in the Alpine space using timber from the region‘s forests. CIPRA provides information on the project goals in various publications and also organises excursions and workshops. “Disseminating knowledge – networking people” is the motto of “Future in the Alps”, another of CIPRA‘s projects.

With its focus on sustainable development, CIPRA‘s objective is to exploit the potential of the Alpine space at many levels. In doing so, CIPRA pursues a double strategy: on the one hand, political development with the Alpine Convention, and on the other, a bottom-up approach with information, projects, initiatives and networks – so that life in the Alps will continue to be worth living in the future too.

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CIPRA International

International Scientific Committee on Research in the Alps (ISCAR)

Mountain research across boundaries

ISCAR was founded in 1999 in order to contribute to the implementation of Articles 3 and 4 of the Alpine Convention, which deal with international cooperation in science and research. The focal points of ISCAR's work are inter- and transdisciplinary research, pan-Alpine approaches and key issues relating to sustainable development in the Alps. In order to promote research and scientific cooperation, ISCAR, together with partner organisations, has developed various core activities:

- Organisation of ForumAlpinum (since 1994)
- Development of a research programme as part of the work programme of the Alpine Convention (since 2005)
- Cooperation in pan-Alpine projects (on the conservation of biodiversity and ecological networks) and in European networks (on research into global change in mountain regions).

ISCAR activities are based on the ISCAR Convention, which was signed by national research institutions (Academies of Sciences / Arts and national institutes) from Austria, France, Bavaria, Italy, Slovenia and Switzerland. Each of these six partners delegates two members to the Committee, taking account of the humanities and natural sciences. In 2000, ISCAR was formally recognised as an official observer of the Alpine Convention and in this role represents research or contributes its specialist scientific expertise in the official bodies of the Alpine Convention.

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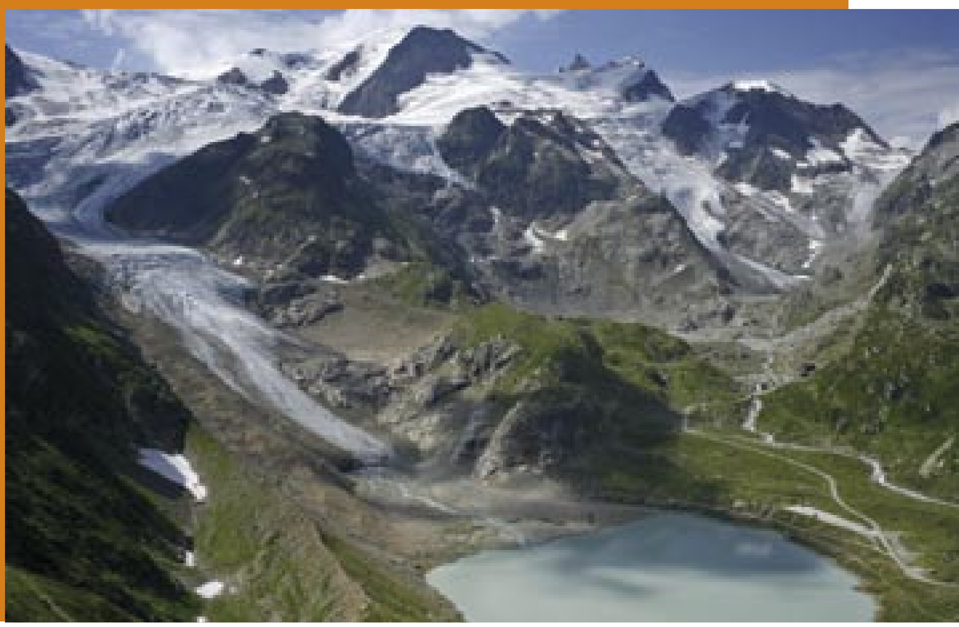
ISCAR
International Scientific Committee on Research in the Alps



View from Susten Pass (Switzerland) over the Steingletscher glacier with glacial lake

“Alliance in the Alps“ local authority network

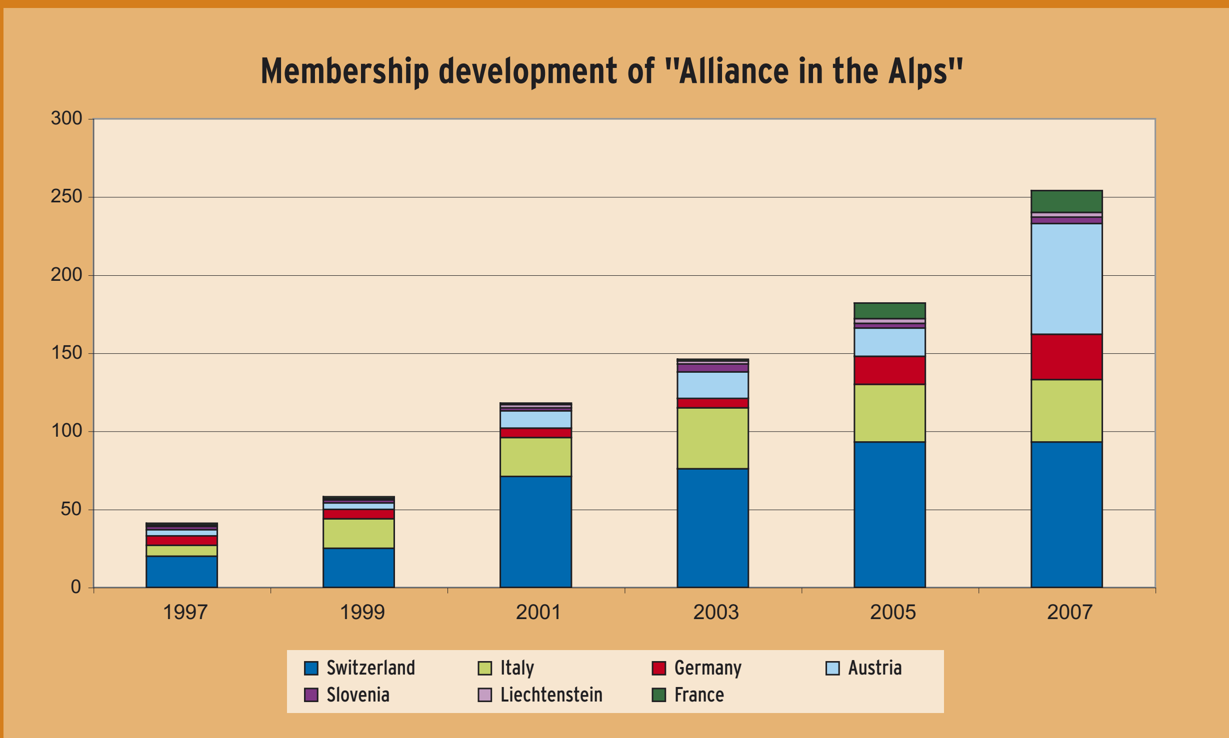
Context

The Alps are a living space and an economic, cultural and recreational area of eminent importance at the heart of the European continent, shared by numerous peoples and countries with specific and diverse natural environments, cultures and history. This living space is of great significance for non-Alpine regions as well – notably as a provider of key transport routes, as an indicator of climatic changes, and through its numerous models of cooperation between cultures, political systems and organisations.

At the same time, there are major differences in the individual legal systems, natural landscape conditions, settlement, agriculture and forestry, economic status and development, transport use, and the type and intensity of tourism.

The steadily growing demands being made on the Alpine region by human communities and the major changes which have taken place here over the last 100 years mean that more intensive efforts are needed to achieve sustainable development so that a high quality of life can be maintained throughout the Alpine region. Sustainable development must take place together with stakeholders and requires adaptation to the specific needs of each region and municipality.

The “Alliance in the Alps” network is an association of local authorities from seven Alpine states. These local authorities are pioneers in the efforts to promote the sustainable development of their municipalities and regions.



Alphorn players in Bad Hindelang, Bavaria

Basis

The basis of the network is the Alpine Convention. The Convention is viewed as the guiding principle for sustainable development in the Alpine region and its implementation should be filled with life wherever individuals are able to shape their future, i.e. in the community.

The member municipalities work to achieve a balance of ecological, social and economic objectives, guided by the following principles:

Goals

The main objective is the implementation of the protocols of the Alpine Convention at local level. This requires the involvement of citizens in Alpine-specific Local Agenda 21 processes as a means of working together to develop the local habitat. Active exchange between stakeholders in the municipalities is the driving force behind the network, enabling members to learn from each other. A key element in this context is the initiation of joint projects for all member municipalities in the network.

Organisation

The "Alliance in the Alps" network is a registered association and was founded in Bovec, Slovenia, in October 1997. Its membership comprises municipalities from seven of the eight Alpine states. The Alliance's Executive Board consists of representatives of one municipality from each of the seven member states. All the network's publications and events are in the four main languages of the Alps: German, French, Italian and Slovene. Regional associations have been established in Switzerland and Austria.

The 250 or so member municipalities are advised by mentors in their mother tongue and, via these mentors, can introduce topics into the network's activities and receive support for the implementation of their own projects and events. These in turn also ensure effective networking and individual information exchange through their own contacts.

The value-added and benefits are apparent, above all, in the thematic workshops. The exchange of experience and information, problems and solutions becomes far more diverse and innovative as a result.

- Safeguarding holistic policies for the conservation and protection of the Alps
- Safeguarding sparing and sustainable use of resources, taking account of the precautionary principle, the "polluter pays" principle, and the principle of cooperation. Strengthening transboundary cooperation in and for the Alpine region.

A lack of snow in December 2006 in the Füssener Jöchle ski resort in Tyrol (Austria)

Major projects

INTERREG III B Project: DYNALP

In 2003 the "Alliance in the Alps" local authority network, together with the municipality of Mäder in Austria as the lead partner and 53 other partners (municipalities and regions) from Switzerland (17), Liechtenstein (1), Germany (8), Italy (11), Slovenia (2) and Austria (15), launched the DYNALP project under the EU Community Initiative INTERREG III B Alpine Space Programme with a total cost framework of € 2,100,000.

The main objectives of the EU Community Initiative INTERREG III B Alpine Space Programme are to establish the Alpine space as a powerful area in the European network of development areas, and to initialise and support sustainable development on a transboundary basis – in other words, it pursues the same objectives as Alliance in the Alps.

The DYNALP partners implement projects within the framework of the above-mentioned goals and exchange experiences across linguistic and cultural boundaries. The projects address the implementation of one or several of the following four protocols of the Alpine Convention: Tourism, Conservation of Nature and the Countryside, Mountain Farming, and Spatial Planning and Sustainable Development.

DYNALP²

DYNALP² is an "Alliance in the Alps" project. With DYNALP², the "Alliance in the Alps" network is continuing the work on sustainable development and implementation of the Alpine Convention initiated by the INTERREG DYNALP Project. DYNALP² implements the findings from CIPRA's Future in the Alps project at the community level and promotes lively exchange between the municipalities. The results and findings are therefore useful to many people. DYNALP² is scheduled to run for a term of just over three years, from April 2006 to June 2009. The Project has a total funding volume of € 1,775,000. The MAVA Foundation for Nature Conservation, Switzerland, is covering € 1,275,000 of that amount.

The core and single largest budget item of DYNALP[2] are projects in communities which make a real contribution towards implementing sustainable development and the Alpine Convention. Projects in the amount of € 20,000 or € 40,000 receive up to 50% funding.

DYNALP[2] focusses on one or more of the following topic areas: Regional Value Added, Governance Capacity, Protected Areas, Mobility, New Forms of Decision-Making, and Policies and Instruments.

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Allianz in den Alpen
Alliance dans les Alpes
Alleanza nelle Alpi
Povezanost v Alpah

The cows are brought down from the alm, Allgäu, Bavaria

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"Alliance in the Alps" local authority network

www.planat.ch
National Platform for Natural Hazards, Switzerland (including PLANALP)

www.alparc.org
Alpine Network of Protected Areas

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