StartClim

Start Project: Climate Protection

First analyses of extreme weather events and their impacts on Austria

Final Report

Project Leader

Institute of Meteorology und Physics,
BOKU - University of Natural Resources and Applied Life Sciences, Vienna
Univ.-Prof. Dr. Helga Kromp-Kolb.

Contracting Parties

Austrian Federal Ministry of Agriculture, Forestry,
Environment and Water Management
Austrian Ministry for Economics and Labour
Austrian Federal Ministry for Education, Science and Culture
Österreichische Nationalbank
Austrian Hail Insurance
Federal Environment Agency

Administrative Coordination
Federal Environment Agency

Vienna, November 2003

StartClim
“Start Project: First analyses of extreme weather events and their impacts on Austria“

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Vienna, November 2003

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Acknowledgement

StartClim would not have come about without the untiring efforts of
Prof. Dr. Stefan Schleicher.

Major contributions to the realisation of StartClim and the Final Report were made by:

- Ingeborg Schwarzl, a reliable assistant in co-ordinating and editing
- Christian Frischauf, creative lay-outer and assistant to the editors
- Andreas Türk und Andrea Stocker, reliable administrators of the homepage
- Martin König, supportive administrative project coordinator and
- Herbert Formayer, Andreas Frank, Thomas Gerersdorfer, Helga Nefzger, Susanne Ostertag und Petra Seibert by willingly taking on additional tasks, such as technical support, communication, data collection, proof reading, etc.

Our thanks to all of them.

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Abstract

In 2002, Austrian climatologists founded a research platform under the title AustroClim. Its goal is to meet the challenges that climate change poses to science and to support the necessary decisions that need to be made in the political and economic sectors and by each and every individual. This is to be achieved in an interdisciplinary approach that will provide the basis for the decision-making process. In light of AustroClim's call for a coordinated climatological research effort, and based on an initiative of the Austrian Federal Minister of the Environment, six funding partners[1] have commissioned the Start Project Climate Protection: „**StartClim – First Analyses of Extreme Weather Events and their Impact in Austria**". The BOKU - University of Natural Resources and Applied Life Sciences as representative of the AustroClim Research Platform agreed to act as the project leader for StartClim. The administrative tasks were assumed by the Federal Environment Agency.

Based on the contractor's specifications, three tasks were pursued in StartClim by a total of approximately twenty research facilities:

- A Analysis of extreme weather events in the past, their impacts and economic dimensions as well as elements of future scenarios in Austria
- B Synopsis of the weather factors that triggered the flood event in 2002 and their economic impacts
- C Development of a draft concept for a long-term climate-climate change impact research program in Austria

The precondition for the analyses of extreme events as required in **Task A** is the availability of sufficiently long time series of meteorological data as well as chronicles of weather-induced damages over a sufficiently long period, because such events are rare by definition. The overview of available data and their accessibility was therefore an important part of StartClim.

An improved plausibility-tested data set of air temperature (mean and extremes), precipitation sum and snow height on a daily basis was prepared for 71 Austrian stations for the period 1948 to 2002. These 50-year time series are sufficient to describe single meteorological elements (e.g. daily temperature maximum and minimum) and their statistical measures, but for most parameters time series of at least 100 years are needed. The archive of daily meteorological data before 1948 was unfortunately lost during the second world war, but information relevant to extreme events can also be found in monthly data sets, e.g. monthly extremes of temperature, number of ice-, frost-, heat- and heat- days, maximum precipitation in each month, etc. These data sets were retrieved, subjected to a plausibility check and corrected where possible for 20 stations for periods extending before 1948. Methods to homogenize the inconsistencies of the data sets due to displacement of stations, changes in instrumentation, etc. are not yet available. Nevertheless, the data sets in their current state already open up a number of possibilities for analyses that are of interest to different disciplines.

The analysis of the 50-year data set using extremal statistics shows e.g. for the station Vienna, Hohe Warte, a significant increase of extreme summer temperature within the last 50 years (see Figure). Note that the extremes of winter minimum temperatures in Vienna have not become correspondingly less frequent.

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[1] Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management
- Austrian Federal Ministry for Education, Science and Culture
- Austrian Ministry for Economics and Labour
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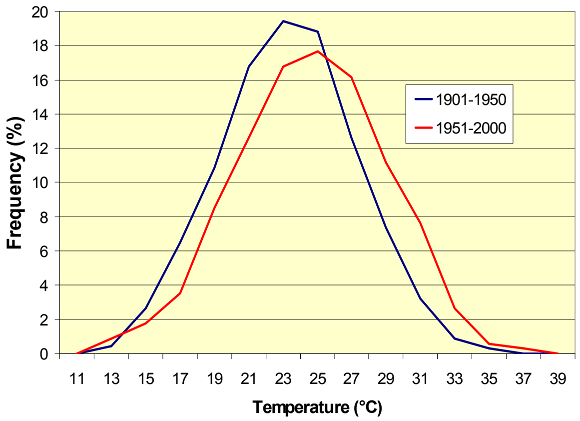
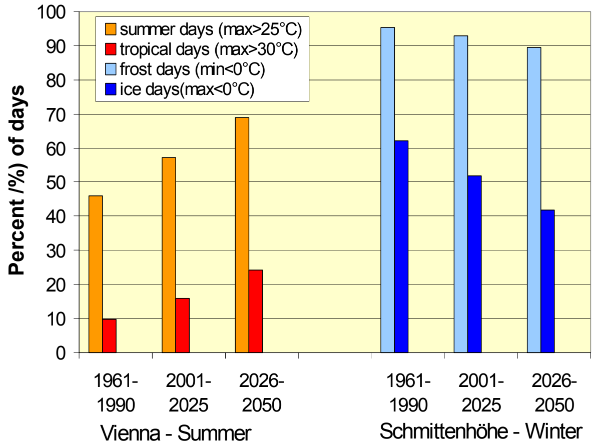
To determine potential future frequencies of extreme events, two methods were developed and tested to diagnose extreme events in different regions in Austria from global climate model (GCM) scenarios. One of these methods used a new clustering procedure to identify seven synoptic patterns which are characteristic for heavy precipitation events in Austria. The patterns differ considerably with respect to frequency of occurrence and regional impacts. This new method, which takes weather development prior to the extreme event into account, also shows promise for storm and drought events.

The second method relies on classical statistical downscaling methods, which have not been applied to extreme events so far. Canonical Correlation Analysis (CCA) and the Analogue technique used on monthly and daily scales, respectively, lead to robust results for the temperature, while uncertainties in precipitation are much larger. For the selected global climate change scenario, the frequency of days with temperature extremes above 30°C (heat days) doubles within the next 25 – 50 years, while in about 2000 m a.s.l. (e. g. Schmittenhöhe, 1964) the warming leads to a decrease in the number of days with temperature continuously below 0°C (ice-days) by about one third (see Figure).

Frequency distribution of daily temperature maximum; Vienna – summer (Observations)



Frequency of days with temperatures above 25 and 30°C in summer (Vienna) and extremes below 0°C (Schmittenhöhe 1964 m) (Model results)



Closely linked to extreme weather events are floods, mud slides, avalanches, droughts, etc. These events are determined not only by the weather, but also by human interventions (land use, protective measures, etc.). The survey, documentation, analysis and evaluation of the impacts of weather-induced extreme events for selected regions and sectors in Austria was one of the foci of StartClim.

An information system (MEDEA - Meteorological extreme Event Data information system for the Eastern Alpine region) was developed to eventually bring together from different scientific fields a wide range of data on extreme weather events and weather-induced events in Austria. The system has been successfully tested with a first set of data. An overall picture of an extreme event and the complete chain from weather event to possible long-term economic impacts can only be gained through the simultaneous availability of information ranging from meteorological data to data on damage, impacts, etc. Systematic inclusion of information on data uncertainty is a necessary step towards improved uncertainty and risk estimations in the evaluation of extreme events.

Two types of extreme events were studied in detail: The time series gained from the data base on torrents, set up in 1972 by the Austrian Federal Office and Research Centre for Forests (BFW) in Vienna, can be significantly enlarged by data from chronicles available at the district level, e.g. for the districts Landeck and Imst in the Tyrol (Institute for Forest and Mountain Risk Engineering– WLV), that registered events beginning in the year 1274. Methods were suggested on how the collection, administration and processing of data should be documented in the future in order to ensure largely uninterrupted records. Quantitative data on precipitation or run-off are missing in the chronicles. Sediment deposits and the number of damaged objects are only partially recorded quantitatively. In some cases the monetary value of the damaged objects is documented in the form of an overall damage estimate. The torrent database of the BFW also does not include figures on damage, apart from the reconstruction costs of destroyed or damaged control and protection measures. The registration of damage costs is not centrally organised, and data are therefore not readily available. MEDEA could integrate these data and make them available, e.g. for cost-effectiveness considerations for the planning of precautionary and protective measures.

The second area studied was agriculture: for seven agricultural crop species in three regions of Austria, the kinds of extreme weather causing bad harvests were analysed. The database consisted of area-based agro-statistical surveys and the monthly means of meteorological parameters from 1869 to 2002. Selected results include:

- Milder winters are especially advantageous if no extreme temperatures occur in February. This is beneficial mainly for winter cereals and grapevine.
- Dry weather in spring is especially disadvantageous for spring cereals.
- Cereals require dry weather in the harvest months to avoid yield losses.
- Dry, hot summers are unfavourable for sugar beet and corn, to a lesser extent for potato.

Insurance policies are intended to protect against excessive losses due to extreme events. The flood event 2002 and unsuitable measures taken by the Austrian “Katastrophenfonds”, a national fund for damage compensation after natural catastrophes, triggered a study that discusses reforms affecting the entire system of risk transfer from natural catastrophes in Austria. In a comparison of risk transfer systems for catastrophes in six countries, ineffective or even counterproductive elements of the Austrian system are analysed; better solutions that have been implemented elsewhere are presented.

With a focus on the specific problems of individuals, insurance companies and public authorities that face the general problem of flood risk, a proposal is made for re-designing certain elements of the risk transfer mechanism in Austria that would cope better with the issues of incentive compatibility, efficiency and social acceptability.

For five economic sectors expert knowledge was gathered on the specific impacts of various extreme weather events, the availability of data for in-depth studies, the perception of vulnerability within the sectors and on current and planned adaptation and mitigation measures. The result indicates that insufficient awareness is often coupled with data insufficiencies; moreover, past efforts have often been restricted to technical protective measures. Integrated adaptive strategies comprising a package of technical, spatial planning, organizational, economic, and climate- and education policy measures are rare exceptions. Policy suggestions for these sectors include general political measures (e.g. enhancing public risk awareness), fiscal and regulatory measures (e.g. integrated spatial planning) and measures to ensure that basic needs can be met after natural disasters.

The second major topic of StartClim (**Task B**) dealt with the meteorological situation and the economic repercussions of the flood event in August 2002; it represents a contribution to the ongoing research program FloodRisk.

The potential of improving the accuracy of areal precipitation values elicited from a network of irregularly spaced stations by the use of the objective analytical method “VERA” was shown for the flood events 2002. Areal precipitation is an important input into hydrological run-off models and greater accuracy in real time operational services would help to obtain a better evaluation of the situation earlier on during an extreme event. A suitable incorporation of additional information, such as satellite and radar data, could boost the performance of VERA-analyses even further.

A detailed verification of meteorological forecast models with regard to the August 2002 flood event is a necessary requirement for the development of effective early warning systems. In the framework of StartClim it was quantitatively shown that the forecast skill strongly depends on the temporal and spatial scale, as well as on the observational data used, and the area under consideration. In general, forecasts for alpine areas affected by orographic upslope precipitation are more reliable than those for lowland regions because, in the latter, convective processes make a larger contribution to heavy precipitation events. The relative forecast error can be significantly reduced by increasing the duration for which a forecast (precipitation sum) is made. This is because forecast errors partially compensate each other over the duration of an event A reduction of the relative forecast error by increasing area size can be achieved only when one approaches the typical scale of a province. It is not merely the size of the catchment area but also the size of the synoptic disturbance itself that determines forecast skill. Compared to other events of the last 4 years, precipitation amounts during the first part of the August 2002 flood were forecasted poorly, whereas forecasts during the second part were better than average. Hourly maxima are still unpredictable and generally underestimated. Probability forecasts based on ensemble predictions can contribute to improved pre-warnings (or ‘watches’) in the sense that they yield the potential spectrum of precipitation scenarios.

An improvement in short term forecasts for extreme events might also be achieved by combining the spatial and temporal dimensions through the analytical tool VERA, as this would permit investigating small-scale flow characteristics and displacements. Key numbers to improve nowcasting of extreme weather events and to evaluate climatological time series could be developed.

Regarding the economic impact of the flood event 2002 a consistent data set of damages in Austria was collected, that has been checked for plausibility, completeness and internal consistency. It is based on the notifications of losses to the state authorities, on additional information given by the states, the communities and municipalities, public and commercial entities and results of additional investigations.

By feeding this information into a geographic information system (GIS) visualisation of space related data and interactive queries along selected search criteria at different levels of aggregation have become possible. The geoinformation system (Database and GIS) is a valuable tool for problem oriented analysis and representation of the collected information. In case of general application for the documentation of the notification of losses after flood events (e.g. through the WEB) all data required by the different stakeholders, applicants, municipalities, state and federal administrations, auxiliary organsiations and other NGOs etc. should be included in one database and readily available. Rapid accessibility and unified documentation across district and state borders would be guaranteed and at the same time, a sound base for scientific analyses would be laid.

This database was used to run conventional model calculations in order to estimate the economic effects of the 2002 flood event. The results show that the macro-economic impacts were small and that the positive effects of the investment demand in 2002 can be interpreted as a transitory shock. The slightly negative consumption effects reflect the reduced available income of the affected households.

Adequately depicting the economic repercussions of extreme events requires going beyond traditional analyses involving the overall political economy. A concept was therefore developed to expand conventional economic models to include the key role of the interplay between stock and flux factors (e.g. possessions and money flow).

Using a Kamptal community as a case study, the disturbances the 2002 flood event triggered in the social metabolism as well as the social response patterns to these disturbances were investigated. Resource consumption rose by approximately 60% and energy consumption by 11% compared with a reference site. Opportunities to utilize potential energy-savings were largely not taken due to the restructuring measures during the reconstruction phase; the reconstruction was directed solely at re-establishing the original situation. The surveyed material and energy flows therefore exclusively represent supplementary burdens that are not balanced by significant long-term reductions.

Only few of the queried persons were fully aware of the influence that economic activities have on global ecological cycles. Although more than half of those polled considered such flood events to be a possibility, only few households had actually made contingency plans. More information and additional incentives are apparently necessary to better utilize the inherent opportunities in such flood events.

StartClim was also involved at the interface between science and education. One group of students used questionnaires to interview about 100 relatives and family acquaintances on the issue of extreme weather events. The gathered information was compared to data from meteorological stations. This process familiarized the students with data collecting and quality control methods and at the same time confronted them with the issue of climate, climate change and extreme weather events. The data gathered by the students were integrated into the database MEDEA, making them available to the climate change research community.

Another group of students from higher grades developed their own questionnaires on the consequences of the 2002 floods. This type of cooperation between scientists and educational institutions raises the awareness of a large group of people of different ages for climate change issues. It also provides valuable information on public perception of extreme weather events and the questions that citizens are interested in when confronted with climate change. This could be helpful to decision makers in policy decisions, crisis management or insurance issues. Last but not least this adds value to scientifically gathered data because it broadens the scope by incorporating the aggregate perspective of the affected population.

StartClim projects have supplied a wealth of new data and understanding that are also of practical relevance. They have also made important contributions to the evaluation of data availability, data quality and of methods in view of their potential to help answer questions related to extreme events in a changing climate.

This work was essential for the development of a long-term research programme on climate change in **Task C** of **StartClim**; it takes national needs and research developments into account and is embedded in the pertinent international research landscape. In cooperation with the research community, a programme was developed that is application oriented in its topics, but will also require a certain amount of basic research as well. The main questions to be addressed:

- How will the climate develop on the regional level and what will its impact on natural systems be?
- What risks and opportunities for the economy and for society can be expected through climate change and climate change policies?
- Can the understanding of alpine climates, their changes and impacts gained in Austria be of help in Africa, South America and Asia?

were broken down into a number of research activities that provide the necessary information on climate change in the strict sense of the word, and that analyse the sensitivity, adaptation potential, vulnerability or mitigation potential of individual economic sectors.

1 Preface

1.1 The history of StartClim

In 2002, Austrian climatologists founded a research platform under the title AustroClim. Its goal is to meet the challenges that climate change poses to science and to support the necessary decisions that need to be made in the political and economic sectors and by each and every individual. This is to be achieved in an interdisciplinary approach that will provide the basis for the decision-making process. In light of AustroClim's call for a coordinated climatological research effort, and based on an initiative of the Austrian Federal Minister of the Environment, the six funding partners:

- Austrian Federal Ministry of Agriculture, Forestry,
  Environment and Water Management
- Austrian Federal Ministry for Education, Science and Culture
- Austrian Ministry for Economics and Labour
- Österreichische Nationalbank
- Austrian Hail Insurance
- Federal Environment Agency

have together commissioned the

Start Project Climate Protection – StartClim -
First analyses of extreme weather events and their impacts on Austria

The Federal Environment Agency (UBA) administrated the Start project climate protection for the contracting parties.

The project leader – representing the AustroClim research platform – is Univ.-Prof. Dr. Helga Kromp-Kolb, Institute for Meteorology and Physics of the BOKU-University of Natural Resources and Applied Life Sciences. Together with Univ.-Prof. Dr. Stefan Schleicher, Department of Economics, University Graz, Prof. Kromp-Kolb developed the scientific program and the call for proposals on 10 project topics.

The overall project, based on the contractor's specifications, was subdivided into three topics:

- Topic A
  Analysis of extreme weather events in the past, their impacts and economic dimensions as well as elements of future scenarios in Austria
- Topic B
  Synopsis of the weather factors that triggered the flood event in 2002 and their economic impacts
- Topic C
  Development of a draft concept for a long-term climate-climate change impact research program in Austria

The final selection from the 26 project proposals submitted within the deadlines set followed the recommendations of the scientific advisory committee (external experts) and the coordinators of the Flood Analysis Report of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) in cooperation with the StartClim coordinating group.

1.2 Report structure

The present report consists of an overview of the results in both German and English along with a (separately bound, two-part) documentation in which the individual projects are described in detail by the respective project teams.

Over the course of the work, the increasing cooperation between the individual subprojects yielded clusters of thematically related projects. This topic-based grouping of subprojects proved to be very useful in the final project workshop and has therefore been adopted here in slightly modified form.

To provide a better overview, the projects are compiled in four broad themes, whereby the first two are parts of project topic A:

1. Evidence for extreme meteorological events in Austria: Survey and analysis of past events as well as appraisal of future developments over the next few decades. This section encompasses StartClim projects 1, 2, 4 and 5.
2. Impacts of weather-related extreme events: Data collection, documentation, analysis and evaluation for selected regions and sectors. This section encompasses Start-Clim projects 3, 6 and 8.
3. The flood event in Austria in August 2002: meteorological analyses and assessments. This section encompasses StartClim projects 7, 9, 10, as well as 12 to 14.
4. Long-term climate research program

These topics are also incorporated in two projects, StartClim.11, that serve as an interface between the research and education sectors. They are presented at the end of topic 3.

Each of the four broad themes are provided with an introductory section that presents a general overview indicating the relative positions and relationships of the projects, and that briefly describes each project. Each section ends with a presentation of the advances made in the framework of StartClim and the remaining research deficits.

1.3 StartClim statistics

StartClim consists of 16 subprojects that encompass 50 persons from almost 20 different institutions, representing nearly 100 months or scientific work including compiling the report. The breakdown of participating scientists reveals 15 women and 21 contributors under 35 years of age.

In order to promote scientific exchange between the individual subprojects, four workshops were held between March and November 2003. All participating scientists were invited to present the results of their ongoing work and to discuss linkages between the subprojects. Beyond the contacts made between the subprojects, a considerable number of valuable scientific contacts were established with colleagues outside the StartClim community. Here, the exchange between socio-economists and natural scientists was deemed as especially crucial and future-oriented.

Information and data exchange within the StartClim community was promoted by setting up an FTP server and a StartClim homepage (http://www.austroclim.at/startclim/) at the Institute for Meteorology and Physics of the University of Agricultural Sciences.

A Brainstorming Workshop was organized in Vienna on 11 April 2003 to develop a long-term climate research program. The participants included about 70 scientists from the AustroClim platform.

In summary, StartClim achieved very good results considering the very short project duration available to treat such a broad and complex range of issues. This was possible because the participating research institutions invested considerable additional resources in what they felt was an interesting and necessary task.

1.4 Reference database

An open, partially commented reference database on the topic climate change and extreme events was compiled in the framework of StartClim. It will be made available to all future research projects in the field and is to be enlarged in that process.

This database has been compiled based on Bibtex, a share-ware software, and currently encompasses 400 entries dealing with climate change and extreme events. The literature references are partially commented and abstracted, so that the information content actually exceeds that of other databases that merely provide citations.

The database is currently located on the StartClim FTP server and therefore available to all StartClim partners. In the future, it will be accessible to all members of the AustroClim platform. This, however, will require additional programming efforts.

2 Aims of StartClim

The aim of the "Start project" StartClim is to provide specific, applicable results on the occurrence of extreme events related to climate change and on their economic dimensions. Three priority topics structured the working program and were selected for the Start project:

- Analysis of extreme weather events of the past, their impacts and economic dimensions, along with elements of future scenarios for Austria
- Synopsis of the factors that triggered the 2002 flood event and their economic repercussions
- Development of a draft concept for a long-term climate-climate change impact research program in Austria

The rationale behind the topic selection: extreme weather events, such as those experienced with increasing frequency in Austria over the last years, pose an ever higher risk. Combined with ongoing climate change and the expansion of human activities into natural habitats, this phenomenon poses a threat to society as a whole and calls for comprehensive preventive measures.

The research required in this context must be embedded in a broader strategy that would enable long-term planning and systematic steps, including basic research. Such a strategy is still in the earliest stage of discussion in Austria and the present program is designed to promote this process (Part C).

The specific case study presented in Part B is tailored to the short-term, practical requirements and considerations stemming from the 2002 flood event.

Part A goes one step further and considers the information needs of the general public and of policy-makers with regard to extreme events. Clearly, a research program with a duration of less than one year cannot be expected to deliver specific answers to every issue. Although StartClim cannot replace a much-needed, full research effort, it can help to define and evaluate the necessary lines of research. Part A consists of two topics. The first is devoted to the evidence for extreme meteorological events in Austria; it deals with data collection, analysis past events and assesses future developments over the next decades. The second is devoted to the effects of weather-related extreme events and deals with data collection, documentation, analysis and evaluation of extreme events in selected regions and sectors.

3 Evidence of extreme weather events in Austria

3.1 Introduction

Research on extreme meteorological events related to climate change is still in the early stages, but there is good cause to believe that such extreme events will become more frequent in the future in light of ongoing climate changes:

- Simple statistical considerations show that shifts in median values are accompanied by increases in certain extreme values and that these are intensified when variances of the distributions increase. Only if the variances are reduced would extreme events occur at the same or even lower frequency. There are currently no indications, however, that variances are decreasing.
- A warmer and therefore more humid atmosphere generates more rainfall per unit time, potentially accelerating the water cycle.
- There is evidence that extreme events accompanied phases of climate change in the past.

Research and modelling approaches have shown that the alpine region reacts particularly sensitively to climate change. For example, the temperature increase over the last 140 years in Austria is approximately twice as high as the global average. This calls for investigating whether the heightened climate sensitivity is also reflected in an increased frequency of extreme events in the alpine region.

Extreme meteorological events in Austria encompass phenomena as diverse as heavy rains, uninterrupted rain, storms, hail events, heat, cold, and dry spells as well as tornados. The common features of all these extreme events are that they

a) occur only rarely (otherwise they would not be classified as extreme) and
b) are of limited duration.

In many cases, extreme events are strongly delimited spatially, such as hailstorms or certain heavy rains.

This means that accurately documenting them requires data taken on short time scales and fine spatial resolutions, i.e. that the weather station grid be very dense and, depending on the event, yield measurements on a daily, hourly or even higher scale of resolution.

To date, climate change in Austria has largely been analysed based on the systematically tested and homogenized long-term series of monthly data taken by the Central Institute of Meteorology and Geodynamics (ZAMG), i.e. monthly temperature means, monthly average precipitation, etc. The oldest series of these data stretch back as far as 1767.

The so-called “monthly sheets” from which these data are taken also contain – beyond the primarily investigated monthly mean temperatures, total precipitation, etc. – information relevant for extreme events. This includes daily maximum and minimum temperature as well as the number of frost-days, ice-days, summer-days and heat-days per month, the largest amount of precipitation within 24 hours for each month, and the monthly number of days with precipitation. Little work has been done with these series and they have been neither quality controlled nor homogenized.

Daily average values, daily totals, daily maxima and minima – i.e. the values upon which the “monthly sheets” are based – are first available for most Austrian stations beginning in 1948 because the archives with the older data were lost in an air-raid while being transported to Berlin during the second world war.

The analysis of extreme events relies primarily on the series containing daily data, although the monthly extreme values can also provide valuable input. An important aim of StartClim was therefore to examine the plausibility of the series of daily data from selected Austrian stations, thereby making them available for research efforts devoted to extreme events (StartClim.1). The small-scale nature of some such events also means that the number of available series along with their spatial density become very important.

As most of these series start in 1948 (with few exceptions), it was important to use the few long-term series and the data from the monthly sheets to examine how representative the information from the shorter series is with respect to climate change. StartClim.2 was devoted to this task.

These two projects enabled initial conclusions to be drawn about trends, changes in frequency distributions, etc., although with reservations because the series remain to be homogenized.

Going beyond analyzing the past to making predictions about potential future developments requires utilizing the scenario calculations of the Global Climate Model (GCM).

The analysis of these climate scenarios with respect to extreme events is also hampered by poor spatial resolution. There is a wealth of literature on methods of regionalizing (downscaling) monthly data, but the development is by no means complete. Science has only recently begun to devote an effort to downscaling extreme events: only few papers have been published on this topic and the methodology is in an early stage. Two StartClim projects are devoted to this issue: StartClim.5 examined statistical regionalization methods and adapted them, both on a monthly and daily basis, for downscaling extreme events. For this purpose, monthly and daily data from the years 1948 to 2000 were statistically linked with the large-scale meteorological fields of a GCM (reanalysis). This approach allowed first trends to be calculated for extreme events under altered climate conditions. In the second project, StartClim.4, a more complex regionalization method was developed; it more accurately reflected the temporal and spatial development of weather conditions, an aspect that is especially important for precipitation events or storms.

Fig. 1 again summarizes the contributions of the four projects: StartClim.1 provides the daily data for the period 1948 – 2002 and analysis them with respect to extreme value statistics. StartClim.2 incorporates the period prior to 1948 in order to test the relevance of the trends calculated in StartClim.4 and StartClim.5, and, to the extent possible, to enable the expansion of the time period that would be so crucial for such rare events. StartClim.4 and StartClim.5 use the available data to establish the correlations with the larger-scale meteorological structures; these are then applied to the fields calculated by Global Climate Models in order to determine future trends in extreme events.

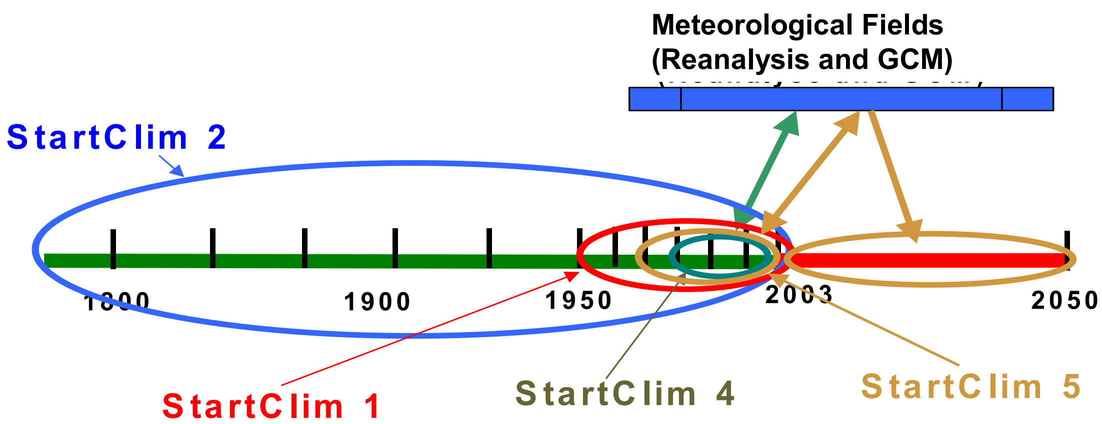


Fig. 1: Contribution and interrelation of the StartClim projects 1, 2, 4 and 5.

3.2 Quality control and statistical characteristics of selected climate parameters on the basis of daily values in the face of extreme value analysis (StartClim.1)

Within the frame of StartClim it was the task of StartClim1 to provide an improved data set for selected climate elements on a daily base using different tools for quality check. Moreover StartClim1 was responsible for some first statistical evaluations in respect of extreme values. Daily values of climate parameters are especially important for investigations of climate extremes. However, data errors as well as inhomogeneities can either partially or even completely mask the climate change signal. Therefore a detailed quality control and quality improvement have to be the first steps of extremal statistics of climate elements.

Within StartClim1 data from 71 Austrian stations were checked for quality and improved (Fig. 2). Climate elements included air temperature (mean, extremes), precipitation sum and snow height for period the 1948-2002. Though the limited time frame of StartClim admitted only the use of simple methods of quality control and quality improvement, the tools applied resulted in a remarkably better data quality. The methods used were computations as well as visualisations of suspicious data values. These values were checked individually (comparison to original tables, comparison to neighbouring stations) and were corrected or completed with a neighbouring station.

Fig. 2: StartClim.1 climate station network

The final step of data quality control was the check of data series for homogeneity. This was done using daily regressions of air temperature and snow height with altitude (the method does not work for precipitation). Time series of individual stations' residuals from regression models were both a final quality control as well as for cumulated residuals a measure of data series homogeneity. It was shown that:

- all StartClim.1 series are inhomogeneous.
- level of data quality and data homogeneity is quite different for individual series.
- Vienna Hohe Warte and Sonnblick are the stations with best data quality and homogeneity.
- all stations have to be homogenized if used for further climatological evaluations or, alternatively, the series can be used only for homogenous sub-periods
- the method used to check homogeneity is effective but there is a need for efficient tools of data homogenization

Statistical evaluations of climate extremes using descriptive methods were done for the station Vienna Hohe Warte, the station with the highest data quality and homogeneity; for other stations the series would have to be homogenized first or the effect of the inhomogeneities on the results of extremal statistics would need to be evaluated. The time series of 0.1 and 0.9 quantile using a moving window technique showed a remarkable increase of extreme values of maximum air temperatures for summer in Vienna (shift by 2°C in the period 1948-2002). Minimum air temperatures during winter showed no clear trend (for 0.1 quantile).

Comparison of all quantiles of the period 1901-1950 with those of 1951-2000 showed the highest shift for the temperature maximum in spring and summer (shift of up to 2°C). Again the comparison for minimum temperatures showed much weaker changes (increase of up to 1°C from 1901-1950 to 1951-2000) compared to the maximum temperatures (Fig. 3).

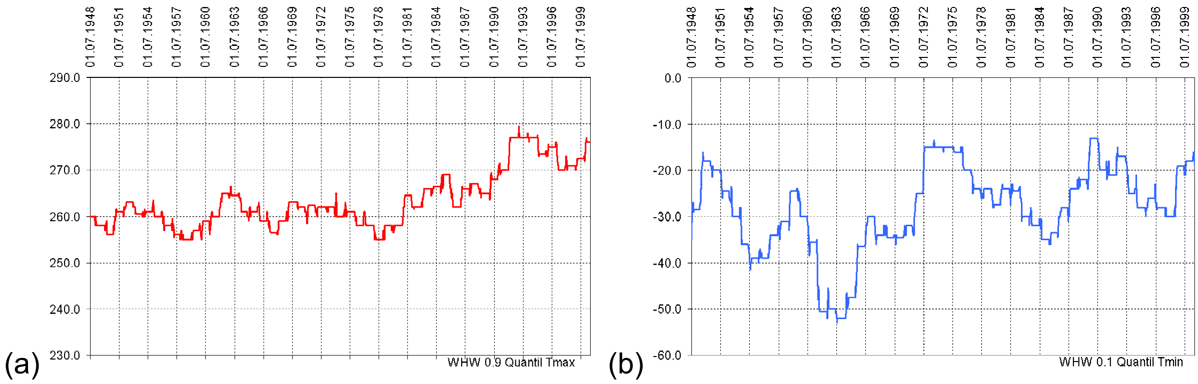


Fig. 3: (a) 0.9 quantile of maximum air temperatures and (b) 0.1 quantile of minimum air temperatures for Vienna Hohe Warte (in 1/10°C)

This means that the uppermost 10% of the daily maximum temperatures in summer range 2° higher than 50 years ago, while the extreme minimum temperatures in winter have not changed significantly.

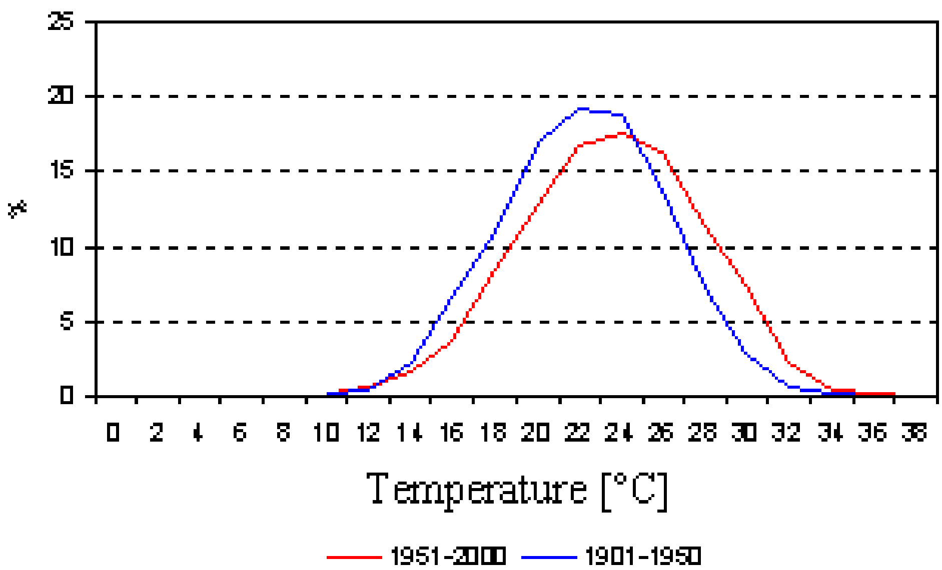


Fig. 4: Comparison of frequency distributions of maximum temperatures in the time series of Vienna Hohe Warte 1901-1950 and 1951-2000 in summer

A comparison of the frequency distributions (Fig. 4) or of all quantiles (Fig. 5) of the period 1901-50 with that of 1951-2000 shows the most significant changes for the maximum temperatures in spring and in summer; with up to 2°C increase of extreme values in the later period. The analysis of the changes in quantiles again shows much weaker warming of the minimum temperature in winter (somewhat more than +1°C in the period 1951-2000).

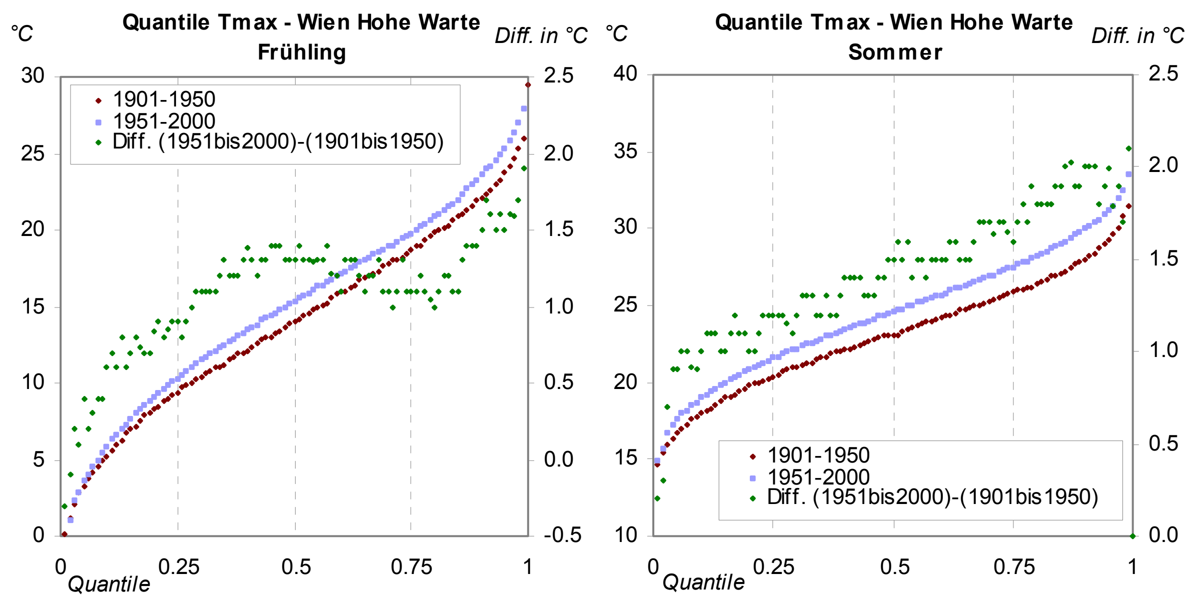


Fig. 5: Quantiles of maximum temperature series Vienna Hohe Warte for the time periods 1901-1950 and 1951-2000 for both spring and summer, as well as differences of quantile series

A comparative POT (peak over threshold) analysis for the same two periods for maximum air temperatures showed a remarkably increase in the rate of exceedence during summer as well as an increase of the mean excess for both low and high threshold values (with no change for ca. 34°C). Analogous POT analyses for minimum air temperatures (for the same two time periods 1901-1950 and 1951-2000) did not show similar clear temporal changes.

Precipitation in Vienna Hohe Warte shows no clear temporal trend in any of the statistical analyses performed.

3.3 Analysis of the representativeness of a data collected over a span of fifty years for the description of the variability of climatíc extremes (StartClim.2)

3.3.1 Investigating and digitizing monthly extremes resp. data, that can be analysed with regard to extremes

Records of instrumental measurements in Austria go back to the end of the 18th century. However, most of the data sets available at the Central Institute for Meteorology and Geodynamics (ZAMG) have only monthly resolution, because most of the original material (daily data) was lost during World War II. The potential of the monthly data was not completely utilised before StartClim.2. To obtain climate series of at least 100 years that are statistically exploitable, monthly extremes as well as data, that can be analysed with regard to extremes, were digitized, using various sources, such as Yearbooks of the ZAMG and of the Central Bureau of Hydrography (HZB), as well as unpublished archival data collections of the ZAMG.

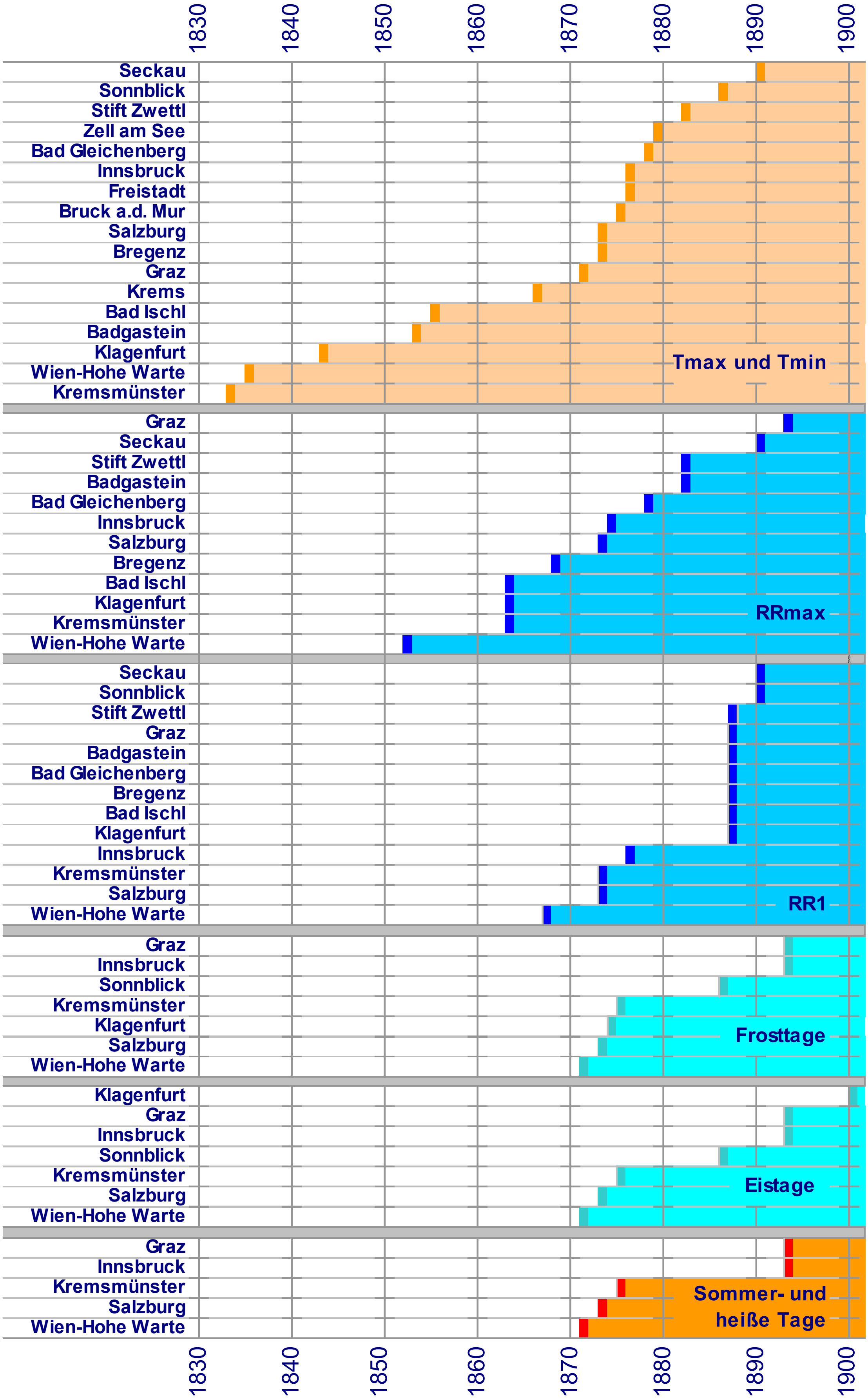


Fig. 6: Complete time series up to 2002 for all StartClim.2-stations and –parameters

With few exceptions the new data sets were not complete, but had gaps of a different extent. To close the gaps, a variety of methods was used. Due to different spatial representativity of climate parameters and varying availability of additional data needed to complement the time series, the same methods were not applicable to all stations, parameters and periods. Before and after completing the data sets a plausibility check was carried out. The result is a new data set, that is available for further research now (Fig. 6).

3.3.2 Influences of Inhomogeneities on the Results of Statistical Analyses

Inhomogeneities are among the most important problems in the analysis of climate variability. Therefore, the influence of the inhomogeneities of the data sets, that already passed a quality inspection within the framework of StartClim.1, was studied.

By means of a subset of examples it was shown, that inhomogeneities of the time series could falsify the trend (Fig. 7) or could even lead to a trend reversal (Fig. 8). Additionally, problems concerning climatic averages and displacements within frequency distributions can arise.

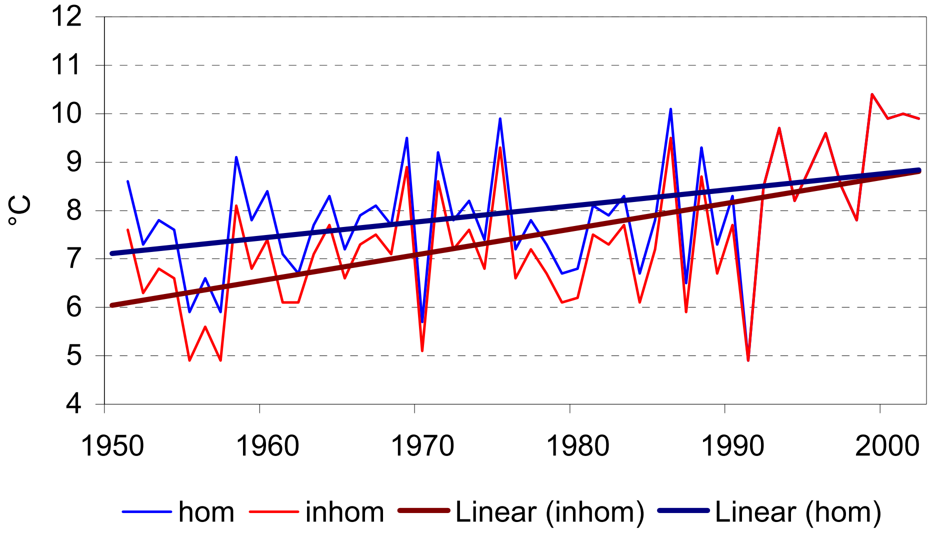


Fig. 7: Time series and trends of the mean daily minimum of air temperature at Klagenfurt in May, 1951-2002: Inhomogenized data would simulate a trend of 2.7°C, after homogenization, the trend showed a value of 1.7°C.

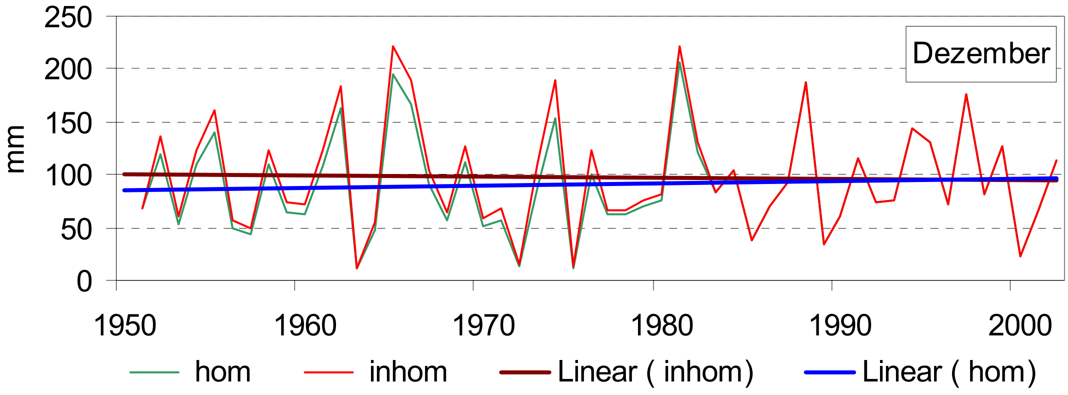


Fig. 8: Time series and trends of precipitation sums at Bregenz in December, 1951-2002: a slightly negative trend turned into a slightly positive trend after homogenization

3.3.3 Representativity of the period 1951 – 2002 with regard to the description of the variability of extreme values

For randomised periods (10 to 50 years) of complete time series frequency distributions based on daily as well as monthly data were determined and their statistical characteristics were compared with those of the complete series. As was to be expected, the shorter the sample, the lower the probability that the extremes of the total time series can be found within the sample. By systematic analysis the periods necessary to reproduce statistical characteristics of the complete time series within an uncertainty limit were determined. Furthermore, it has to be taken into account, that aside from frequency distributions also means and intra-annual variations can be falsified by time series that are too short.

The analysis of the sample from 1951-2002 showed, that it describes the daily temperature maximum and minimum within an accuracy of +/-1°C and the daily precipitation sum within an accuracy of +/-10% for P1, P50 and P99. Monthly extremes e.g. P10 of the absolute temperature maximum or the frequency of frost-, ice-, summer- and heat-days gained from the period 1951-2002 are not as representative. The same applies for the intra-annual variation of precipitation: it cannot be described within a deviation of 10% of the monthly precipitation sum.

The following table shows, how long a time series has to be to describe the variability of extremes within specified limits.

Besides the temporal representativity, the spatial representativity of the stations has to be considered, taking into account the complex topography of Austria. Primarily, this concerns the precipitation complex. Thirty homogenized long-term rain-gauge stations are sufficient to describe monthly precipitation sums in the less mountainous areas (Böhm et al., 2003), but four stations are totally insufficient to assess precipitation on a daily basis in Austria. Daily precipitation sums are spatially much less homogeneous than monthly precipitation sums. It has been shown, that the mean de-correlation distance (common variance 0.5 at least) in the Alpine region is in the range of 105 km for monthly sums, but of 42 km for daily data (Scheifinger et al., 2003). In the case of intense rain it is even lower. For daily precipitation sums of at least 30 mm (measured at the station Vienna-Hohe Warte) the correlation between stations sinks below 0.5 within the urban area (about 15 km) (Böhm, 1979). The StartClim projects 12 and 13 include considerations of station representativity for the flood event in August 2002.

3.3.4 Research needs

In the context of the task of StartClim.2 clear research needs became apparent:

- Development of methods to adjust inhomogeneities of daily data sets.
- Increase of spatial density of the data sets (precipitation and snow) that already passed a quality inspection within the framework of StartClim.1 for the period 1951 - 2002.
- Increase of spatial density of the data set of long-term series on a daily basis (at least 100 years) for the precipitation complex making use of the archives of the Hydrological services.
- Make long-term series of the snow complex available using the archives of the Hydrological services.
- Extend the work to include complexes not considered in StartClim.1, such as humidity, radiance / cloudiness, air pressure and wind.

Tab. 1: Length of a time series of an element necessary to determine different percentiles (P1 = 0.1 percentile, P5 = median, P99 = 0.99 percentile) with a certain accuracy compared to the total time series (results of the station Vienna [203m])

Based on monthly data:		**Years**	**1953-2002**
absolute maximum of the air temperature (+/-1 °C)	P 10	100	NR
	P 90	100	R
	P 50	100	R
absolute minimum of the air temperature (+/- 1 °C)	P 10	100	R
	P 90	10	R
	P 50	20	R
Frost days (+/- 10% of the grand average)	P 10	100	NR
	P 90	100	NR
	P 50	50	R
Ice days (+/- 10% of the grand average)	P 10	50	R
	P 90	>100	NR
	P 50	100	NR
Summer days (+/- 10% of the grand average)	P 10	100	NR
	P 90	100	NR
	P 50	100	NR
heat days (+/- 10% of the grand average)	P 10	100	NR
	P 90	>100	NR
	P 50	100	NR
mean precipitation sum in monthly resolution (+/-10%)		100	NR
mean precipitation sum per year (+/-10%)		30	*R
precipitation sum per year (+/- 50 mm)	P95	100	*R
	P5	50	*R
Inter-annual variation of precipitation (coverage of the yearly variations without consideration of the absolute amount)		50	*R
Extreme daily precipitation sum per year (+/-10 %)	P 10	<50	R
	P 90	<50	R
	P 50	<50	R
Yearly number of days with precipitation (+/-10%)	P 10	50	R
	P 90	50	R
	P 50	50	R
Based on daily data:			
Daily maximum of the air temperature (+/-1°C)	P1	50	*R
	P99	100	*R
	P50	30	*R
Daily minimum of the air temperature (+/-1°C)	P1	50	*R
	P99	20	*R
	P50	20	*R
Daily precipitation sum (+/-10 %)	P1	10	*R
	P99	30	*R
	P50	20	*R
*1951-2000; NR: not representative; R: representative			

3.4 Testing statistical downscaling techniques for their applicability to Extreme Events in Austria on the basis of GCM-fields (StartClim.5)

3.4.1 Introduction

The present coupled global circulation models (GCM) have good ability to reproduce the climate in the global to continental scale. In order to derive regional scenarios from the GCM – scenarios, different downscaling methods were developed in the last decade. Statistical techniques are less demanding concerning the infrastructure than dynamic methods and can be adapted relatively simply to specific problems (Hewitson et al.,1996). In these procedures, a statistical coherence between observed meteorological data and large-scale fields is derived (from a few GCM grid points up to continental structures).

So far these methods have been used mainly for climatological investigations, whereby monthly means were used as input on the regional as well as at the global scale. Therefore primarily variations of the large-scale circulation pattern are examined. Newer projects, like the project STARDEX of the European Commission, are concerned with the derivation of information on extreme events from climate change scenarios by means of statistical procedures on a daily basis.

The aim of the present project was to clarify how useful different statistical downscaling methods are to obtain information on extreme events in Austria and to make first estimates of possible changes in the frequency of extreme events in Austria based on global climate change scenarios.

3.4.2 Downscaling methods

A method on monthly base, using the Canonical Correlation Analysis (CCA) and the Analogue method using daily data were compared; both methods had been adapted to Austria (Matulla and Haas 2003, Groll 2002).

The Canonical Correlation Analysis is very popular in the field of meteorology, especially climate research uses CCA for downscaling of temperature, precipitation, etc. (von Storch et al. 1993). The method has been tested for the alpine region (Gyalistras et al. 1994). It was developed by Hotelling (1936) and is a linear method that finds relations between characteristic patterns of variability. It is constructed to successively choose the patterns whose time series have a maximum correlation.

In validation experiments it was shown that the temperature gives high correlation ($R^2 \sim 0.65$) between observed and modelled time series (Matulla und Haas, 2003). Precipitation has a far lower correlation and regional and seasonal differences occur. Most of the correlations are significant with a confidence of 95%. The CCA gives the better results than an approach using multiple regression (Matulla und Haas, 2003).

In the Analogue Method is based on patterns of analogue atmospheric situations. The method used here searches for similar patterns on the basis of Principal Component Analysis (PCA), i.e. statistically similar patterns are searched for in the large scale meteorological fields (Zorita und von Storch 1999). The most similar pattern is defined by the minimum distance of the PC's. It is assumed that two large scale patterns that are similar have the same local scale weather elements (precipitation, temperature,...).

Validation experiments for the Analogue Method also showed a high correlation for temperature ($R^2 \sim 0.7$) but there are difficulties in reproducing precipitation. The temporal correlation is reduced and only few stations reach the 95% significance level.

3.4.3 Possibilities and limitations of the methods regarding extreme events.

Since the CCA method is based on monthly data (on the local as well as on the large scale) it is not possible to obtain direct information on extreme events. However, it is possible to derive information regarding e.g. moderate extreme events like heat-days (maximum daily temperature more than 30°C) or ice-days (maximum daily temperature below 0 °C). This is possible since the statistical correlation between monthly means and the temperature distribution is very good. In Fig. 9 this correlation for heat- and summer-days (maximum more than 25 °C) is shown for Vienna.

If this statistical correlation is applied to climate change scenarios, summer-days increase in Vienna from 46% for the period 1961-1990 to almost 70% for the period 2026-2050 and the number of heat-days doubles in this period (Fig. 10). On the other hand the number of frost- and ice- days at station Schmittenhöhe drops by 6% and 20%.

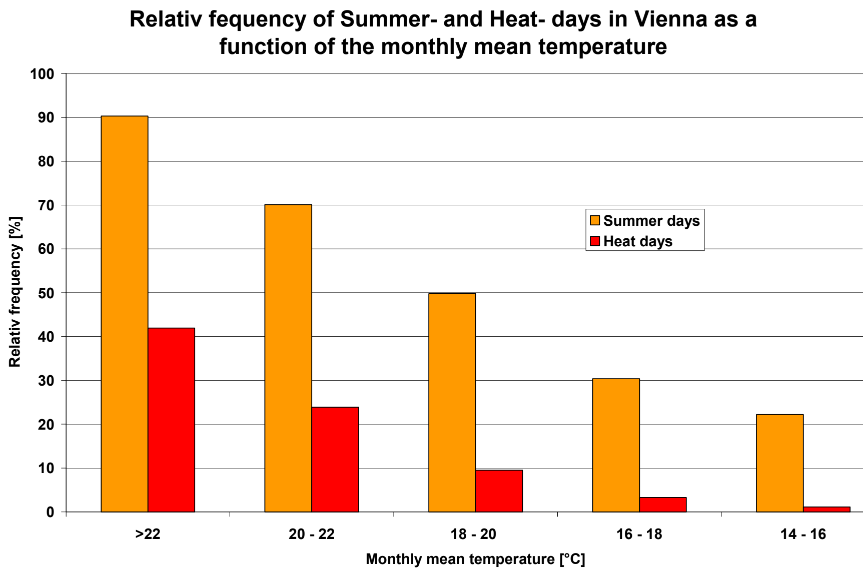


Fig. 9: Relative frequency of summer- and heat- days (daily maximum temperature exceeding 25 °C resp. 30 °C) in Vienna, as a function of the monthly mean temperature.

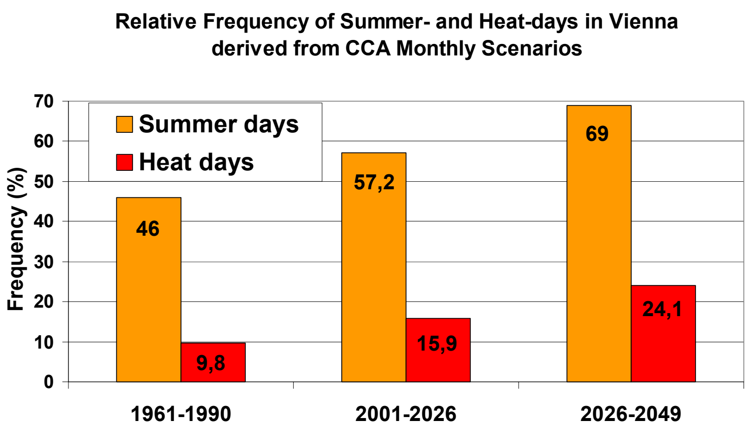


Fig. 10: Changes in the relative frequency of summer- and heat-days in Vienna during the first half of the 21st century. Derived from CCA- monthly scenarios.

It is not possible to deduce similar transfer-functions for precipitation and especially heavy precipitation events, because the monthly precipitation sums may consist of many precipitation events of low intensity or of few events with high intensity; this cannot be distinguished.

However for very dry periods some statements can be made, as they last several weeks and can be seen in the monthly meteorological fields.

The relative frequency of precipitation classes (mm) for the southern region of Austria in spring is shown in Fig.11. The frequency of seasons with moderate precipitation sums (150 to 200 mm) increases from about 36% at present to over 50% in the next 50 years, and the very wet months become rarer.

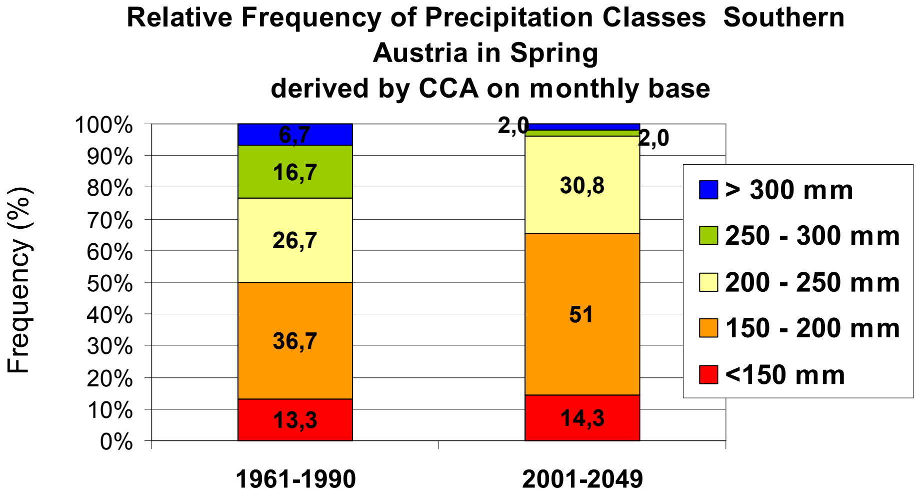


Fig. 11: Relative frequency of precipitation classes [mm] for the spring season in the south-east of Austria. Derived with the CCA technique.

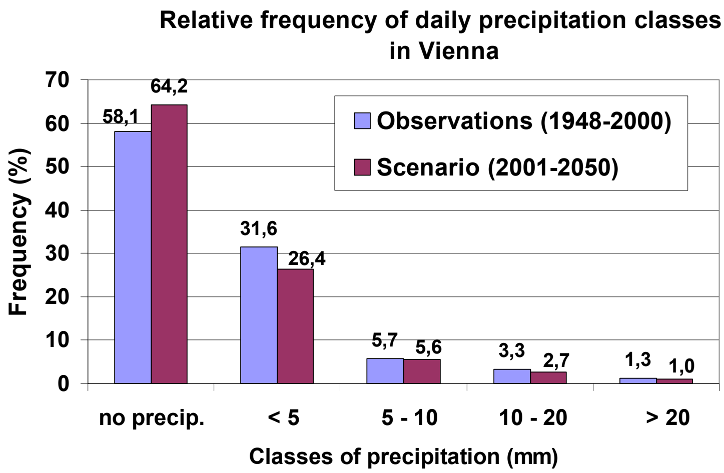


Fig. 12: Relative frequency of daily sums of precipitation [mm] in Vienna, observed and derived with the Analogue technique.

Since the Analogue method provides results on a daily basis, these results can be used directly to obtain statistics on extreme events. But because the temporal correlation is very poor on daily data, especially concerning precipitation, the results are only used for a climatological interpretation.

As an example Fig. 12 shows the relative frequency for precipitation. In this scenario the number of days without precipitation increases by about 6%, mainly balanced by a reduction of days with precipitation less than 5 mm.

3.4.4 Conclusions

In general the statistical coherence between the local weather and the large scale meteorological fields is sufficient to downscale temperature in both techniques. For precipitation this coherence weakens in both techniques. The approach on monthly base (CCA) seems to yield better results for precipitation, as the fraction of significant correlations is much higher. On daily base, the temporal correlation for precipitation nearly vanishes, although the method is able to reproduce statistical properties like frequency of precipitation, the probability density function and even the occurrence of wet- and dry spells.

On a monthly base information about extreme temperature events can only be derived indirectly. Scenarios on daily base would be more suitable for such analyses. However due to the poor correlation on this time scale the interpretation of the results is diufficult.

As GCMs, even if they are quite similar on the global scale, can differ substantially on the European scale, only ensemble scenarios, derived from different GCMs, should be used in climate impact studies.

3.5 Development of a method to predict the occurrence of extreme events from large-scale meteorological fields (re-analyses and GCMs) (StartClim.4)

The content of this project is the development of a method to derive synoptic patterns which may cause heavy precipitation in Austria from large-scale meteorological fields as delivered by meteorological models. Conventional weather typing schemes for the Alpine area (e.g., Kerschner, 1989) are not suited for this type of study as they lack the temporal dimension and the characterisation of intensity, and because they cannot be applied to meteorological fields calculated by global climate models.

The investigations need to be carried out on a time scale resolving synoptic events. For this purpose, kinematic 3-D back trajectories (tracks of air parcels) are being calculated (Stohl et al., 1995). They represent aggregated meteorological information and include also the temporal evolution which is often important for the character of a weather situation. In combination with the daily precipitation sums at 132 Austrian climate stations a cluster analysis is carried out to find related weather situations.

In the development of the method care was taken to allow for some uncertainty in the position of the extreme event: not even for the actual weather forecast models it is possible to forecast well the location of convective storms; however, warnings for larger regions are also valuable. For future climate scenarios, this uncertainty is even more important.

3.5.1 Methods

Historical meteorological fields of the years 1979 until 1983 (ERA-15) were used for the calculation of the trajectories. In order to compare two trajectories (they describe the movement of air parcels) with each other, it is necessary to define a distance function. Trajectories are calculated for eight different arrival points and on eight vertical levels. Each day, this calculation was made for eight different arrival times. As an additional information, specific humidity and potential vorticity at the point of arrival of each trajectory was included in the investigation. For all dates and times to be investigated, the horizontal and the vertical distance between the trajectories can be calculated, as well as the differences of the values of potential vorticity and humidity at the point of arrival, and stored in a matrix. In order to make different parameters comparable, we normalise the distances with a typical value of the standard deviation. The meteorological input to the cluster algorithm is obtained by summing up selected distance matrices.

A hierarchichal clustering algorithm (Anderberg, 1973) is used to group the heavy precipitation cases. The method was extended such that in each step elements can be regrouped. The number of clusters which are used in the end depends on the variation of the mean distance of the new group.

3.5.2 Results

3.5.2.1 Precipitation regions

A cluster analysis of the daily precipitation at the Austrian climate stations was carried out for the period 1979-1993, using the correlation coefficient as a measure of similarity. This resulted in seven precipitation regions with similar behaviour with respect to precipitation:

- Western Austria (Vorarlberg and most of Northern Tyrol),
- Northern "Stau" (northeastern part of Tyrol, parts of Salzburg and Upper Austria),
- Wald- and Mühlviertel (northern parts of Upper and Lower Austria),
- Eastern Region (Vienna, northern Burgenland, parts of Lower Austria),
- Ennstal-Semmering (northern Styria and southern Lower Austria until about the Rax),
- Southeast (southern Burgenland, central and southern Styria, lower Carinthia), and
- Southern "Stau" (East Tyrol, upper Carinthia)

If these analyses are carried out separately for summer and winter, some modifications result. In summer, the northern part of Burgenland moves into the Ennstal-Semmering region, probably as an effect of thunderstorms coming from the Wechsel region. The Wald- and Mühlviertel regions also grow in summer a bit towards the east. In the winter half year, this region moves almost completely into Upper Austria. The Ennstal fits better into the Northern "Stau" region in winter and the Southern "Stau" region grows somewhat in winter, too. A comparison with the catchment areas defined in StartClim.14 shows that the catchments of Enns and Traisen together roughly correspond to region Ennstal-Semmering as defined here. The region Mühl- and Waldviertel forms a separate group also for the catchments. The typical northern "Stau" regions include the catchments of Traun and the Salzkammergut.

For each of these regions, the days with extreme events were studied.

3.5.2.2 Synoptic patterns

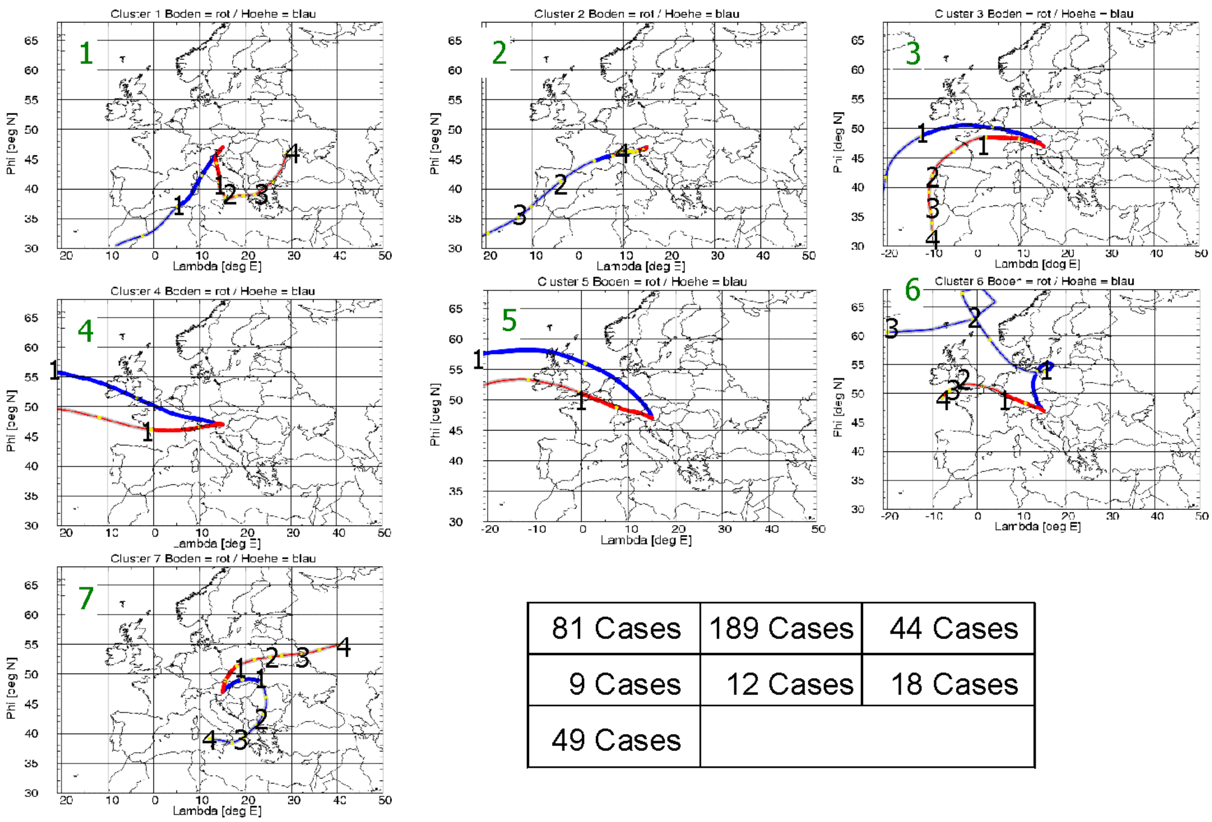
Days on which precipitation exceeded the 98th percentile of the respective region in at least one of the above-defined regions of Austria were defined as "extreme events". The 399 cases found were divided into similar groups on the base of the trajectory information with the help of the cluster algorithm. As shown by extensive tests, the selection of the trajectory information has considerable influence on the clustering result. Trajectories in two different levels are important to obtain information about a veering of the wind with height and thereby also information about temperature advection. Level 2 (500 m above ground) and level 7 (500 hPa, about 5 km) give the best results. The simultaneous use of trajectories arriving at different times of the day is important in order to include the translation speed of precipitation systems. Furthermore, the potential vorticity was included in the evaluation.

The 399 days with heavy precipitation were divided into 7 synoptic patterns with the clustering algorithm; their frequency varies considerably. In Figure 13, typical cases for each pattern are characterised by a ground-level and a higher-level trajectory each.

- Cluster C1 can be called a typical southern "Stau" and occurs in 20% of the cases. It is characterised by a southerly flow at higher levels as well as near ground. The ground-level trajectory shows how the air is taking up humidity over the Mediterranean Sea which is subsequently rained out in the southern "Stau" of the Alps.
- Cluster C2 is a quite different type. Very slow movements near ground (the trajectory hardly leaves Austria within four days) indicate a weak-pressure situation. At higher levels, a well-pronounced southwesterly flow prevails. This pattern is characterised mainly by thunderstorms which are widespread ahead of approaching cold fronts and which can

be strong. These events can occur in almost all of Austria and the pattern is relatively frequent (46% of the cases).

- Pattern C3 is the most frequent one of the three patterns with northwesterly flow identified by the algorithm (11% of all cases). The ground-level trajectory stays a long time over the Atlantic Ocean, thus enabling strong humidification of the air. The fronts coming from the Northwest are – apart from the convective events (C2) – the most frequent cause of heavy precipitation days.
- The two other patterns with northwesterly flow (C4 and C5) are discriminated from C3 by rather fast trajectories at ground level as well as at the higher level. In cluster C4 (2% of the cases), the ground-level trajectories come directly from west. This should cause heavy precipitation in the west of Austria (west "Stau" effect).
- Pattern C5 (3% of the cases) shows a northwesterly flow at both levels, which is strong especially at higher level and has a pronounced northerly component there. Especially uplifting of warm air can cause heavy precipitation in north "Stau" areas.
- Pattern C6 is characterised by a so-called cut-off low in the region east of Austria. A well-developed, typically circular low-pressure system at higher levels in the (north-) east of Austria causes cold-air advection at its rear. This cold air inflow at higher levels destabilises the air and thus is conducive to precipitation. In the northern "Stau" areas this effect is enhance by forced uplifting of the air and produces high amounts of precipitation.
- As the seventh pattern the algorithm identifies the so-called Vb situation. In this situation, which has a frequency of 12%, a low is formed south of the Alps which then moves on towards the northeast. These situations are often connected with heavy precipitation because the air which is lifted in the depression has taken up a lot of humidity over the Adriatic Sea. Typical is also the inflow of cold air from the north near ground which is the reason why this pattern can cause heavy winter storms in the east of Austria.



81 Cases	189 Cases	44 Cases
9 Cases	12 Cases	18 Cases
49 Cases		

Fig. 13: Weather patterns connected with heavy precipitation as identified by the clustering algorithm. The central trajectories of each cluster are shown for two arrival levels (red: 500 m above ground, blue: approx. 5 km above ground). The numbers along

the trajectories indicate how many days before arrival the air was at this point and thus represent the velocity. The central element of each cluster is the one which has the smallest mean distance to all other elements of the respective cluster. Right below the figure the number of cases out of the total of 399 heavy precipitation days in the years 1979-93 are given.

Figure 14 illustrates the geographical distribution of the heavy precipitation, characterised by the median of the daily precipitation for each of the seven weather patterns with respect to the total number of cases in this pattern (all consisting of days with precipitation exceeding the 98th percentile in at least one region of Austria). The pattern C1 causes heavy precipitation almost exclusively in the southern "Stau" regions (in 50% of the cases daily totals of more than 50 mm) while there is no or little precipitation north of the Alps. Pattern C2 can bring heavy precipitation all over the country, but the intensity is clearly lower in the northeast. The most frequent northwesterly flow pattern C3 brings high precipitation values primarily to the northern "Stau" regions. Pattern C4 exhibits a westerly "Stau" effect as visibly by the maximum in the Arlberg region. Most affected by pattern C5 is the northern "Stau", like for C3, however with lower amounts in the extreme west and clearly higher ones in the Ennstal (median reaching 40 mm!). Weather pattern C6 (cut-off low in the east) causes the most intense precipitation in the typical northern "Stau" regions. For the Vb type (C7), the northeast of Austria and the eastern part of the northern "Stau" receive the highest amounts of precipitation. Daily precipitation values exceed 20 mm which is quite a lot in the rather dry eastern region. Next to pattern C2, the Vb pattern is the second-most important pattern for heavy precipitation in southern Styria. In addition it should be kept in mind that the median presented here does not represent the highest possible daily sums which are typically higher by a factor of 2-3.

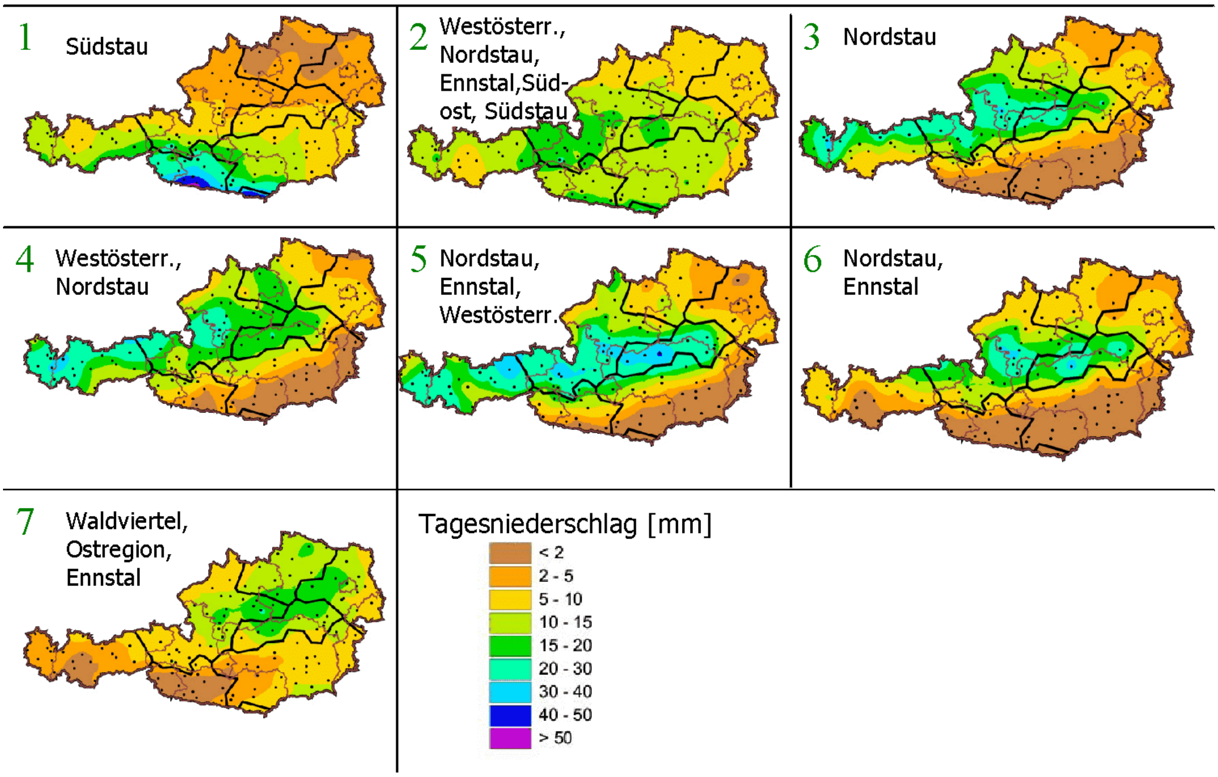


Fig. 14: Median of the daily precipitation in the single clusters (numbered as in Fig. 13). The median is the value which is exceeded by 50% of the days in the cluster. In addition the 7 precipitation areas of Austria are marked (heavy black lines). For each map, the regions most affected by this pattern are listed. The dots mark the stations used.

3.5.3 Outlook

The results obtained can be well interpreted and qualitatively correspond to the existing experience. This is encouraging for a continuation of this new path. The usability for downscaling purposes should be checked and could offer an alternative or at least support for the purely statistical approach of Startclim.5.

The present study is only a first step into an exciting new direction. Through the inclusion of a larger number of extreme events it would be possible to improve and support the results. Based on the analyses of the projects Startclim.1 and Startclim.2, daily precipitation data for the past 50 years are available. Historical meteorological fields exist for the past 40 years, enabling a temporal extension of the method. This would also allow the consideration of more extreme events than the 98th percentile. Studies such as year-to-year variability, seasonal distributions and possible trends of the synoptic patterns are possible. As the method was developed with large-scale fields, an application to climate model control runs and scenarios (time-slice calculations) is possible, and it should, together with the assignment algorithm which was not presented here and which has still to be improved, enable inferences about the possible future occurrence of the synoptic patterns. Also the development of the method for other events such as wind storms, extreme temperatures and draughts, but also more complex ones such as floods or avalanches, is possible in principle.

3.6 Summary of progress

- Plausibility tested series of daily mean temperatures, daily temperature extremes, daily total precipitation, and daily snow levels for 71 stations in Austria between 1948 and 2002.
- First statistically significant evidence on changes in extreme values in Austria based on the best currently available dataset.
- Plausibility tested and roughly homogenized data series from the monthly sheets from nearly 20 stations that are particularly relevant for extreme events. The timeframes for which these data are available range from 50 to 100 years.
- Information as to the required measuring period necessary to derive trends or shifts in the frequency distributions within defined levels of precision. The results show that certain parameters can be very satisfactorily analysed based on the available 50-year period, whereas others would require longer series in order to draw equally reliable conclusions about trends, etc.
- Two statistical methods were applied to interlink local extreme weather events with large-scale meteorological fields.
- For individual stations, the future developments in the frequency of extreme events such as heat- and summer-days or frost- and ice-days were calculated.
- Evidence was provided that more complex approaches must be found to analyze extreme precipitation events. The analogue method is quite simple but needs further development before being applicable to more far-ranging considerations about extreme events.
- A method to interlink local extreme weather events with large-scale weather patterns as a preliminary step to analyzing future GCM climate scenarios with regard to their effect on the frequency of occurrence and the intensity of extreme weather events. The method is reliable for precipitation events but is principally transferable to other extreme events such as storms.
- An analysis of regions that are often simultaneously affected by extreme precipitation events, such as the “Südstau” or the so-called Ennstal region. Such a result could be incorporated into plans developed by catastrophe management.

3.7 Research needs

- There is an urgent need to develop a method to homogenize climate data on the basis of daily values, considering the great demand for approaches based on daily data sets.
- Once appropriate methods are available, a spatially sufficiently dense dataset that encompasses several climate elements should be homogenized for Austria.
- The statistical downscaling procedures should be applied to the then available daily datasets and be expanded to include other parameters.
- Efforts to improve the precipitation downscaling must be intensified considering the importance of flood events.
- The downscaling results for precipitation could be both improved and supported by investigating a larger number of extreme events and using the then available daily precipitation values of the last 50 years.
- As the analogue method can only rely on past values to develop local climate projections, it would be desirable to further improve the method specifically for extreme events.
- Ensemble scenarios derived from various GCMs must be used in climate impact research because they also consider dynamic changes in the statistical downscaling procedures; in the GCMs, these can be quite different even when they yield similar results on the global scale.
- Investigations on year-to-year variability, seasonal distributions and potential trends in weather patterns can also be done with the trajectory-clustering method, also applicable to climate control runs and scenarios (time-slice calculations), which allow conclusions to be drawn about the potential future occurrence of weather conditions. Expanding the method to additional events such as storms or extreme temperatures, but also to floods or avalanches, is also theoretically possible.

4 Impacts of weather-induced events: collection, documentation, analysis and evaluation for selected regions and sectors

4.1 Introduction

Subsequent events such as floods, mudslides, avalanches, drought, etc. are closely related to weather phenomena. Beyond the weather-related triggers, these events are also influenced by human interventions (spatial planning, land-use). A clear distinction between the two influencing complexes is generally not possible, considering the temporal trends of such subsequent events. This, however, would be necessary in order to achieve an understanding of the expected impacts of climate change. Careful documentation of the events could contribute to such analyses.

As it was not possible to investigate all subsequent events in the framework of StartClim, a selection was made: rockslides, floods, mudslides, landslides and avalanches are special problems in the alpine region. This is compounded by the particular sensitivity of the alpine region toward climate change. StartClim.3a therefore investigated what sources of information are available on historical extreme events and what data can be incorporated in a documentation in order to make optimal use of the material in the interdisciplinary sense.

A second sector that is highly and immediately impacted is agriculture. Here, it is necessary to extend the analysis and to ask to what degree changes in agricultural yields actually reflect meteorological factors (StartClim.3b).

A database is required in order to actually access and utilize the collected data: its structure must enable the inclusion of a wide range of data types and sources (StartClim.3c). The data collected in the framework of StartClim will be entered into this database (MEDEA) during StartClim itself. It is designed to be maintained, expanded and continuously updated in the framework of future climate projects. Special focus is placed on the issue of data uncertainty and its characterization.

Extreme weather events have directly observable economic repercussions. This goes beyond agriculture to directly impact the insurance sector, for example, which is examined more closely in the framework of StartClim.8.

Based on the economic interrelationships, virtually all economic sectors are to some degree directly or indirectly influenced by extreme weather events. StartClim.6 attempts to determine the relevance of such extreme events for the various economic sectors and also to document the degree to which various businesses are aware of the problem and their capacity to react accordingly.

4.2 Extreme Events: Documentation of hazardous events in Austria such as rock avalanches, floods, debris flows, landslides, and avalanches (StartClim.3a)

4.2.1 Documentation of extreme events: Databases and Chronicles

Opportunities for research and practical applications offered by an event-related documentation of severe events are shown for rock avalanches, floods, debris flows, landslides, and avalanches.

The most comprehensive database regarding number of events as well as information per event is that of the Austrian Research Centre for Forests in Vienna (BFW - Database) documenting debris flows and floods in Austria since 1972. In a cooperative effort, several Institutes at the University of Natural Resources and Applied Life Sciences have set up an event-oriented database for avalanches (Fuchs et al., 2001), that currently includes all known events up to 2002 in the Paznauntal, Pitztal and Salzkammergut, for example. The Austrian

Federal Office and Research Centre for Forests in Vienna (BFW) maintained a database for avalanches that cause damage in the period 1968 to 1993 (Luzian, 2002).

An initial analysis of the 4122 events recorded in the BFW Database shows that 36 % of the municipalities covering a total area equivalent to 55 % of Austria were affected by severe torrents, debris flows and floods (Fig. 15). Torrents are generally limited to small catchment areas: 40% of the events are registered in catchment areas smaller than 10 km², 20 % in areas smaller than 1 km².

Areas on the northerly and southerly slopes of the Alps, such as the Salzkammergut, the district Zell am See or the Gailtal, and a few inner alpine areas, such as the Upper Inn Valley, are most frequently affected. In the municipalities Saalbach Hinterglemm, Bad Goisern und Abtenau more than 40 events occurred during the 32 years documented.

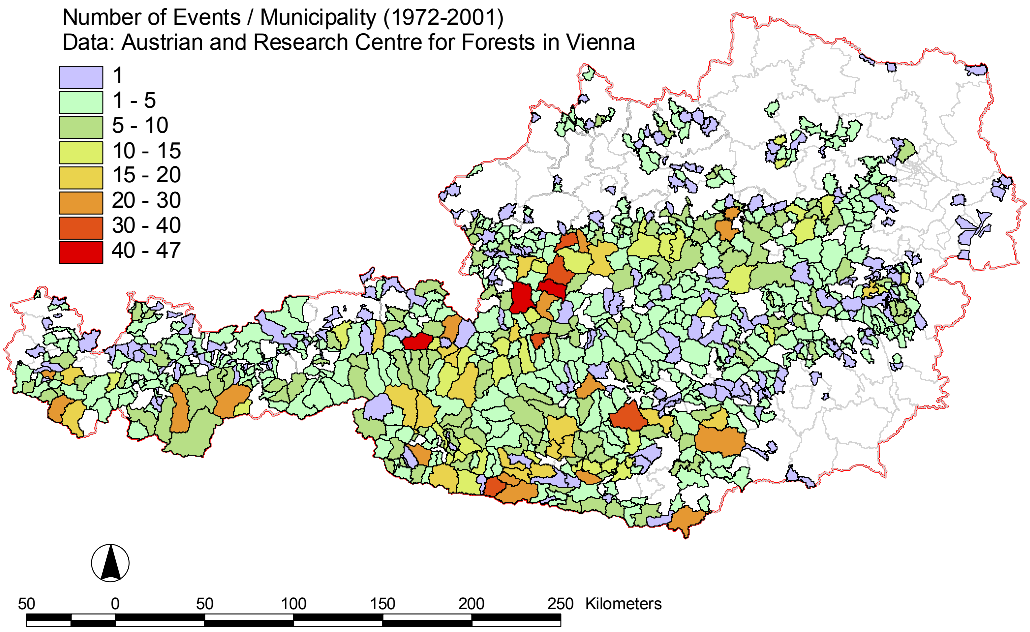


Fig. 15: Events per municipality in Austria (1972-2001)

The BFW Database contains quantitative data on precipitation (such as amounts and duration) as well as on sediment deposits. The chronicles discussed below document neither. The monetary figures on damage are limited to the reconstruction costs of destroyed or damaged defense measures. The costs of damages are not centrally compiled, and the data are therefore not readily available, e.g. for cost-effectiveness considerations in planning precautionary and protective measures. One aim of MEDEA could be to bring these data together in an integrated database.

In the chronicles of the Institute for Forest and Mountain Risk Engineering(WLV), the events were categorized as debris flows, floods and rock avalanches. The triggering processes (thunderstorm/intense shower or continuous rain) were only qualitatively documented, the sediment deposits and damaged objects only partially. Spatial and process-related information, such as the length of mud slides or the spread of deposits in the debris cone in the form of charts, maps or descriptions are available neither in the BFW Database nor in the chronicles.

The events listed in the WLV-chronicles are either based on observations and documentations by staff members of the WLV or on information gathered from archives of municipalities, parishes or interviews with older persons. The source of information and the method of retrieval are frequently unknown. Documentations are full of gaps and the information be-comes increasingly incomplete the farther back in time, so that only very severe events are recorded in the very early period of the chronicles. Damages are often described only as lump sums, without detailing the damages on individual objects. The study of additional historical sources, such as Fliri´s Chronicle of the Tyrol (1998), can enhance the information on the events listed in the chronicles and can add numerous additional events.

Documentations of extreme events are an important basis for planning protective measures and therefore the demands on data quality are very high. The collection, administration and processing of data should be fully documented, thus a data coding similar to the one developed in the Project DOMODIS (Hübl, J., Kienholz, H., Loipersberger, A., 2002) was proposed for the new data information system MEDEA.

4.2.2 Case study: Events in the districts Landeck and Imst

As a supplement to the BFW Database, chronicles of events in the districts Landeck and Imst maintained by the Institute for Forest and Mountain Risk Engineering (WLV) in the Tyrol were assessed. The information was collected in generalized categories, which enabled a linkage to the BFW Database. This yielded a substantial extension of the time series, enhancing the chances of learning about extremely rare events (Fig. 16).

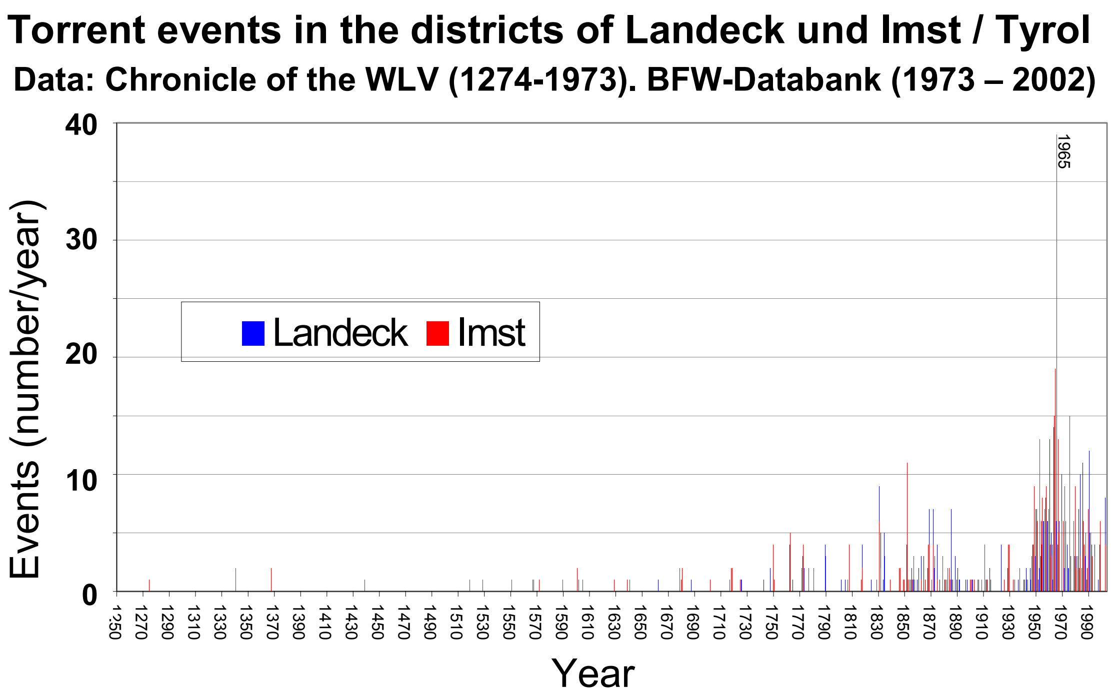


Fig. 16: Frequency of torrent events in the districts Landeck and Imst based on the chronicle (1274-1973) and the BMLFUW Database (1973–2002)

The chronicle of the WLV lists 261 events in the district Landeck and 378 events in the district Imst. The documented damage events accumulate in the early 19th century and reach a first density peak in the mid-19th century, and a second one more than 100 years later. The highest frequency per year occurred in 1965, before the recordings of the BFW Database start.

Documentation of the events in the village Umhausen, district Imst, begins with the chronicle of the WLV in the year 1749. To date, 64 events have been documented in the chronicle of the WLV and the BFW Database, most of them in the chronicle. Some known events were found neither in the chronicle nor in den BFW Database.

The events occur at different intervals and often co-occur with events in other catchment areas (Fig. 17). The infrequency of events is illustrated by the maximum interval of 89 years at the Acherbach; this value is more than 30 years higher than the maximum interval at Farstrinne. The events in the Farstrinne and Murbach catchments areas show that the maximum intervals became increasingly shorter in the 20th century. The greatest density of events were recorded in the Farstrinne catchment between 1850 and 1860: 6 events in 10 years. In contrast, the density of events in the Acherbach and Murbach catchments are distinctly higher in the 20th than in the 19th century. Moreover, the BFW Database provides the first report of damage in the Schreibebach catchment.

The reasons behind the temporal correlation between the events may lie in meteorological triggers or be related to topographic features; a classic example is the well-known “storm swaths” in Pinzgau. The catchment areas have not yet been investigated in detail in this respect, and it would be important to collect scientifically founded information about the origin and course of event rainfalls in this region.

The erosion potentials and the predisposition of the catchment areas could be additional triggering factors. According to Zimmermann (1997), this predisposition of the catchment areas plays a role in the development of extreme events. Heavy precipitation must be accompanied by a minimum bedload potential in order to trigger such events.

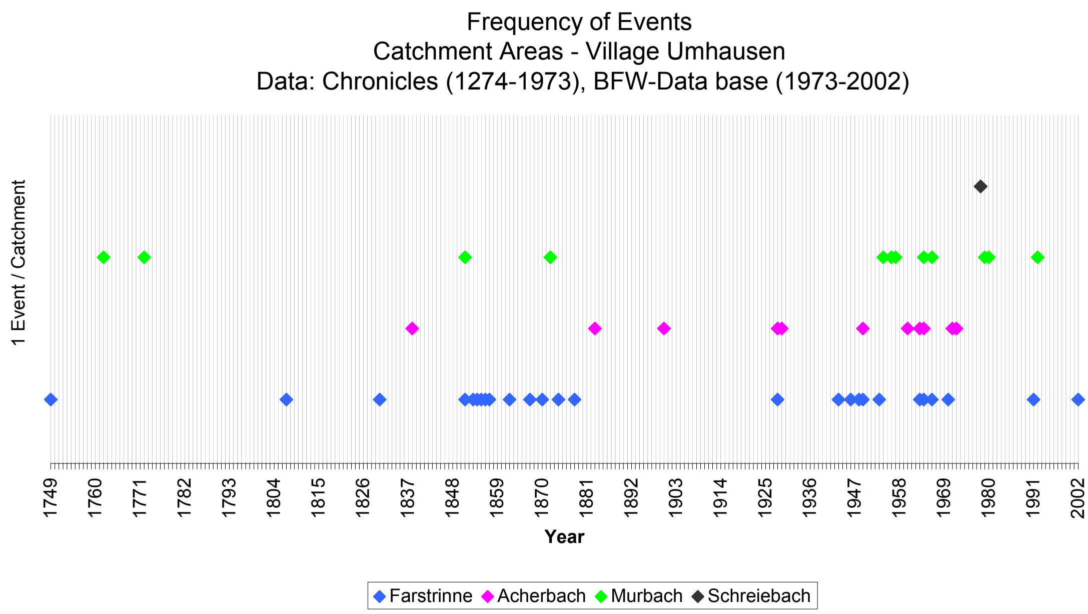


Fig. 17: Frequency of events in the catchment areas of the village Umhausen/ Imst based on the chronicle (1274-1973) and the BFW Database (1973 – 2002)

The spatial extent of the triggering events cannot be determined based on the chronicle data in the village Umhausen because the chronicle contains no information on erosion potential.

The specific deposition of solids is greatest in mud flows, as shown by investigations of the specific depositions by mud flows in Austria (1972-2001): the values were more than four times higher than the specific depositions during flood events with greater bedloads. The analysis of the BFW data also revealed that the specific deposition increases all the greater the less the catchment measures under 10 km². In the municipalities Laneck and Imst, objects were mostly damaged by mud flows: 77% of the documented events in the two municipalities were mud flows. Since 1973 no more buildings were destroyed by torrents, whereas the chronicle reports 20 destroyed houses and several destroyed houses in each of 7 events.

80 % of the documented events in the districts of Landeck and Imst were found in the chronicle of the WLV and 20 % in the BFW Database.

4.2.3 Perspective

Records and information in chronicles are generally incomplete. The study of additional historical sources, such as the "Chronicle of Nature in the Tyrol" by Fliri, 1998, can enhance the information on the events and the number of the events can be significantly increased. The available BFW Database and the chronicles should be completed and homogenized with additional information.

Detailed studies of events in the individual streams provide the foundation for deriving event patterns that are related to catchment area features analogous to Zimmermann (1997). The development of a catchment area typology would contribute to a better assessment of future torrent damage events. The data compiled in the chronicle and the BFW Database, however, are insufficient for such a detailed analysis. This led to the recommendation that the predisposition and the impacts of the events on the catchment area be defined as a variable disposition in future documentations.

Even in the catchment areas, the events are spatially delimited. This necessitates surveying ersosion processes in sub-catchment areas and/or catchment area sectors such as upper-, middle-, or lower reaches in order to better document the course of the events.

Mapping the solid deposition in a manner analogous to the event cadaster of natural threats (StorMe) of the "Eidgenössischen Forstdirektion" in Switzerland (http://www.wald.gr.ch/aufgaben/1-1-1-3-ereigniskataster.htm) would, as a component of the event documentation of mud flows, enable a better assessment of event intensity. This, in turn, would allow an improved evaluation of the vulnerability of society to extreme events. MEDEA could provide the necessary instrument for the archiving task.

In the framework of additional investigations, the damaged objects could be analyzed in greater detail with respect to the development of human settlements. This would permit a determination of the damage potential and provide the basis for risk assessment of extreme events in the sense of the causal chains described in StartClim.6.

Overall, an effort should be made for a more detailed compilation of events than that currently is done in the BFW Database. The documentation of "major" events (wide-ranging and/or severe damage) always requires a separate event documentation.

4.3 Documentation of the impact of extreme weather events on agricultural production (StartClim.3b)

Agricultural production has always been subject to weather-related variations. To date, we lack systematic studies on the magnitude of this effect on the yields and profitability of major crops in Austria. The degree of crop losses through extreme events has only relatively recently entered public awareness due to insurance claims paid out to farmers, whereby multiple-threat insurance policies specifically are a relatively new product on the insurance market. Statistical analyses of trends, however, require considerably longer data series that the insurance sector can currently provide. Knowledge about the degree of vulnerability of agricultural production in the past would increase the accuracy of the impact assessments in future climate scenarios.

The key tasks of this subproject are to provide an overview of data series of agricultural yields extending as far back as possible, to statistically evaluate them, and to link them with the respective meteorological conditions. This procedure is designed to answer the following questions:

- How can agricultural-technological influences on yields such as management measures, plant breeding and application of chemicals be distinguished from weather influences?
- Which growth phases of agricultural crops are particularly sensitive to which meteorological parameters?

- How large are the regional differences in these sensitivities?
- To what degree do the different crops differ in their sensitivity?

The following approaches are available to develop solutions:

a) Application of plant growth models using historical weather conditions as inputs.

b) Primarily selecting extreme weather conditions and secondarily linking them to the production data.

c) Primary selection of crop yields that deviate extremely from the mean values and secondarily linking them to the weather conditions.

Variant a) appeared to be too time-consuming within the short period available in the project, especially because parameterizations of the models for different production areas in Austria were lacking. Variants b) and c) can be considered to be equivalent working procedures. Ultimately, based on the agrobiological expertise available in the project team, variant c) was selected. This reflects the need for a critical selection and evaluation of historical yields as a crucial (yet still missing) foundation for the analyses. Conversely, the Meteorological Service (ZAMG) had already conducted important preliminary work for the selection of meteorological conditions.

Seven agricultural crops (winter wheat, spring barley, corn, sugar beet, potato, grapevine, apple) were analysed for their yields in three regions (Eastern Austria, Southeast-Styria, pre-alpine region of Upper Austria) on a province and on a district basis from 1869 to 2002. These yield data were normalised with the running mean to take account of changes in the seed material, in agricultural practices and of gradual climate change. Relative and absolute differences from these means below the 5^{th} or above the 95^{th} percentile were used to identify years of very low and very high yields.

The comparison of the monthly meteorological parameters (database: homogenized data from ALOCLIM; Auer et al., 2001) during years with very poor yields with the same parameters of the standard reference period (1961–1990) earmarked those months specifically for each parameter, crop species and region, when years with poor yields differed significantly from the reference period:

- Years with very low winter wheat yields showed two distinct signals common to all three regions: February temperatures were significantly below average and the precipitation sum in July was especially high. Additionally, the May temperatures were lower than average in Upper Austria, and in both Styria and Upper Austria April and May were very humid.
- Spring barley showed high sensitivity to drought. Especially in the Pannonian region (Eastern Austria) bad harvests occurred if temperatures were above average. Above-average rain in the harvest month July was disadvantageous.
- Corn is also sensitive to drought periods in summer, especially in Eastern Austria. In the harvest month of October, bad weather is a risk factor determining whether a year would develop into a negative extreme.
- Bad years for potatoes are generally characterized by high precipitation sums. Moisture enhances the risk of infection and rapid propagation of fungal diseases. In recent decades, however, low yields were also caused by drought, which could indicate a gradual shift in the main reasons for low yields.
- Sugar beet is especially sensitive to wet periods in April when most of the sowing is done. Seedling development requires sufficient warmth for rapid growth. In summer, however, drought in all three regions, including the more humid ones, reduced yield significantly.
- Grapevine productivity suffered most from deep frosts in February and from moist and cool conditions during the summer months, including the month of anthesis (June).

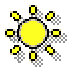
Heat or drought were of negligible importance. Recent changes towards brighter and drier summers as well as fewer frosts might make grapevine a possible winner of climatic change.

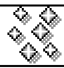
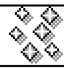
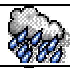
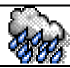
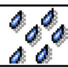
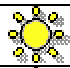
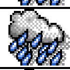
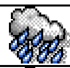
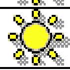
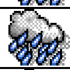
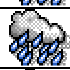
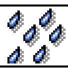
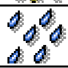
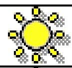
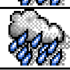
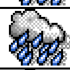
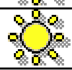
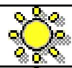
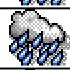
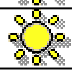
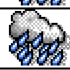
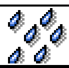
- Apple production was adversely affected by high temperatures in March and by low temperatures in February and April. Additional risk factors were too wet conditions in April and May (during anthesis) and in July.

As the table shows, the influences of the weather described here are not extreme events of the type discussed in the other projects. Monthly weather data had to be used because data on a daily base were not yet available. Extreme monthly averages, however, are frequently highly correlated with individual extreme events. Analysing these short-term events for the period before the second world war is difficult and was not possible within the present project.

The study should be expanded to include all important crop species and production areas. The new temporally better resolved meteorological data set should be used to determine the importance of shorter-term extremes.

Tab. 2: Weather-induced risk factors for low yields in the regions Eastern Austria, Southeastern Styria and Upper Austrian pre-alpine regions for different products.

The symbols mean:  very low temperatures,  high precipitation sums,  draught,  cool and wet conditions

Riskfactors for bad harvests in three regions in Austria 1869 - 2002							
	Winter-wheat	Summer-barley	Corn	Potato	Sugar-beet	Wine	Apple
January							
February							
March							
April							
May							
June							
July							
August							
September							
Oktober							

An extension of the analyses to the meteorological conditions of years with extremely high yields would also allow for a more comprehensive understanding of the chances and risks of future climatic developments.

Simulations of yields with plant growth models could help to verify the derived results regarding weather conditions and yield. The comparison might also give indications as to the importance of short-term extreme weather events. Agro-economic estimates could be coupled with such results.

4.4 Meteorological extreme event data information system for Austria: MEDEA (Meteorological extreme Event Data information system for the Eastern Alpine region) (StartClim.3c)

MEDEA is primarily designed to compile data (and secure them over the mid- and long-term) on extreme meteorological events from various scientific disciplines. An overall picture of extreme events can only be gained if the full range of data – meteorological to socio-economic data – is simultaneously available, and if the causal chains specified in StartClim.6 are supported by data throughout.

At the next level, the explicit incorporation of data uncertainty would be a necessary step toward improved uncertainty and risk assessments in the analysis of extreme events. This will be an important and often demanded contribution to incorporating these issues in climate and climate impact research.

From the medium-term perspective, MEDEA should also give the Austrian climate research community the opportunity to conduct analyses directly from the database.

The structure of the MEDEA event database was modelled after the MORIS data information system of the Federal Environment Agency with regard to the following requirements:

1. Ability to encompass a wide data spectrum (e.g. georeferenced – not georeferenced, „hard“ scientific (measurement) data – „soft“ socioeconomic data) (compare Fig. 18)
2. Ability to be expanded when new requirements are specified by future research projects or programs (e.g. ProVision)
3. Integration of uncertainty information into the various data(sets).

A preliminary object classification for MEDEA was carried out (compare Fig. 19).

After the first examination and evaluation of various (potential) data sets, these were classified in:

- observations
- modelling
- theory and
- consensus.

In the future, representing uncertainty within these classes at the necessary level of precision will require information on the processing of the data and on the underlying raw data.

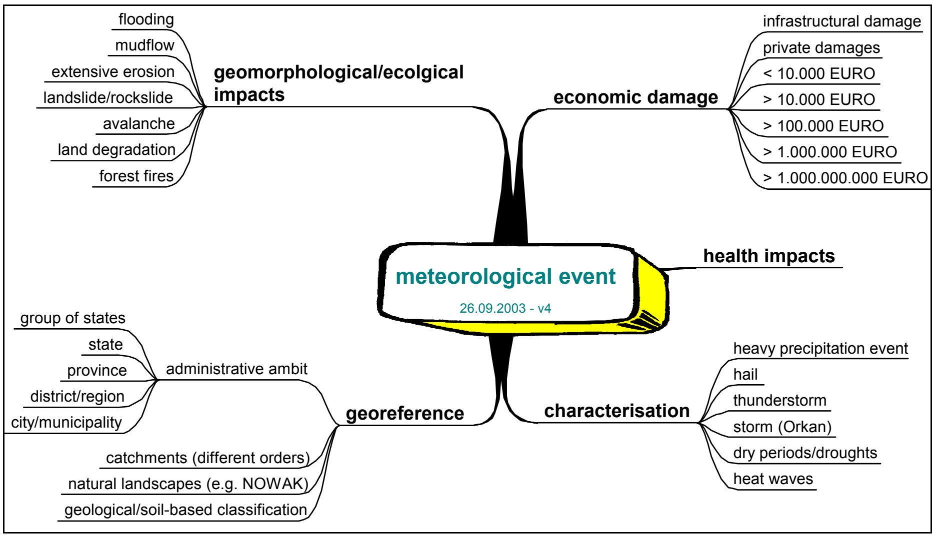


Fig. 18: The data spectrum required for a meteorological extreme event.

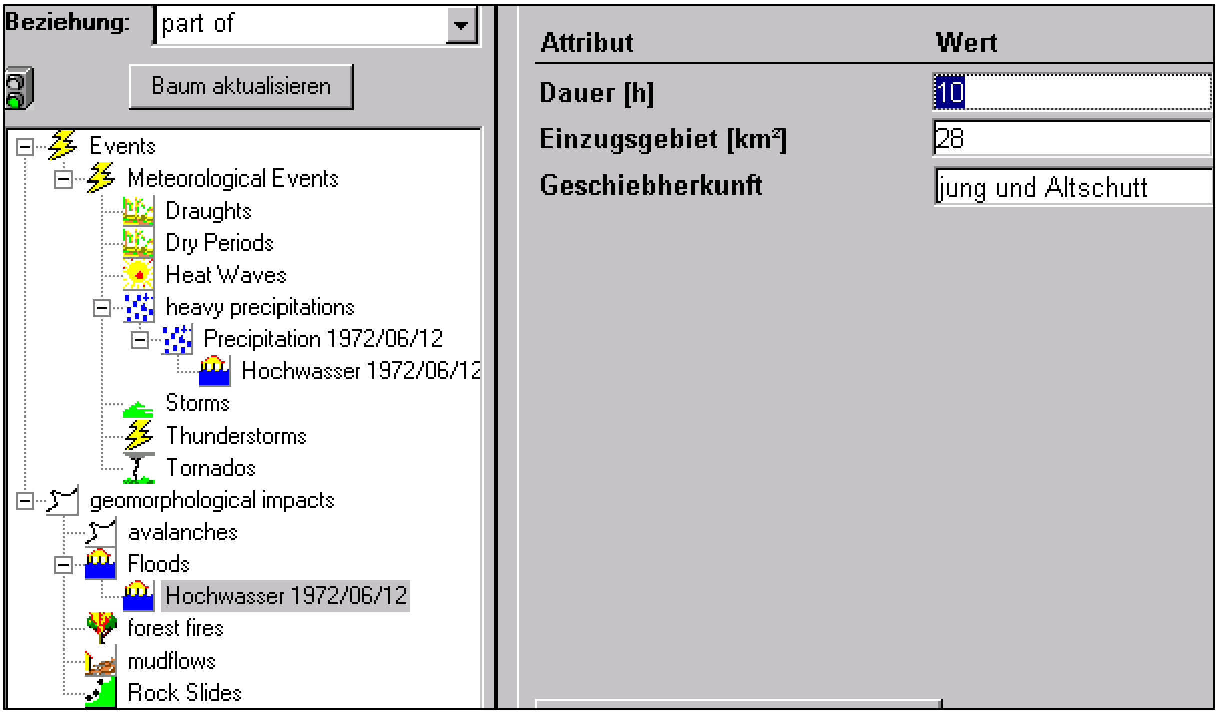


Fig. 19: Extract from the object classification in MEDEA.

The first StartClim data were successfully entered in MEDEA. They currently include test data from various StartClim projects along with test data from the BFW's damage databank for torrent events and from Mr. Alois Holzer's Austrian tornado databank. Additional datasets can be incorporated at any time, although currently data entry is possible only on a client-/server basis. The contact person for the entry of new data is Mr. Herbert Schentz (herbert.schentz@umweltbundesamt.at).

Data output is flexible: it can be done in xls as well as in mdb or xlm (and various other data formats).

Upon completion of the StartClim project, the database work will have to be continued in order to establish it on a long-term basis in Austria. An expansion to include the Alpine region on one hand and the European level on the other hand is currently under consideration.

Within Austria, the operators of several professional databases have expressed an interest in a cooperation because the scientific data in those databases would be improved with the MEDEA input. This cooperation is viewed both as a platform for initiating interdisciplinary scientific research as well as an instrument to advise interested scientists. Quality assurance considerations dictate linking the databanks rather than incorporating all the data in MEDEA. Ideally, users, once they have clarified their access rights, should not notice that they are dealing with several databases.

4.5 Risk management and public welfare in the face of extreme weather events: What is the optimal mix of private insurance, public risk pooling and alternative risk transfer mechanisms? (StartClim.8)

The floods in Austria in 2002 demonstrated clearly that economic risk management in Austria is in need of improvement. This is endorsed by a comparison with national risk transfer systems in other countries and their experiences in the face of natural catastrophes.

Countries included in the comparison were chosen with respect to availability of systems descriptions on the one hand and in view of a broad spectrum of solutions on the other. Included is also a risk transfer mechanism referring to earthquakes in Turkey, because Turkey, after the recent catastrophes, reformed its formerly insufficient arrangements only during the last years with support of the economic expertise of the World Bank.

For every country the options of individuals (or economic entities) to insure their belongings against the hazards of floods were examined, but insurance against other hazards were also touched upon. Three essential details of the national risk transfer systems were studied; they can be assigned to the important topics of incentive theory, social balance or actuarial efficiency:

1) How does risk assessment eliminate adverse selection (Incentive theory)?
2) How are premia organised and can individuals in risk-prone areas afford them (social balance)?
3) How does risk limitation for primary insurance companies work (actuarial efficiency) ?

The overview in Table 3 depicts the differences in some main characteristics of the respective national risk transfer arrangements.

Tab. 3: Overview of risk transfer systems in selected countries. The more points attributed to a country, the more valid the described circumstance; ticks indicate that the instrument is available in that country.

Country	A	D	CH	F	E	USA	TR
Level of public involvement	•		• • •	• • •	• • •	• •	• • •
Social concerns implemented	• •	• •	• • •	• • •	• • •	•	• • •
Minimisation of Moral Hazard	•	• •	•	• •	• •	• •	• •
Incentive for collective risk reduction	•	•	• • •	• • •	•	• • •	• •
Premia cost	• • •	• •	•	•	•	• • •	•
Adverse selection	• • •	• •				• • •	
Map of risk-prone areas used		✓				✓	✓
Obligation to be insured			✓	✓	✓		✓
Obligation to insure			✓	✓	✓	✓	✓
Public transfer payments	✓	✓		✓	✓	✓	n.v.
Risk differentiated premia	✓	✓	✓			✓	✓

Based on theoretical models, the respective practical situations of individuals, insurance companies and public authorities in Austria are studied. The results show that incentives for risky action (moral hazard) and for unfavourable mixtures of contracts due to adverse selection, both of which are important factors for market failure, have not been recognised as problems and were even aggravated through recent government interventions. The theoretical model describing the problems of public enterprise is a tool to analyse the partly contradictory targets of safeguarding individual liberties and rights, economic efficiency and social justice; however, additional research is needed here.

The lists of individual instruments that, within a redesign of a national risk transfer mechanism for Austria, address the above-mentioned features of an incentive compatibility, economic efficiency and social acceptability includes:

Problem cluster 1: The market is unregulated and the state's intervention intensifies market failure

- Adverse selection (Suggested solutions: Better availability of Mapping of risk prone areas, Bundling of risks, Enforced extension of coverage, Obligatory insurance)
- Lack of availability (Suggested solutions: State subsidy for catastrophe hazard insurance, State provides coverage, State provides reinsurance)
- Risk is increasing (Suggested solutions: Flood insurance pool, Recourse to European Union solution)

Problem cluster 2: No incentives for risk prevention

- No incentive for individual risk prevention / Moral Hazard (Suggested solutions: Risk differentiated premia, Risk differentiation at subscription, Limited coverage, Deductibles)
- No incentive for local authorities to avoid risks (Suggested solutions: Give all institutions involved a say in prevention, Deductibles for local authorities)

Problem cluster 3: Ambiguous distribution effects

- Low social compatibility (Suggested solutions: Collective solution, Supported premia)

Problem 4: Risk for the national budget

- Budget risk (Suggested solutions: Higher staffing of catastrophe funds, Recourse to European Union mutual agreements, Insurance at the international reinsurance market or Debt, issuing Cat Bonds)

4.6 Adaptation strategies for economic sectors affected strongly by extreme weather events: Economic evaluation and policy options (StartClim.6)

4.6.1 Fundamental requirements for a comprehensive analysis of extreme events

The investigation of the interrelation between climate change, extreme weather events and their economic impacts is still a very young field of research and a range of unsolved problem areas exists. The study of the literature and the dialogue with researchers and representatives from various sectors of the economy led to the following figure (Fig. 20) depicting the need for research in different areas and showing their interactions.

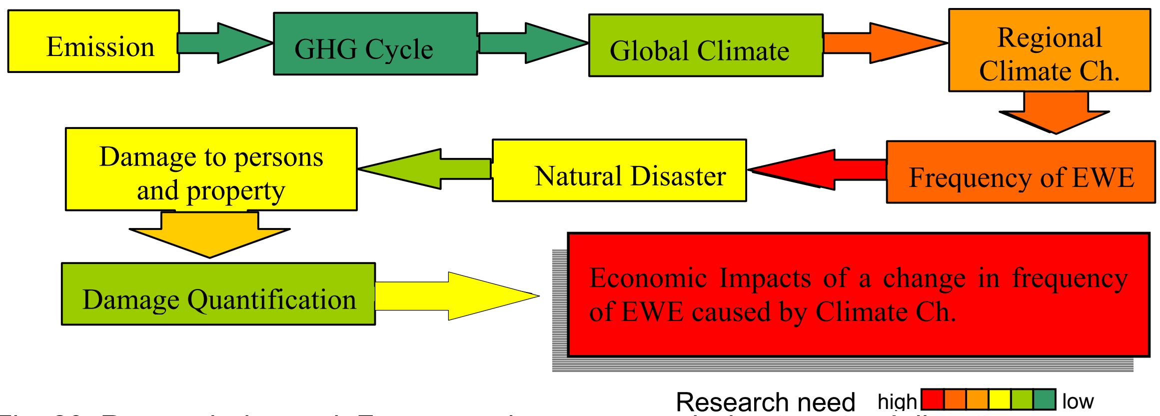


Fig. 20: Research demand: From greenhouse gas emission to natural disasters

To achieve a comprehensive economic evaluation of the impacts of extreme weather events (red box in the figure above), both the underlying data structure as well as our understanding of the whole functional chain (i.e. the interconnections between greenhouse gas emissions, climate change, extreme weather events and damage levels) has to be improved. The fundamental problem lies in the step from the meteorological approach of the analysis of extreme weather events to the economic approach of examining natural disasters and their economic impact. The difficulty lies in the lack of understanding of the link between these: human interventions that transform extreme events to catastrophes. While extreme weather events may lead to natural disasters and entail extensive damage, this is by no means necessarily the case. The frequency of extreme weather events is not a straight-forward indicator for the frequency of events with extensive damage. Thinking in functional chains, as depicted in Figure 21 for the interrelation between precipitation and flood damage, is necessary.

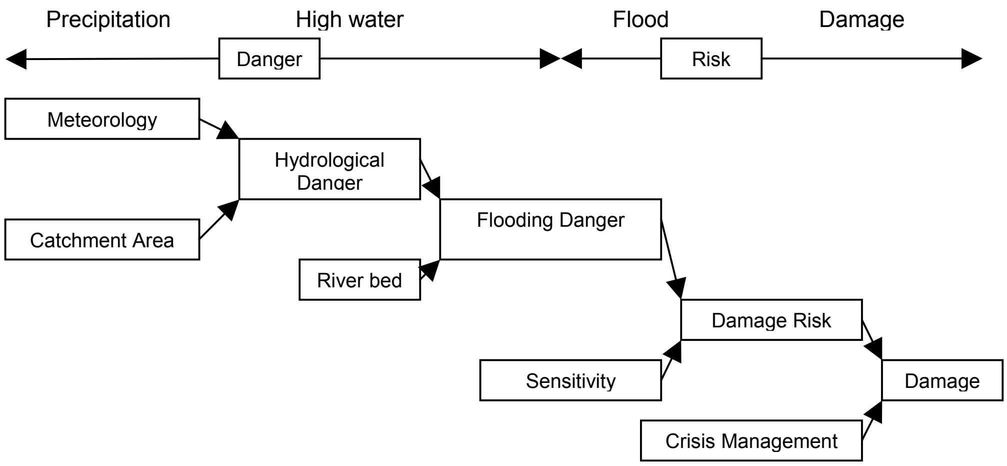


Fig. 21: Functional Chain for Flood Damage (OCCC 2003, p. 35)

Todays knowledge about these interrelations is still insufficient to provide a reliable basis for political decisions. Prevention strategies intended to avoid disaster damage can be implemented at many different points of the functional chain and may thus affect different groups (e.g. specific economic sectors, local municipalities, individuals). The complexity of potential solutions is also increased by the fact that solutions tend to depend on knowledge drawn from a wide variety of research fields (ranging over the natural, social, and technological sciences). There is thus an urgent need for long-term interdisciplinary research on this matter in order to integrate all perspectives and interrelations and provide for a comprehensive solution strategy. Simultaneously, dialogue between researchers, politicians and representatives of the affected economic sectors has to be improved.

4.6.2 Sectoral analysis

The present lack of data makes a comprehensive economic analysis of the impacts of extreme weather events impossible. Therefore sectors especially sensitive to extreme events were selected and in an intense dialogue with representatives from these sectors data on the representatives' own appraisal of the risk exposure from different events (floods, storms, draught, etc.) were gathered. This was coupled with information on how the sectors coped in the past and what measures were intended to cope better in the future. The general appraisal of the sensitivity of each sector is summarised in Tab. 4.

Tab. 4: Impacts of extreme weather events on different economic sectors and availability of relevant data, based on publications and interviews with experts and stakeholders.

EWE/Sector	Energy/ Water	Insurance	Agri-culture	Forestry	Tour.	Health care
Avalanches	I/ yes	II/ yes	I/ yes	III/ yes	III/ yes	III / yes
Floods	III/ yes	III/ yes	II/ yes	I/ yes	II/ yes	III/ yes
Hailstorms	0/ no	III/ yes	III/ no	0/ no	0/ no	I/ no
Storms	I/ no	III/ yes	II/ no	III/ yes	II/ yes	II/ no
Summer draught	II/ no	III/ yes	III/ yes	I/ no	0/ no	II/ no
Winter-aridity	0/ no	0/ no	II/ no	0/ no	III/ yes	0/ no

Category	Sector Sensitivity for each EWE	Abbreviation	Sector
0	(practically) no damage	Yes	Data about EWE impacts on this sector available
I	Negligible	No	No data available, own assumption in combination with literature
II	Sensitive	Energy/Water	Energy- and Water management
III	Very sensitive		

The dialogue with the representatives of the sectors revealed very different levels of data availability and, based on this, partly unfounded risk perceptions. Research was ongoing only in those sectors that have become aware of potential damage and the necessity of adaptation (e.g. in the insurance and agriculture sectors).

What the representatives of the economic sectors believed to be the core political measures necessary for improving future adaptation to and mitigation of extreme weather event impacts was summarised in three categories:

- **General political measures:**
    - Enhancement of the public risk awareness
    - Provision of public access to relevant information regarding EWE,
    - Increased support for scientific research in order to provide a firm basis for policy decisions
    - Implementation of the Kyoto Protocol.
- **Fiscal and regulatory measures:**
    - Integrated spatial planning (including clarification of responsibilities),
    - Improved or adjusted systems of official cost allocation for water management (e.g. implementation of extreme event mitigation measures might make hydroelectric power stations unprofitable)
    - Stimulation of individual responsibility by promoting appropriate insurance packages
- **Measures to ensure basic need coverage after natural disasters:**
    - Harmonization of the nine state laws regarding emergency aid,
    - Public provision of financing for crisis intervention,
    - Establishment of an official disaster manager, and

- Establishing a legal basis for absence from work for helpers during natural disasters

The results of the dialogue with the sectoral representatives were presented in the framework of an expert workshop in September 2003. New contacts were established between the research, political and economic sectors, which was an important step in promoting transdisciplinary research.

4.7 Summary of progress

- An overview is compiled of the data available on rockslides, floods, mudslides, landslides and avalanches.
- As case studies, the chronicles of the districts Landeck and Imst were evaluated, considerably enlarging the series contained in the torrent damage database.
- Recommendations were developed for necessary and useful additions in the documentation of extreme events; their implementation is currently being discussed with the relevant authorities and institutions.
- The first systematic studies on the correlation between weather conditions and crop yields were conducted for seven agricultural crops in three regions of Austria based on long-term yield statistics. This revealed clear evidence for certain weather conditions that are particularly unfavorable for yields.
- An event database was established. It is to be updated in the course of future research efforts and be made accessible to the relevant scientists.
- A system was developed to consider uncertainties in databases that contain data from various disciplines and from quite different sources.
- An overview was compiled of the risk transfer systems in selected countries. This served as a basis to discuss the improvement potential in Austria.
- A theoretical model was developed to shed light on problems associated with public spending and the sometimes contradictory goals involved in the respect for individual rights, economic efficiency and the social justice of risk transfer systems.
- Recommendations for the design of an incentive-compatible, efficient and socially fair risk transfer mechanism were developed for Austria.
- The expert workshop held in the framework of this project was the first step at employing an analysis of demand to promote discussion between the interdisciplinary EWE research and the individual economic sectors, despite difficult framework conditions (poor data availability when breaking the perspective down into the individual economic sectors).

4.8 Research needs

- The analysis of additional historical sources can substantially improve and expand the information content of the chronicles.
- The development of a catchment area typology based on the (sparsely) available data could help to better assess future torrent damage events.
- Damaged objects should be analyzed in more detail in light of the development of human settlements. The damage potential and the fundamentals for the risk assessment of extreme events in the sense of the causal chain described in StartClim.6 could then be determined.
- The presented evaluations of the correlation between weather and agricultural yields should be expanded to include all important agricultural crops and production sectors;

these should then be linked to the temporally more highly resolved meteorological data gained in the framework of StartClim.

- Analogous, detailed studies of the meteorological conditions that help maximum crop yields would be a step toward achieving a more comprehensive picture of the risks and opportunities that future climate development might harbor.
- Calculating yields using plant growth models would enable testing the correlations obtained between agricultural production and meteorological conditions. The comparison might also provide insights into the influence of extreme events in the narrower sense. Such analyses could provide a basis for agro-economical estimates.
- The MEDEA database should be linked to existing databases and users should ultimately be given access via the internet.
- Certain aspects of the theoretical risk transfer model should be improved.
- The necessity arises for longer-term interdisciplinary research in order to incorporate these interlinkages into a comprehensive solution-seeking strategy. This should be accompanied by an intensified dialogue between the research, policy and economic sectors.
- The dependence of additional economic sectors on potential changes in the frequency of natural catastrophes needs to be studied. The construction business is a prime example: case studies (e.g. the 2002 flood event) that quantify profits and losses are identified as an important goal. The infrastructure sector is another example because much of the damage created by natural catastrophes affects transportation networks.
- The dialogue between the research and economic sectors should be utilized for specific case studies on individual extreme weather events and on individual sectors (e.g. the effect of the 2003 heat wave on Styrian agriculture). The focus should be on collecting economic damage data.
- The catalogue compiled on adaptational measures should be examined in greater economic detail for the individual sectors.

5 The August 2002 floods in Austria

5.1 Introduction

The research activities in this sector are also understood as a contribution to the “Floodrisk” analysis currently being conducted in comprehensive form under the charge of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW).

From the meteorological perspective, two goals are being pursued. The first is to carefully analyze the weather and precipitation situation in order to provide suitable meteorological data for the analyses conducted by hydrologists. The second is to improve our overall understanding of the processes, measurements and models in order to reduce the potential damages by providing improved meteorological and hydrological advice. Progress in this respect can be achieved through:

- better use of information from available measuring station grids (StartClim.13),
- better understanding of the performance and capabilities of available models (StartClim.14), and
- better analyses of available models with respect to extreme events (StartClim.12).

Compared with the meteorological and hydrological assessments of flood events, the economic analysis of such extreme events is relatively underdeveloped. This calls for determining the amount of recorded damage; how this is done can decisively influence the speed and efficiency of the aid and support measures (StartClim.9). The details on the type of damage to houses, households, businesses, infrastructure as well as to agricultural land and forests can be used to derive lessons for planning at all levels in regions subject to flood risks; this information can also serve to better assess the long-term subsequent effects of such an extreme event (StartClim.7). This includes aspects such as the local effects on the distribution of income and wealth, the demand for replacement investments and the resulting effects on local, regional and supraregional economic activity.

The phenomenon of extreme events represents at least a three-fold challenge for economic research in the narrower sense. First, to what degree are the tools of economic data analysis and prognosis useful and to what extent must they be modified? Second, to what degree is the current accounting system focusing on an national accounting in need of amendment in the direction of a capital accounting? Third, what course does the necessary renewal process of the capital stock take after an extreme event? (StartClim.10)

Analysing the collected data using classical economic models gives rise to the paradox that catastrophes typically tally as a positive economic event. First conceptual steps in the direction of an economic model that goes beyond money flows to incorporate the loss of values – thus solving the paradox – are currently being undertaken.

5.2 High-resolution precipitation analysis (StartClim.13)

Precipitation measurements contain gaps and never cover the area of interest homogenously For the planning of networks, the calculation of areal precipitation for hydrological and run-off models, for the evaluation of sxtreme events and for many scientific research questions interpolation schemes to supply precipitation data on regular, high resolution grids are needed.

Different values of areal precipitation will result, depending on the interpolation scheme, even in case of a very dense precipitation network as was available during the floods of 2002 in Austria. The quantification of the uncertainties in the areal precipitation is an important contribution to the quantification of the uncertainties in hydrological and run-off models.

Operational real time analysis of areal precipitation in high spatial and temporal resolution including objective data quality control can contribute to an improved catastrophy managament in case of extreme precipitation events.

The model investigated at the Institute of Meteorology and Geophysics in Vienna called VERA (Vienna Enhanced Resolution Analysis, Steinacker et.al., 2000) is based on a variational approach, the method is similar to the spline algorithm. The method is based on the idea of searching a mathematical function going through all the measurements, where the maximum smoothness of the function is given as the boundary condition. The values of the function at the grid points are the result of this analysis.

In Fig. 22 the result for such an analysis is shown for August 12, 2002. The irregularly distributed stations are denoted by black dots, the coloured areas represent the intensity of precipitation.

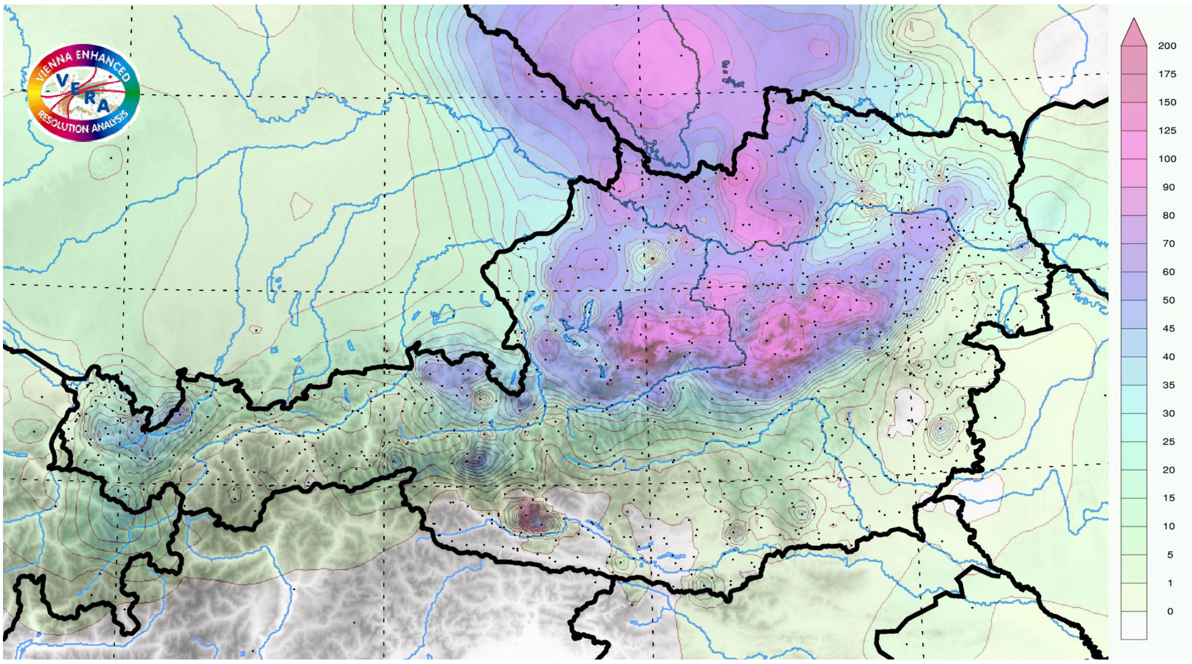


Fig. 22: Precipitation analysis for August 12, 2002 (08 12 2002 06 UTC to 08 13 2002 06 UTC), analysed with VERA, 1. and 2. derivation minimised, grid distance 4 km.

Statistical characteristics of VERA interpolations for the flood situations in 2002 were practically identical to those of interpolations by Kriging, a frequently applied tool using statistical variations, when grid distances were identical. Refinement of the grid from the operational 16 km to 8 km or 4 km did not result in a significant increase in accuracy for the data set available in real time, which has an average distance of 20 km between stations.

To make meaningful analyses in areas with few measurement stations additional information, such as radar or satellites data, model output data, or typical structures of the precipitation distribution (for example the increase of precipitation with elevation) should be taken account of by the procedures. This additional information can be introduced using so-called fingerprints. Fig. 23 shows two examples of such analyses.

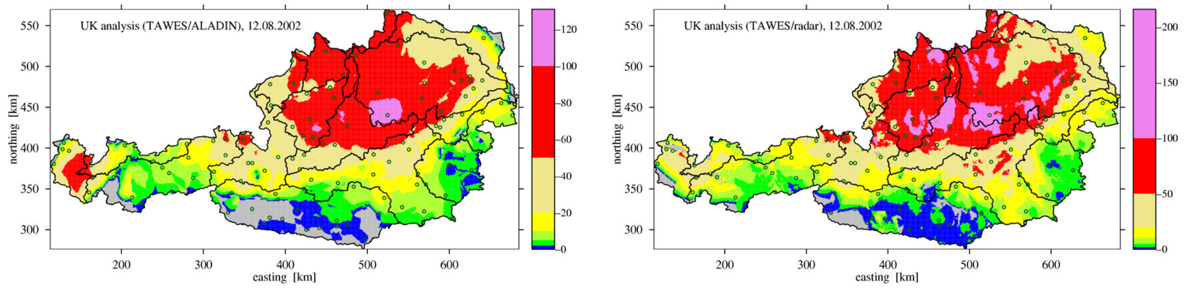


Fig. 23: Analyses based on the operational data set from the TAWES network for the 12th August 2002. On the left: combined with the Aladin model output, on the right combined with calibrated Radar-measurements.

Although the additional information as introduced in VERA definitely influences the resulting precipitation field, no systematic improvement of the analyses was found. More research is needed to exploit the potential of the available information.

As long as the fingerprint technique does not sufficiently improve the results, missing data in regions with dense measurement networks may have a strong influence on the result of the analysis. To quantify this error VERA interpolations were made with sub sets of the available data and the remaining stations were used for a quality check of the analysis. Fig. 24 shows the result for 100 of these analyses.

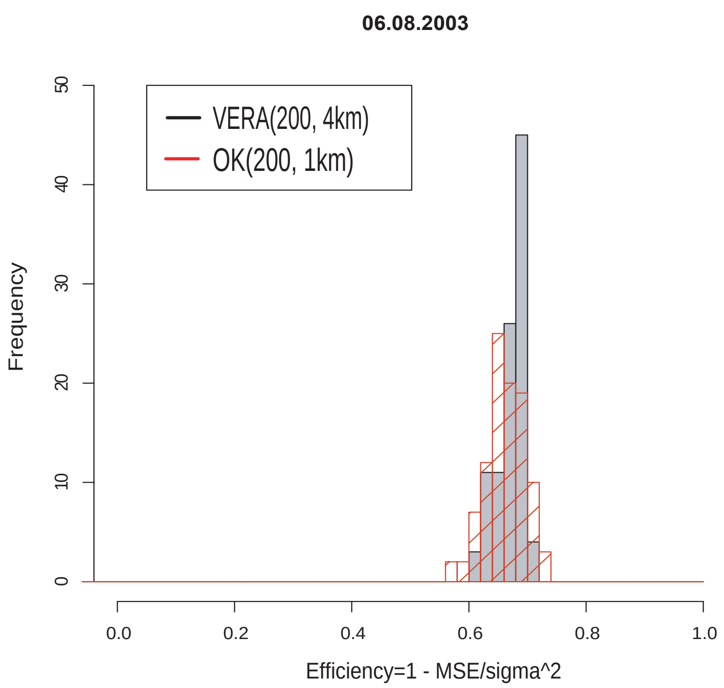


Fig. 24: Efficiency (1 – root mean square error/variance) for 100 analyses with VERA and Kriging, each using 200 measurements sites within Austria

The narrow distribution of the results calculated with VERA indicates that VERA is not strongly affected by unfavourable distributions of measurement sites. For real-time analysis this is very promising, because on a routine basis measurements are few and data from some stations might be missing.

Finally, the quality of the measurements is of importance. Erroneous data can occur and must be detected and eliminated automatically in the operational service. The quality control implemented in VERA tests every value by fitting a surface through the values at the neighbouring stations. If the resulting value at the station being tested corresponds to the measured value, the value is marked as correct, otherwise a corrective term is suggested. The effect of such corrections on the results is shown in Figure 25.

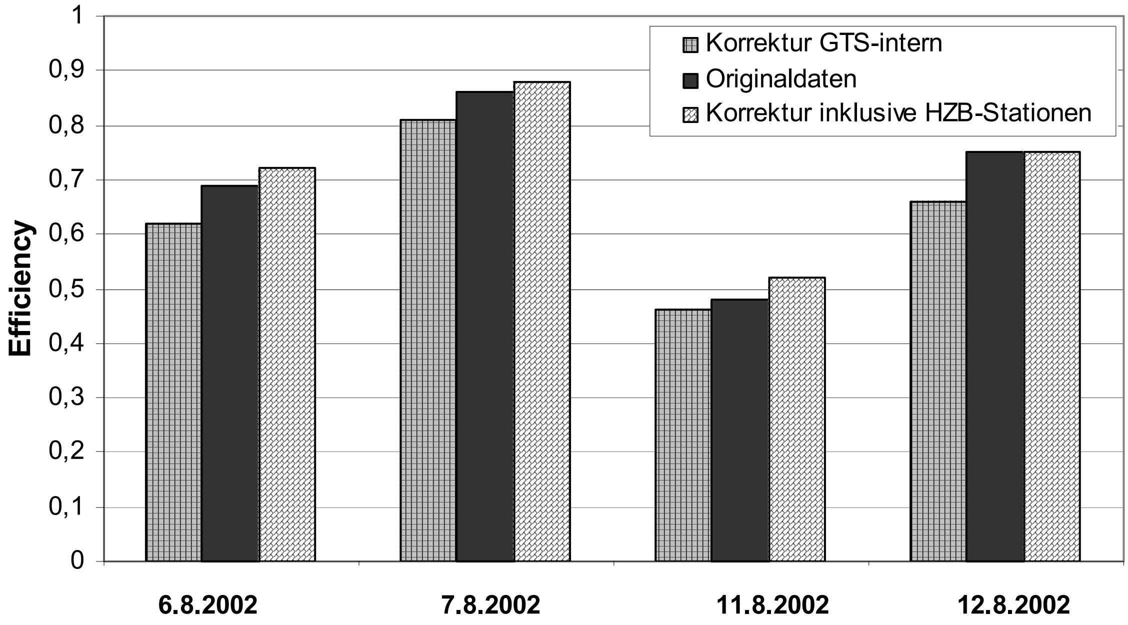


Fig. 25: Analyses calculated with VERA for different quality-checked and non quality-checked data sets for the 4 days investigated

The figure shows that the analyses with quality-checked data is superior only if many stations (Fig. 25: “Correction including HZB-Stations”) are available for the quality check. Using only the operationally available stations (“Korrektur GTS-intern”) leads to a deterioration of performance. Further investigations are clearly needed.

Summing up, the investigations show that VERA is basically suitable for operational high resolution precipitation analyses in real time regarding the available data density and the computational time. The quantification of the error in the analysis has shown that the error varies with the weather situation. Work needs to be invested, e.g. to better exploit available additional information (fingerprint technique) and to improve the quality check.

The areal precipitation calculated by these analyses can be used to verify numerical weather predictions (see StartClim.14) on the one hand, and in real time to feed into hydrological models, which should improve the decision base in case of extreme precipitation events.

5.3 Performance of meteorological forecast models during the August 2002 floods (StartClim.14)

5.3.1 Introduction

The analysis of the quality of the predictions of numerical meteorological forecast models during the August 2002 floods (Haiden, 2003) and for other extreme precipitation events in the recent past can help to understand the reliability of the models on the one hand and the need for improvement on the other. In case of the flood event 2002, the Lokalmodell (LM) of the German Weather Service (DWD) and the global model by the European Center for Medium Range Weather Forecast (ECMWF) are included in the evaluation of weather models run in Austria. The quality of the predictions is reviewed regarding location, time, intensity and total amount of precipitation.

For hydrological purposes the computation of areal precipitation means for defined catchment areas is more useful than the direct model output on single grid points. Since 1999 the Austrain weather service (ZAMG) operationally analyses and predicts areal precipitation amounts for 26 regions in Austria and adjacent areas, using observations from TAWES stations, KLIMA stations and stations from the Central Bureau of Hydrography (HZB) as well as the model output from Aladin-Vienna, which is run at ZAMG (Andrade-Leal et al., 2002; Haiden und Stadlbacher, 2002). The following discussion is based on this material.

The 26 precipitation areas defined by the ZAMG have a number of similarities with the areas defined in StartClim.4 for extreme precipitation events. The regions Wald- und Mühlviertel are considered to be areas of homogeneous precipitation in both cases. The areas of North- and South-“Stau”regions can be grouped in a similar fashion. Differences occur e.g. for the catchment area of the Traun, that is not part of North”Stau”region here, contrary to the results of StartClim.4.

In general, the precipitation event of 6.8. – 8.8.2002 was underestimated by all models, independant of the starting point. Only shortly before the event a precipitation signal showed up in the model Aladin, but significantly weaker than in reality. For the second event, from 11.8. – 13.8.2002, a qualitative indication is to be found in the ECWF model three days in advance, which was confirmed in the Aladin model runs one and two days later.

5.3.2 Dependence on the observational database

ZAMG operates approximately 140 TAWES stations which measure precipitation amounts with a temporal resolution of 10 minutes; on the average, one station represents an area of 600 km². The rain gauges of the Central Bureau of Hydrography (about 1000 in Austria) are more dense, but measure precipitation but once per day.

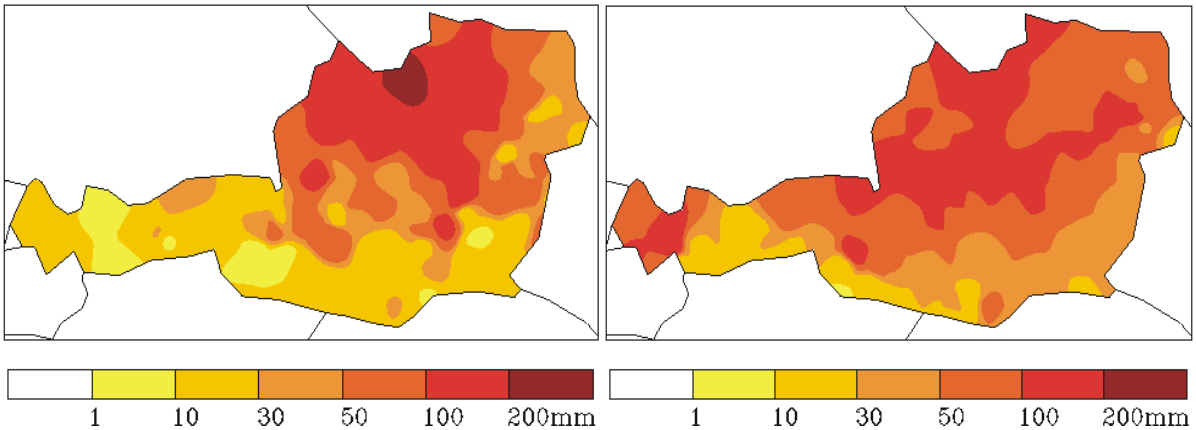


Fig. 26: Precipitation sums interpolated from TAWES data to a 10x10 km Grid. Left: 6.8.2002 12 UTC – 8.8.2002 12 UTC. Right: 11.8.2002 – 13.8.2002.

The first part of the flood event 2002 is characterized by a relatively homogenous distribution of precipitation. Consequently, different analyses and interpolation methods, which are compared in Fig. 27 (6.8 - 8.8.2002), do not vary significantly. The second period from 11th to 13th of August 2002 was more strongly affected by small scale phenomena which lead to significant differences (up to 20%) between the highly resolving HZB measurements compared to TAWES.

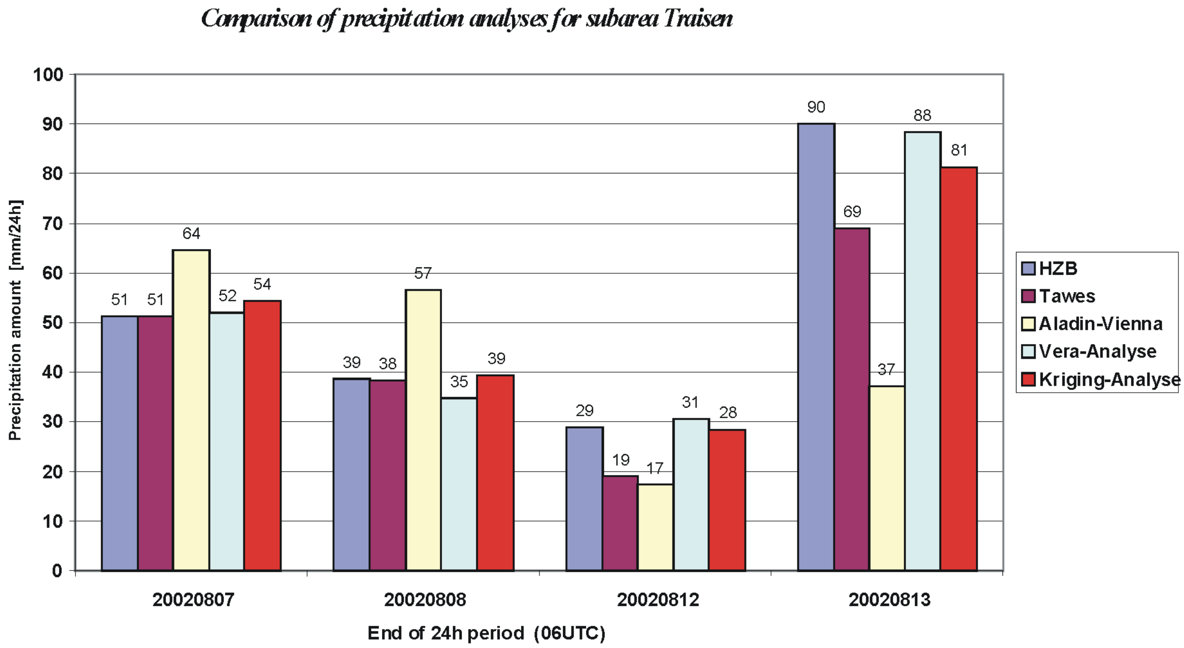


Fig. 27: Comparison of 24-hourly precipitation amounts obtained using different datasets and analysis methods for a sub-area of catchment area 13 (Traisen) for four different days of the August 2002 flood event. The columns denoted 'HZB', 'Vera-Analyse', and 'Kriging-Analyse' are based on HZB data. Precipitation amounts predicted by the Aladin model are also shown ("Aladin-Vienna").

5.3.3 Dependence on catchment size and forecast duration

The smaller the area for which a precipitation forecast is made, the larger the uncertainty. Fig. 28 clearly shows the strength of the spatial compensation effect that makes forecasts for larger catchments more reliable. By reducing the area size from 5000 km² to 2000 km² (within the drainage area Traisen), the mean absolute error of the Aladin precipitation forecast (using hydrological measurements for verification) almost doubles. Reducing the domain further to 100 km² roughly doubles the error again. Although this area dependence has been evaluated for a specific catchment only, the order of magnitude probably applies to other areas as well.

A comparison of observed and modelled time series of precipitation shows phases of overestimations and phases of underestimation of precipitation intensities. For the design of a flood warning system it is important to know whether an increase of the forecast duration (period over which precipitation sum is calculated) reduces the error significantly. For many areas, a reduction of the mean error from 40 – 60% to 20 – 40% is obtained by increasing the duration up to 48 hours (Fig. 29). This is especially obvious for the areas Traisen and Enns, which contain mountainous areas. Another region where orographic blocking effects play an essential role is the region "Salzkammergut". There the model shows good results even for short forecast durations. On the other hand the model output does not significantly improve with increasing duration in this area. The region Mühl-/Waldviertel shows the smallest temporal compensation effect.

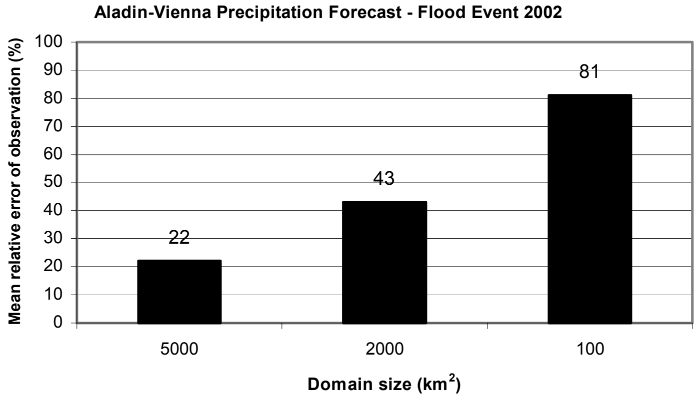


Fig. 28: Relative error of the precipitation forecast (Aladin), averaged over the August 2002 flood event (7.,8.,12.,13.8.2002, 24-h totals) for drainage area Traisen (5000 km²) and two smaller sub-areas (2000 km² and 100 km²). Verified with HZB observations.

The average errors of the 6-hr forecasts during extreme precipitation events in the period 1999 – 2002 are slightly larger than for the August 2002 event for most regions (60-70%). For longer periods (48 hr sums) the error drops to 20-50%, similar to the 2002 case (Fig. 29 and 30).

Observed single-hourly peaks are rarely simulated well by the model. However, the overall timing and temporal evolution of the event corresponds qualitatively well to observations.

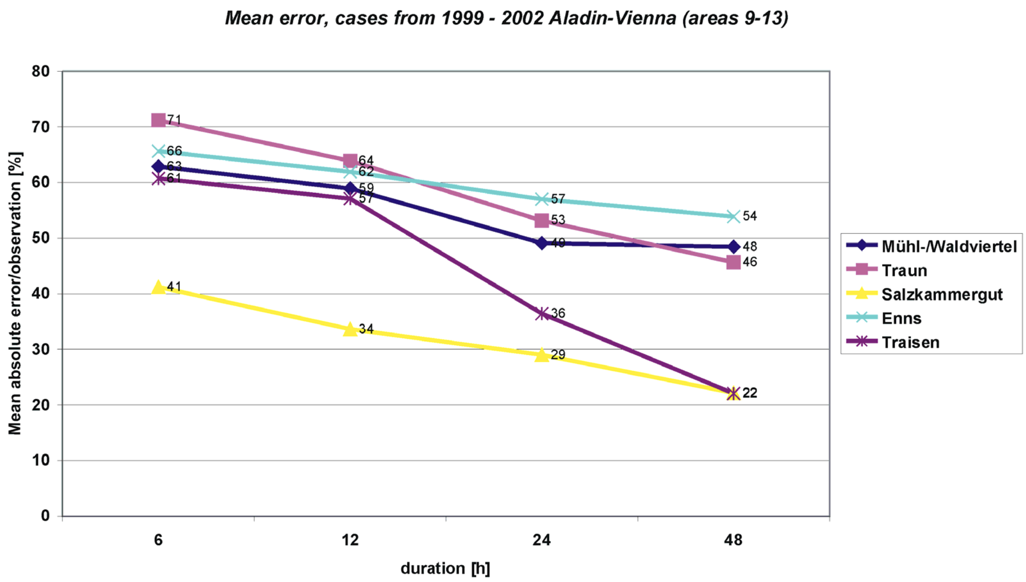


Fig. 29: Mean absolute forecast error in percent of precipitation forecast of Aladin (1999-2002 cases) as a function of forecast duration for 5 areas.

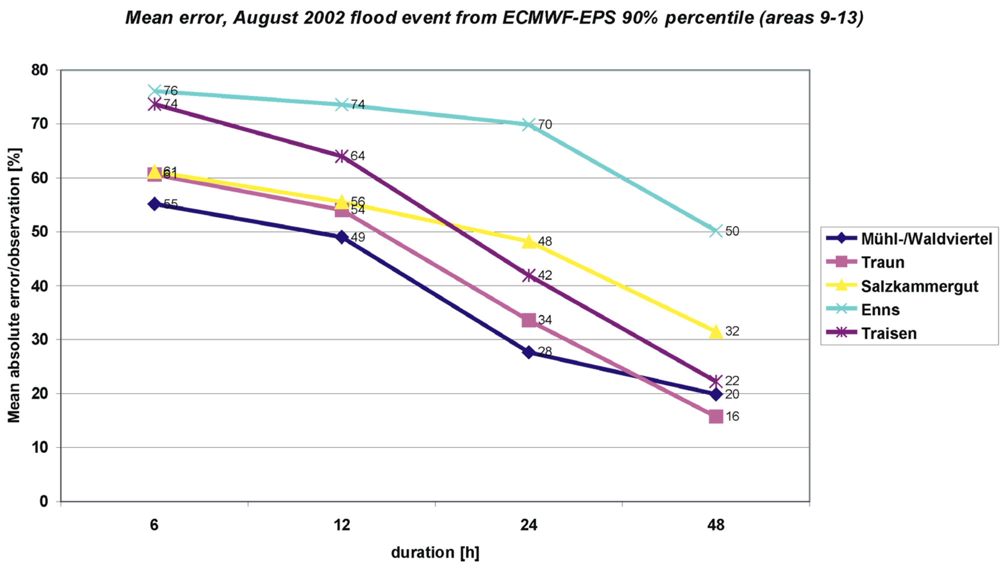


Fig. 30: Mean absolute forecast error in percent of precipitation forecast of ECMWF EPS-90% (August 2002 flooding) as a function of forecast duration for different areas

5.3.4 The benefit of EPS - forecasts

In order to evaluate the uncertainty of numerical models the use of Ensemble Prediction System forecasts has become an important tool. The system consists of 51 different forecasts with each one slightly disturbed in its initial state compared to the reference run. The resulting bundle of forecasts can be used to derive percentiles or probabilities of precipitation exceedance. A verification of EPS forecasts for the flood event 2002 shows that the median (50% - percentile) gives no indication of an extreme event. EPS mean errors do not differ much from the operational run, even higher error values are partly produced (especially if short durations are used). It was found necessary to increase the percentile up to 90% in order to gain a signal for extreme precipitation and reduce the error down to 15 - 30%. The region Enns is an exception, where a significant overestimation of precipitation amount is produced.

In terms of a flood warning system the benefit of the 90% percentile lies in a pre-warning or a "heavy-precipitation-watch' rather than in the warning itself, as it would lead to frequent false alarms if applied uncritically.

5.4 Developing an innovative approach for the analysis of the August 2002 Flood Event in comparison with similar Extreme Events in recent years (StartClim.12)

5.4.1 Introduction

In order to understand extreme precipitation events knowledge of the temporal and spatial components of the weather is needed. Therefore an attempt was made in StartClim.4 to extract information on the location and intensity of extreme precipitation events from large scale meteorological fields and their development. In StartClim.13 this is attempted by analysing the smaller mesoscale. While in the climatological approach of StartClim.4 one of the conditions was that the procedure must be applicable to model runs of global climate models (GCMs), the aim of the present project is to contribute to an improved short term forecast of extreme events.

With the help of VERA (Vienna Enhanced Resolution Analysis, Steinacker et.al., 2000), an analysis tool that was specifically developed for the alpine area a coupling of the temporal and spatial components of the weather can be achieved. This makes it possible to determine small-scale characteristics of the flow and displacement. This kind of investigation was used on some extreme weather events. Using this technique on many different weather situations, key numbers can be found, that help to improve the nowcasting of extreme weather events.

5.4.2 Method

VERA was used to analyse pressure fields of weather situations similar to the one which caused the flood event in 2002. VERA (Steinacker et al. 2000) is akin to a thin-plate-spline but includes a data quality control module and uses additional physical information

By objective methods key numbers (derivatives of higher order) can be derived from the pressure fields, that are suitable to characterize precipitation prone systems. With the help of the second temporal derivative, front passages can be detected, while the second spatial derivative (Laplace operator) is tied to the rotation of geostrophic flow at each grid point, and the temporal derivative of the Laplace operator leads to information about changes of the rotation of the flow.

5.4.3 Results

It is important to choose a suitable grid point distance to calculate the derivatives. If the distance is too large, only systems of the synoptic scale are resolved and the structures on the mesoscale, which are strongly connected to extreme weather events, are ignored. If the distance is too small, small-scale turbulence prevails. This is exemplified in Figure 31.

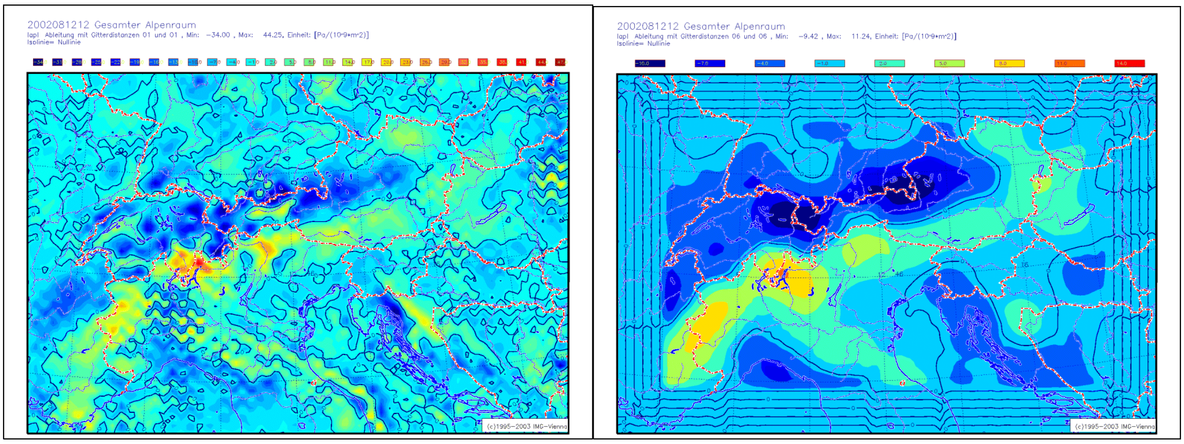


Fig. 31: Laplace, 12.8.2002 12 UTC using a distance of (left) one, (right) six grid point distances

The derivatives on the left side of Fig.31 were calculated for too short distances: the larger structures are only indicated and small scale effects prevail. On the right side larger grid distances are used and the small-scale disturbances can no longer be seen.

Fig.32 shows clearly the difference between fast and slow displacement of systems. The first system, which crossed Austria on the 11.1.1999 between 9 UTC and 24 UTC, produced the first series of peaks (between 12 o´clock and midnight). The displacement from West to East (from Munich via Kremsmünster to Eisenstadt) can be identified by their consequitive occurrence along the time axis. The second system crossed Austria on the 13.1.1999 and was much faster - the peaks occur at nearly the same time at all stations.

The first results in regard to the significance of pressure derivatives are very promising. Investigations of different weather situations with different derivatives would be necessary to obtain more detailed and differentiated statements about different weather systems. It can be assumed, that the key figures will vary for different weather systems. The more dimensional vector of those key numbers could be used to estimate the expected intensity and characteristic of weather phenomena of interest. Thus better analyses and an improvement of short-term predictions can be expected. A combination of derivatives of different meteorological parameters, e.g. wind and temperature, could describe additional features of extreme weather systems.

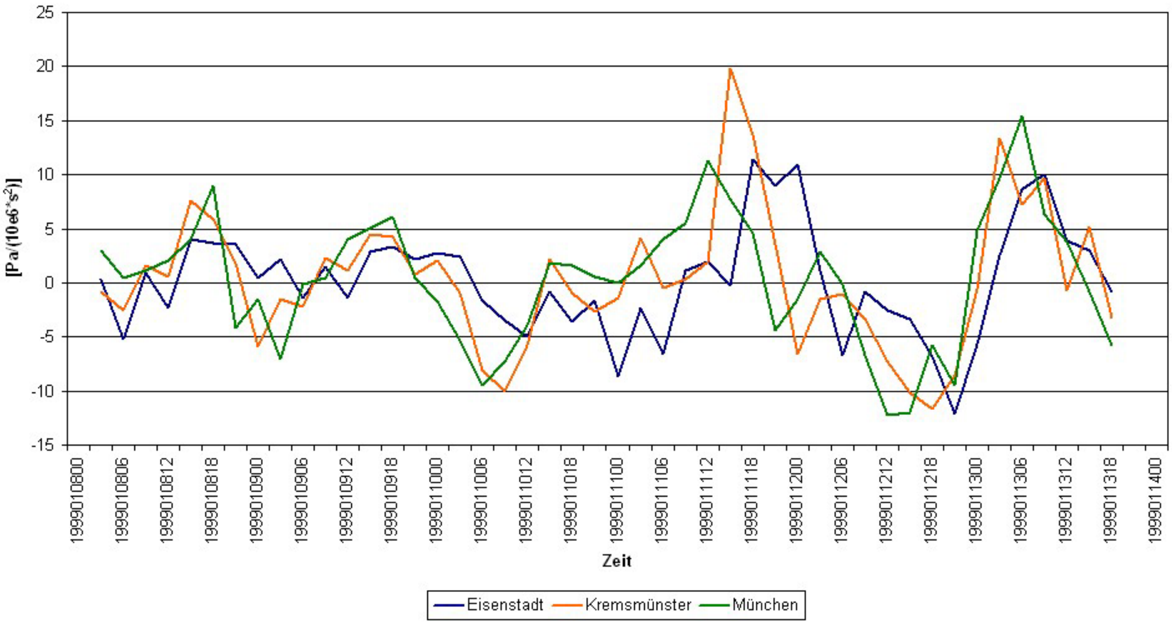


Fig. 32: Time series of second time derivative during a precipitation event in January 1999

An investigation of the correlation of predicted precipitation and the key numbers of the derivatives of the weather systems, could lead to an improvement of the precipitation predicted by the models.

A treatment of time series, for example in connection with the FWF-Project VERAClim, which calculates three-hourly pressure fields of a climatological period, would allow the development of an objective, small-scale weather classification. This could help to analyse the climate and its change during the last years by calculating trends of the derivatives. Frequency and development of extreme weather events could be studied.

5.5 Summer 2002 Floods in Austria: damage account data pool (StartClim.9)

5.5.1 Introduction

The Platform „Hochwasser" (Flood) of the Centre for Natural Hazards and Risk Management (ZENAR) of the BOKU - University of Natural Resources and Applied Life Sciences was founded shortly after the flood event 2002 with the aim to help with the collection of data and eventually to understand causes and effects of the event from a scientific point of view. Many individuals and institutions contributed to the documentation that was published as a result of this effort (Habersack & Moser, 2003). The data gathered formed the primary basis for the work done in framework of StartClim.

The collected data on damages, especially the notifications of losses submitted to the state governments, were checked for plausibility, completeness and internal consistency and supplemented with information from municipalities, public and commercial institutions and from additional investigations. As far as possible, the data were unified regarding categorisation, format, etc., also taking account of the needs of the economic models as applied in StartClim.10, and organised in a database.

In order to avoid many of the problems that occurred due to the fact that several districts and states were affected and collected data independently using different systems, an interactive system for damage notifications was developed.

By feeding the information into a geographic information system (GIS) visualisation of space related data and interactive queries along selected search criteria at different levels of aggregation are possible. The geoinformation system (database and GIS) is a valuable tool for problem oriented analysis and representation of the collected information.

5.5.2 Data base Flood 2002: Preliminary Damage

The immediate losses of private values have been registered to a high percentage. But damages in the categories late consequences and consequential losses, costs for relocation, losses due to business interruptions, etc. are not yet available in any detail. The costs reported here are therefore only a preliminary assessment based on incomplete statements of losses. The following discussion is based on these (incomplete data), unless otherwise specified.

More than half of the damages registered so far occurred in Lower Austria. Upper Austria and Salzburg are next in damages. Styria was not much affected by the floods in August 2002 and in the Tyrol the data collection is not yet completed.

The figures in Table 5 shown the damages refunded by the states, as known at present. Caution must be used when interpreting these figures: they certainly do not reflect the complete costs of damages due to the floods in August 2002. The gaps in the determination of damages are still large: Damages handled by insurances are not included. At present there is e.g. an ongoing discussion about relocating people and buildings that were affected out of the areas with high risk of floods. These costs cannot be estimated yet. In many cases the registration of damages is not yet completed.

On the base of estimates of the Austrian Institute of Economic Research (WIFO) for the Office of the Federal Chancellor and additional estimates by the Federal Ministry of Agriculture, Forestry, Environment and Water Management and others, the most important, not yet well documented damages will amount to an additional 900 million €. These estimates still do not include costs of relocations, effects on tourism, indirect economic losses and other factors that will only evolve with time.

Tab. 5: Table of damage costs (incomplete). More complete figures are expected to evolve from the project Floodrisk in 2004 (last update August 2003).

Overview of available financial damage data, floods August 2002
for most affected states in Austria (in €)
Data base August 2003

		NÖ		OÖ		SBG		STMK		T	
		Damage in €	%-part	Damage in €	%-part	Damage in €	%-part	Damage in €	%-part	Damage in €	%-part
Private	Sum					8,580,000	13.4%				
	Investments					10,035,600	15.7%				
	Sum	394,064,681	60.66%	110,838,223	23.90%	18,615,600	29.14%	3,444,142	13.30%		
Companies	Buildings					4,209,000	6.59%				
	Investments					6,313,500	9.88%				
	Storage					3,507,500	5.49%				
	Production losses										
	Sum	137,365,436	21.15%	230,261,744	49.64%	14,030,000	21.97%			2,318,263	19.46%
Agriculture and Forestry	Buildings										
	Investments										
	Production losses										
	Sum	28,938,297	4.45%	36,059,843	7.77%	12,227,000	19.14%	3,356,612	12.96%		
Public	Buildings	46,500,000	7.16%	37,895,298	8.17%	895,074	1.40%	3,500,000	13.52%		
	Investments										
	Infrastructure	42,500,000	6.54%	48,784,702	10.52%	18,104,926	28.35%	15,594,455	60.22%		
	Sum	89,000,000	13.70%	86,680,000	18.69%	19,000,000	29.75%	19,094,455	73.74%	3,749,153	31.48%
no category	Others	240,268	0.04%							5,843,584	49.06%
Sum States / %-part		**649,608,682**	**53.5%**	**463,839,810**	**38.2%**	**63,872,600**	**5.3%**	**25,895,210**	**2.1%**	**11,911,000**	**1.0%**
Preliminary states sum		**€ 1,215,127,302**									
Consequential costs, economic value losses, dumping costs, restoration costs (estimation, Stalzer/2003)		**ca. € 900.000.000**									
Costs for leaving inundation areas, consequences for Tourism, economical disadvantages...		**at the moment no data available**									

After the editorial deadline new figures were made available as of November 14th 2003 (Table 6). According to the Ministry for Internal Affairs the costs covered by insurance add up to about 400 Million €. The newest reports from the affected States raise the costs by 250 Million €. Repair costs for infrastructure at the federal level (flood protections, traffic systems: rivers, railways and roads) are numbered at almost 130 Million € (Sources: Ministry of Internal Affairs, Governments of Lower Austria, Upper Austria, Salzburg, Styria and the Tyrol, BMFLUW, 2003).

Tab. 6: Revision of Table 5 to include the newest data on damages, as made available after the editorial dead line; valid as of November 14th 2003. (Sources see above).

Overview of available damage costs, floods August 2002
for the most affected States in Austria (in €)
Data base November 2003
(Source: Mannsberger/BMLFUW)

		NÖ		OÖ		SBG		STMK		T	
		Damage in €	%-part	Damage in €	%-part	Damage in €	%-part	Damage in €	%-part	Damage in €	%-part
Private	Sum					8,580,000	7.8%				
	Investments					10,035,600	9.2%				
	Sum			178,000,000	26.10%	18,615,600	16.99%	3,224,677	12.45%	4,060,080	42.02%
Companies	Buildings					4,209,000	3.84%				
	Investments					6,313,500	5.76%				
	Storage					3,507,500	3.20%				
	Production losses					11,000,000	10.04%				
	Sum			280,000,000	41.06%	25,030,000	22.84%			1,200,000	12.42%
Agriculture and Forestry	Buildings									1,724,300	17.84%
	Investments										
	Production losses					2,000,000				907,000	9.39%
	Sum	593,800,000	86.01%	50,000,000	7.33%	14,227,000	12.98%	3,356,612	12.96%	2,631,300	27.23%
Public	Buildings					895,074	0.82%	3,500,000	13.52%		
	Investments										
	Infrastructure					50,800,000	46.36%	15,594,455	60.22%	1,772,000	18.34%
	Sum States	42,311,281	6.13%								
	Sum villages	54,311,000	7.87%								
	Sum	96,622,281	13.99%	174,000,000	25.51%	51,695,074	47.18%	19,094,455	73.74%	1,772,000	18.34%
no category	Others										
	Sum States / %-par	**690,422,281**	**45.5%**	**682,000,000**	**44.9%**	**109,567,674**	**7.2%**	**25,895,210**	**1.7%**	**9,663,380**	**0.6%**
	Preliminary states sum	**€ 1,517,548,545**									
Consequential costs, economic value losses, dumping costs, restoration costs (estimations Stalzer 2003)		ca. € 900.000.000									
Federal infra structure		ca. € 130.000.000									
Costs covered by insurance (Min. of Internal Affairs)		ca. € 400.000.000									
Relocation costs, effects on tourism, buisness interuptions, etc.		Currently no data available									

5.5.3 Collecting, reporting and analysing future datasets

Experience gained from collecting and analysing data from the flood in August 2002 in conjunction with the suggestions for disaggregation of data by the WIFO (startClim.10) was used to build up a new data model for a future assessment system. Standardized categories are needed for

- types of damage
- classification in categories
- larger scale spatial reference
- local spacial reference

in order to facilitate comparability, aggregation and local geographical attribution.

An easy-to-use data base driven, platform independent web application will support data input. Based on the experience gained, the new application contains various rules to avoid redundant and erroneous data input. An important feature is the restriction to registered users. Documenting and analyzing data in a geographical information system (GIS) is only useful if the data are spatially referenced. This is realized by relating to administrative units (e.g. communities, municipalities) and localizing the site of damage through postal addresses.

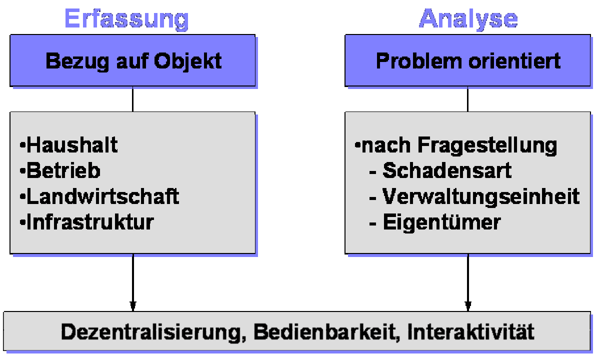


Fig. 33: Method of collection and analysis of data

If the system (data base and GIS) for the documentation of the notification of losses after flood events (e.g. through the WEB) were generally applied henceforth all data required by the different stakeholders, applicants, municipalities, state and federal administrations, auxiliary organisations and other NGOs etc. would be included in one data base and readily available. Rapid accessibility and unified documentation across district and state borders would be guaranteed and at the same time, a sound base for scientific analyses would be laid.

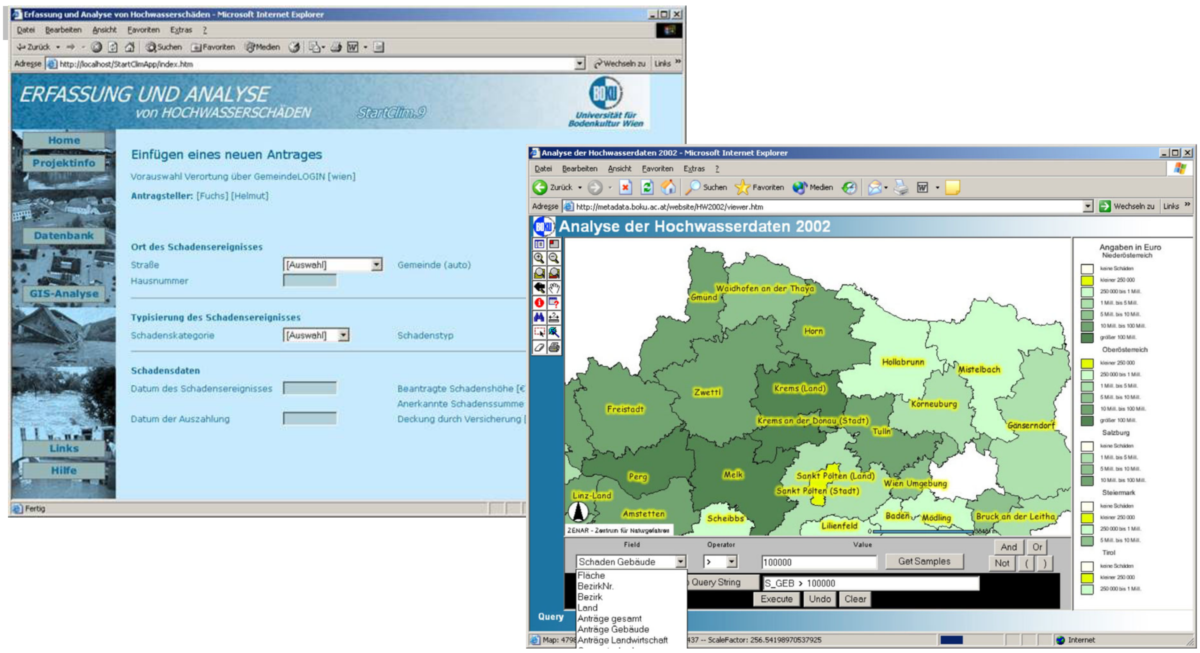


Fig. 34: Data base and GIS application

5.6 Economic aspects of the 2002-Floodings: Data analysis, asset accounts and macroeconomic effects (StartClim.10)

Over the past decades, economists have begun to take a greater interest in natural disasters, due to their growing frequency or at least the growing economic damage generated by such events. A comprehensive evaluation, extending beyond conventional national accounting, of their economic consequences, including their impact on welfare, nevertheless is a relatively new research question.

In extending conventional macroeconomic approaches beyond their traditional limits it appears to be of key importance to obtain a proper account of the damage caused by natural disasters. The gross domestic product (GDP) includes such factors only to the extent that replacement investments are made, which in calculating the GDP, however, are considered to contribute positively to economic growth. GDP records only the flows of goods and services of an economy, but fails to consider stocks of produced and natural capital. As a result, neither the damage actually caused nor the welfare effects resulting from such damage are registered correctly. Thus, with the assumption that the demand of private households is concentrated not so much on goods but rather on consumer services (e.g. housing of a given quality) which are "produced" by the use of capital stocks and goods, the welfare level is (indirectly) determined by the stocks. Consequently, when it comes to evaluating the effects of extreme weather events, it is the interdependencies between stocks and flows which are relevant.

In its Module 1, StartClim.10 considers concepts for the development of a micro-/macroeconomic model framework that would integrate such aspects. Within the scope of this project, it was found impossible to implement such a framework in the existing WIFO model (MULTIMAC IV). The macroeconomic effects of the flood of 2002 were therefore quantified in Module 2 of StartClim10 using a conventional macroeconomic system.

The flood that occurred in the summer of 2002 produced considerable damage, in the form of loss of property and loss of production in both the private and public sectors. An economic analysis was performed to break down loss categories by the type of damage and affected groups (private households, business, public sector, agriculture). To this end it is necessary to gather a comprehensive and consistent database. In view of the fact that each individual Austrian State (Bundesland) used its own method to assess the damage, it is difficult to aggregate the data in order to arrive *ex post* at a total comprising all losses in Austria, as the sums available are incomplete and are, to a certain extent, based on estimates.

The findings of StartClim.9, which aimed at the development of a database of losses caused by the flood, serve as an input for a model-based evaluation of economic effects. Table 7 provides the requisite breakdown of losses and the information available from the database. Property losses (especially buildings) are included with a relatively high degree of completeness, whereas no data are available on production losses at the business level. Gaps are also substantial with regard to government subsidies to business.

Tab. 7: Database for model simulation (requested and available data)

	Households	Business	Agriculture	Public authorities
Buildings	x ✓	x ✓	x	x ✓
Durable consumer goods	x ✓		x	x
Investment goods		x ✓		
Storage		x ✓		
Loss of production		x	x ✓	
Infrastructure				x ✓
Subsidies	x ✓	x	x ✓	

The data collected by StartClim9 from the five States most affected by the flood add up to a subtotal of € 1.2 billion. A breakdown of subtotals by categories is given in Table 8. Here, the highest sum by far is the property loss suffered by households. Of the States affected by the flood, Lower Austria reports the highest subtotal (almost 54 percent), followed by Upper Austria (some 38 percent), Salzburg (5.3 percent), Styria (2.1 percent) and, lastly, Tyrol (0.8 percent).

The available data were incorporated in the WIFO model along the sectoral lines of private consumption, manufacturing as well as farming and forestry. The model simulation is based on the assumption that the capital stock lost was replaced in the same year (i.e. 2002). Private households financed the requisite investments from their current disposable income, whereas business financed theirs from the cash flow, and the funds for compensating flood victims and replacing lost infrastructure were taken from the public budget, thus depleting funds for other expenditures.

Tab. 8: Reported flood damage in Mio. € (incomplete figures) Source: StartClim.9

	Million €	Percentage shares
Households		
Buildings	243	
Investment goods	284	
Total	527	43.4
Business		
Buildings	115	
Investment goods	173	
Storage	96	
Total	384	31.6
Agriculture, total	80	6.6
Public authorities		
Buildings	88	
Infrastructure	129	
Total	218	17.9
Other, total	6	0.5
Recorded sum of losses	1,215	100.0

The replacement investment to restore lost capital stock triggers a positive macroeconomic demand, an effect equal to a transitory shock. On the other hand, such replacement investment reduces the disposable income of households, curtails company cash flows and cuts into other public consumption. In the model dynamics, this acts as a negative macroeconomic impulse.

For the overall economic effects see Table 9. In the first year, the GDP effect is positive, albeit quite negligible in its dimension. For the subsequent years, the GDP effect is negative, yet its impact is similarly negligible. Compared to the baseline, overall consumption is slightly reduced, due to the cut in disposable income. Spending on furniture consequent to flood damage is markedly above the baseline for all years. In order to finance such investments, consumption had to be curtailed in the other categories. The positive impulse of the first year was found to be ebbing in the subsequent years. No effect was found on exports, whereas imports grew moderately in the first year of simulation, due to the greater investment demand.

Tab. 9: Macroeconomic findings on the impact of the floods in 2002

	2002	2003	2004	2005
	Difference to baseline in %			
Private consumption	-0.11	-0.08	-0.07	-0.05
Gross asset investments	0.96	0.04	-0.07	-0.09
Exports	0.00	0.00	0.00	0.00
Final demand	0.09	-0.03	-0.04	-0.04
Imports	0.17	-0.01	-0.03	-0.02
GNP, real	0.06	-0.03	-0.04	-0.04

5.7 Material Flow orientated Analysis: Changes in the social metabolism due to the 2002 floods in Austria. Case study of an affected community (StartClim.7)

For a village of the Lower Austrian Kamp Valley (Zöbing) disturbances of the material throughput due to the floods of 2002 were investigated in an exemplary manner. Material damage as well as additional material inputs are assessed and the societal reaction to the disaster analyzed. The main questions asked were

a) whether the disturbance caused a long-term increase or decrease of the levels of resource consumption; and

b) whether the disaster presented an opportunity of structural renewal that has a beneficial effect on the societal consumption of materials and energy.

Answering these questions is intended to help to understand the effects of such extreme events on societal resource use and its concurrent environmental effects. In addition, the effects of the damage on the economy and the social life of the community are analyzed.

The case study stands for numerous other communities who suffered under similar conditions in August 2002. Finally, the study also may be seen as a contribution to the methodology of damage assessment in that it shows possibilities of including Material and Energy Flow Analysis (MEFA) into an integrated damage assessment of such disastrous events. Biophysical damage assessment differs from monetary accounts in that it is not subject to unstable values and economic insecurities.

The damage assessment clearly shows the enormous material and energetic burden due to the floods and the relevant societal activities. The biophysical account lists all materials disposed and those additionally consumed during relief and reconstruction activities.

Resource consumption rose by 60% compared to a reference community due the event (Fig. 35). Advance production-related material burdens and transport loads are pressurizing factors that could not be accounted for in this local-level study. Energy use is particularly relevant for the societal contribution to global climate change. Due to the floods, the community experienced an 11% increase in energy throughput (Fig. 36). The energy consumed (fossil and biotic energy carriers, electricity) has an immediate effect on additionally emitted CO_2 amounts.

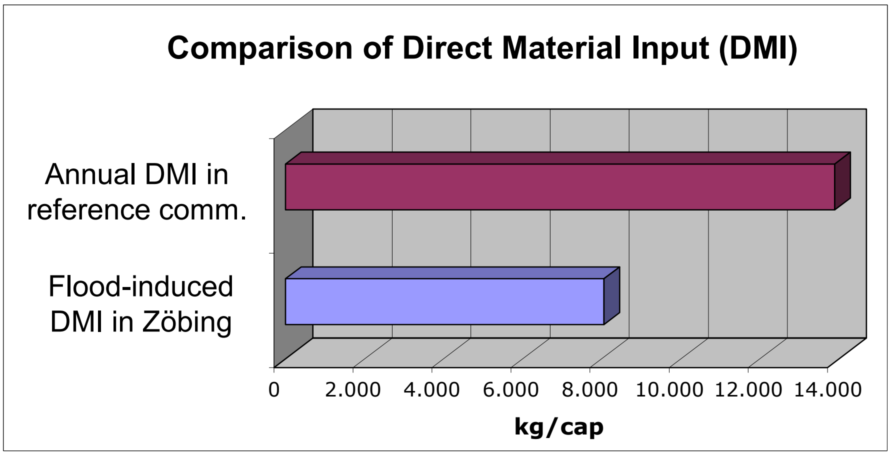


Fig. 35: Consumption of resources due to the floods 2002 as compared to average annual values. aufgrund des Hochwassers 2002 im Vergleich zum durchschnittlichen jährlichen Ressourcenaufkommen (Source: Investigations in Zöbing Juli 2003; Haas 2003)

The potentials for future energy saving due to restructuring in the wake of reconstruction were not exploited (Fig. 36). The victims of the disaster and the public bodies missed the opportunity for implementing ecologically friendly resource use. Material and energy flows due to the floods must be seen as a mere addition to yearly consumption levels.

The application of MEFA in this applied field is a first attempt to use it as an instrument for damage assessment. In contrast to the usual usage as an economic balancing scheme, the current study shows how a »natural« disaster potentially raises the level of resource consumption and thereby the pressure exerted by society on nature. Instead of using the disaster as an opportunity for restructuring, the aim in the community has been to return to the original conditions as quickly as possible.

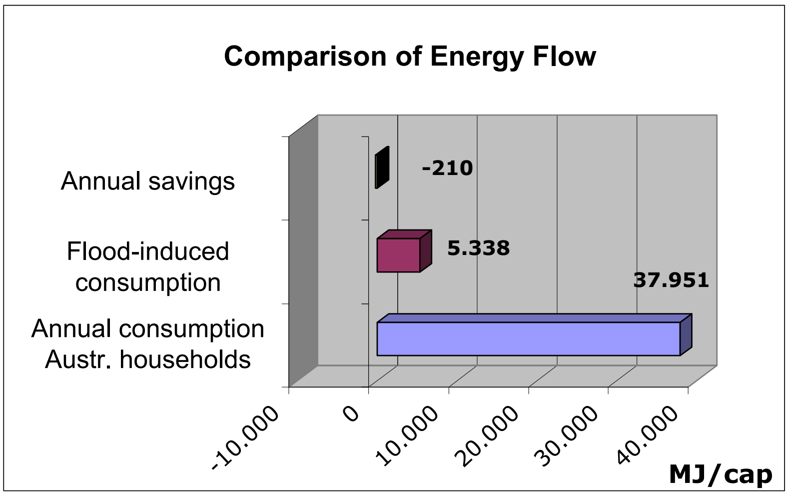


Fig. 36: Longterm savings in energy consumption (primarily due to improved isolation in some households) as compared to flood-induced energy consumption for repairs and reconstructions and the average energy consumption of Austrian households in 2001 Household consumption was selected for comparison as this is the dominating factor in Zöbing; the flood-induced increase in energy consumption in Zöbing is also dominated (75 %) by households. (Source: Statistics Austria – Energy balance: Zöbing Juli 2003)

There is a low awareness among the victims about the effects of economic activities on global ecological cycles. Also, although many acknowledge the possibility of a recurrent event only very few engage in precautionary measures. One clear reaction to the floods has been that many households have switched from an oil-based to a LPG-based heating system. Some households have selected flood-resistant furniture and floorings in the course of reconstruction.

Apparently more information and more incentives would be necessary to make better use of the opportunities inherent in such catastrophes.

5.8 Summary of progress

- Precipitation analyses to determine the rainfall per unit area using the VERA analysis method, which is specially tailored to the alpine region, have principally proved their operational applicability. This enables a better assessment of ongoing events in the case of specific crises.
- The VERA analysis method, developed in Vienna, also contains good promise to detect important features of extreme weather systems in the alpine region and therefore to improve both diagnoses and short-term predictions.
- For the first time, a complete, Austria-wide representation of the damage caused by an extreme flood event has been compiled based on a uniform scheme.
- Data on the 2002 flood event are available in sufficient scope and quality to provide a solid basis for the various scientific analyses.
- A prototype of a Web-GIS application was developed in order to collect and visualize future flood damage. If this gains general acceptance in practice, it would greatly improve the processing of damage reports, the allocation of relief funds, and both accelerate and improve the statistical and administrative data processing procedure.
- Concepts to develop a micro-/macro-economic model framework that would incorporate the interdependencies of stocks and flows were discussed.
- As determined by conventional macro-economic systematics, the effect of the flood on the gross national product (GNP) had a positive sign in the first year, although the magnitude is rather insignificant. In subsequent years, the GNP bears a negative sign. Overall, however, the effect on the GNP is negligible.
- For the first time, material and energy flow analyses were applied outside their traditional framework as auditing tools and were used to calculate additional resource flows.
- Proof was provided that the “social reaction” of a town to a “natural” catastrophe considerably increases the level of resource utilization and thus increases pressure on the environment.
- The investigated case study revealed that, rather than using the opportunities afforded by the restructuring measures after the catastrophe, the population merely attempted to restire the original condition.

5.9 Research needs

- Improve the accuracy of precipitation analyses, for example through the appropriate incorporation of additional information (e.g. radar or satellite data).
- Improve the VERA analysis methods for synoptic systems and apply it to a wide range of weather situations.
- Study the correlation between the predicted precipitation and the scales derived from the specific weather systems in order to better predict precipitation amounts.

- Develop an objective, small-scale classification of weather situations to assess climate and climate change over the past years, including extreme weather situations.
- Continue research devoted to the joint collection, analysis and documentation of the relevant processes and damages.
- Further develop the Web-GIS application into a practical instrument that could be used nationwide to formulate damage reports after natural catastrophes.
- Implement the conceptual frameworks that would incorporate the interdependencies of stocks and flows in the current WIFO model (MULTIMAC IV).
- Expand the current national economic damage balance to include material and energetic dimensions. Such an approach would provoke discussion on the ecological impacts of social actions (for example related to CO_2 reduction goals) in the event of future flood catastrophes.

5.10 Projects at the interface between science and education (StartClim.11)

StartClim explicitly looked for involvement at the interface between science and education. The experience shows, that schools (or individual teachers) look favourably on cooperations with researchers and interest in applied climate change research is high. However, when performing such projects, it is important to calculate sufficient time for preparation on both sides and to take into account the annual school cycle. Teachers loose sight of their classes during summer holidays. In view of tight school budgets, it is helpful if school expenses can be covered by the project.

One group of students used questionnaires to interview about 100 relatives and acquaintances on memories of past extreme weather events. Task groups compared the collected data with data from weather stations and hail damage claims. Various aspects were discussed:

- Are the events related from memory plausible in the light of scientific records?
- Are there differences between individual perception and the exceedance of certain thresholds at weather stations?
- What is the difference between the two data collection methods?
- How does information contained in the two data sets differ?
- Do more recent events override the memory of events in the past?

The process familiarized the students with data collecting and quality control methods and at the same time confronted them with the issue of climate, climate change and extreme weather events. The data gathered by the students were integrated into the data base MEDEA, making them available to the climate change research community.

Another group of students from higher grades developed their own questionnaires on the consequences of the 2002 floods. questionnaire in small groups after they have listened to an introduction talk on climate change and the impacts of floods on society's metabolism. One class decided to perform an opinion poll on the questions by asking affected and not affected people, people from private households and from farms. A second class focused on areas of concern they are interested in and developed questions for expert interviews. Among the questions chosen were:

- What is the quality of flood forecast?
- How much oil was released uncontrolled in the district of Krems? Are there consequences for the drinking water?
- What were the causes of the floods? Do hydropower plants influence floods?
- Does an extreme event change the way of thinking? Will people move away from hazard zones?

- Has the flood altered the community, has it changed communications patterns between the people?
- How were donations distributed? Was this efficient and just?
- Has the flood changed the purchasing patterns? What are the impacts on real estate prices?

Cooperation between scientists and schools raises the awareness of a large group of people of different ages (Students, teachers, parents, etc.) for extreme events and climate change issues. It also provides valuable information on public perception of extreme weather events and on the questions that citizens are interested in when confronted with them. This could be helpful for policy decisions, crisis management or insurance policies. Last but not least it adds value to scientifically gathered data because it broadens their scope by incorporating the aggregate perspective of the affected population.

6 Long term Climate Research Program

A long term research programme on climate change is proposed, that takes account of national needs and research developments and that is embedded in the pertinent international research landscape. The links to other climate related Austrian research activities and the differences are explained. Although the research problems are application oriented, their solution will also require basic research. The main questions to be addressed

- How will climate develop on the regional level and which will und its impact on natural systems be?
- Which risks and opportunities for economy and society can be expected through climate change and climate change policies?
- Can understanding of alpine climates, their changes and impacts gained in Austria be of help in Africa, South America and Asia

are broken down into a number of research activities that provide the necessary information on climate change in the strict sense of the word, or analyse sensitivity, adaptation potential, vulnerability or mitigation potential of individual economic sectors. Possible Austrian contributions to the understanding or solution of climate related problems in the third world are addressed in an illustrative manner.

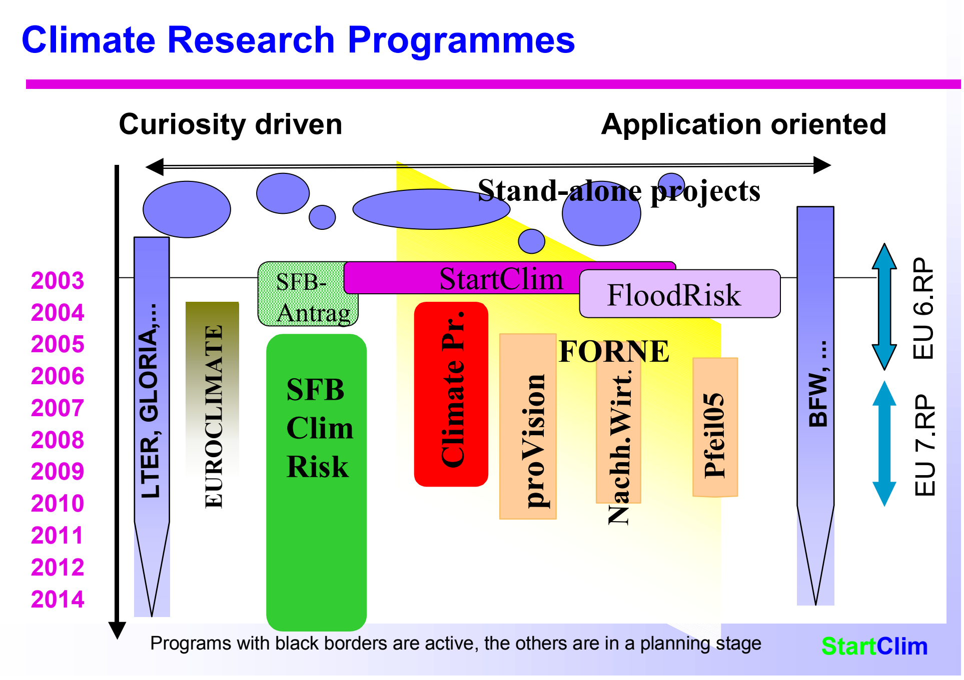


Fig. 37: Active and planned climate relevant research programmes in which the proposed Climate Program (red) is embedded.

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Figures and Tables

Figures

Tables