The importance of high quality regional scientific information in coping with global climate change

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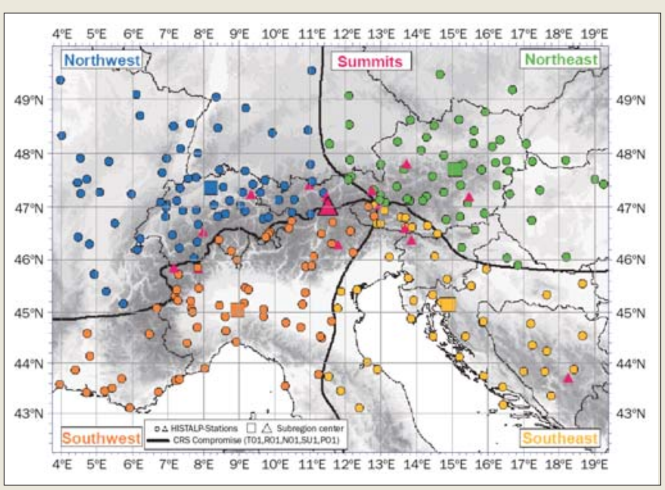
ZAMG, the Austrian weather service, regards the production, the quality control and the analysis of high-quality climate data as one of its core duties. This includes the maintenance of a meteorological network adequately vast to cover the complex terrain of the country. However, national borders do not usually correspond precisely with climate domains. In the late 1990s ZAMG began formal and informal cooperation with the national met-services and other data providers of the greater alpine region (GAR) to create and maintain the common climate database HISTALP.[1]

The intention was to aim for the following principles:

- Long term — fully exploiting the potential of systematically measured data
- Dense — network density adequate with respect to the spatial coherence of the given climate element
- Quality improved — outliers removed, gaps filled
- Homogenized — earlier sections adjusted to the recent state of the measuring site
- Multiple — covering more than one climate element

The greater alpine region in south-central Europe



Showing its five principal horizontal and vertical coarse resolution sub-regions and the network of HISTALP stations for long climate time series

Source:

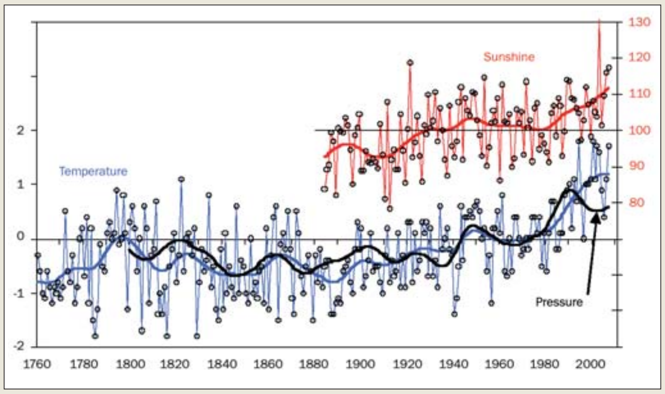
- User friendly — well described and kept in different modes for different applications, in scientific research as well as for technical, educational applications and for providing quality information about climate variability and change for the general public.

So far HISTALP has concentrated on longer monthly series (some 30 of them starting in 1800 and earlier) allowing us to better solve the homogeneity problem — for which severe problems still exist with respect to daily or sub-daily series. However, the first steps towards the inclusion of daily series are underway. HISTALP data are kept in three modes: station-mode (original and homogenized for all seven climate elements); grid-mode-1 (anomaly series of temperature, precipitation and air pressure at a grid size of 1 degree latitude-long, respectively); and CRSM-mode (coarse resolution sub-regional means — anomaly series of all seven climate elements as spatial means of five principal sub-regions of the GAR, objectively detected via PCA).

The GAR is climatologically characterized by a complex terrain of three different large scale climate regimes: Atlantic-maritime influences from the west versus continental climate from the east, as well as the Mediterranean climate with its annual cycle of subtropical highs further north in the summer and further south in the winter. These three horizontal regimes are overlain by the vertical gradients of all climate parameters. This makes the region interesting for scientific study; specifically the study of a situation where nature and human societies exist in a sensitive mountain region. The area serves as a great example of the potential practical applications that can be derived from regional climate change research.

A few examples serve to illustrate some of the leading climate change and variability patterns, as well as demonstrate their scientific and applicative relevance. Firstly, the GAR has warmed twice as much as the northern hemisphere land surface since the late 19th century.[2] The main driving force behind this additional 1°C warming above the global background is a northward shift of the subtropical high pressure system. Put simply, this has produced more incoming radiation. This synoptic feature is clear

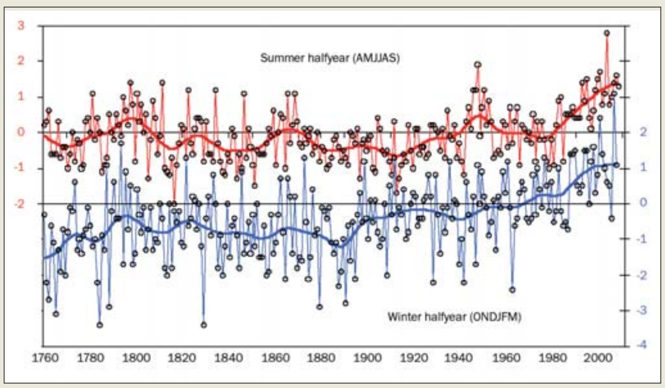
Regional annual mean time series of three closely linked climate elements in the GAR



Blue shows a low elevation mean temperature, while red indicates high elevation mean sunshine. Black shows low elevation mean air pressure and is the only smoothed curve

Source:

GAR mean temperature between 1760 and 2007



Low elevation mean temperature series for the summer- and winter-half years between 1760 and 2007

Source:

because of the high elevation sunshine, which is neither influenced by low stratiform clouds nor by anthropogenic changes of atmospheric turbidity (global dimming versus global brightening). As a rule of thumb, we can state that the region has warmed by another 1°C beyond the given 1°C stemming from the global background.

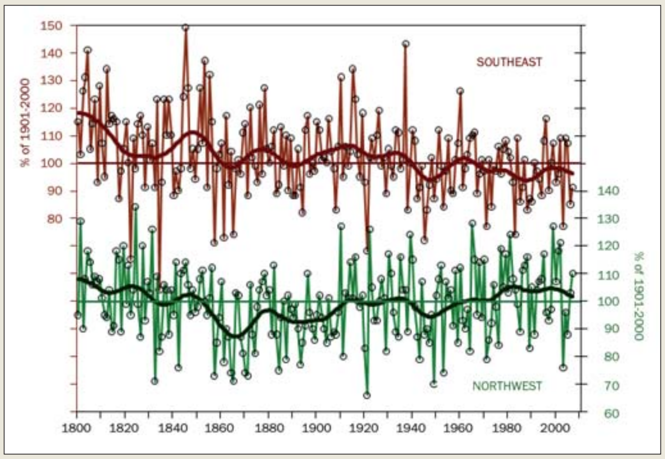
Of course this covers only annual series averaged over the entire GAR. For temperature this makes sense, as the average overall single HISTALP series is highly representative for each of the sub-regions concerning the decadal to centennial evolutions: they have warmed at the same rate in Marseille, Karlsruhe, Budapest and Perugia, as well as for the mountain observatories at altitudes between 2,500 (Säntis) and 3,500 metres above sea level (Jungfraujoch). So the mountains of the Alps may be more sensitive in respect to some climate impacts, but they are not in terms of their reaction to climate forcing.

This similarity of temperature trends with respect to different sub-regions is not applicable with regards to different seasons. In general, 19th century winters were colder in comparison to summers of the early instrumental period. This results in a general decrease of the annual amplitude during the past two and a half centuries. As the majority of natural proxies used for the estimation of indirect climate reconstruction provide more summer than winter information, such proxies tend to have a summer bias and should not be regarded as being representative for annual trends — at least in the Alps. A good example is the coincidence of mild winters and cool summers in the 1910s that produced remarkable glacier advances — advances that cannot be explained through the annual temperature means.

The high spatial homogeneity of temperature trends does not exist for precipitation. For the two principal sub-regions — northwest at the windward side of the Alps towards the prevailing western winds and southeast at the leeward side — we have observed opposite centennial trends. The northwest has seen a long-term increase of approximately 10 per cent in the last 150 years, while the southeast has seen a 10 per cent decrease in the same period. Only the first part of the 19th century saw a parallel decreasing trend in both sub-regions. This dipole-like structure corresponds to the same pattern expected for the 21st century by most of the regional European climate model experiments. What we can learn from the past is that the gap between wetting and drying is most likely to sharply following the main crest of the Alps — with a smooth transition over hundreds of kilometres less likely.

The last example concerns different long-term trends in the third dimension, for which only a region like the Alps can provide the necessary information. Namely, a comparison of the annual mean air pressure evolution at both low elevation stations and high elevation observatories. In the Alps a number of summit observatories have produced 100 to 150 years of air pressure series, opening up the unique possibility of applying the principle of 'relative topographies' (calculating the virtual temperature of an air column from the ratio of the air pressure at its upper and lower boundaries). The high elevation air pressure curve has increased to a much greater degree than the low elevation sites' equivalent (which has also increased). So, the principle mechanism is most accurately explained by the measured air pressure series: the air columns between low- and high-elevation measuring sites have warmed, expanded and thus transported more mass above the summit observatories, while the total mass above the low elevation sites has only changed due to large scale synoptic rearrangements. The practical importance of such independently measured 'non thermometric temperature series' is high. If they show the same warming as those measured directly using thermometers, then this overrules once and for all the argument that global warming is merely the product of increasing heat islands in developing cities. This idea has been described already in Auer et al.[3] and we are currently working on an in-depth analysis of the concept. Initial internal results show the feasibility of such an analysis, but only under the condition of a carefully homogenized series that allows the isolation of a climatic signal of approximately 1 hectopascal/century from the non-climatic noise of the original series.

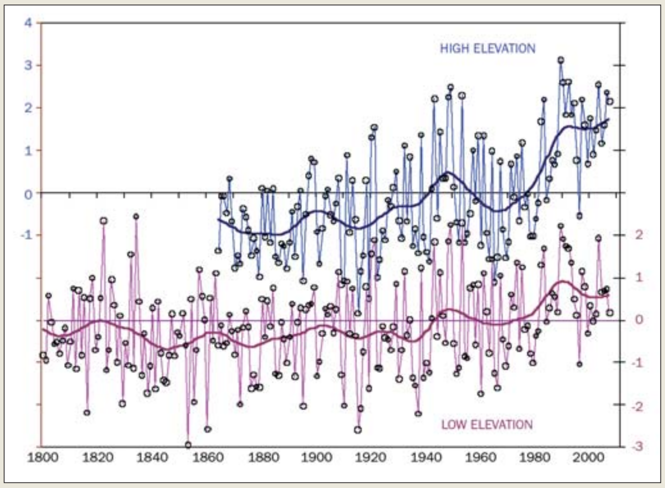
Sub-regional annual precipitation



Two sub-regional annual precipitation series for the northwestern and southeastern CRSs of the GAR

Source

Sub-regional annual air pressure



Two sub-regional annual air pressure series for the mean low elevation series below 600 metres at sea level and for the high elevation summit sites above 2,000 metres at sea level

Source

This last example in particular is intended to illustrate that high quality climate data is an indispensable precondition not only for sophisticated scientific research, but also for practical interdisciplinary application, as well as for political discussion in the general public.

Reaction of glaciers to climate change in the Austrian Alps

Glaciers are among the natural phenomena on Earth with the highest sensitivity to the climate. Thus a small change signal in the climate — especially in global radiation, air temperature or precipitation — can result in a distinct change of glacier mass and even, after a time delay, an advance or retreat of the glacier front. This high sensitivity makes glaciers especially valuable when:

- Documenting climate impact and climate change
- Deriving climate proxy information from observations of glacier changes.

Additionally, ice cores from glaciers and ice sheets are among the most important climate proxy sources.

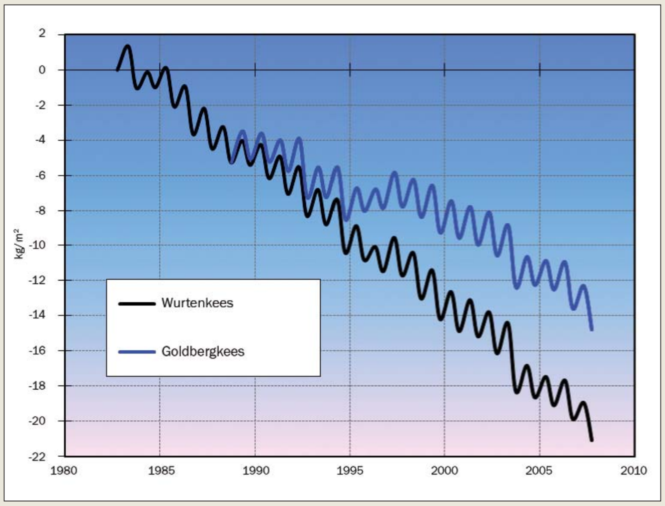
Beside Scandinavia the European Alps are among those regions worldwide with the longest series of documented glacier changes. In particular, documents of glacier changes include paintings and photographs, front position measurements, volume changes (from interpretation of maps, aerial photographs and satellite data) and measurements of mass balance and glacier surface flow. Outside of these observations the mass balance of a glacier is the key measure, as it constitutes a direct and timely signal of climate perturbation. Observations of mass balance date back only to about the 1950s in the Alps and about the 1940s in Scandinavia. Contrary to mass balance observations, systematic front position measurements of Alpine glaciers go back as far as the late 19th century, but are limited by aggregated information including both climate and glacier dynamics. The advent of regular front position observation prompted an international glacier monitoring effort, which is today coordinated by the World Glacier Monitoring Service.[4]

The retreat of the Wurtenkees glacier

The retreat of the Wurtenkees glacier (eastern Austrian Alps) evident in photographs taken in 1896 and 1999

Source

Accumulated specific mass balances for the Wurtenkees and Goldbergkees glaciers



Observations since 1983 show that, on average, Wurtenkees loses one metre per year

Source

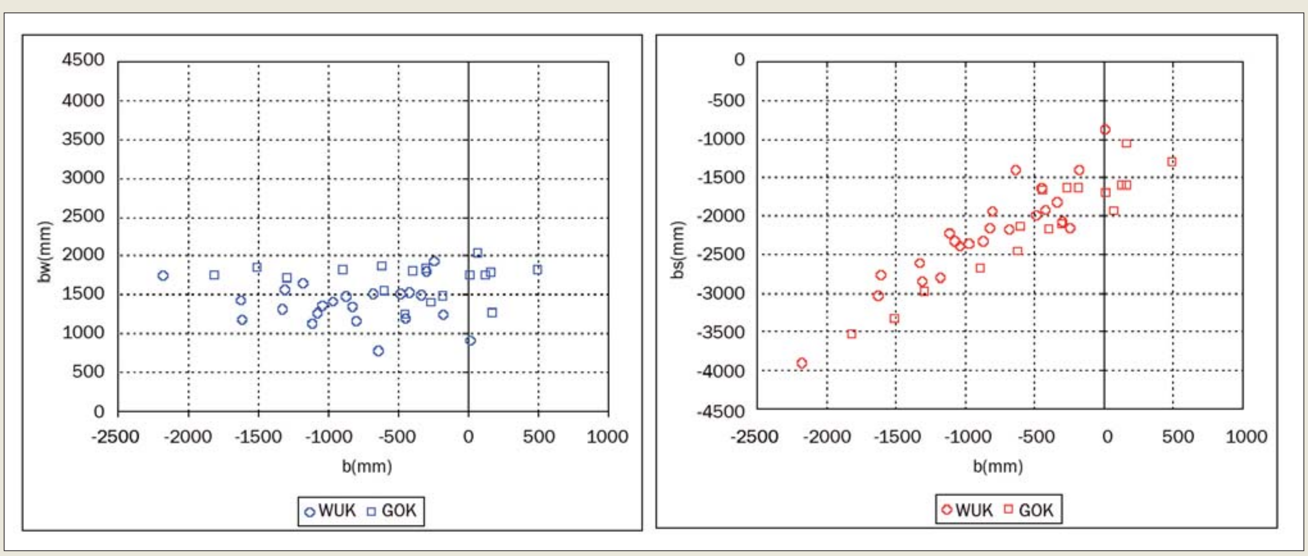
Image: Gernot Weyss

Science walk to Sonnblick Observatory in July 2006. A national park ranger explains the first information board of the glacier trail

ZAMG runs a detailed glacio-hydrological monitoring programme in the Sonnblick region of the eastern Austrian Alps covering three smaller glaciers (about 1 square kilometre) and the largest glacier in Austria; Pasterze. Since the end of the 19th century all the glaciers investigated have shown a general retreating trend, and in particular a clear retreat since the beginning of the 1980s, which is a common signal of Alpine glaciers. The retreating trend observable since the end of the 19th century is clearly visible in photographs of glacier Wurtenkees taken in 1896 and 1999. The Sonnblick region is characterized by strong climate gradients; from a high precipitation region north of the Alpine main divide to an inner-alpine dry valley south of the Alps. The monitoring in this area includes measurements of glacier mass balance (for both winter and annual net balance), surface flow, glacial discharge and ionic composition of snow cover. The monitoring is part of a research programme by the nearby Sonnblick Observatory, which covers a wide range of atmospheric chemistry as well as physics, mountain meteorology and permafrost research.

The spatial patterns of climate are well reflected in the mass balance of the glaciers, with much higher winter accumulation at the glacier north of the Alpine main divide compared to the glaciers south of it. The north-south pattern is also visible in the annual net balance of glaciers

Net balance relationships



Relationship between annual net balance (b) and winter net balance (bw, left) and summer net balance (bs, right) for Wurtenkees (WUK) and Goldbergkees (GOK) from observations since 1983

Source

Wurtenkees and Goldbergkees with more negative mass loss for Wurtenkees. On average Wurtenkees loses about 1 metre (mean over total glacier size) of ice per year under the present climate. As maximum ice thickness for this glacier is less than 80 metres, the vanishing of most of the glacier area is to be expected within a few decades.

Several studies[5] were carried out to understand the climate-glacier mass balance relationship for the glaciers of the Alps and the Sonnblick region in particular. It was shown that only the summer season (melting of snow and ice) and not the winter season (accumulation of snow) estimates affects annual net balance. Such studies have shown that only summer balance is highly correlated to annual net balance and that variability of summer balance is much higher compared to winter balance. However, it has to be taken into account that this result is derived from observations going back only as far as 1983 (a period with strong glacier retreat) and that in earlier periods this relationship may well have been different.

An important discussion in Alpine glaciology refers to the question of the contribution of such glaciers to river flow. This was studied in the small catchment area of Goldbergkees (close to Sonnblick),[6] as well as in the much larger catchment area of Upper Pinzgau (river Salzach). Upper Pinzgau covers about 600 square kilometres, of which 5 per cent is glacierized. Detailed modelling approaches[7] show that for a year with average climate conditions the contribution of glaciers to the river flow of the main rivers of the Alps is negligible. However, under climate conditions measured in 2003 the contribution of glaciers to the river flow of larger rivers was significant and ranged up to 70 per cent in August 2003 for the Salzach in Upper Pinzgau. Because 2003 can be used as a realistic scenario for future climate states (up to around 2100) the importance of the glaciers to river flow can be easily estimated. If glaciers vanish in the future we can expect a significant deficit for the large rivers of the Alps, as well as a net loss of discharge for smaller rivers.

Local climate information for two central Alpine valleys in an inter- and trans-disciplinary dialogue

Events such as the latest International Scientific Congress on Climate Change in Copenhagen have roused public knowledge of climate change to some extent. However, do people really feel sufficiently informed and what are their opinions and attitudes on climate change? *A Tale of two Valleys — the contrary strategies in two neighboring Alpine valleys to deal with climate variability and climate change*, an Austrian interdisciplinary research project on regional climate change (www.zamg.ac.at/a-tale-of-two-valleys) combined the local knowledge of people in region and scientists to create an overall picture of the perception of climate change. Schools and selected stakeholders have also formed part of the project team to cover the aspects of long-term climate variability, natural dangers and risks, landscape and land-use, tourism, employment and income, demography, mobility, education and gender.

Two small municipalities confronted with regional climate change impacts decided to develop local scenarios in response. Income for both municipalities is largely dependent on winter tourism. However, the dominant touristic concepts are somewhat contradictory. The first concept is a glacier ski resort called Mölltaler Gletscher in Flattach (1,373 inhabitants and an employment rate of 47 per cent). This clashes with the other idea of a national park concept and a fairly small 'family and 50+ skiing region' in Rauris (3,107 inhabitants and an employment rate of 45 per cent). Touristic income and employment bears a close relation to snow availability, although artificial snow can compensate somewhat during warm and snowless winters.

An opinion poll carried out in these two villages showed that about 70 per cent of adult inhabitants feel well informed about climate change. However, special questionnaires distributed in regional schools indicated that the sample of 14 to 15 years old adolescents were unsatisfied with their information level on climate change.

Simplified information and cooperation was at the centre of the concept from the start. Start-up meetings were held in each of the municipalities and partner schools. Those meetings, held in January 2006, offered lectures presented in an understandable scientific language, keeping in mind scientific correctness and sufficient time for personal thoughts, discussions and questions. In July 2007 three science days were organized in the project region. Public scientific lectures and informative posters were combined with talks from local authorities and supplemented by a 'scientific walk' to the high mountain Sonnblick Observatory (3106 metres). This involves a walk through climatic and sensitive vegetation zones near the glacier region up to the high alpine area. Scientific knowledge of climatology, glaciology, tree-ring research, biology, history and sociology were merged with local expertise to produce the experience.

Since glaciers constitute highly visible evidence of climate warming a glacier trail has been constructed in cooperation with the alpine club Naturfreunde. This *Gletscherlehrpfad Goldbergkees* guides participants through the history of climate and glaciers. Thirteen information boards have been installed to form a trail, which runs between 2,190 and 2,395 metres above sea level, to document long-term glacier retreat and its relationship to climate.

Special partnerships have been established between the project team and schools to promote the idea of 'cognition = research + education'.[8] Climate change topics have been integrated with the curriculums of more than one field of study including: physics and chemistry, geography and economy, history, biology, language courses and even music. Besides dealing with ecological and economical questions students gained insight into the work and methods of scientists. A follow-up effect is also expected with the transfer of this newly acquired climate change awareness from the school children to their families.

Another good example how to raise awareness on climate change in school pupils is demonstrated by the efforts of the children of Hauptschule Rauris. On the occasion of the annual *Rauriser Literaturtage* they presented their thoughts and attitudes on climate change in the form of songs, stories and poems.

During the running time of the *A Tale of Two Valleys* study local scenarios were developed and presented to the citizens of Rauris and Flattach. The majority of residents favoured a scenario based on sustainability. However, on the other hand, the majority of residents did not believe that the sustainability scenario was the one likely to be selected.