StartClim2004

Analyses of Heat and Drought and their Impacts in Austria

Final Report

lebensministerium.at

bm:bwk

Die Österreichische Hagelversicherung

OESTERREICHISCHE NATIONALBANK

Verbund Austrian Hydro Power

BUNDESMINISTERIUM für WIRTSCHAFT und ARBEIT

umweltbundesamt

February 2005

StartClim2004

Heat and drought and their impacts in Austria

Final Report

Project Leader

Institute of Meteorology,
Department of Water-Atmesphere-Environment
BOKU - University of Natural Resources and Applied Life Sciences, Vienna
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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
Verbund AHP

Administrative Coordination
Federal Environment Agency

Vienna, February 2005

StartClim2004
„ Heat and drought and their impacts in Austria “

continues

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

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Vienna, February 2005

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Abstract

In 2002, Austrian climatologists founded the research platform 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] commissioned the Start Project Climate Protection: „StartClim – First Analyses of Extreme Weather Events and their Impact in Austria" (StartClim2003). 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.

StartClim continued in 2004 by sponsoring research on "heat and drought" and is now set up as a program initiating research in climate change topics not yet established in Austria. StartClim research projects are intended to subsequently be carried farther in the framework of normal research funding or as studies commissioned by interested stakeholders.

In 2004 the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, the Austrian Federal Ministry for Education, Science and Culture and the Austrian Hail Insurance supported StartClim with additional funds. The "Österreichische Nationalbank" finances one StartClim project on insurance options through its normal research funding channel. The Verbund AHP joined as new partner, financing a project on the consequences of heat and draught on the availability of water. The last two projects will not be finished before fall 2005.

The focus of StartClim2004 is „Heat and Drought". This was chosen to enable a first analysis of the extremely hot year 2003. Five projects on this topic were funded:

StartClim2004.A comprehended the add-on of a humidity parameter to the dataset compiled in frame of StartClim 2003 on the one hand and the analysis of hot and dry periods in Austria on the other.

Since the middle of the last century the number of hot days has increased significantly. The largest increase (about 25 days) occurred in regions of lower elevation, but an increase of 1 to 2 days can still be observed at elevations of about 700m above sea level. In detail, the analysis of the frequencies of hot and dry periods in Austria for selected stations of the (quality checked) StartClim dataset showed very differentiated results: Local environmental effects can partly compensate the effect of elevation.

The variability of the number of dry periods is dependant on the location, on the duration of the period and on the season. Only the autumn season can be seen as consistent for the whole country concerning the decreases in the frequency of occurrence of dry periods lasting 10 to 30 days. The well known "Altweibersommer" no longer occurs with the same reliability as in former times.

Adding vapour pressure data to the StartClim dataset could be of great value for future analyses, because these data enable analyses of e.g. evaporation and comfort. Daily means of 71 StartClim stations were quality checked and are available now. The rich treasure of

[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
- Österreichische Nationalbank
- Austrian Hail Insurance
- Federal Environment Agency

meteorological data in Austria is not utilized yet and should be processed further to be available for research.

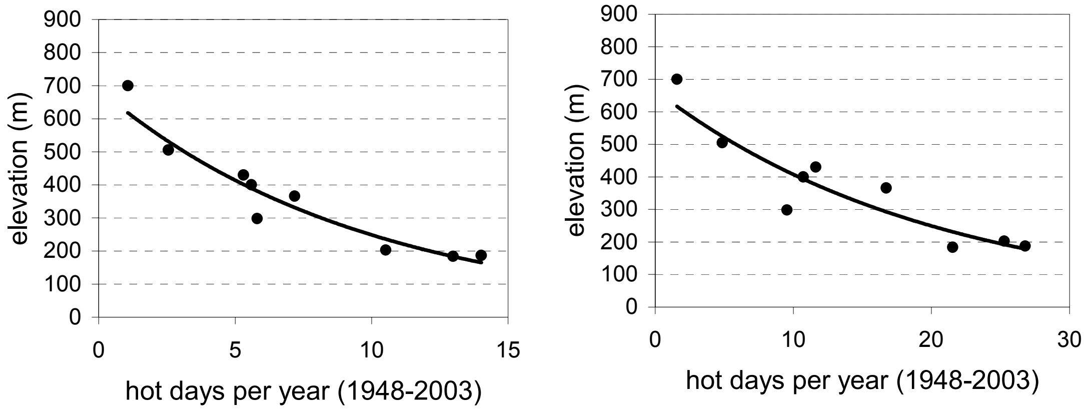

Fig.: Hot days according to Kyselý (left) and increase of hot days (right) as functions of elevation in the years 1948 to 2003 in the North, East and South-East of Austria on the basis of daily temperature maxima

The aim of **StartClim2004.B** was to investigate the usefulness of three different approaches of downscaling methods with special emphasis on summer droughts and heat waves in Austria in the 21st century. Therefore a statistic and a synoptic method using daily data from the ERA40 reanalysis project and ECHAM4 GCM-Scenarios were used. Further, data from the regional climate model (RCM) derived within the EU-project PRUDENCE were analysed for Austria.

The analysis of temperature showed similar results for all three approaches. In the analysed periods the scenarios show an increase of heat days from less than 10 per year up to about 30 in northeast of Austria within a period of 30 years. Also, in the period 2070-2100 we can expect up to 40 heat days per year.

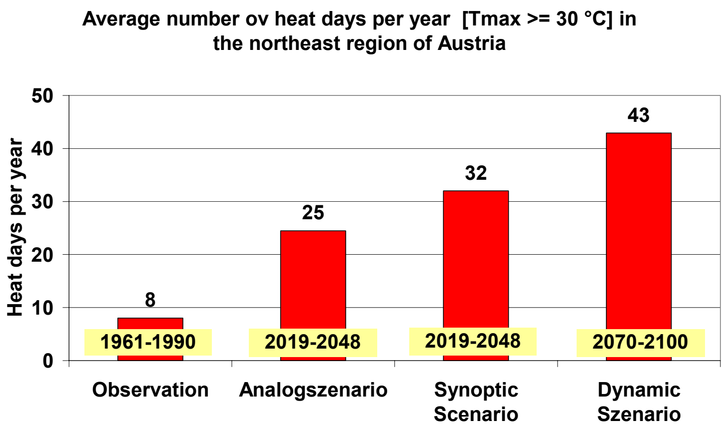

Fig.: Average number of heat days in the northeast of Austria: observed and as obtained from various downscaling methods.

The results of the precipitation scenarios are much more uncertain. This concerns the statistic approach as well as the RCM. The statistic approach shows a strong dependence of the predictor used. The RCM is not capable to generate the precipitation in the southeast of Austria correctly. In the northeast the mean precipitation is almost correct, but the interannual variance is too large and we also see great differences of the persistence of droughts.

Summarising, we see that all three methods show similar results for temperature and temperature extremes. This proves the robustness of the regional temperature scenarios and increases their credibility. But it also means that the cheapest method i.e. the presented synoptic method is sufficient. The precipitation however has to be regarded as rather uncertain and a direct application of this in impact studies should only be performed in combination with an analysis and a correction.

StartClim2004.C investigated the effects of drought and heat on agriculture partly using meteorological data examined by StartClim in the previous year. The drought year 2003 clearly showed the vulnerability of agricultural crop production in Austria caused by unfavourable weather conditions. On a district scale low precipitation sums were compensated in some regions by an optimal distribution of rain and moderately high temperatures. Crop-specific time-windows with high sensitivity to drought and high temperatures exist. Except for maize, all crop yields were more sensitive to high temperatures than to low precipitation sums, especially in the eastern part of Austria. Yield depressions caused by high temperatures increased during the past 130 years, most prominently during the past 15 years, whereas the depressions caused by low precipitation do not vary much.

Spatial variability of actual drought stress levels is high due to soil conditions. Agrometeorological drought indices showed a good relationship to yield depression in 2003 at the field scale, when adapted to the most sensitive crop-specific phenological phase. The remote sensing drought index NDVI determined during the main growing period (June) showed the best relationship to the yield depression in 2003; however its quality strongly depends on the date of observation and the phenological stage of the crop. A few meteorological indices also showed satisfactory results, but further testing using data of several years is needed to confirm the robustness of these results. A combination of methods could improve the results at the field scale, and help the interpretation of the causes of yield depressions, especially heat stress vs. drought stress.

The main goal of **StartClim 2004.F** was the further development of the meteorological extreme event database MEDEA (Meteorological Extreme event Data information system for the Eastern Alpine region). In addition, better access to the collected data for scientists was aimed for. MEDEA is designed to provide a long term archive for data related to extreme weather events in Austria for climatologists as well as climate change impact researchers. Current plans include an on-line interface as well as analysis and modeling tools for MEDEA.

Currently, the data integrated into MEDEA has an exemplary character. Based on agreements reached this year with various data providers, the data contained within MEDEA will be extended to allow scientists access to larger quantities of relevant data.

Long term plans for MEDEA include testing the possible use of Grid technology in order to build a network of decentrally stored databases. A simple prototype is planned for 2005 within the framework of the Austrian Grid Initiative. This prototype could be used as a basis for further development of MEDEA.

At the interface between science and education in **StartClim2004.G** new approaches for the communication between researchers and schools were tested. The question treated was: „Is there a relationship between heat and student output?” Output was measured as the ability to concentrate using a psychological test (Test d2) in May and June 2004 in a class of 15 and 16 year olds (ORG Hegelgasse) in Viennna. Additionally students recorded their subjective thermal comfort. Both data sets were linked with temperature and humidity measured in the classroom and outside. Although unfortunately none of the school days was very hot, and in spite of irregular presence and participation of students, the method proved very promising: a weak but significant correlation between room temperature and power of concentration was found.

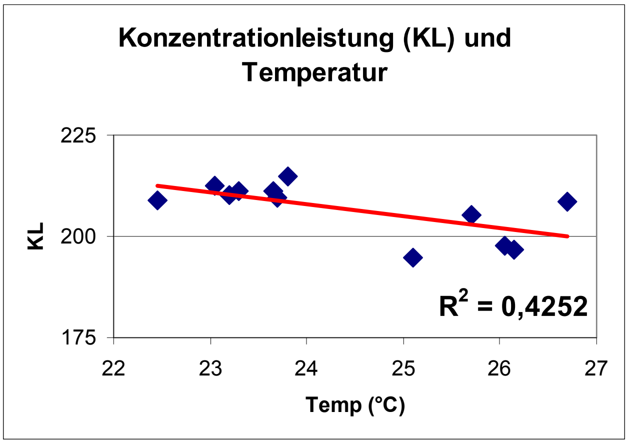

Fig.: Relation between temperature and power of concentration (KL, 50% of the 15 to 16 year olds have KL=141-184 at the first test)

Direct cooperation between scientists and schools is a very effective but expensive process of the science-society dialog. However, with respect to the recent public discussion on the shortage of university graduates and scientists in Austria it is important to raise the interest in science and research in the young people.

1 The Research Initiative StartClim

1.1 History of StartClim

In 2002, Austrian climatologists founded the research platform 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 (see page 5) 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.

StartClim continued in 2004 by sponsoring research on "heat and drought" and is now set up as a program initiating research in climate change topics not yet established in Austria. StartClim research projects are intended to subsequently be carried farther in the framework of normal research funding or as studies commissioned by interested stakeholders. It is also aiming at giving young researchers a start on these new topics. Finally, it offers added value by providing an unbureaucratic way of jointly financing research by widely different funding institutions.

In 2004 the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, the Austrian Federal Ministry for Education, Science and Culture and the Austrian Hail Insurance supported StartClim with additional funds. The "Österreichische Nationalbank" finances one StartClim project on insurance options through its normal research funding channel. The Verbund AHP joined as a new partner, financing a project on the consequences of heat and drought on the availability of water. The last two projects will not be finished before fall 2005.

The focus of StartClim2004 is „Heat and Drought". This was chosen to enable a first analysis of the extremely hot year 2003. Five projects on this topic were funded.

1.2 StartClim2004

1.2.1 Aims

The StartClim 2004 topic is "Heat and Drought", a selection that affords the opportunity for first analyses of the extremely hot summer of 2003. Meteorological time series made available in the framework of StartClim2003 were enlarged to include a moisture parameter and they were analysed in view of heat and drought. As before, future scenarios for Austria were downscaled from global models (GCMs). Analyses of impacts of heat and drought focussed on agriculture. The data bank MEDEA for data related to extreme weather events was made more easily accessible to the scientific community. Finally new approaches were made at the interface of science and education.

1.2.2 Structure of the Report

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

The summary also includes a short retrospective on the origin of StartClim, its aims and some results of the 2003 projects. By addressing those projects of the year 2003 that are connected to the topic of 2004 the continuity on one hand and the development of topics on the other becomes visible. A complete list of StartClim projects, the institutions and researchers involved can be found in the annex.

1.2.3 How StartClim2004 worked

The organisational structure of StartClim2004 was similar to that of StartClim2003. StartClim 2004 consists of five subprojects that encompass 26 persons from eight different institutions, representing nearly 50 months of scientific work including compiling the report. The breakdown of participating scientists reveals 10 women and 11 contributors under 35 years of age.

In order to promote scientific exchange between the individual subprojects, two workshops were held with the presence of members of the scientific scientific board. All participating scientists were invited to present the results of their ongoing work and to discuss linkages between the subprojects.

The Information and data exchange within the StartClim community was again supported by the FTP server and the StartClim homepage (http://www.austroclim.at/startclim/) at the Institute for Meteorology of the BOKU University of Natural Resources and Applied Life Sciences.

Scientific literature pertaining to the 2004 projects was added to the literature data base that was set up during StartClim2003 and is available from the StartClim home page, as are all the project reports.

1.3 StartClim2003 – Retrospective

StartClim 2003 was devoted to three topics, of which only one, “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” is addressed here, because the results or methods are of importance for the 2004 projects.

The precondition for the analyses of extreme events 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.

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. For the period before 1948 information relevant to extreme events found in monthly data sets, e.g. monthly extremes of temperature, number of ice-, frost- and heat-days, maximum precipitation in each month, etc. were retrieved, subjected to a plausibility check and corrected where possible for 20 stations.

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 circulation model (GCM) scenarios. 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.

An information system (MEDEA - Meteorological extreme Event Data information system for the Eastern Alpine region) was developed to eventually bring together a wide range of data on extreme weather events and weather-induced events in Austria from different scientific fields. 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.

Especially relevant for the StartClim2004 work was the analysis of the kinds of extreme weather causing bad harvests in seven agricultural crop species in three regions of Austria. The database consisted of area-based agro-statistical surveys and the monthly means of meteorological parameters from 1869 to 2002. Selected results include that dry weather in spring is especially disadvantageous for spring cereals and dry, hot summers are unfavourable for sugar beet and corn, to a lesser extent for potato.

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. This information was compared to data from meteorological stations. 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 database MEDEA, making them available to the climate change research community.

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.

2 Results of Subprojects

2.1 StartClim2004A: Analysis of Hot and Dry Periods in Austria; Enlargement of the StartClim Data Set to the Element of Vapour Pressure

2.1.1 Analysis of Hot Periods

Hot Periods in Austria were analyzed by using the following, modified definition of Kyselý for the timeframe 1948 to 2003:

1. 3 consecutive days must show a daily temperature maximum of at least 30°C,
2. the maximum of each following day does not drop below 25°C and the mean temperature maximum during the whole period is at 30°C or above.

Only 12 of the 71 StartClim stations with plausibility checked daily temperature maxima proved suitable for this analysis. Data sets of the other stations were incomplete or the elevation above sea level excluded the occurrence of hot periods as defined above.

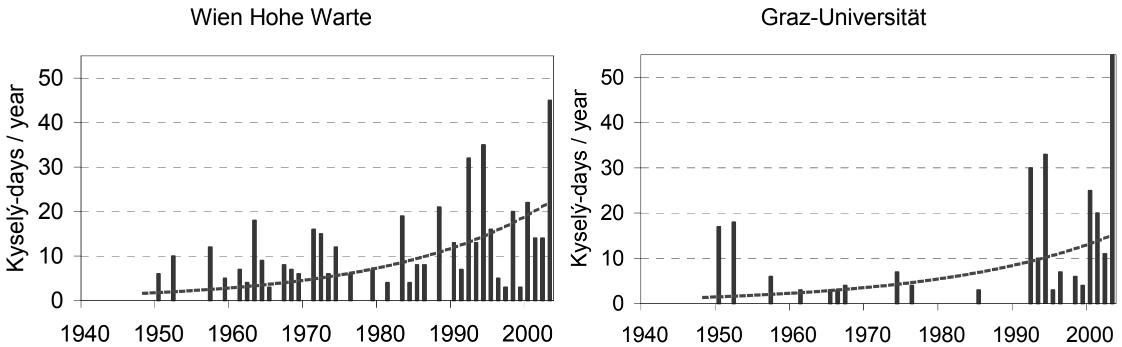

Fig. 1: Time series of the yearly number of Kyselý-days for the stations Wien Hohe Warte and Graz-University

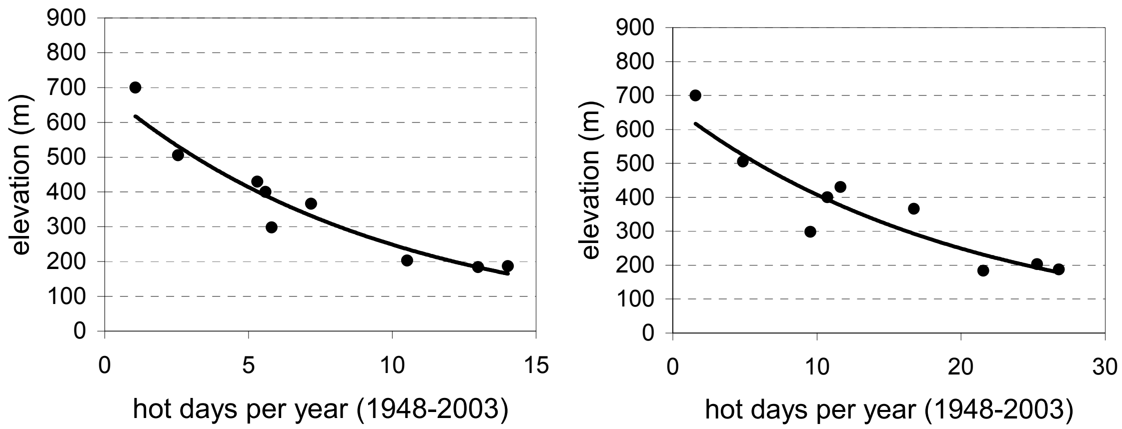

Fig. 2: Hot days according to Kyselý (left) and the increase of hot days (right) as a function of elevation during 1948 to 2003 in the North, East and South-East of Austria on the basis of daily temperature maxima (rounded to whole degrees C)

On the whole, the number of hot days per year under the terms of Kyselý has increased significantly since the middle of the last century, as can be seen in Figure 1 showing the stations Wien Hohe Warte and Graz-University. The largest increase in the last 50 years (Fig. 2.) occurred in regions of lower elevation (about 25 days at 200 m, about 6 at 500 m and 1 to 2 at 700 m above sea level. As compared to about 12, 2.5 and 1 day at the beginning of the period). The year 2003 is the year with the largest number of days meeting the Kyselý criteria of the whole data collective. Also at the majority of stations the longest hot period was recorded 2003. Naturally, without exception the longest hot periods occur in summer, but hot periods cannot be excluded in springtime and autumn.

2.1.2 Analysis of Dry Periods

The differentiation between drought and dry spells or dry periods is difficult. Drought defines periods of extraordinary dryness caused by a severe lack of precipitation and simultaneous high temperatures. A dry spell is a space of time with a distinctive lack of precipitation without a consistent definition of the criteria concerning temperature and precipitation amounts. In fact, the criteria refer more to the water demand of different applications, such as agriculture, forestry or water management.

In the present analysis a dry period comprises timeframes of at least 10 consecutive days with no more than 1 mm precipitation per day. Uninterrupted periods of such days were counted for 30 stations, classified in frequencies from 5 to 5 days and allocated to seasons. Periods that stretched into two seasons, were allocated to the season with the larger part of the dry days.

About one third of the stations show a rising trend in the frequency of dry periods, one third a downward trend, while the rest of the stations do not show any trend. The variability of the frequency of dry periods is highly dependent on local circumstances, on the duration of the period and on the season. Only the autumn season shows a consistent picture in the whole country.

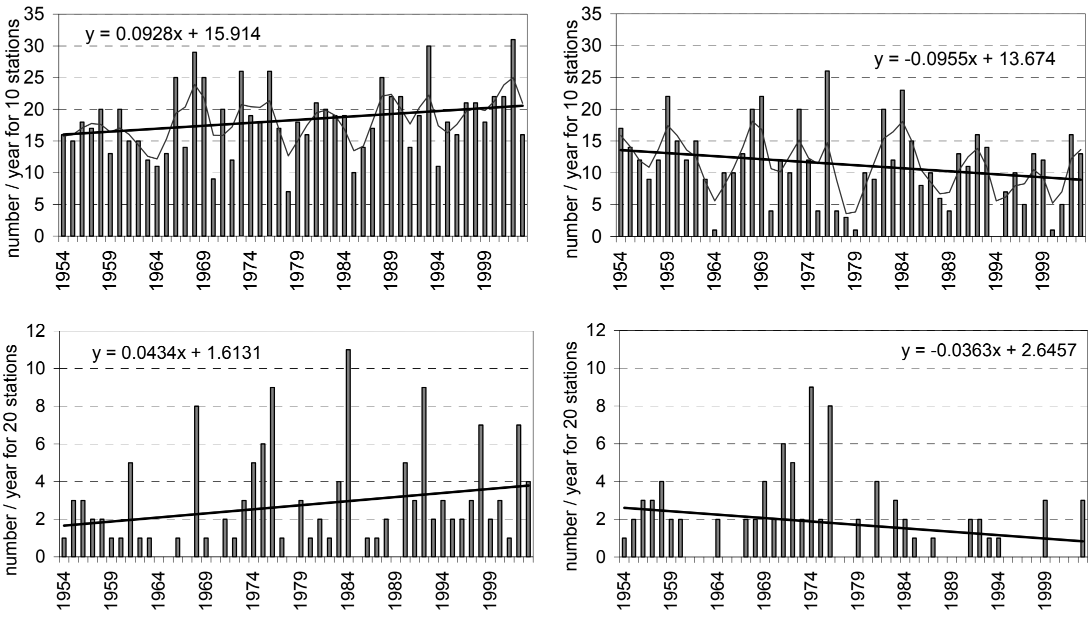

Fig. 3: Time series of dry periods with durations of minimum thresholds of 10 days (top) and 20 days (bottom) in Austria. left: sum of 10 stations with upward trend, right: sum of 10 stations with downwards trend. Single values and linear trend 1954 to 2003 without taking the seasons into account.

In springtime there is no explicit change or trend. The spatial distribution of the stations does not show regional patterns of increase or decrease. There are remarkable accumulations of dry periods in individual years.

In the summer season an increasing tendency of dry periods with a duration of at least 10 days can be detected for two-third of the stations. Regarding dry periods with a duration of 20 days and more, the eastern part of Austria between Lienz and Hohenau an der March shows a slight increase of the frequency. The year 2003 with 52 events of at least ten days and the year 1983 with 6 events of at least 20 days showed an exceptionally large accumulation of dry spells. In 1959, dry periods with a duration of at least 30 days were found at three stations.

In contrast to the other seasons, dry periods in the autumn season show a decrease of durations with at least 10 and 20 days in the whole country. The typical periods of fine autumn weather termed „Altweibersommer“ are no longer as numerous as they were during the 1950s and 1980s.

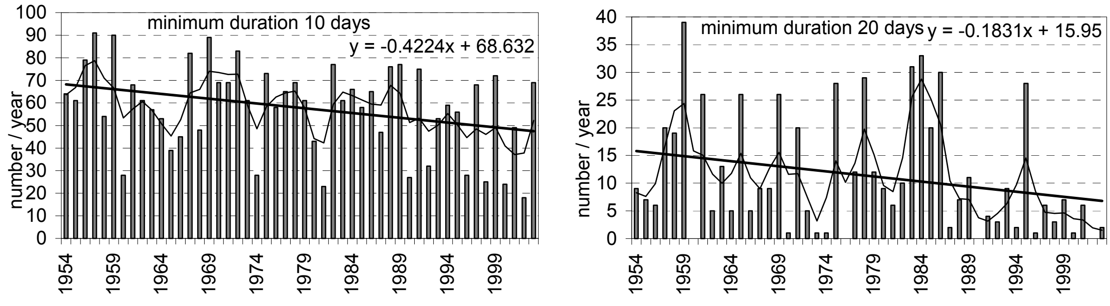

Fig. 4: Time series of dry periods of minimum durations of 10 and 20 days in Austria in autumn (sum of 30 stations). Single values, smoothing over 5 years and linear trend 1954 to 2003

The winter is the season in which dry periods occur most frequently: one period with a duration of 10 to 14 days per year and station, every second year a period of 15 to 20 days duration. The longest dry periods so far (more than 80 days) occurred in the South of Austria in winter. Particularly around the year 1990, an accumulation of dry winter periods occurred. A positive trend for durations of at least 10, 20 and 30 days can be found at two-third of the stations, but without regional patterns. Due to the large year to year variability the trends are not statistically significant.

Additionally, the collective of all stations showed clearly that data sets of 50 years are often too short to detect extreme values or trends.

2.1.3 Enlargement of the StartClim Data Set to the Element of Vapour Pressure

The dataset compiled in the framework of StartClim2003 included plausibility checked data series of temperature and precipitation. Vapour pressure was now added and provides better research possibilities regarding the analyses of evaporation, comfort, etc..

Several methods were used, single and in combination to detect errors in the data sets and to assess their magnitude. The ensuing correction of detected errors in the observed values at 7, 14 and 19 / 21h was based on different methods complementing one another or on combinations of methods, such as the comparison of digital data and original records, recalculations to correct miscalculations in the existing data, comparisons between the recorded and calculated values of relative humidity, charts of air temperature and vapour pressure, comparisons of the single values with the stations-specific curves of wrapping extremes etc..

In single cases of very poor data quality, blocks of data had to be rejected because of insufficient coherence of air temperature and vapour pressure: Those data were incorrigible.

2.1.4 Research needs

The Austrian archive of climatic data is still not completely utilized. On the one hand raw records of meteorological elements are not made available yet. On the other hand even processed data have to be analysed to improve their quality. The following needs of research result from this:

1.) Developlemt of methods to adjust inhomogenities of daily data and to practise them on long data series

2.) „Data Recovery“ – Raising the accuracy of daily extreme temperatures to 1/10 for all StartClim-stations

3.) Higher spatial resolution of the StartClim Data Set (especially for elements as precipitation and snow)

4.) Enlargement of the daily data set of long periods (at least 100 years) for the elements precipitation, air temperature and snow.

5.) Enlargement of the StartClim data set with further elements as sunshine, cloudiness, pressure and wind speed

2.2 StartClim2004B: Investigation of regional climate change scenarios with respect to heat waves and dry spells in Austria

The year 2003 has shown that even in Central Europe heat waves can have wide consequences. The aim of this project was to compare three methods to estimate to what extend information can be obtained from GCMs concerning summer droughts and heat waves in Austria in the 21 century.

Three methods were used and compared to gain information on the robustness of the regional climate scenarios. The methods are:

- Statistical downscaling on a daily basis (analog-method) evaluated for temperature and precipitation concerning heat waves and droughts.
- Evaluation of a regional climate change scenario from the EU project PRUDENCE in two regions of Austria concerning heat waves and droughts.
- Synoptic downscaling investigation and comparison of GCM output with reanalysis data and the derivation of statistical models concerning heat waves.

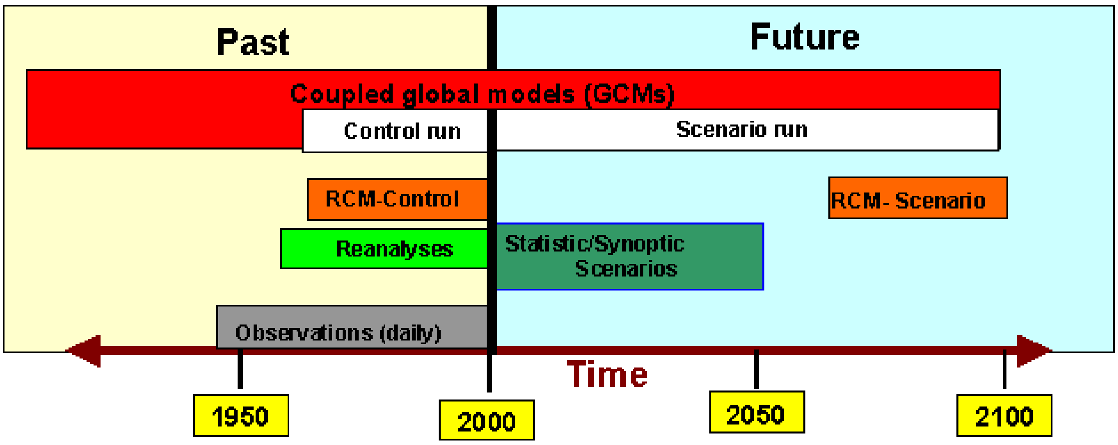

Fig. 5: Schematic illustration of the datasets used and of the time periods considered.

2.2.1 Methods

For the statistic and the synoptic scenarios the GCM model ECHAM4/OPYC3 was used, based on the IS92A emission scenario (without aerosols) for the time period 2000-2048. The PRUDENCE scenario was based on the GCM HadAM3H run with the SRES A2 scenario. Within this model the regional climate model (RCM) CHRM from the ETH Zürich was nested for the time period 2070-2100. The comparison of the scenarios among each other and against the observations was not performed on single stations but in defined regions gathering a few stations together. This was done due to the fact that the RCM output can not be directly compared with single point measurements. All methods investigate the northeast of

Austria while the RCM and the analogue-method also have been applied to the southeast region in Austria.

The analog-method compares GCM data of meteorological fields on a daily basis with the reanalysis ERA40. The most similar field is assumed to have identical weather. So each day of the scenario is connected to a day from the observation. This method works well for temperature. Precipitation shows some difficulties since the large scale field has a very poor statistical correlation to the local scale in Austria on a daily basis. This is especially true in the summer season, since very local convective processes (thunder storms) are of major importance then.

Regional climate models are similar to GCMs. But, by regarding only a small region (e.g. Europe) using the GCM output as boundary value, they have a higher resolution what results in an important improvement especially in the Alps.

In order to calculate heat days for regions in Austria directly from meteorological fields (horizontal resolution 2.5° x 2.5°) a multiple regression model was used to find a functional connection between the observed maximum temperature in the summer half year (April to September) and a large scale meteorological field from the reananlysis ERA40 (synoptic downscaling). In a second step it was investigated if the cumulative percentage of the GCM grid point values have a similar shape and annual characteristic as those of the ERA40 data. After this was accomplished the difference of GCM control run to scenario was calculated for each percentile and set of the ERA40 data. Then the statistical model was run for the GCM data.

2.2.2 Results

All methods give about the same results for heat day frequency in the northeast of Austria which can be seen in Figure 6. For the time period 2019-2048 we see an increase from less than 10 days at present up to about 30. The results for 2070-2100 give more than 40 heat days which means that almost each second day has a maximum temperature of more than 30 °C.

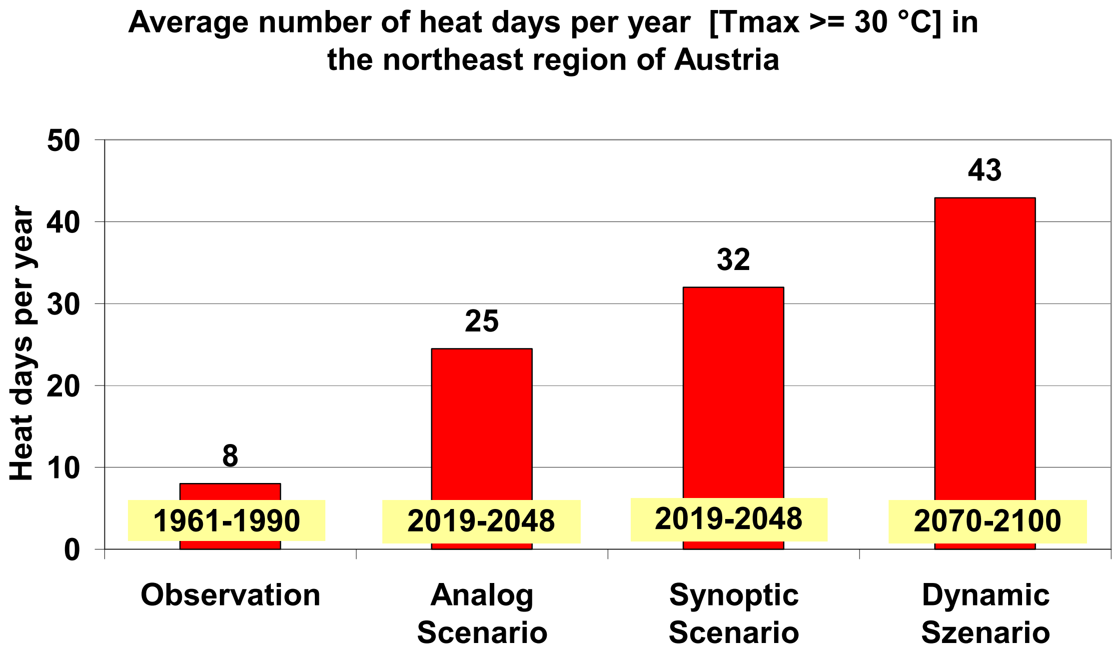

Fig. 6: Mean number of heat days in the northeast of Austria: observed and as obtained from various downscaling methods.

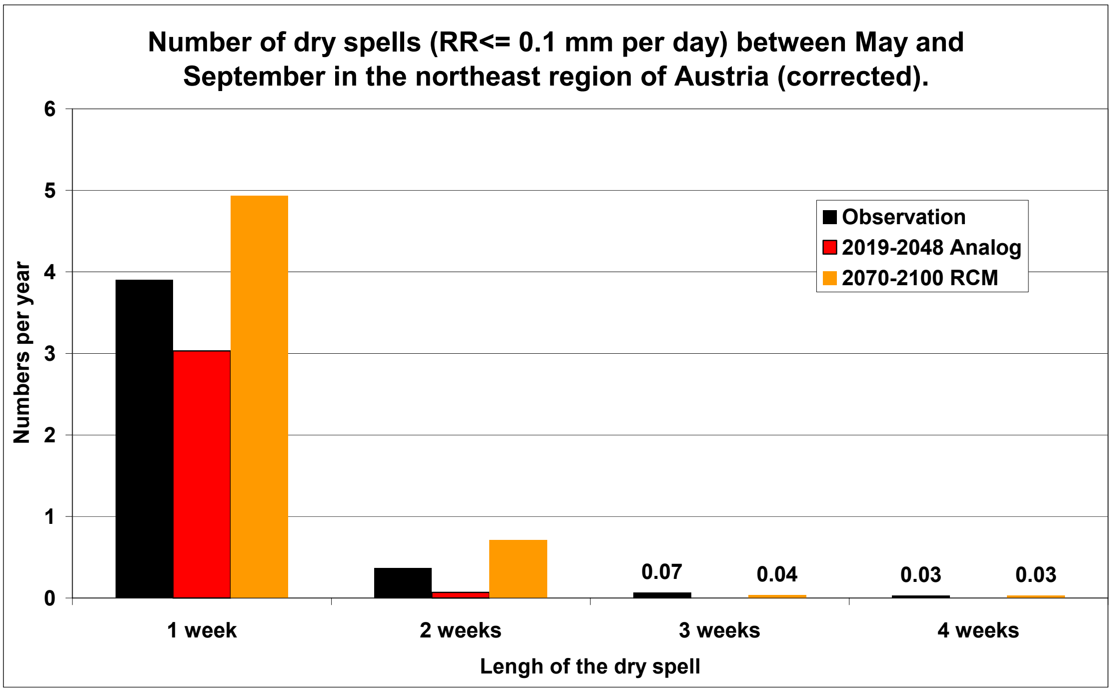

Fig. 7: Number of dry spells from May to September in the northeast of Austria: observed and obtained from various downscaling methods.

The temperature in the northeast of the RCM control run shows similar results as the observations. Only the inter-annual variability of the RCM is a little larger. In the southeast although the maximum temperature of the RCM was about 2.5°C to warm in summer. The main reason therefore is in our opinion the massive underestimation of the precipitation in this region in summer. The RCM produces only about half of the actual precipitation amount and the number of days without precipitation is underestimated by about 15 %.

The results of precipitation are much more uncertain. This is true for the analog-method as well as for the RCM. The statistical method has a strong dependence on the predictor field. For example the sea level pressure gives an increase of precipitation for the period 2019-2048 (shown in Figure 7) while the relative topography of 850 - 700 hPa gives a reduction of precipitation, although both predictors show similar results with the ERA40 data. The RCM has difficulties to get the precipitation correct in the southeast. In the northeast the mean values are approximately correct however the precipitation of the inter-annual variability is too large. Furthermore the persistence of dry spells is different.

The evaluation includes only the chances of control run to scenario. The results of the frequencies of dry spells are summarized in Figure 7. Because the statistical method gives an increase of precipitation of about 20 % we also see a reduction in the frequency of dry spells. The RCM scenario shows a reduction of about 20% and a corresponding increase of droughts.

Summarizing, we see that all three methods show similar results for temperature and temperature extremes. This proves the robustness of the regional temperature scenarios and increases its credibility. But it also means that the cheapest method i.e. the presented synoptic method is sufficient. With this approach it is therefore possible to obtain cheap and quick results and comparisons of different GCMs. The precipitation although has to be regarded as rather uncertain and a direct application in impact studies should only be performed in combination with an analysis and a correction.

2.3 StartClim2004C: Analysis of drought effects in 2003 on Austria's agriculture – comparison of methods

Agricultural plant production as a receptor of drought and heat impacts during the year 2003 – this was the topic dealt with in this subproject by means of agrostatistical and (agro)meteorological methods as well as remote sensing. These methods were compared and tested for their suitability

- to explain the yield reductions found in 2003
- for future forecasts and monitoring of effects of unfavourable weather conditions

The investigations were carried out at two different spatial scales (district and field plot scale). On the district scale meteorological parameters and their influence on yields were examined. This approach offered a more refined spatial and temporal resolution than it had been possible so far on the basis of available data for Austria. By using official agricultural yield statistics, productivity data of spring-barley, winter(soft)wheat, maize and grassland (meadows) for the years 1997–2003 were deployed; meteorological input data were taken from one representative climate station for each district. Precipitation and temperature data for the respective (particular) vegetation period were calculated in semi-monthly resolution to derive indicator values for drought periods. These were correlated with the corresponding yield data of the seven-years period. On the basis of these correlations those meteorological parameters and time windows were selected which showed the most pronounced relation to the observed yield variations.

The results gave evidence for the importance of differentiation between geographical regions and crop species. In the east of Austria water shortage and high temperature periods more frequently limit yield than in more westerly production areas. Thus the lack of significant deviations from the long term average of precipitation and temperature was more important in avoiding yield reductions than for the rest of Austria. Consequently models for eastern Austria explaining yield as a function of meteorological conditions could not be easily transferred to other regions of Austria. Similarly, it is necessary to consider species-specific models for stress effects. Cereals depending more on spring and early summer precipitation because of their shorter vegetation period suffered less from the drought 2003 than maize and meadows. Grassland was affected most by the summer drought (Fig. 8).

Contrary to the overall trend, several regions and districts did not experience yield reductions for the studied species compared to the years 1997 – 2002. Detailed analysis showed that interruptions of the rainless periods and reduced maximum temperatures occurred in these regions. This emphasises the effectiveness of these factors in avoiding stress effects even when the sum of precipitation are below average.

The comparison of the importance of the various meteorological parameters showed that high temperatures were more crucially limiting for plant production especially for barley, wheat and grassland than a deficit of precipitation. Again this dependence was most clearly exhibited in the eastern production areas. The inclusion of long term series (130 years) revealed that the sensitivity to the prevailing maximum temperatures has risen clearly in the last 30 years.

In the context of these evaluations there were calculated the estimated yield depressions for standardized precipitation reductions or temperature increases at defined time segments for all investigated species on the basis of regression models. Average maximum temperature increases by 1 °C in June meant barley and wheat grain yield reductions by 0.1 to 0.15 $t.ha^{-1}$ whereas the same temperature increase in August reduced maize grain yield and grassland productivity by 0.2 to 0.45 $t.ha^{-1}$. Standard error estimates were in the range between 10 and 20 % (for barley, wheat and grassland) to 40 % (for maize). Models for smaller regions (provinces) were superior to models for larger regions (several provinces). Only in certain cases more than 50 % of data variance could be explained by multiple regression and neural network models if just meteorological parameters were used. These limitations gave evidence for the importance of additional inputs as they are applied in agrometeorological models.

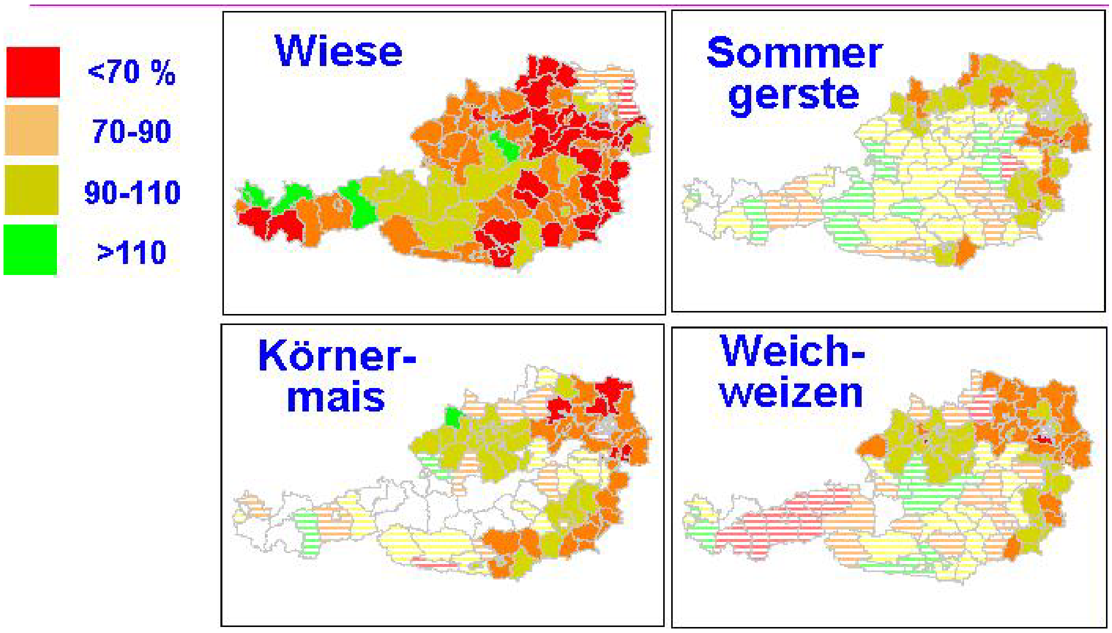

Fig. 8: Yields of grassland (meadows, top left), spring barley (top right), maize (bottom left) and soft wheat (bottom right) in Austria's political districts for the year 2003 in percent of the yields of 1997 to 2002. Green: yield 2003 above average 1997-2002; yellow: yield equal to average of 1997-2002; orange or red: moderately or significantly under the average of 1997-2002. Acreage of respective crop in hatched-coloured districts is below 1% of the total district area .

Agrometeorological models/indices, meteorological indices and remote sensing indices were investigated at the smallest spatial scale (field level), because at field level much more representative input data (soil information, crop management) are available. In particular the crop yield depressions of the drought year 2003 relative to the wet year 2004 were considered.

Drought indices are a relative measure of drought, at first without a relation to a specific impact. The investigations within the frame of the StartClim project showed different results related to crop yield depression. The agrometeorological models/indices and remote sensing indices (NDVI) could better explain variations (and depression) in yield at the field level in 2003 than meteorological indices, when they were related to a 3-month main growing period. The best models could explain between 60 % and 83 % of yield variability.

For agrometeorological models and indices not only the spatial, but also the temporal resolution plays an important role (Fig. 9); the models performed better when they were adapted to the most drought sensitive phenological periods of the crops. At the field scale the agrometeorological models and indices confirm the results at the district level, showing that spring cereals were less affected by drought in 2003 than e.g. maize, because significant drought stress was starting in June. The high variability of simulated drought stress between different fields at the same location pointed out the important impact of soil type and soil water storage capacity at the field level.

A few meteorological precipitation based indices showed good results if they were related to the 6-month period from April-September; however, this can be a specific phenomen of this year. An extension of the investigations to several years with different meteorological conditions is necessary to test the robustness of these methods. If precipitation based indices and indices which include also temperature would be robust, a combination of this methods could be used to distinguish between heat and drought effect on crop yield. Agrometeorological models and indices, which consider water balance of crop stands, can directly estimate the status of drought stress, and therefore distinguish between heat stress conditions without drought stress. Remote sensing indices such as the NDVI, are snap shots of plant stand conditions and can be a good indicator for spatial representative drought stress damage, when the optimal time period is selected. An additional combination with remote sensing indices could be an innovative step for a better use of drought indices (through decreasing of uncertainties and a better spatial resolution) for detection of yield depressions by drought.

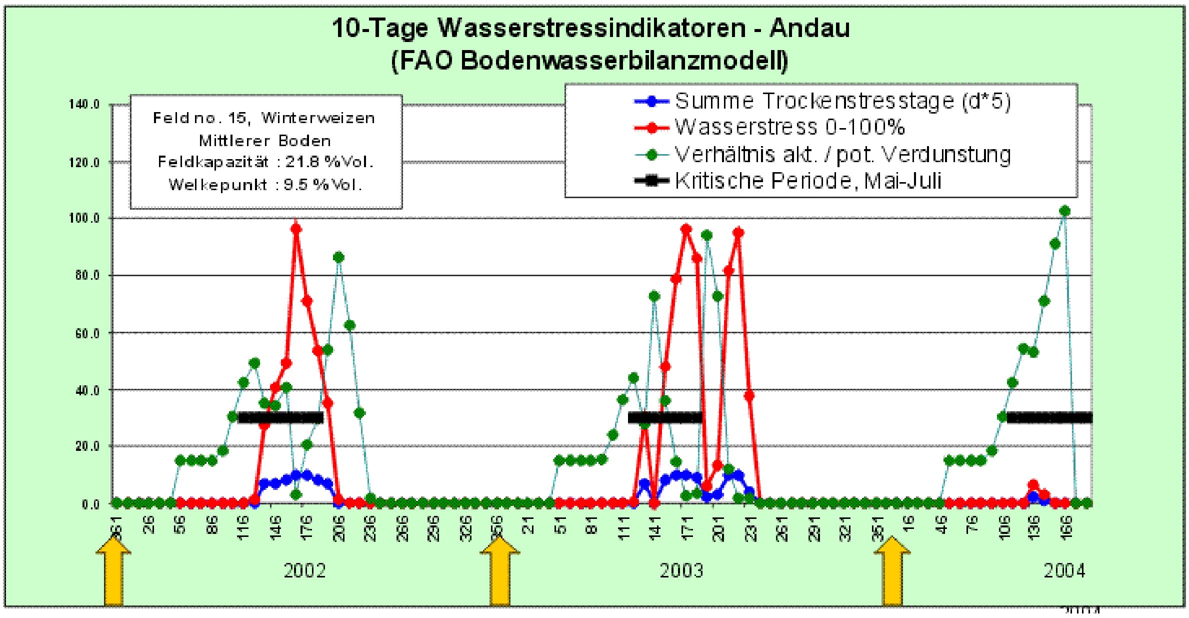

Fig. 9: Calculated drought stress parameters based on the FAO model for Marchfeld and winter wheat on a soil with medium soil water storage capacity.

The results of the different drought indices on the district and field level points out the possibility of a spatial optimization of agricultural production models, whereby a balance between a good data base and low spatial resolution on the one hand and (mostly) marginal data base and high spatial resolution on the other hand – depending on the application – has to be found. An improvement of results from statistical-meteorological indices (which are limited by their inputs) needs the consideration of soil and crop specific information as it is the case for site related agrometeorological models and indices. These methods therefore have a better potential to explain the reasons of yield reductions but have a high demand on spatial representative input data (e.g. for use in a GIS). The availability of spatial data and the tools for their presentation however, is improving, so that there is a big potential and research need in that area, in specific in combination with remote sensing techniques. Additionally, field related information becomes more and more attractive and important by adatped GIS technologies at the farm level (such as estimation of drought damage) and the spatial accuracity and representativeness becomes economically more significant for some applications (such as ÖPUL measures).

2.4 StartClim2004F: Contiunation and further development of the MEDEA event data base

The main goal of the event database MEDEA that was initiated within StartClim for the collation of meteorological extreme events is the mid- and long-range storage and safekeeping of diverse types of interdisciplinary datasets related to meteorological extreme events in Austria. Additionally, it should provide access to the Austrian climatology community for specific analysis and queries.

One major key to the success of this project is the participation and cooperation of all significant data providers in the field of meteorological extreme events. This year, much effort was invested in negotiations with various data providers which will hopefully allow integration of their data sets during 2005. In order to fulfill the requirements agreed upon in these negotiations, it will be necessary to annotate all data with pertinent metadata such as the data owner. For certain cases it will also be necessary to integrate a billing system into MEDEA that will allow us to charge handling fees to be transferred to the data owners as well as charges for the commercial use of the data provided.

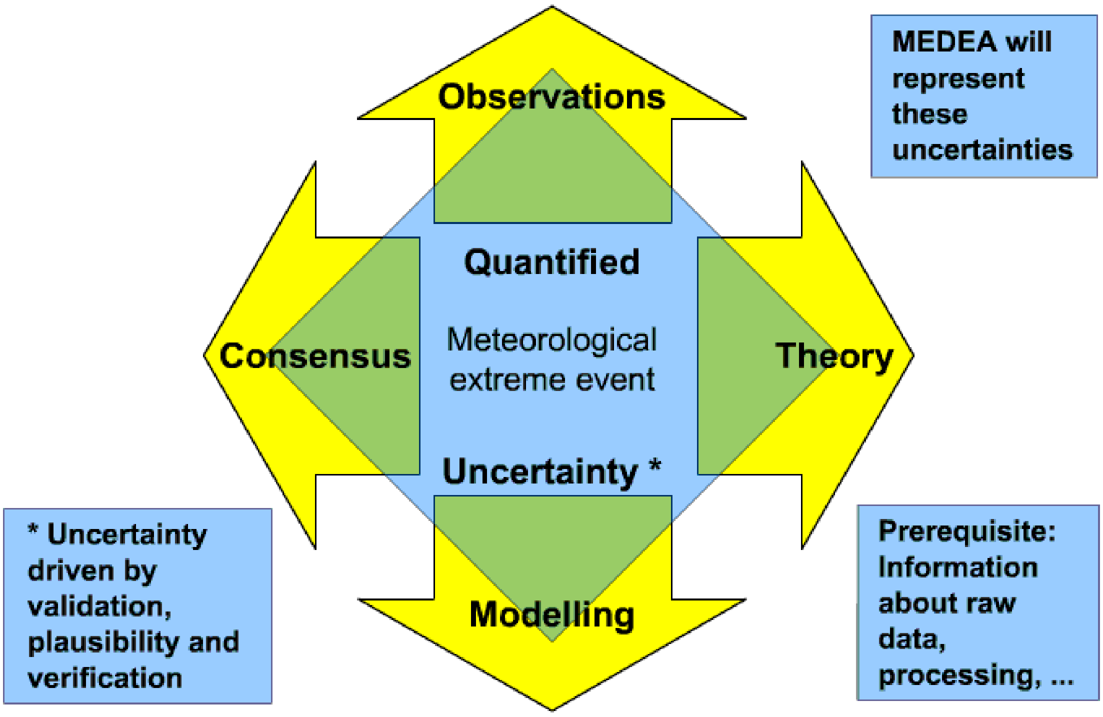

Fig. 10: Uncertainty Concept Moss/Schneider (ZITAT)

To date the following types of data have been entered into MEDEA:

- Flood data from BFW
- Meteorological data from ZAMG
- Results of surveys to exterme events from BOKU
- Data about tornados from the association TORDACH
- Agricultural-economic data from the Austrian Research Centers Seibersdorf (ARCS)
- Verified historic data about creek and stream events in Tirol from BOKU

The fact that this data comes from diverse sources and thus not all data is of the same quality, accuracy and dependability is of great significance. This information must be included in the database in the form of metadata.

The „Uncertainty Concept“ from Moss and Schneider is used as a basis for the categorisation of the data (Fig. 10)

Seen from a technical point of view, MEDEA is based on the MORIS technology, and thus integrates its core ontology for the classification of the data (Fig. 11). This core ontology is an integral component of the MORIS information system that has proven effective for structuring diverse types of ecological data.

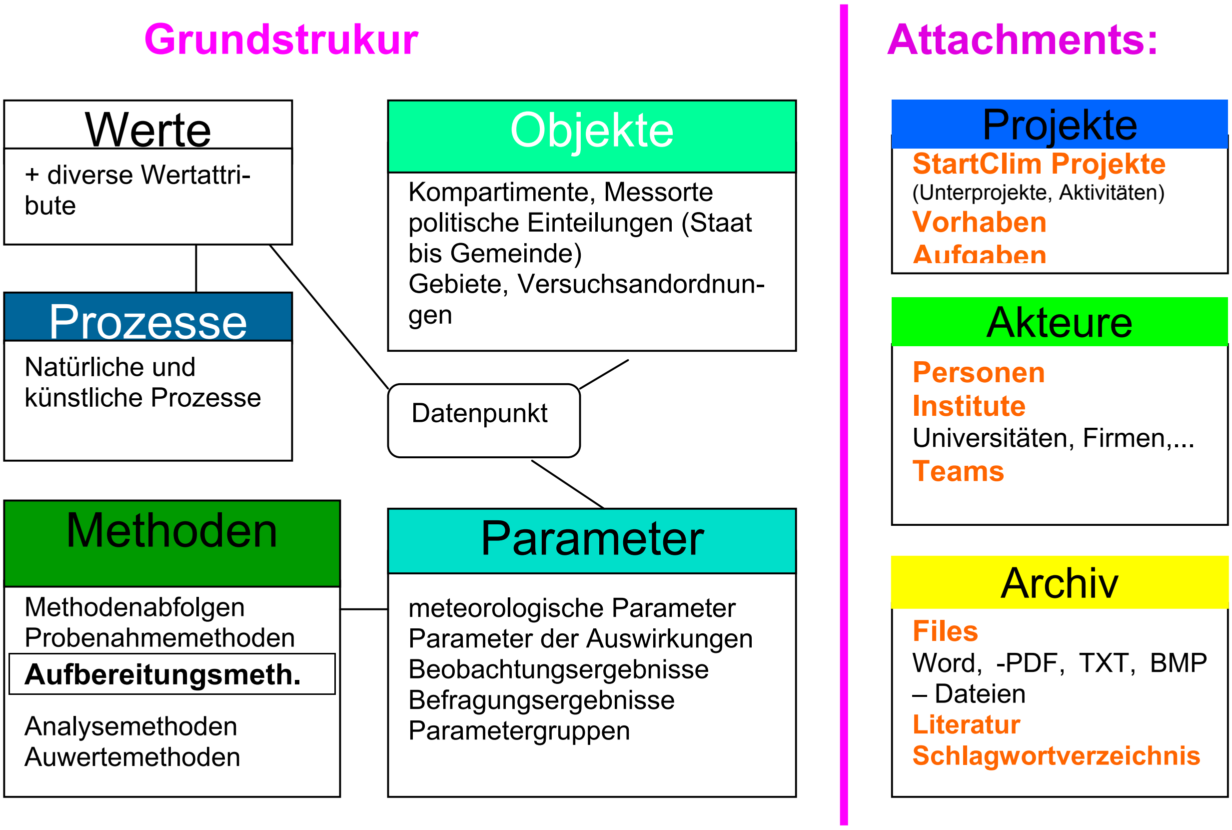

Fig. 11: MEDEA Core Ontology

Following steps are planned for the near future:

- Integration of new project data from StartClim2004
- Exemplary internet interface
- User requirements workshop in March 2005 about the requirements for the MEDEA Web-Client
- User workshop 2005/2006: hand-on training on MEDEA for the StartClim community
- 22. March 2005: Submission of the proposal for MEDOUSA in FP6 in the field of "**Ontologies for Extreme Events**" in cooperation with BOKU, ZAMG, BFW, CH, F, D, IT, Fi, NL,...

An important step for MEDEA will be the creation of the Internet-Client as well as the two user workshops for requirements and training. This will allow users simple access to the data contained in MEDEA and thus increase the willingness to in turn provide data for integration.

Additionally, we are currently evaluating the advantages of Grid Technology for networking decentrally maintained databases. This technology makes it possible to network decentrally located and inhomogeneously formatted databases in such a way that all the end user sees is one central data source. At the same time, each data owner maintains the sovereignty over his data set, and can continue to extend and expand this set.

When too many inhomogeneous data sets are brought together it quickly becomes difficult to maintain an overview of the data. It is often not clear what data is available in what degree of quality as different institutes often gather the same type of data using different methods, which can often lead to a great variance in the results. Ontologies can be of help in this area if they allow the user to annotate not only the type of data (i.e. hourly rainfall) collected but also important factors such as the method used or who actually collected the data. With this additional knowledge it is easier to judge the applicability of the existing data. Only through the addition of this type of metadata is the use of such a wide data source practicable.

It is currently planned to create a prototype of such a data grid in the framework of the Austrian Grid Initiative, which could serve as a basis for further extension of MEDEA. In order to transfer MEDEA to this new technology the appropriate funding must first be secured.

2.5 StartClim2004G: "Is there a relationship between heat an productivity?" A Project at the Interface Science-Education

The successful cooperation with schools was continued in StartClim2004.G with the subject „Is there a relation between heat and productivity?" in a class of 15 and 16 year olds (ORG Hegelgasse) in Viennna. Students and teachers have great interest in practiclly and directly becoming acquainted with science and its working methods as well as in climate change and its impacts. As teachers tell in such projects students learn much more than in normal lessons.

Trying out new approaches in educational science and atmospheric and psychological sciences at the same time was the special but successful challenge of this project. On the one hand the question was to objectively record and quantify the relation between heat and productiviy. On the other hand the cooperation between school and science was to be discussed and evaluated.

Productivity was measured using a psychological test (Test d2) that was easy to carry out. This test measured the power of concentration as concentration is one of the main essentials for productivity. As it exists no general definition heat was measured as subjective estimation of thermal comfort (climate conditions of environment where persons feel comfortable, that means they do not want warmer or cooler conditions) through students and by recording temperature and relative humidity in the classroom, the teachers room and outside.

In May and June 2004 no extreme temperatures on school days were measured, for that reason no uncomfortable days, either. Additionally the irregular presence of students (only 5 out of 22 students where "always present") reduced the qualitiy of data. Nevertheless quite good results could be achieved. Interpretation of the data was reduced to simple methods that were available and well-known in school (MS Office, used in IT-classes). The new method to measure productivity is very promising: the relation between room temperature and power of concentration could be quantified although the circumstances where adverse in this case (see fig. 12).

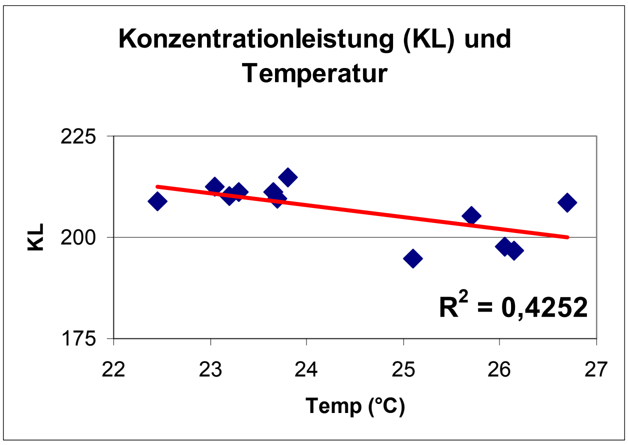

Fig. 12: Relation between temperature and power of concentration (KL, for 50% of the 15 to 16 year olds KL=141-184 at the first test)

For better understanding the influences on the power of concentration additional parameters, for example indoor air quality, could be measured in following research projects.

The processes of the cooperation between science and school were analyzed including students and teachers impressions. One important result of this analysis was that special attention must be directed to the transfer of knowledge. Scientific knowledge is at hand of the scientists and must be transported to teachers in a appropriate way. Teachers have more competence to impart knowledge to children and young persons. On the one hand material as scientific reports and material made for using in lessons is necessary, on the other hand sufficient time must be given to explaining the scientific methods and the subject of the project to teachers. For there is no time scheduled for this in the existing structure of the Austrian school and training system the process of transporting scientific knowledge can only work successfully if teachers are very engaged and are for example willing to spend their leisure for the project work as well.

For all the expenditures of time and costs the direct contact between scientists and students is important for both sides and is an essential contribution to a successful cooperation. Students do not only extend their thematic knowledge, they also gain more social competences by working together on one project (fig. 13). Some of what students have profited in this project they will become aware of only later.

Fig. 13: Students create posters for the public presentation of their poject in October 2004

Direct cooperation between science and schools is a very effective but expensive process of the science society dialog. With respect to the resent public discussion of the shortage of university graduate people and scientists in Austria it is important to raise the interest in science and research in young persons.

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Annex

Subprojects of StartClim2003

The reports can be fond on the StartClim2004-CD-ROM as well as in the StartClim-hompage (www.austoclim.at/startclim/)

StartClim.1: Quality control and statistical characteristics of selected climate parameters on the basis of daily values in the face of Extreme Value Analysis
Central Institute of Meteorology and Geodynamics
Wolfgang Schöner, Ingeborg Auer, Reinhard Böhm, Sabina Thaler

StartClim.2: Analysis of the representativeness of a data collected over a span of fifty years for the description of the variability of climatic extremes
Central Institute of Meteorology and Geodynamics
Ingeborg Auer, Reinhard Böhm, Eva Korus, Wolfgang Schöner

StartClim.3a: Extreme Events: Documentation of hazardous events in Austria such as rock avalanches, floods, debris flows, landslides, and avalanches
Institute of Forest and Mountain-Risk Engineering,
BOKU - University of Natural Resources and Applied Life Sciences
Dieter Rickenmann, Egon Ganahl

StartClim.3b: Documentation of the impact of extreme weather events on agricultural production
ARC Seibersdorf research
Gerhard Soja, Anna-Maria Soja

StartClim.3c: Meteorological extreme Event Data information system for the Eastern Alpine region - MEDEA
Federal Environment Agency, Martin König, Herbert Schentz, Johann Weigl
IIASA, Mathias Jonas, Tatiana Ermolieva

StartClim.4: Development of a method to predict the occurrence of extreme events from large-scale meteorological fields
Institute of Meteorology and Physics
BOKU - University of Natural Resources and Applied Life Sciences
Andreas Frank, Petra Seibert

StartClim.5: Testing statistical downscaling techniques for their applicability to Extreme Events in Austria
Institute of Meteorology and Physics,
BOKU - University of Natural Resources and Applied Life Sciences
Herbert Formayer, Christoph Matulla, Patrick Haas
GKSS Forschungszentrum Geesthacht, Nikolaus Groll

StartClim.6: Adaptation strategies for economic sectors affected heavily by extreme weather events: Economic evaluation and policy options
Austrian Humans Dimensions Programme (HDP-A)
Department of Economics, Karl-Franzens-Universität Graz
Karl Steininger, Christian Steinreiber, Constanze Binder, Erik Schaffer
Eva Tusini, Evelyne Wiesinger

StartClim.7: Changes in the social metabolism due to the 2002-floodings in Austria: case study of an affected community
Institute of Interdisciplinary Studies of Austrian Universities (IFF)
Willi Haas, Clemens Grünbühel, Brigitt Bodingbauer

StartClim.8: 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 transfer mechanisms
Department of Economics, Karl-Franzens-Universität Graz
Walter Hyll, Nadja Vetters, Franz Prettenthaler

StartClim.9: Summer 2002 floods in Austria: damage account data pool
Center of Natural Hazards and Risk Management (ZENAR),
BOKU - University of Natural Resources and Applied Life Sciences
Helmut Habersack, Helmut Fuchs

StartClim.10: Economic aspects of the 2002-Floodings: Data analysis, asset accounts and macroeconomic effects
Austrian Institute of Economic Research (WIFO)
Daniela Kletzan, Angela Köppl, Kurt Kratena

StartClim.11: Communication at the interface science - education
Institute of Meteorology and Physics,
BOKU - University of Natural Resources and Applied Life Sciences
Ingeborg Schwarzl
Institute of Interdisciplinary Studies of Austrian Universities (IFF)
Willi Haas

StartClim.12: Developing an innovative approach for the analysis of the August 2002 Flood Event in comparison with similar extreme events in recent years
Department of Meteorology and Geophysics, University of Vienna
Simon Tschannett, Barbara Chimani, Reinhold Steinacker

StartClim.13: High-resolution precipitation analysis
Department of Meteorology and Geophysics, University of Vienna
Stefan Schneider, Bodo Ahrens, Reinhold Steinacker, Alexander Beck

StartClim.14: Performance of meteorological forecast models during the August 2002 floods
Central Institute of Meteorology and Geodynamics
Thomas Haiden, Alexander Kann

StartClim.C: Design of a long term Climate-Climate-Impact Research Program for Austria
Institute of Meteorology and Physics,
University of Natural Resources and Applied Life Sciences
Helga Kromp-Kolb, Andreas Türk

StartClim.Reference database:
Implementation of a comprehensive literature data base on climate and climate impact research as a generally accessible basis for future climate research activities
Institute of Meteorology and Physics,
University of Natural Resources and Applied Life Sciences
Patrick Haas