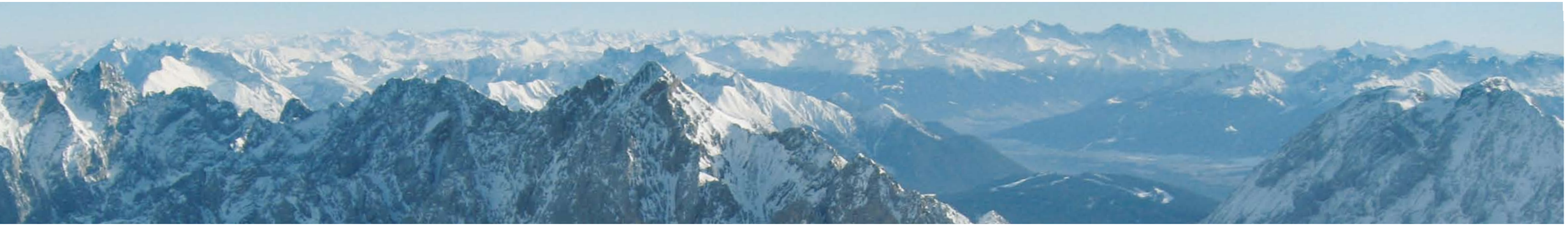
ClimChAlp

Climate Change, Impacts and Adaptation Strategies in the Alpine Space

Strategic Interreg III B Alpine Space Project

COMMON STRATEGIC PAPER

ClimChAlp
Interreg III B Alpine Space



Bavarian State Minister of the Environment, Public Health and Consumer Protection

One of the most sensitive European regions is increasingly exposed to climate stress: The Alps are heating up faster than other areas. In the Bavarian Alps for example, the average temperature in the past 100 years increased by 1.5°C - doubling the global average. Especially in the highly sensitive Alpine Space this leads to enormous transformations, ecologically as well as economically. To meet these challenges, the Free State of Bavaria with the ClimChAlp project has brought stakeholders from all Alpine countries together. The ClimChAlp results provide a profound basis for further work. Therefore I would like to thank our partners: Adaptation to climate change today is one of the most important fields of action in the Alpine Space and only together we will be able to master the task.

Dr. Otmar Bernhard, MP

Secretary General of the Alpine Convention

On the base of scientific knowledge, the ClimChAlp project successfully approaches adaptation to climate change in the Alps. We hold in high regard all initiatives supporting a common alpine strategy to tackle climate change in the Alps. The Permanent Secretariat, which is currently working in close cooperation with alpine countries to prepare an international action plan on climate change, welcomes the outcomes of the ClimChAlp project as a useful contribution to the institutional work currently in progress.

Marco Onida

CONTENT

Project and Partnership

Administration authorities, researchers and experts from seven Alpine countries worked together closely to analyse and highlight the impacts of climate change in the Alpine Space and to elaborate the basis for adaptation strategies. The strategic ClimChAlp project "Climate Change, Impacts and Adaptation Strategies in the Alpine Space" was initiated by the Bavarian State Ministry of the Environment, Public Health and Consumer Protection. It was carried out in the framework of the Community Initiative INTERREG III B. The project with a total budget of approximately 3.5 million Euros (ERDF share 1.7 million) ran from March 2006 to March 2008.

Overall Recommendations for Managing Impacts of Climate Change

The aim of the ClimChAlp project was to find ways for the communities in the Alpine Space to cope successfully with the impacts of climate change whilst ensuring sustainable development in the area. Based on the results of the project, the transnational ClimChAlp consortium developed the following overall recommendations for policy makers, administration and stakeholders.

- Transnational cooperation in the Alpine Space should be intensified further to allow experiences, knowledge and methods to be exchanged fruitfully between administration, technical authorities and scientists. Continuous and long-term transnational and interdisciplinary cooperation for the development of common tools for risk prevention and management is indispensable, as is the implementation of harmonised adaptation strategies. To be efficient and effective, this cooperation should interlink the experiences and results elaborated in different projects.
- Climate scenarios are a prerequisite for any future activity. Therefore, climate data sets have to be harmonised in terms of temporal and spatial resolution to get more reliable model data for future climate scenarios. Methods for correcting uncertainties in model projections have to be developed and tested to derive regional impact scenarios with a high spatiotemporal resolution.
- Broadening and deepening the knowledge on climate change and its related impacts in the Alpine Space represents the basis for the elaboration of sustainable adaptation strategies. In this context, environmental indicators should be monitored, trends identified and projections for future developments continuously updated using climate scenarios.
- Monitoring zones of already known or presumed slope deformations or other natural hazards (e.g. floods, avalanches, glaciers, debris flows) should be used for identifying critical areas as well as for protecting already existing settlements. This constitutes the basis for a significant reduction in costs for protective structures and damage restoration. Monitoring should be seen an essential element of prevention. It can be used as an early warning system and ultimately contributes essentially to an integrated risk management. This should be complemented by regionalised sensitivity analysis to identify the areas where particular precautions are necessary in the context of climate change.
- Historic data as a retro-perspective analysis tool should be included for all kinds of monitoring and scenario building. Therefore, adequate databases should be continuously maintained on a transnational level. Transnational cooperation and information exchange should be promoted and data exchange facilitated. Furthermore, detected trends should be validated on a transnational level.
- A common transnational terminology concerning the assessment of risks and harmonisation of different approaches of danger and hazard mapping should be elaborated to enable efficient transnational cooperation. Such harmonisation which follows homogenous minimum quality standards is also postulated by the Alpine Convention. Furthermore, models for intersectoral (e.g. flood, erosion, slope deformations, etc.) hazard mapping should be developed and discussed on the transnational level.
- Hazard maps are still lacking in many municipalities. Comprehensive databases that hold all relevant spatial information on the municipality and sub-local level should be established. Geographic Information Systems containing land-use, land cover, all available sectoral risk information and binding spatial regulations are the most appropriate tool for this purpose. Such databases allow the detection of climate change-related spatial risks and are the precondition for adjusting and enhancing spatial planning on the local and regional level.
- Risk-oriented spatial planning and risk governance play a key role in the reduction of spatial vulnerability. Thus, it is necessary to develop a generalised, clear conceptual model of regional spatial vulnerability, and to elaborate an operational, transferable methodology for integrative vulnerability assessment.
- Risk communication can be substantially improved by the initiation of a "risk dialogue" between experts, practitioners, administration and the public. Dissemination of information on possible impacts of climate change should be substantially improved on both the political and public level. Through this process, inhabitants and land-owners should be informed about the on-site risks and individual responsibility for risk prevention precautions. Policy-makers should discuss and clarify, in principle, the balance between state and private responsibility for risk prevention, precaution and adaptation, also promoting a direct involvement of insurance companies.
- Raising awareness, transdisciplinary communication and cooperation were identified as key factors for climate change adaptation. Therefore, transnational campaigns on risk management and communication should be implemented to support adaptation actions on the local, regional, national and transnational level. Policy-makers, administration, researchers, associations, NGOs, enterprises as well as the general public should be actively involved in these campaigns.
- Cooperation between science and practice should be improved. Interface management between spatial planners, technicians, industry, leading economic branches and service providers, as well as the police, the army, fire brigades, civil protection and also politicians and other stakeholders should be optimized.
- The transnational Flexible Response Network established within ClimChAlp should be maintained and developed further. Transregional and transnational coordination of natural hazard management techniques should be enforced. Intensifying cross-border cooperation, sharing experience and knowledge on integrated natural hazard risk management at the operational and strategic level is the best way of facing all relevant effects of climate change regarding natural hazards and risks.

- A transnational and interdisciplinary, integrated approach based on natural hazard and risk management and elaborated masterplans (e.g. including local emergency training measures) should be continuously adjusted during and after extreme events. This represents the basis for a sophisticated early warning system. Although this kind of prevention requires adequate financial means and does not show immediate results, it is, in the long run, the cheapest and most sustainable way to save lives and goods, especially in a changing climate.

Conclusions and Outlook

The ClimChAlp project produced a valuable methodological basis and recommendations for both adaptation to climate change and the further development of effective transnational cooperation in this context. Specific recommendations are outlined in the subsequent chapters. The overall results of the project have been synthesized in an Extended Scientific Final Report (ESFR), which is available for download on the ClimChAlp Website **www.climchalp.org**. For further information, the ClimChAlp partners can be contacted.

The ways in which climate change manifests itself in the Alpine Space are as heterogeneous as the region itself. Therefore, in a step by step adaptation plan for the years to come, the results and recommendations elaborated in ClimChAlp should be implemented above all within local and regional adaptation strategies. The established networks and databases have to be maintained and advanced to enhance knowledge and improve integrated risk management. Further case studies on regional and local level are needed to improve the knowledge of climate change impacts and to transfer new findings into adequate and applicable adaptation measures in the Alpine Space.

BACKGROUND: CLIMATE CHANGE IN THE ALPINE SPACE

Climate Changes Globally – but Impacts Differ from Region to Region

Climate change is a fact. The real dynamic of climate change has surprised even scientists who have been dealing with the problem of climate modelling for twenty years. The observed reality shows a much faster increase of average temperatures than models predicted a mere ten years ago. Although climate change is a global challenge, its impacts can differ significantly within several kilometres if topography and microclimate vary distinctly. Especially mountain regions like the Alpine Space are characterised by a broad range of natural site conditions varying on the small scale according to natural parameters such as altitude, temperature, precipitation, exposition or soil type. But climate change is not the only driving force changing the living conditions of the Alpine Space. The pressure exerted on natural resources by the regional population and by exogenous claims, above all transport and tourism, is still unceasing. Therefore the combination of the impacts directly caused by local and regional interferences and the global phenomenon of climate change leads to a new level of environmental stress and natural hazards.

Type and dynamics of change vary from region to region in the Alps. While some areas will be increasingly endangered by natural hazards, others will face problems with regard to water scarcity in very dry summers. Some regions will have to cope with decreasing snow reliability and therefore need to modify their winter tourism products, others will be the "winners" benefiting from their high altitude and the corresponding snow guarantee.

Developing Regional Adaptation Strategies through Transnational Cooperation

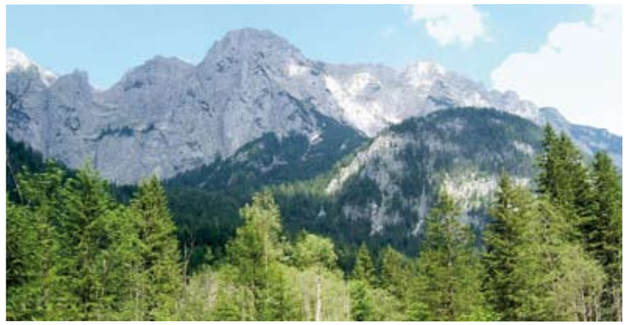
The debate on global level concentrates on the aspects of climate protection and climate change mitigation. Regional and local activities rather focus on adaptation issues. With regard to the considerable variety of climate change impacts in the Alpine Space, no single adaptation strategy can be sufficient or adequate. Individual strategies and corresponding measures have to be found in each Alpine region. Nevertheless, regional strategies will partially be quite similar or even identical. Transnational cooperation therefore helps to exchange knowledge and best practice examples but also enables the discussion of open questions. Crucial cooperation issues in terms of climate change adaptation in the Alpine Space are:

- Developing a climate model which can be applied to the entire Alpine Space and the Alpine topography. Current models use grids of 10 x 10 km but are derived from data of 200 x 200 km grids. It is obvious that a much higher resolution is needed for the Alpine Space with its small-scaled site condition variations.
- The high risk potential in the Alpine Space results from its geomorphology with high mountains, deep valleys, permafrost areas and glaciers in combination with events of heavy rain- or snowfall and exceptional gradients of

Projected increase in annual average temperature

(averaged over 30 years) for the year 2055 in Austria, relative to the climate reference period 1961-1990 (climate model ECHAM5/REMO, scenario A1B)

ECHAM5/REMO processed by Max-Planck-Institute of Meteorology, Hamburg; commissioned by Umweltbundesamt Dessau; analysis and graphic design: Umweltbundesamt Vienna, 2007.

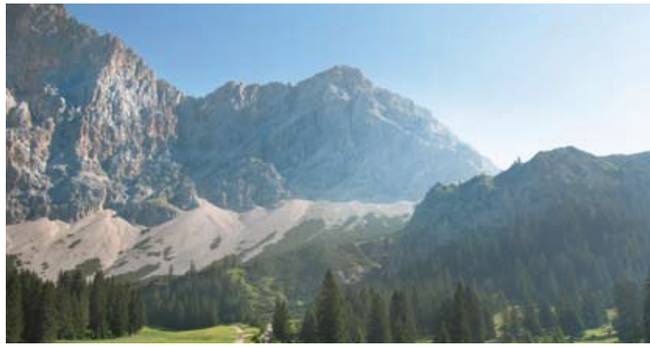


day and night temperature. A better understanding of existing risks and of the respective effects of climate change is a prerequisite to reach efficient prevention strategies.

- Even though the Alpine Space usually is admired because of its amazing and unaffected nature, numerous regions within the alpine arc are prosperous economic areas within the European Union. Safeguarding and developing the regional key economies in a sustainable way is urgently required in order to keep and create labour opportunities for the alpine population. Therefore, the elaboration and discussion of future scenarios describing the potential impacts of climate change to the regional key economic sectors can contribute to an adaptation in tourism, agriculture or forestry. Furthermore, new approaches in spatial development, settlement and infrastructure planning as one component of an integrated and sustainable risk prevention strategy can be identified on such a basis.
- As a matter of principle, Alpine towns and cities are more vulnerable to natural hazards than the surrounding lowlands. In spite of enormous endeavours in the field of risk prevention, natural disasters will be part of the future life of the alpine population. The adjustment of existing protection measures or the construction of new technical solutions against flooding, avalanches or mudflows will probably not meet the demands or take too much time. Therefore, early warning systems and general awareness raising for climate-change related risks are essential.

Supporting Decision-Makers

At present, climate change is on top of the political agenda and a focal point for the media. Unfortunately, the debate is often based on imprecise information and not at all regionally differentiated. Generalised statements such as "in the future artificial snow making in the Alps will not be possible anymore" or "the Alpine summer will be warm, dry and sunny" are of no help for the preparation of suitable adaptation measures on regional level. Instead they disturb the Alpine population. Even decision-makers often have serious problems in finding reasonable answers when reflecting on local issues with regard to climate change: Does investment into a specific tourist infrastructure still make sense? Which technical risk prevention measure is the best for my town? When and in which way shall I inform my fellow citizens about a specific natural hazard?



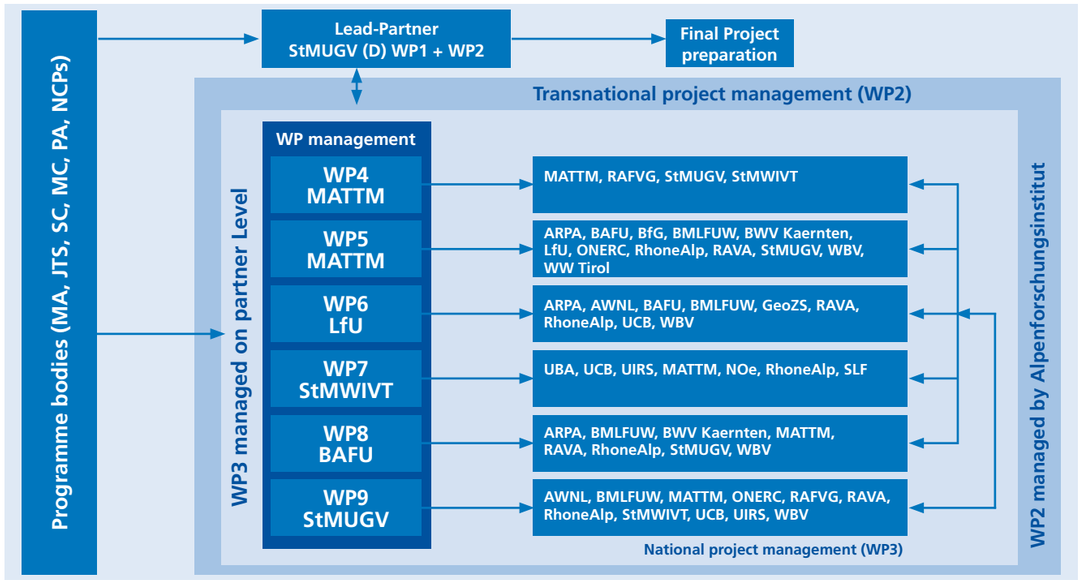
Against this background, the main mission of the ClimChAlp project is to raise awareness and support policy-makers, public administration from national to local level and stakeholders in the Alpine Space by providing solid background information on climate change impacts and offering recommendations on how to manage future challenges. This paper briefly summarises the project results and shows a range of reaction options – not only in terms of counteracting climate change related threats, but also in terms of capitalising on potential chances.

THE CLIMCHALP PROJECT

During an ambitious two years work plan, administration authorities, researchers and experts from seven Alpine countries closely cooperated to analyse and highlight the impacts of climate change in the Alpine Space and to elaborate the basis for adaptation strategies. The joint project "Climate Change, Impacts and Adaptation Strategies in the Alpine Space" was initiated by the Bavarian State Ministry of the Environment, Public Health and Consumer Protection.

Preparing the project, a transnational partnership involving 22 partners from a broad range of fields concerned with climate change and its impacts was set up. Finally the strategic project was approved within the last call of the Community Initiative INTERREG III B Alpine Space at the beginning of 2006. It was allocated in Programme Priority 3, Measure 3 – "Cooperation in the field of natural hazards." The project with a total budget of approximately 3.5 million Euros (ERDF share 1.7 million) ran from March 2006 to March 2008. Beside the technical Work Packages (WP 1 Project Preparation, WP 2 Transnational Project Management, WP 3 National Project Management), the project comprised following thematic Work Packages:

- Work Package 4: Information and Publicity Activities
- Work Package 5: Climate Change and Resulting Natural Hazards:
- Work Package 6: Monitoring, Prevention and Management of Specific Effects of Climate Change on Nature
- Work Package 7: Impacts of Climate Change on Spatial Development and Economy
- Work Package 8: Flexible Response Network
- Work Package 9: Synthesis and Processing



Besides stating the dimension of climate change and its impacts in the Alpine Space, the main objective of the project was to develop transnational adaptation strategies and measures in the fields of natural hazards, risk prevention, spatial development and economy. To this end, major emphasis was laid on an integrated project approach by closely linking all involved actors and thematic Work Packages from the very beginning.

Based on the main project findings and concrete results of the particular Work Packages, this brochure presents the most important transnational recommendations for decision-makers. The proposals, elaborated by the transnational ClimChAlp expert consortium, address the main challenges related to climate change as well as crucial future fields of action and research fields to be tackled by policy, administration and stakeholders in order to ensure sustainable development in the Alpine Space. In the following chapters these recommendations are listed for each Work Package, also including information on the specific background, Work Package activities and outcomes as well as a short outlook.

The detailed results of the single Work Packages have been compiled in the Extended Scientific Final Report (ESFR) which is available at **www.climchalp.org.** Special references to the Extended Scientific Final Report will be given in the Work Package chapters.

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CLIMATE CHANGE AND RESULTING NATURAL HAZARDS

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BAFU (CH)	**WW Tirol** (A)
LfU (G)	**ONERC** (F)
RAVA (I)	**RhoneAlp** (F)
StMUGV (G)	**WBV** (I)

Background

The existence of the human-induced climate change has become increasingly evident as the reports of the Intergovernmental Panel on Climate Change (IPCC) provided more accurate global climate assessment data, most recently in 2007. There is now widespread agreement that the current warming is due to the combination of a natural fluctuation and anthropogenic forcing of the climate. Increased glacier retreats and permafrost degradation as well as snow cover decrease have been observed in many mountainous areas and especially in the European Alps. Slight changes in the mean annual temperature may coincide with dramatic changes on an hourly, daily or even monthly basis, which is the timeframe relevant for natural hazards, permafrost degradation and many other developments. Changes in the temperature and precipitation patterns have various consequences on a mountain environment, for example, snow cover reduction, glacier retreat, thawing of permafrost, vegetation shifts. Global warming might change the river discharge patterns, including an increase in the frequency and intensity of floods and droughts. Other kinds of hazards might also be exacerbated by climate change, e.g. glacial hazards, forest fires, mass movements and many more. It is likely that the consequences of climate change will have an impact on socio-economic systems downstream, dependant ultimately on water resources provided by the "water tower" of Europe, the Alps.

Main Objectives, Activities and Outputs

In order to assess possible effects of past and present climate change in the Alpine Space, historical processes involving natural hazards in the Alpine area were analyzed. To provide information on possible developments until 2100, a comprehensive assessment of the currently available global and regional climate projections for the Alpine Space was carried out. Model outputs available at the end of 2007 were considered. Based on some of these regional climate projections, small scale hydrological modelling in selected river basins of the European Alps was performed in order to identify possible climate change signals. In addition, climate impact scenarios on forest biodiversity and land use in the Alps as well as future scenarios of natural hazards were studied. Partners also determined critical factors and future risks potential for some model regions and highlighted gaps and research needs.

Climate change

In many cases, no general trends for the whole Alpine Space can be identified, though the picture becomes clearer when sub-regions north and south of the main Alpine ridge are analyzed separately.

- Temperature: Observations converge on a strong and general increase of the temperature in the Alps, with different magnitudes depending primarily on the emission scenarios and models used to predict the future climate and the country being examined. Model results show a trend of continuous warming: the mean alpine temperature could increase by 3 to 5° C in summer and 4 to 6° C in winter by the end of the 21st century.
- Precipitation: General trends concerning observed mean precipitation have not been found. However, heavy precipitations tend to increase in various seasons depending on the considered territory. Though models have difficulties calculating precipitation patterns especially in mountain areas, most projections until 2100 tend to decrease in summer and to increase in winter. Snow cover: General decrease of the snow cover is observed both in terms of height and duration especially at low and medium altitudes throughout the Alps, coupled with warming of air temperature. This decreasing trend is very likely to continue throughout the 21st century for all alpine countries.
- Glaciers: A retreat of the alpine glaciers has been observed since the end of the Little Ice Age. The disappearance of medium altitude glaciers and a general reduction of glacier volumes and lengths are being predicted for the 21st century.
- River discharge patterns: Significant changes in precipitation, snow cover and glaciers would be reflected in the river discharge patterns and induce a long term decrease of available water resources after a temporary increase în the upcoming decades characterized by heavy melting rates.

- Permafrost: Observations show degradation of permafrost and rock glaciers in the Swiss and French Alps, linked to increased temperature and a change in snow cover. According to model results, this trend would be enhanced with temperature increase.
- Vegetation: Observations show the migration of certain species toward higher altitudes. In the future, the composition of the vegetation group might change in altitude and latitude, inducing a loss of biodiversity, especially of the most endemic species that have a very limited climatic tolerance.

Resulting hazards

- Floods: An increase in the intensity and frequency of floods has been detected in some regions of the Alps (e.g. in South Germany). In the future, an increase of winter floods and decrease of summer low waters is expected, as well as an earlier flood peak due to snow melting.
- Debris flows: In recent years debris flows have tended to originate at higher altitudes in some parts of the Alps (e.g. Ritigraben and Écrins massif), with an observed decrease in some medium altitude areas. The increase in the amount of material available close to glaciers and the evolution of heavy precipitation patterns could in turn induce local increases in the evolution debris flow activity.
- Avalanches: A change in avalanche hazards in connection with climate change is uncertain, though it is assumed it would follow snow cover evolution. A decrease in avalanche hazards is likely in low and medium altitudes, though heavy precipitation events might counterbalance this trend by triggering general avalanche situations.
- Glacial hazards: Loss of stability of the hanging glaciers and the increase of number and size of proglacial lakes as a consequence of glacier retreat and ice temperature increase, seem to be the two main consequences of climate change in the context of glacial hazards.
- Mass movements: An increased number of rock falls were observed at high altitude during the 2003 heat wave. The degradation of permafrost in steep slopes is a major factor for the reduced stability of rock walls and the rock fall pattern. Increased precipitation might lead to more frequent and extended slopes instabilities.

Recommendations for Managing Impacts of Climate Change

Climate change monitoring and modelling in the Alpine Space

- An analysis of the existing climate data is a prerequisite for planning any kind of climate change adaptation activity. There are climate datasets available for the Alpine Space, but the existing potential is not fully exploited because many datasets have different temporal and spatial resolutions and need to be homogenized.
- In mountains, precipitation is highly variable in space and time, due both to orographic effects and the interaction of mountains with wind fields. To improve knowledge of the precipitation pattern, it is necessary to implement dense rain-gauge networks, and to combine them with the use of meteorological radars. These results would have hydrological, agronomical and natural hazard management applications.

- Higher resolution climate models and further analysis of the influence of large scale circulation patterns in the Alpine Space is needed in order to provide more reliable estimates of future changes in the climate in the region.
- To get more reliable model data for future climate changes at the spatial and temporal scale relevant for natural hazards, methods for correcting uncertainties in model projections have to be developed, tried and tested.
- It is important to maintain the existing glacier observation networks that can also provide input data for related topics, such as water availability, landscape and tourism issues.
- To complete the snow cover observation networks, new methods like those based on remote sensing and snow cover/climate coupled models should be promoted.
- More observations of permafrost and related parameters (air temperature and snow cover pattern), both in steep and gentle slopes are crucial for providing inputs for the permafrost models and to improve the understanding of the permafrost evolution.
- It is necessary to develop scientific studies on two main effects of climate change on mountainous forest vegetation: change in species composition inside forest stands, and evolution of the timberline's altitudinal limits. These two effects are central to the potential role of forests as protection against natural hazards in a changing climate.

Adaptation of natural hazards assessment to climate change in the Alpine Space

- Detected or modelled trends (e.g. design events) should be used to adapt the risk management tools to non stationary climatic conditions (e.g. re-evaluation of design events and crisis management).
- Existing flood data analyses and hydrological studies mainly consider peri-alpine large rivers (e.g. Rhine), while their tributaries are less studied. Therefore, particular focus should be given to those rivers and alpine torrents that have direct consequences for the Alpine Space. Precipitation-runoff models should be improved in order to assess the future impact of climate change on floods. Investigations are needed to bridge the gap between statistically derived and hydrologically calculated design floods. The interaction with climate change induced land use changes has to be improved.
- A continuation of the effort to assess the potential future evolution of debris flow and torrential floods in the Alps is needed. This could be achieved through the establishment of a better hydro-meteorological observation network. Better observations in the vicinity of glaciers and periglacial areas are also needed.
- Promotion and establishment of more accurate and systematic methods for trend detection and collection of avalanche data is strongly recommended, especially in areas where human settlements are threatened by avalanche activity. A better observation network (snow pack, meteorology and avalanches) with a good spatial density and long term observations can improve the accuracy of predictions.
- There is a lack of observations for mass movements and rock falls occurring above 2500 m a.s.l. It is necessary to continue to develop the existing data base as well as the meteorological indicators that are relevant for the considered hazard. In addition, there is a need to develop permafrost observation on steep rock walls to improve 3D models.
- Glacial hazards in the Alps have not lead to major catastrophes during the last decades. For this reason the research has not focussed on such natural events. Nevertheless, heavy variations of glacier extensions could generate new hazards (eg. new lakes dammed by unstable moraines or dominated by potential ice avalanches). Thus, the database "Gridabase" developed in the frame of the FP5 GLACIORISK programme (2001-2003) as well as numerical models should be used to evaluate future scenarios of glacial hazards.

Conclusions and Outlook

Both observations and model simulations demonstrate that the Alpine Space is one of the areas most sensitive to climate change in Europe. It is also the area where the highest uncertainties remain because of specific difficulties in monitoring and modelling arising from its topography. The complexity of the phenomena contributing to natural hazards and the small spatial and temporal scale at which they occur is a challenge for the task of monitoring and modelling alike. From an economic point of view this leads on to the question of the viability of monitoring at this scale. Thus, the observation networks for environmental parameters linked with climate change and natural hazards should be promoted, harmonized and merged in order to build robust data series for the whole Alpine Space and its sub-regions. Where possible, historical trends should be detected and their consequences analysed in collaboration with the appropriate alpine public authorities. In the meantime, research on regional climate models should be promoted and its progress integrated into the Alpine Space strategy for adaptation and risk management measures. For example, decision making can be facilitated by a set of well defined climate change scenarios based on climate change projections from the EU-Project "Ensembles" (available in 2008) in conjunction with regional climate model runs for the Alpine Space.

Coupling selected climatic outputs with impact models (e. g. hydrology, plant growth, erosion) should be encouraged in order to develop possible impact scenarios, plan further focused observation programs and prepare useful information on which decision makers can base concrete policies and responses.

WORK PACKAGE 6 · Leader: LfU (G)	
ARPA (I)	**AWNL** (LI)
BAFU (CH)	**BMLFUW** (A)
GeoZS (SLO)	**RAVA** (I)
RhoneAlp (F)	**UCB** (F)
WBV (I)	

Background

From the geological point of view, the Alps are a young mountain range which is still rising up. The land-forming processes are still ongoing. Most natural slopes are only in a sub-stable equilibrium. Climatic factors play an essential role for this equilibrium. Any change in these factors has the potential to shift this sensitive balance. The 4th IPCC report (2007) and the results of Work Package 5 indicate several changes in the climatic factors which will lead to a destabilisation. With regard to climate change consequences e.g. for permafrost, IPCC states (1): "The lower elevation of permafrost is likely to rise by several hundred metres. Rising temperatures and melting permafrost will destabilise mountain walls and increase the frequency of rock falls, threatening mountain valleys."

More generally speaking, an increase in different forms of landslides has to be expected. Climate change may trigger new movements, reactivate "dormant" landslides or accelerate already moving slopes. Thus, severe problems are foreseeable in the Alpine Space, threatening not only buildings and infrastructure like roads, railways and cable cars, but also human lives. In order to keep endangered areas habitable and to protect people, slope monitoring has become a very important prevention tool. The last decade brought a wide range of new slope movement detection technologies providing new prediction possibilities.

Main Objectives, Activities and Outputs

The transnational expert consortium of Work Package 6 focussed on monitoring of slope deformations as a representative element of a comprehensive hazard management. The main aim was to contribute to the improvement of risk prevention and management in this specific field. To this end, the broad variety of present slope monitoring techniques and their application in vulnerable areas was compared, assessed and enhanced. In this framework, a compilation of best practice examples was generated underlining the benefits and possibilities of current monitoring methods.

Particular effort was dedicated to the clarification of possibilities and limits of state of the art slope monitoring techniques. As a matter of fact, each approach showed strengths and weaknesses depending on the framework conditions and surroundings where they were applied. Thus, standardised proceedings are not possible, above all because each hazardous site shows specific problems.

Furthermore, an international expert network on slope monitoring has been established. A fundament for this network is a new database providing background information on monitoring methods and corresponding experiences as well as contact details of concerned authorities and experts. The expert network represents the basis for long-term cooperation even beyond ClimChAlp.

Recommendations for Managing Impacts of Climate Change

Enhancing appreciation of slope monitoring in the Alpine Space

- Due to climate change and its geologic consequences, monitoring of slopes will gain further importance. It is a crucial tool for landslide prediction and prevention. The potential of slope monitoring is well known to experts, but not to non-technical or non-scientific stakeholders. Thus, slope monitoring should be encouraged and enhanced in terms of political and public perception by adequate awareness raising activities.
- Slope monitoring has to be regarded as an important element of hazard management. A comprehensive management approach also includes hazard identification, hazard assessment and hazard information. The required information can be provided by Geographic Information Systems and related databases which also include historical information.

Starting slope monitoring and disaster prevention as early as possible

- Generally speaking, slope monitoring should be applied more intensively in the Alpine Space. This can contribute in an anticipatory way to the protection of human beings, settlements, public and private infrastructure. To meet such demands, monitoring and subsequent prevention activities should be initiated in endangered areas as early as possible.
- The earlier prevention of disasters caused by slope movements starts, the lower are the required financial means. Slope monitoring is an essential component of disaster prevention and thus should start in due time.
- Due to slow deformation rates, a detailed deformation analysis often takes time, sometimes several years. When the circumstances allow it, this time horizon should be accepted. It can only be reduced by increasing the accuracy of measurements. However this normally also means an increase in effort and costs.
- In spite of all potentials and benefits of slope monitoring, it has to be considered clearly that monitoring cannot replace any necessary protection measures.
- Prevention basically starts with land-use and local development planning, in which slope monitoring together with other geological information can play an essential role.

Reducing costs for prevention, protection and damage restoration by slope monitoring

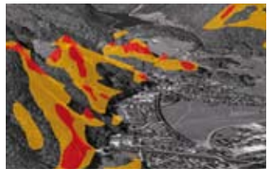
- The most suitable mean in terms of cost reduction is basically to avoid any building and infrastructure in endangered zones. Slope monitoring can be used for identifying critical areas in territories yet undeveloped.
- In many cases, slope monitoring is much cheaper than establishing protection works. If the circumstances allow it, investing in monitoring as a precaution measure is much more economical than restoring damages caused by landslides and rockfalls.
- If protection is indispensable, slope monitoring can contribute significantly to the preparation and implementation of suitable measures. For slopes which are already in movement, monitoring provides often the only possibility for prediction. It therefore constitutes the basis for any geo-mechanical interpretation. Investing in deformation analysis can remarkably reduce costs for adequate retention and technical protection constructions.

Paying special attention to monitoring of permafrost zones

• Under future climate conditions, the intensity of debris flow processes in permafrost areas is expected to increase. Thus, maintenance costs for existing protection structures must be aligned.

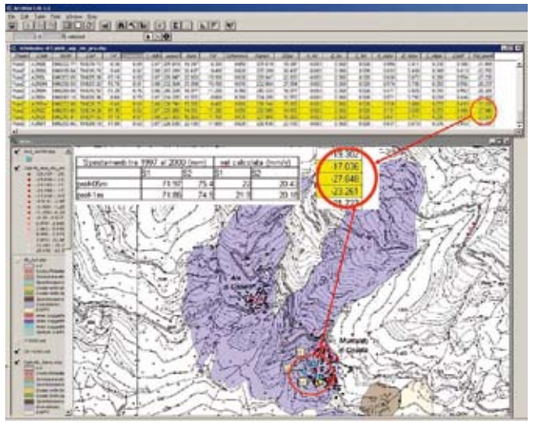
• Ongoing permafrost changes in rock cliffs remain poorly understood because of the difficulties in carrying out in situ measurements. So far, permafrost studies are mainly based on modelling with few existing instrumented sites. Therefore permafrost change and its impacts have to be monitored conscientiously in these highly sensitive areas to gain better input data for the improvement of models.

Harmonising danger rating in the Alpine Space countries



• The increasing landslide potential notwithstanding, there is still no transnational rating of connected threats. Therefore, steps towards a harmonisation of the rating of the danger arising from moving slopes should be taken in all countries of the Alpine Space. A common understanding in this respect has to be regarded as a crucial precondition for transnational collaboration in the field of geologic risk assessment. Such a harmonisation is also postulated by the Alpine Convention.

• In the same way maps and information systems related to geological hazards have to be harmonized. Danger maps, hazard maps, susceptibility maps and if need be also risk maps should follow a minimum standard in all Alpine countries. To achieve this, the harmonisation of specific terms in the form of a multilingual glossary is recommended.



Further developing and enhancing slope monitoring technologies

• The slope monitoring methods are evolving rapidly, especially those based on remote sensing. Further improvements are to be expected in many fields, and knowledge is changing constantly. Nevertheless, there is a distinct need for further research and development.

• Irreplaceable traditional monitoring methods like terrestrial surveying should be further developed and enhanced. Their practical application should be supported by the regional authorities.

• Further research is especially required in the fields of remote sensing, GPS, radar and laser technologies. Regional and national authorities should support the development of these methods and contribute to the financing of test applications in close cooperation with scientists.

• New technologies enabling the detection and analysis of unstable areas within large alpine regions – which could not be identified by means of remote sensing until now – should be promoted.

Supporting international networks of researchers and practitioners in the Alpine Space

• In order to exchange experiences and to foster harmonisation, a vivid international network of researchers and practitioners in the Alpine Space is required. It is recommended to concerned decision makers to support the creation and establishment of such a network. The ClimChAlp project can be regarded as an initial step towards such a transnational long-term collaboration.

• Intensive exchange of experience and knowledge between scientists, administration and further stakeholders will provide a significant transnational added value in the field of hazard management

Conclusions and Outlook

Slope monitoring represents a crucial and valuable tool for hazard prediction and risk prevention in the Alpine Space. It is especially essential in such areas which will suffer severely from climate change impacts. Therefore, it is now of major importance to identify the endangered areas in order to start or enhance prevention measures.

Slope monitoring may serve as an early warning system. The project results show that this is only possible in special cases and with a high technical and socio-political effort. So their use should be carefully evaluated and limited to the most critical cases only.

Although prevention requires adequate financial means and does not show immediate results, it is on the long term the cheapest and most sustainable way to save lives and goods. The corresponding importance of slope monitoring is fully recognised by experts, but not yet by policy-makers and the public. Thus, risk communication has to be improved substantially.

Depending on the specific site conditions, experts can choose the most suitable slope monitoring technology from the broad variety of approaches available. The Work Package 6 results may help to find advantages and disadvantages of the many methods proposed. Therefore it supports the identification and application of the method that corresponds best to the site-specific problems. However, time for a comprehensive monitoring is in most cases restricted. Therefore the inclusion of historic data as a retro-perspective analysis tool is substantial, because it widens the time span observed and thus helps to determine the probability of an event. The term "slope monitoring" is used in a very broad context. A large variety of methods and approaches exists and these might be applied. The present knowledge concerning state-of-the-art slope monitoring has been gathered and documented in the extended WP6 report. However, monitoring methods are evolving rapidly. Further improvements are to be expected in many fields of slope monitoring and the knowledge is growing constantly. Therefore the WP6 report elaborated by the partnership represents first of all a status quo. There is the clear need for continuation of the transnational collaboration and exchange of information especially regarding experiences made with new methods.

Sources

(1) IPCC, Intergovernmental Panel on Climate Change (2007): Mitigation of Climate Change. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Geneva.

WORK PACKAGE 7 · Leader: StMWIVT (G)	
MATTM (I)	**NOe** (A)
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UBA (A)	**UCB** (F)
UIRS (SLO)	

Background

Climate change will pose enormous challenges to spatial development in the Alpine Space and to key economic sectors like tourism, forestry and agriculture. Several recent studies like OECD 2007 (2) identified the increasing exposure of settlements and infrastructures to natural hazards as well as growing losses in winter tourism due to reduced snow cover as the primary vulnerabilities to climate change in the Alps.

As far as spatial development is concerned, spatial conflicts between natural hazard protection on the one hand and settlement and infrastructure development interests on the other hand will grow, especially in the valley floors where space is limited anyway. Safeguarding the existing structures and enabling future development at the same time will therefore become a main task for spatial planning on regional and local level. For winter tourism, decreasing snow reliability could in the long run turn into a major problem for skiing areas at lower altitudes while those at higher elevations could have a competitive advantage. In the field of forestry, rising temperatures and changing precipitation patterns will affect pre-alpine and mountain forests severely, above all forests dominated by Norway spruce.

However, climate change will not only have negative impacts, but could also open up certain opportunities – which have to be detected in due time and utilised reasonably. Thus, spatial planning as well as the economic sectors need specific adaptation strategies in the Alpine Space – both in terms of avoiding potential climate change threats and capitalising on possible future advantages.

Main Objectives, Activities and Outputs

In several model regions all over the Alpine Space, the Work Package 7 partners examined challenges and chances of climate change for spatial development, tourism, forestry, agriculture and water management. While some model region studies covered all or several of these fields, some focussed on single issues. In each case, the main objectives were to analyse and assess potential future climate change impacts in the respective field and to set up corresponding change management recommendations.

To this end, qualitative model region scenarios were created for the year 2030 and beyond, based on available climate projections and further input like expert interviews and stakeholder workshops. In order to check whether policy, administration, enterprises and stakeholders take the expected climate change impacts adequately into account, the current strategies and instruments of spatial planning and the economic sectors were reviewed against the background of the scenarios. This cross-check revealed a broad range of need for action, finally leading to a variety of proposals for adjusting spatial planning, tourism, forestry and agriculture in the model regions and – as most recommendations are transferable – in the entire Alpine Space.

Main Recommendations for Managing Impacts of Climate Change

Spatial planning and spatial development

Intensifying the debate on reaction options to climate change impacts

- Adaptation to climate change impacts is a rather novel issue for spatial planning implying a variety of uncertainties. The debate on the reaction options should therefore be intensified between policy-makers, administration, researchers and the public.
- The European Commission Green Paper "Adapting to climate change in Europe – options for EU action" (3) launched the political debate on European level. This initiative should be carried on and concretised by the Alpine Space countries.

Enhancing policy and legislative framework

- Adaptation to climate change should become a core objective of spatial planning on all levels. On EU level, the Commission could set up an Action Plan for spatial adaptation. Adaptation issues should also be integrated in funding programmes. On national / regional level, spatial planning acts and instruments should be adjusted correspondingly.
- Enhancing policy and legislation efforts cannot be limited to spatial planning only. All concerned policy fields should take spatial adaptation more intensively into account.
- The states and their institutions alone cannot cope with the challenges arising from climate change. Thus, policy-makers should discuss and clarify in principle the balance between state and private responsibility for risk prevention, precaution and adaptation.

Identifying, assessing and mapping spatial risks

- Comprehensive databases including all relevant spatial information on municipality and sub-local level should be established. Geographic Information Systems containing land-use and land cover, all available sectoral risk information and binding spatial regulations are most appropriate for this purpose. Such databases allow – in close cooperation with meteorologists, climatologists and the responsible authorities – the detection of climate change-related spatial risks.
- This first step of risk analysis should build the basis for detailed vulnerability assessments covering the factors exposure, sensitivity and adaptive capacity. The assessment procedures should especially identify highly endangered and vulnerable areas.
- As an analysis and assessment outcome, spatial vulnerability maps should be a major goal. They should visualise the vulnerability of the covered area to climate change-related impacts. The assessment and mapping methodology, which has yet to be elaborated, tested and adapted, should be transferable to the whole Alpine Space.

Avoiding and reducing risks by future-oriented integrative planning

- The overall aim of risk-oriented spatial planning is to achieve the greatest reduction of the most unacceptable risks in the most cost-efficient way, and to decide which risks are acceptable if weighted against benefits that may arise from taking those risks.
- Risk reduction and avoidance should be strengthened by intensifying the following approaches:
- Direct risk precaution by keeping highly vulnerable areas and areas required for risk prevention free from development
- Indirect risk precaution by steering development to areas with no or only little vulnerability
- Determining adequate construction regulations and safety measures in local development plans
- For existing settlements and infrastructures with distinct vulnerability, adequate technical protection measures have to be taken. However, especially extensive measures should undergo a cost-benefit analysis.
- A "risk dialogue" should be initiated between administration and the public. This process should inform inhabitants and land owners about the on-site risks and the individual responsibility for risk precaution.

Tourism

Objectifying the debate about climate change adaptation needs

- As tourism industry can adapt services and infrastructure within a few years, an objectification of the debate about short-, medium- and long-term effects of climate change is needed. Current depreciation cycles of tourism infrastructure last 10-15 years. Thus, short- and medium-term impacts are crucial for this key economy and should be focussed on.
- Tourism decision-makers should realise that in most Alpine tourism centres adaptation needs emerging from climate change will rather arise from changing consumer behaviour within the next decade than from direct change of climatic conditions.
- As a basis for product innovation in the Alpine tourism industry, market research about European consumer behaviour should be intensified immediately. The results should provide a solid fundament for future investments.
- Public debate mostly deals with consequences of climate change for Alpine winter sport resorts and glaciers. In regions at lower altitude, winter tourism offers could certainly be diversified and snow-independent alternatives developed. Nevertheless, the summer season is of equal or even higher importance for these destinations. Therefore, tourism innovation strategies have to be regarded as much more differentiated and should be individually developed for each region reflecting the potential of touristic attractors season by season.

Understanding climate change as a driving force of innovation

- Due to strong and continuously growing demand, Alpine tourism developed rapidly from the 1960´s to the 1980´s, mostly by expansion of existing concepts but without real innovation. Hence, the debate about the challenges posed by climate change should be used as an impetus for a new culture of innovation in Alpine tourism.
- Stakeholders involved in the tourism sector should be better qualified in the field of product innovation which goes far beyond modification or adaptation of existing infrastructure and services.
- A comprehensive analysis of interaction between the driving forces climate change, energy prices and demographic change is required to identify future opportunities of the different Alpine destination types. Results should to be discussed in each tourism centre to set up corresponding regional tourism innovation programmes.

Implementing sustainable regional tourism strategies

- Due to short innovation cycles in tourism, long-term development strategies often do not exist. Based on the concept of sustainability, master plans for regional tourism should be created within the framework of participative processes. These tourism plans should be linked with the regional spatial plans.
- The global dimension of climate change and ecologic problems will lead to an increase of environmental awareness in the European society. Thus, sustainable tourism concepts have to be implemented all over the Alpine Space as a prerequisite for future consumer acceptance.

Forestry

- Conversion of Norway spruce (Picea abies) monocultures in lowlands into mixed forests with tree species able to adapt to changing climate conditions should be enforced. In the frame of forest conversion, natural forest regeneration should be strengthened (and browsing damages by ungulates be reduced respectively). However, Norway spruce will still find suitable growing conditions in the higher montane and the subalpine zones.
- Forests with a prior need for action should be identified and treated adequately first. This is particularly important for forests with protective functions (especially for highly vulnerable areas, e.g. for settlements or infrastructure) growing in unstable conditions, on degraded soil and in places with insufficient natural regeneration. Technical protection measures are necessary in places where conversion and regeneration measures are not sufficient for providing the required forest protective function.

- As forest conversion, stabilisation and adaptive management demand enormous budgets, additional financial support will be needed. Furthermore, awareness raising and guidance is necessary especially for private forest owners, e.g. with computer-based decision support tools to help forest managers and owners identifying vulnerable forests and adapting management accordingly.
- With regard to the currently increasing demand for timber as an energy source, policy and authorities should take care of a suitable forestry intensity level. Excessive biomass harvesting should be avoided to prevent forest destabilisation and soil degradation.

Agriculture

- Farming methods should be adapted to changing climatic and site conditions. Adaptation options are for example using adjusted plant species, establishing irrigation systems in dry areas and above all informing farmers about necessary adjustments. A distinct expansion of arable farming should be avoided in traditional grassland farming areas due to ecological and aesthetic reasons.
- Furthermore, agriculture should contribute to risk precaution (especially to soil and flood protection) by applying cultivation methods which are in accordance with the specific location and vulnerability.
- Agricultural policy on all levels should support climate-proof farming practices in the frame of funding programmes (e.g. agro-environmental measures) and compensatory allowances.
- Generally speaking, the states should decide upon the future extent of state aids in case of extensive damages to agricultural harvest (e.g. floods). In this context, it should be discussed which share of future risk will be borne by the state and which share will be transferred to farmers and insurances respectively. In order to minimise climate change related economic risks, farmers should try to diversify their agricultural income.

Conclusions and Outlook

In all treated fields – spatial planning, tourism, forestry and agriculture – awareness raising, transdisciplinary communication and cooperation were identified as key factors of climate change adaptation. These processes have to involve policy-makers, administration, researchers, associations, enterprises as well as the public. As a prerequisite for understanding each other, a "common language" in terms of climate change and its impacts is essential – not only when addressing the public, but also for cross-sectoral cooperation. Another basic requirement is to bridge the gaps between climate research and climate change impact research by reducing uncertainties in deducting spatial and economic impacts from climate change models. Further case studies on regional, local and sub-local level are needed to improve the knowledge of climate change impacts on spatial development and economy and to transfer new findings into adequate and applicable adaptation measures in the Alpine Space.

Sources

(2) OECD (2007): Climate Change in the European Alps. Adapting Winter Tourism and Natural Hazards Management. Paris.
(3) COM (2007) 354: Adapting to climate change in Europe – options for EU action. Green Paper from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Brussels.

WORK PACKAGE 8 · Leader: BAFU (CH)	
ARPA (I)	BMLFUW (A)
BWV Kaernten (A)	MATTM (I)
RAVA (I)	RhoneAlp (F)
StMUGV (G)	WBV (I)

Background

Intensive use of land is the main reason for land degradation. Though the immense investigations in protection structures, the damages caused by natural disasters in the Alpine Space are constantly increasing. On the one hand, the remarkable growth in extent and value of endangered settlements and infrastructures contribute, for a large part, to this evolution. On the other hand, there are areas where natural hazards increase in intensity and frequency due to specific effects of climate change. As shown in the other sections of the ClimChAlp project, the occurrence of natural processes like soil erosion, floods and debris flows in high altitude catchments is expected to increase. In the most sensitive zones of the Alps, changes in natural processes have started to impact on human activities more than in the past producing growing damages to property and economic activities. Moreover, uncertainties arising from climate change analysis and scenarios and their complex coupling with natural hazards make rather complex to determine effective measures for dealing with climate variations and their consequences in terms of risk for human activities. Nevertheless, both observations and models point out that the countries of the Alpine Space are and are expected to be largely affected by the effects of climate change on a cross-border basis. Thus, the advantages of a greater cooperation between the Alpine regions in the development of common solutions, tools for risk prevention and management or adaptation strategies are apparent. The intensification of the transnational collaboration in the Alpine Space is a declared aim of the countries of the Alpine Convention and is also emphasized in the Mountain Forest Protocol of the Alpine Convention, the EU Forest Action Plan, the EU Water Framework Directive and the EU Flood Directive.

Main Objectives, Activities and Outputs

The purpose of WP8 was to provide policy makers, the Alpine public administrations and the Alpine Convention (with special reference to the Platform on Natural Hazards of the Alpine Convention-PLANALP[1]), with a basis for the design of future planning of actions which, in turn, will contribute to cross-border integrated natural hazard risk management and facing specific consequences of climate change.

An overview of existing natural hazard and risk management techniques and practices in the Alpine Space was provided. This collection of current (trans-)national and regional administrative structures and hierarchies responsible for risk management was implemented into the PLANALP-db computer-based information database (accessible on www.climchalp.org). Well proven, effective and innovative solutions for risk management and prevention were identified and collected as best practices. An international expert hearing was organized in May 2007 in Bolzano to address the possible consequences of climate change on frequency and intensity of precipitation events and their effects on discharge, erosion and bedload transport. Having analyzed and compared the existing natural hazard and risk management practices, the institutions and experts involved provided advices concerning future potentials for the optimization of risk management. According to the conclusions drawn, the needs and the opportunities of a trans-regional coordination of natural hazards management techniques are highly advisable. Appropriate structures, methods, measures and a high-level scientific background are prerequisites for the enforcement of a transnational Flexible Response Network (FRN) which aims at improving the cross border cooperation and the exchange of knowledge, experience and best practices applied in different regions.

Recommendations for Managing Impacts of Climate Change

The developed analyses revealed that the integrated approach of natural hazard and risk management is best suited for facing all relevant effects of climate change regarding natural hazards and risks. The following recommendations aim at paving the way for optimizing the adaptation of risk management practices to the effects of climate change:

- Continue to develop a well structured strategy for integrated natural hazard risk management and encourage the implementation of appropriate tools, taking into special consideration climate change scenarios and growing uncertainties in integrated natural hazard risk management and in risk-based decision-making. This requires the cross-sector cooperation of all responsible stakeholders.
- Make use of and enhance existing local, regional, national and cross-border networks of public authorities for natural hazard risk management and improve cooperation and communication activities among different administrative levels and bodies at the regional and national level.
- Continue in the effort to establish a Flexible Response Network (FRN), by intensifying cross-border cooperation, sharing of experience and knowledge on integrated natural hazard risk management both at operational and strategic level. To this end, techniques for effective risk management under uncertain conditions have to be promoted. Skilled experts and practitioners in different fields, including for example regional planners, technicians, the police, the fire brigades, the civil protection, policy makers and the army, need to be involved from different Alpine regions.
- Facilitate the sharing of experience and knowledge available in different Alpine regions by promoting expert hearings focused on the cross-border discussion of problems and on problem-solving approaches based on expert knowledge. Organize education initiatives and training courses especially for young practitioners in integrated risk management at the international level including expert hearings at local and regional level. Continue to widen the PLANALP-db computer-based information database which is based on the strategic requirements of the Flexible Response Network and use it as a platform for communication of best practices at the transnational level.
- Promote the development and updating of hazard maps and their implementation into regional planning. Hazard maps are still lacking in many municipalities of the Alpine Space.
- Promote the individual responsibility of the public towards possible risks connected to natural hazards and climate change and promote a solidarity approach among governments, insurance companies, the private sector and the civil society and between mountain areas and valleys.
- Increase the involvement of the public in planning permanent mitigation measures and local emergency trainings for improving the individual responsibility and the awareness of the public and for increasing preparedness in case of disasters. Promote training and education initiatives to provide planners, architects and citizens with appropriate information about natural hazards and adequate protection measures.
- Increase the maintenance of already existing protection structures to keep the present level of protection and promote the re-examination and further development of protection concepts.
- Design strategies for the establishment of activities during and after extreme events. The improvement of early warning systems, and the enforcement of sustainable solutions in the context of protection and risk reduction strategies are strongly suggested.

[1] Established in 2004 by the 8th Alpine Conference in order to develop joint strategies for natural hazard prevention throughout the Alpine Space and paying a special attention to climate change possible consequences on natural hazards.

Conclusions and Outlook

A sizeable stock of knowledge and experience on protection against, and management of, natural hazards has been developed in the Alpine Space. Thanks to modern media and mobility options, there are no longer limits to the use and the effective implementation of this knowledge into risk management practices. According to the conclusions drawn, a trans-regional coordination of natural hazards management techniques is highly desirable. As explicitly expressed by the Platform on Natural Hazards of Alpine Convention (PLANALP), there is a demand of the Alpine countries for an intensified co-operation in the Alpine Space.

The institutionalization of the Flexible Response Network (FRN) is likely to enforce the efficient use of the available knowledge and experience for further development of integrated natural hazard risk management on a cross-border basis in the Alpine Space. The collaboration among the most relevant stakeholders in risk management on trans-national level within a single network can support the cross-sector and cross-border cooperation in risk management on regional and local level and can help in finding suitable strategies for addressing cross-border problems. Through the promotion of an ongoing transfer of the stock of knowledge and common educational courses for practitioners, the network could provide flexible responses to specific effects of climate changes.

The main beneficiaries of the FRN are the responsible organizations for natural hazard risk management and local actors in charge of the implementation of safety measures together with associations, the education and research institutions, as well as the insurance companies. At the international level, the Permanent Committee and the Platform on Natural Hazards (PLANALP) of the Alpine Convention, the European Forestry Commission (EFC), the Working Party on the Management of the Watershed (FAO), the Mountain Partnership, Interpraevent and EuroMontana can take advantage of the FRN.

A continuous effort is needed to support the institutionalization of this network. The FRN should aim at selecting best practices of integrated natural hazard risk management, promoting cross-border cooperation, "know-how" transfer and participation of talented natural hazard specialists in developing the transnational network and implementing the required joint actions.

The added value that the FRN is expected to produce is appreciable independently from the consideration of the effects of climate change, but it becomes of major importance in changing climatic conditions in order to assure the preparedness of the Alpine Space to unexpected consequences. The added value produced through international cooperation is expected to enhance problem-solving capacities of all the stakeholders in natural hazard and risk management and create and use synergies deriving from the intensified cooperation.

FRN future activities could include a support to PLANALP in periodic reporting on the progress achieved in integrated natural hazard risk management in the alpine regions, launch of PR and communication campaigns with a cross-border scope, dissemination of good examples of natural hazard and risk management, testing of tools for risk-based decision making on a trans-regional level and enhancement of information exchange especially in case of cross-border events producing damages. FRN could also work on the preparation of strategies for decision-making to be applied by competent authorities in case of natural disasters.

CONCLUSIONS AND OUTLOOK

Knowledge on Climate Change in the Alpine Space

Broadening and deepening the knowledge on climate change and its related impacts in the Alpine Space represents the indispensable basis for the elaboration of sustainable adaptation strategies. Especially on the regional and local level decision makers need reliable and comprehensible information to develop feasible reactions to the changed climatic framework and its consequences. At the same time, all efforts invested into adaptation should not lead to a reduction in efforts to mitigate climate change (i.e. reduction of greenhouse gases).

It is evident that climate change influences the alpine ecosystem, land use, water management and other socio-economic sectors in the entire Alpine Space more severely than in other European regions. Growing risks from natural disasters threaten settlements, infrastructure, lives and future development options, causing spatial conflicts between, for example, risk prevention and land use interests. In 2005 the entire northern Alpine region had to cope with extreme floods which caused severe damage in Switzerland, Germany and Austria. Thousands of people had to be evacuated; tens of thousands were without electricity and drinking water. Six people died. Thousands of buildings were damaged and the business interruption losses were enormous.[2]

Simultaneously with the global warming, the uncertainty concerning the conception of protective measures and the definition of design events increases. The direct effects of climate change can hardly be influenced. It is, however, possible to adapt to the resulting consequences of global warming and climate change. Therefore, in addition to the technical measures, strong emphasis must be placed on "soft" measures.

Strategic, Sross-Sectoral and Transnational Approach

In order to succeed, a strategic approach is required. First of all such an approach should focus strongly on transnationally harmonized integrated risk management. But also risk-oriented spatial planning and risk governance should play a key role in sustainable territorial development. Reducing spatial vulnerability and increasing resilience will avoid damages and keep the Alpine Space safe and attractive for living, working and recreation and establishes favourable conditions for growth and competitiveness. To substantially advance the adaptation and mitigation process, stakeholders of all levels must be considered. Not only scientists and experts, but also the public and politicians must be involved. Residents and property owners need to accept individual responsibility as well as authorities and administration. Consequently the improvement of the cooperation between scientists and practitioners is necessary. Interface management between spatial planners, technicians, industry, leading economic branches and service providers, the police, fire brigades, civil protection, politics, the army and other stakeholders should be improved.

[2]Munich RE Group, Topics Geo: Annual review: Natural Catastrophes 2005

The ClimChAlp Project as a Starting Point for Future Activities

The topography of the Alps is the main reason that impacts of climate change affect several countries at the same time and manifest themselves more strongly than elsewhere. To face these challenges it is crucial that continuous and long-term transnational and interdisciplinary cooperation between experts and decision makers is brought forward. An effective transnational cooperation should interlink the experiences and results elaborated in different projects and continuously bring together the knowledge of experts. The ClimChAlp project constituted an important starting point for this indispensable transnational cooperation. Comprehensive databases and expert networks have been established and developed, analyses and simulations have been carried out, knowledge has been enriched and transferred, experiences shared and best practices collected. ClimChAlp delivered valuable information and important tools which will support prevention, management and adaptation to different impacts of climate change in the Alpine Space.

Keeping in mind the increased risks, it is essential that transnational cooperation is pursued continuously and actively and that all efforts are accompanied by adequate resources. The benefits arising from such a well established cooperation can contribute to assuring a balanced and sustainable development of the Alpine Space. The better groups and individuals affected by increased risks are informed, the easier it is to implement precautions and preventative measures. Improved early warning systems and harmonised disaster action plans will help to reduce private and public costs connected to disaster events significantly.

Further efforts have to be made to keep the Alpine Space attractive for investments as well as recreation activities and thus for employment opportunities.

Climate Scenarios and Monitoring

Climate data is a prerequisite for any future activity. There are climate datasets available for the Alpine Space, but their potential is not fully exploited because they have different temporal and spatial resolutions and need to be homogenized. Uncertainties still remain because of specific difficulties arising from alpine topography. Higher resolutions of climate models and further analysis of the influence of large scale circulation patterns on the Alpine Space is needed in order to provide more reliable estimates of future scenarios. Up-to-date environmental monitoring data (e.g. river discharges) in combination with regional climate scenarios represent further crucial fundaments for prospective decision making. Albeit national and regional public authorities gather manifold up-to-date environmental parameters, those are not merged into a common transnational alpine database. Setting up such a transnational database would essentially help to assess the impacts of climate change in the Alpine Space. Furthermore the inclusion of historic data as a retro-perspective analysis tool is substantial for monitoring and modelling of climate change scenarios and all kinds of natural hazards. On this basis methods for correcting uncertainties in model projections have to be developed and tested to derive regional impact scenarios with a high resolution.

Risk Assessment, Spatial Development and Risk Communication

Hazard maps are still lacking in many municipalities. Above all intersectorally and transnationally harmonized hazard maps are barely or not available at all. Therefore transnational and cross-sectoral cooperation must focus on finding a "common language" assessing natural hazards.

However those elements are necessary to successfully continue developing a well structured strategy for integrated risk management and facilitate risk based decision making. It is necessary to promote the usage of hazard maps in regional planning. Comprehensive databases including all relevant spatial information on municipality level and sub-local level should be established. Geographic Information Systems containing land-use and land cover, all available sectoral risk information and binding spatial regulations are most appropriate for this purpose.

Additionally already endangered sites should be continuously monitored. In combination with well elaborated masterplans (e.g. including local emergency trainings) during and after extreme events this approach represents the basis for a sophisticated early warning system, if it is continuously adjusted. Although this kind of prevention requires adequate financial means

CONCLUSIONS AND OUTLOOK

and does not show immediate results, it is, in the long run, the cheapest and most sustainable way to save lives and goods.
At the same time a risk dialogue should be initiated between administration and the public. This process should inform inhabitants and land owners about the on-site risks and the individual responsibility for risk precaution. Policy-makers should discuss and clarify in principle the balance between state and private responsibility for risk prevention, precaution and adaptation, also promoting a direct involvement of insurance companies.

Transnational Cooperation and Regional Implementation

There is a clear need for continuation of the transnational cooperation and exchange of information, especially regarding experiences made with new methods and successful adaptation strategies. Raising awareness, transdisciplinary and transnational communication and cooperation were identified as key factors for successful climate change adaptation.
To be effective, those processes have to involve policy-makers, administration, researchers, associations, enterprises as well as the public. Thus, risk communication as well as spreading of information on possible impacts of climate change has to be improved substantially on the public and political level. Further case studies on regional, local and sub-local level are needed to improve the knowledge of climate change impacts on spatial development and economy and to transfer new findings into adequate and applicable adaptation measures in the Alpine Space.

Flexible Response Network for Transnational, Integrated Risk Management

In this context, a transregional and transnational coordination of natural hazards management techniques is highly desirable. The Flexible Response Network set up in ClimChAlp is expected to enable the efficient use of the available knowledge and experiences for the further development of integrated natural hazard risk management on a transnational basis in the Alpine Space.
It has achieved transnational cooperation between key stakeholders in risk management within an established network. This will encourage and support cross-sectoral and cross-border collaboration on the regional and local level as well as facilitating the advancement of suitable strategies for cross-border issues. Through the promotion of ongoing knowledge transfer and training measures for practitioners, the network could provide flexible responses to specific effects of climate changes.
A continuous effort is needed to support the long-term institutionalisation of the Flexible Response Network. It should aim at selecting important examples of integrated natural hazard risk management, promoting transnational cooperation, "know-how" transfer and participation of renowned natural hazard specialists in developing the Flexible Response Network and implementing the required joint actions.
Within two years of extensive work, the ClimChAlp project produced a very valuable methodological basis and recommendations for adaptation on climate change and for the advancement of an effective transnational cooperation. The ways in which climate change manifests itself in the Alpine Space are as heterogeneous as the region itself. Therefore, in a step by step adaptation plan for the years to come, the results and recommendations elaborated in ClimChAlp should be implemented above all within local and regional adaptation strategies.

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