Universität für Bodenkultur Wien
Department für Wirtschafts- und
Sozialwissenschaften

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Franziska Strauss
Herbert Formayer
Veronika Asamer
Erwin Schmid

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University of Natural Resources and Applied Life Sciences, Vienna
Department of Economics and Social Sciences

Climate change data for Austria and the period 2008-2040 with one day and km² resolution

F. Strauss[1*], H. Formayer[2], V. Asamer[1], E. Schmid[1]

[1] Institute for Sustainable Economic Development, University of Natural Resources and Applied Life Sciences, Feistmantelstraße 4, 1180 Vienna, Austria
[2] Institute of Meteorology, University of Natural Resources and Applied Life Sciences, Peter-Jordan-Straße 82, 1190 Vienna, Austria

[*]Corresponding author
Phone: 0043 (0) 1 47654 3666
Fax: 0043 (0) 1 47654 3692
E-Mail franziska.strauss@boku.ac.at

ABSTRACT: We have developed climate change data for Austria and the period from 2008 to 2040 with temporal and spatial resolution of one day and one km^2 based on historical daily weather station data from 1975 to 2007. Daily data from 34 weather stations have been processed to 60 spatial climate clusters with homogeneous climates relating to mean annual precipitation sums and mean annual temperatures from the period 1961-1990. We have performed regression model analysis to compute a set of daily climate change data for each climate cluster. The integral parts of our regression models are i) the extrapolation of the observed linear temperature trend from 1975 to 2007 using an average national trend of ~0.05 °C per year derived from a homogenized dataset, and ii) the repeated bootstrapping of temperature residuals and of observations for solar radiation, precipitation, relative humidity, and wind to ensure consistent spatial and temporal correlations. The repeated bootstrapping procedure has been performed for all weather parameters based on the observed climate variabilities from the period 1975-2007. To account for a wider range of precipitation patterns, we have also developed precipitation scenarios including higher or lower annual precipitation sums as well as unchanged annual precipitation sums with seasonal redistribution. These precipitation scenarios constitute together with the bootstrapped scenarios of temperature, solar radiation, relative humidity and wind our climate change spectrum for Austria until 2040. These climate change data are freely available and we invite users to apply and comment on our high resolution climate change data.

Key words: regional climate change data; statistical climate change model; uncertainty spectrum; temperature trend; Austria.

1. Introduction

The potentials and limitations of General Circulation Models (GCMs) have been recently summarized by Eitzinger *et al*. (2009). The relatively poor spatial resolution of GCMs allows interpretation of results only at global to continental scales. To model weather developments on regional scales, various methods have been developed which are commonly dubbed as “Downscaling-Methods” or regionalization (Gobiet et *al*., 2009, Loibl *et al*., 2009). Downscaling usually means to transfer the information of the GCM to finer spatial and temporal scales.

Scenarios of GCMs as well as of Regional Climate Models (RCMs) embed many uncertainties arising from:

i) different initializations and parameterizations (many climate components or interactions in the atmosphere can only be assessed by simplified calculations),
ii) assumptions on economic and population growths as well as on implementations of new technologies, and
iii) greenhouse gas emissions resulting from the assumptions made in ii).

The assumptions and initial conditions result in the global temperature paths as shown in Figure 1. Until 2030, the differences from various global temperature scenarios are rather small and increase from 2050 onwards. However, the effect of global temperature projections in the next two to three decades shall not be miss-interpreted: The variabilities in the next decades can be more important than climate change signals from increasing greenhouse gas emissions in this period. In the present analysis we are especially interested in the climate change developments of the next two to three decades.

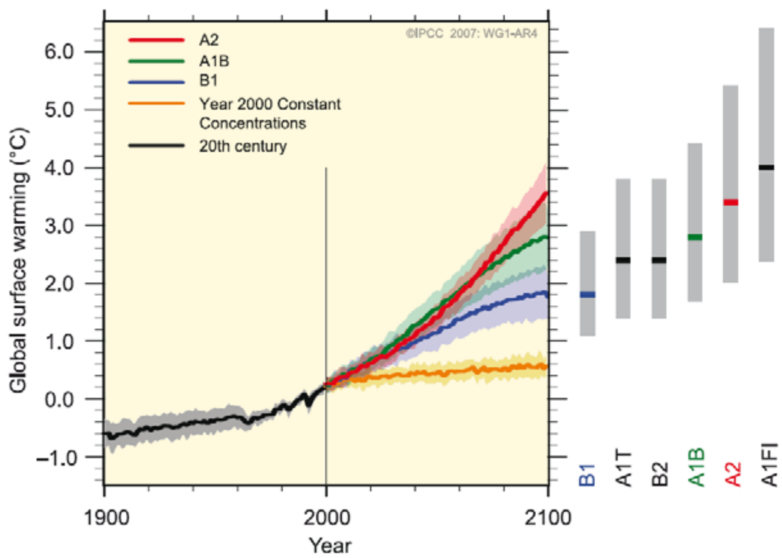

Figure 1: Development of the global temperature paths of different emission scenarios (IPCC, 2007)

Developments of precipitation in the 21st century contain much uncertainty due to various processes which are important for the formation of precipitation such as thermal convection leading to heat-storms at small regional scales or advection leading to frontal precipitation at large regional scales. Most of the relevant processes for the formation of precipitation occur at spatial resolutions much finer than that of GCMs, so that these processes have to be parameterized separately. However, alternative parameterizations of GCMs can lead to large differences in regional precipitation patterns.

As an alternative to RCMs, we have developed a daily climate change dataset using linear regression and bootstrapping methods to project regional climate changes in Austria for the next three decades (2008-2040). The representation of spatial frames and variabilities are important in climate modeling, because regions often show a wide range of different climate patterns (Böhm, 2006). We think that local variations and the development of regional climates in the next three decades can be better captured in statistical climate change models using historical meteorological data.

The primarily aim of our discussion paper is to introduce the statistical climate change model and to describe the high resolution climate change data for Austria. Chapter 2 presents the meteorological data, which are used in our statistical climate change model. The statistical model is briefly described in chapter 3. Chapter 4 outlines the range of precipitation and temperature scenarios, which constitute our climate change spectrum for Austria until 2040. Chapter 5 describes the development of climatic conditions for the period 1975-2007. The results of the statistical climate change model are discussed in chapter 6, and chapter 7 describes in detail the high resolution climate change data, which are freely available. Chapter 8 contains major conclusion of our analysis.

2. Data

Table I provides an overview and description of the meteorological datasets and their applications in our analysis. The climate clusters for Austria have been derived from the ÖKLIM dataset (Österreich Klima; Auer *et al.*, 2000) using mean annual precipitation sums and mean annual temperatures from the period 1961-1990 and are shown in Figure 2. Both weather parameters are available with a resolution of one km² and annual means of the period 1961-1990 in the ÖKLIM dataset provided by the Central Institute of Meteorology and Geodynamics (ZAMG). This dataset has been tested for its quality. The StartClim dataset (Schöner *et al.*, 2003) contains quality tested daily weather station data of temperature, precipitation and snow depth from the period starting around 1950 and ending in 2002. The mean annual temperatures and precipitation sums from the period 1961-1990 are used to find the respective weather stations for the climate clusters. The TAWES dataset (teilautomatisches Wettererfassungssystem; Felkel *et al.*, 1992) contains quality tested daily weather station data of solar radiation, air pressure, temperature, relative humidity, precipitation, wind direction, wind speed, sunshine duration, and soil temperature in depths of 10, 20 and 50 cm. The dataset is available from the early 1990ies to the present. We used this dataset to create statistics on solar radiation which we implemented in the weather generator WXGN (Sharpley and Williams, 1990) to create daily data on solar radiation for the period 1975-2007. The HISTALP dataset (Auer *et al*., 2007) is the only homogenized dataset consisting of monthly temperature, air pressure, precipitation, sunshine and cloudiness records for the Greater Alpine Region (GAR, 4° to 19° E, 43° to 49° N). The longest temperature and air pressure series go back to the year 1760, precipitation to 1800, cloudiness to the 1840s and sunshine to the 1880s. This dataset has been used for temperature trend estimation between 1975 and 2007. The original daily weather station data covering the period 1975-2007 are the basis for our statistical climate change model. The data on solar radiation, maximum temperature, minimum temperature, precipitation, relative humidity and wind speed are provided from ZAMG.

Table I. Overview and description of meteorological datasets available in Austria

datasets	application	period	resolution of space & time	data quality	weather parameters	reference
ÖKLIM	climate clusters	1961-1990	one km² grid; annual means of the period 1961-1990	quality tested	mean annual temperature; mean annual precipitation sum	Auer *et al*., 2000
StartClim	respective weather stations for climate clusters	~1950-2002	weather stations; daily	quality tested	temperature; precipitation; snow depth;	Schöner *et al*., 2003
TAWES	statistics on solar radiation implemented in a weather generator to create daily data	~ 1990 to present	weather stations; daily	quality tested	solar radiation; air pressure; temperature; relative humidity; precipitation; wind direction; wind speed; sunshine duration; soil temperature in depths of 10, 20 and 50 cm;	Felkel *et al*., 1992
HISTALP	identification of temperature trend	~1850 to present	weather stations; monthly	homogenized	temperature; precipitation; air pressure; sunshine; cloudiness;	Auer *et al*., 2007
original weather data	33 year long time series used as basis for our statistical climate change model	1975-2007 (period of interest)	weather stations; daily	not quality tested	solar radiation; maximum temperature; minimum temperature; precipitation; relative humidity; wind speed;	Central Institute for Meteorology and Geodynamics (ZAMG)

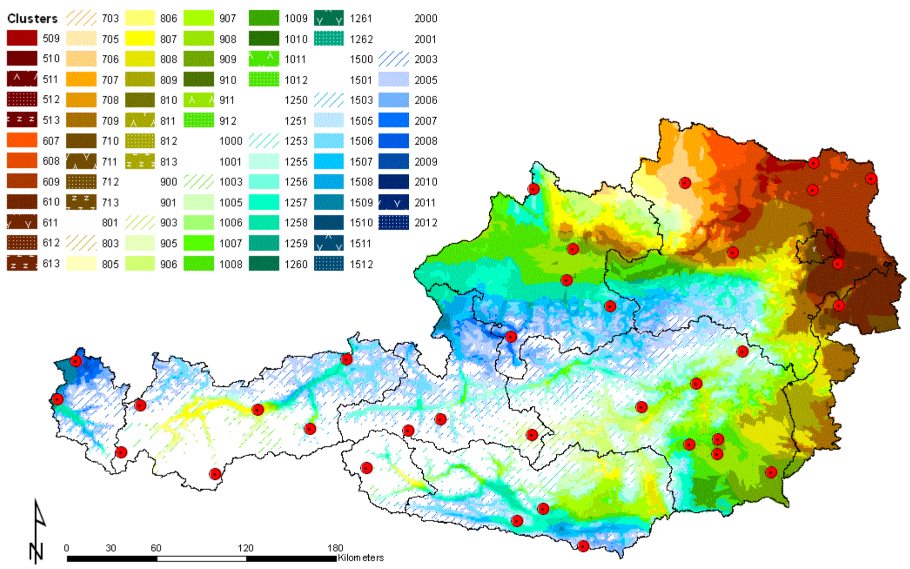

Figure 2. Climate clusters based on precipitation and temperature classes for Austria averaged over the period 1961-1990

Note: The temperature classes 0 and 1 are both shown in white colour independently of the precipitation class; red dots indicate the locations of the respective weather stations.

These original time series data are not quality tested. However, data of the weather stations have been used that represent the climate clusters.

The climate clusters and cluster classification criteria based on the ÖKLIM dataset (Auer *et al*., 2000) are described in the following. The precipitation classes characterize clusters with mean annual precipitation sums such as:

- ≤500 mm which corresponds to the precipitation class 500,
- >500 to ≤600 mm which corresponds to the precipitation class 600,
- >600 to ≤700 mm which corresponds to the precipitation class 700,
- >700 to ≤800 mm which corresponds to the precipitation class 800,
- >800 to ≤900 mm which corresponds to the precipitation class 900,
- >900 to ≤1000 mm which corresponds to the precipitation class 1000,
- >1000 to ≤1250 mm which corresponds to the precipitation class 1250,
- >1250 to ≤1500 mm which corresponds to the precipitation class 1500, and
- >1500 mm which corresponds to the precipitation class 2000.

The temperature classes characterize clusters with mean annual temperatures such as:

- ≤0 °C which corresponds to the temperature class 0,

- >0 to ≤2.5 °C which corresponds to the temperature class 1,
- >2.5 to ≤4.5 °C which corresponds to the temperature class 3,
- >4.5 to ≤5.5 °C which corresponds to the temperature class 5,
- >5.5 to ≤6.5 °C which corresponds to the temperature class 6,
- >6.5 to ≤7.5 °C which corresponds to the temperature class 7,
- >7.5 to ≤8.5 °C which corresponds to the temperature class 8,
- >8.5 to ≤9.5 °C which corresponds to the temperature class 9,
- >9.5 to ≤10.5 °C which corresponds to the temperature class 10,
- >10.5 to ≤11.5 °C which corresponds to the temperature class 11,
- >11.5 to ≤12.5 °C which corresponds to the temperature class 12, and
- >12.5 °C which corresponds to the temperature class 13.

For example, the climate cluster 509 (500+9) represents annual precipitation sums between 400 mm and 500 mm and mean annual temperatures between 8.5 °C and 9.5 °C (see also Figure 2). In total, we have derived 60 climate clusters. The respective weather stations for the 60 climate clusters are listed in Table II. These weather stations have been used to build 33 year long historical time series of daily weather and are the basis for our statistical climate change model. We have selected 34 weather stations representing the 60 climate clusters (Figure 2, Table II) from the StartClim dataset (Schöner *et al*., 2003) by referring to mean annual temperatures and mean annual precipitation sums from the period 1961-1990.

A weather station can be representative for more than one climate cluster. The primal criteria to find a respective weather station for a climate cluster are the mean annual precipitation sums. Mean annual temperatures are adjusted with a correction factor. The temperature correction factor is calculated using the mean annual temperature, which is increasing from 1961 (starting year of classification) to 1975 (starting year of the historical 33 year long daily weather time series) by 0.75 °C. Consequently, the average annual temperature trend is approximately 0.05 °C per year. The temperatures are corrected for each climate cluster using the differences between the class mean together with the fifteen-year temperature trend of 0.75 °C and the mean annual temperature from the period 1975-2007.

Consequently, we have built 33 year long daily weather time series of historical meteorological data (1975-2007) for the 60 climate clusters including the temperature corrections. The StartClim dataset (Schöner *et al*., 2003) has not been used, because it only contains information on temperature, precipitation and snow depth, but data on solar radiation, relative humidity, and wind speed are often needed as well. Therefore, the original daily weather observations from ZAMG consist of solar radiation [MJ/m²], maximum and minimum temperature [°C], precipitation [mm], relative humidity [fractions between 0 and 1], and wind speed [m/s]. However, solar radiation data are often missing, which have been replaced by the TAWES dataset (Felkel *et al.*, 1992) containing daily data on solar radiation for many weather stations in Austria since the early 1990ies. If no TAWES station data were available for the cluster station, we used the TAWES station nearest to the cluster station. Furthermore, solar radiation data are often only available for different time periods. Thus, we created monthly statistics of solar radiation to generate daily values using the weather generator WXGN (Sharpley and Williams, 1990). WXGN has also been used to fill missing data of the other weather parameters in the historical period 1975-2007.

Table II. Respective weather stations for the 60 climate clusters in Austria

longitude (DD)	latitude (DD)	location of stations	climate cluster number			
15.911	46.867	Bad Gleichenberg	909			
9.761	47.511	Bregenz	2007			
15.267	47.417	Bruck an der Mur	807	808	809	
16.561	47.861	Eisenstadt	710			
9.611	47.278	Feldkirch	1259			
10.194	46.978	Galtür	1250	1251	1253	
15.442	46.988	Graz Flughafen	908			
15.448	47.080	Graz Universität	910			
16.550	48.20	Groß Enzersdorf	510			
14.518	47.893	Großraming	1507	1508		
10.350	47.260	Holzgau	1505	1506		
14.191	48.241	Hörsching	810			
11.385	47.261	Innsbruck Universität	906			
13.907	46.678	Kanzelhöhe	1258			
13.840	48.606	Kollerschlag	1257			
14.132	48.055	Kremsmünster	1009			
12.164	47.574	Kufstein	1509	1510		
16.385	48.726	Laa an der Thaya	509			
15.194	47.050	Lobming	1007	1008		
14.250	46.450	Loiblpass	2005	2006		
11.850	47.150	Mayerhofen	1256			
12.717	47.150	Mooserboden	2000	2001	2003	
15.689	47.604	Mürzzuschlag	1005	1006		
11.027	46.867	Obergurgl	1000	1001	901	903
16.370	48.559	Oberleis	607	608	609	
13.000	47.217	Rauris	1255			
16.571	48.111	Schwechat	610			
14.783	47.283	Seckau	907	905		
12.353	46.919	St. Jakob im Defereggental	1003			
15.632	48.202	St. Pölten	709			
15.211	48.628	Stift Zwettl	705	706	707	708
13.810	47.125	Tamsweg	803	805	806	
13.673	46.604	Villacher Alpe	1500	1501	1503	
13.632	47.717	Bad Ischl	2008	2009		

3. Method

3.1 Properties of temperature and precipitation

The original ZAMG data may be inconsistent due to changes or malfunctioning of the measuring instruments, adjustments in the observation methods, or relocations of the weather stations. Therefore, the time series data are not necessarily adequate for trend analysis (Heilig, 2007). Consequently, a complementary dataset - the monthly HISTALP data (Auer *et al.*, 2007) - was used for the temperature trend calculation, because it has been homogenized. We have calculated temperature trends between 0.03 °C per year and 0.04 °C per year in the Northern part and between 0.04 °C per year and 0.05 °C per year in the Southern part of Austria (left picture in Figure 3). For individual HISTALP weather stations the representativeness for a whole cluster is low, especially in the winter season. The station Zwettl (48.6° N and 10.17° E) is for example located in a cold pool which is a small scale effect and not necessarily valid for the whole weather cluster. Therefore, we decided to investigate the temperature trends without using the winter season (right picture in Figure 3). We have only investigated the vegetation period from March to November, because our major focus of applied climate change analysis is on agricultural issues. This approach has produced a more uniform trend with only one outlier namely Seckau (47.28° N and 14.78° E) with 0.03 °C per year. We have determined one national mean temperature trend on linear and seasonal time dependencies of approximately 0.05 °C per year for Austria, which corresponds to a temperature increase of 1.65 °C in 33 years.

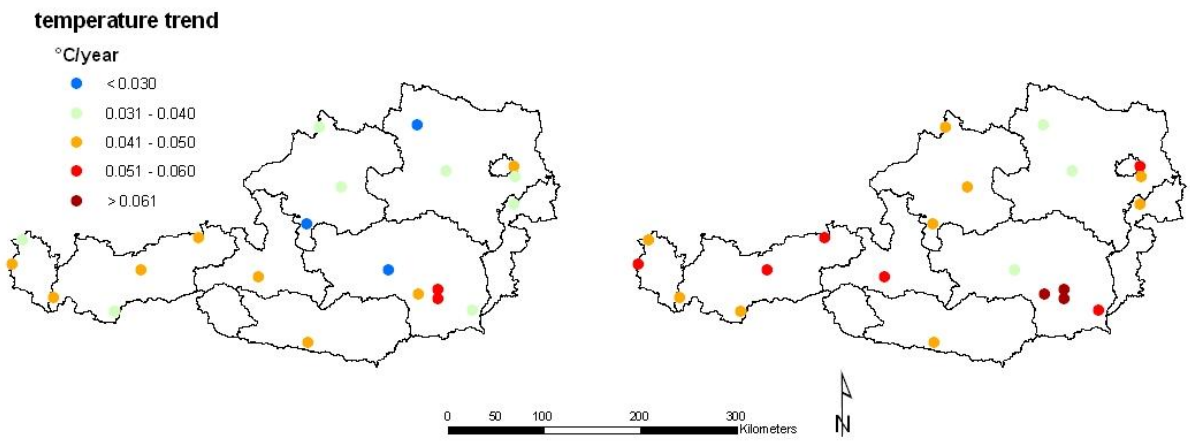

Figure 3. Linear temperature trends in Austria between 1975 and 2007 of selected HISTALP weather stations considering the annual period (left), and the vegetation period from March to November (right)

Unlike temperature, no clear linear or seasonal trends are discernible in the precipitation data, because of a large random noise. Consequently, we assume that there is no trend in precipitation for any of the climate clusters in the next three decades. However, several scenario assumptions for precipitation have been made as described in section 4.

3.2 The statistical climate change model

The statistical climate change model (Strauss *et al.*, 2009) is based on historical daily meteorological data. It is used to project stochastic daily weather data for the period 2008-2040. We assume that climate variability is not changing significantly in the next three decades and corresponds to the variability observed in the past (1975-2007). The statistical climate change model describes time dependencies in terms of linear and seasonal patterns in the following way:

$$Y_t = \alpha + \beta t + \gamma_1^{(s)} \sin(2\pi t) + \gamma_1^{(c)} \cos(2\pi t) + \gamma_2^{(s)} \sin(4\pi t) + \gamma_2^{(c)} \cos(4\pi t) + \varepsilon_t \qquad (1)$$

where Y is the climate variable (only applied for maximum temperature and minimum temperature) and t is the calendar time in years. The sines and cosines represent seasonal variability. The random residual ε follows a Gaussian distribution.

We consider one average historical temperature trend for Austria which leads to fixed regression coefficients for maximum and minimum temperatures representing the effects per day. The residuals are defined as the difference between the daily observations in each climate cluster and the average historical temperature trend. The particular use of daily temperature residuals to represent future variations is an integral part of the statistical climate change model. The stochastic feature of the statistical climate model comes from picking a random month in the past to allocate temperature residuals coming from the average historical temperature trend and observations of all the remaining weather parameters (solar radiation, precipitation, relative humidity and wind) within this month. For example, the random generator has selected for the first year of estimation 2008 January residuals/observations from 1980, February residuals/observations from 1976, March residuals/observations from 1998, and so forth. It results in one set of weather data for the period 2008-2040. Thus, the temperature trend in the future scenarios can vary from the average historical temperature trend in the sense that the warming can be lower or higher due to the allocation of temperature residuals. The bootstrap re-sampling has been repeated 30 times for the period 2008-2040 to get a better estimate of the spread of the statistical climate change scenarios.

To assure not only the consistency in time but also in space, we consider per bootstrap re-sampling one random draw for all climate clusters. For example, the random generator has selected for the first year of estimation 2008 the month January in the year 1980 from which the daily residuals/observations have been used for all particular climate clusters. Thus, we have used in total 30 random draws that are responsible for the re-allocation of data and residuals of temperature for all climate clusters.

4. A climate change spectrum for the period 2008-2040

Temperature and precipitation scenarios have been developed to build a climate change spectrum for the period 2008-2040. We have selected three out of the 30 bootstrap re-allocations (section 3.2), where the average temperature (mean of minimum temperature and maximum temperature) for the period 2008-2040 is at its maximum, average, and minimum. These three temperature scenarios with the corresponding data of solar radiation, precipitation, relative humidity and wind are the basis for exogenously assumed changes in precipitations. The daily precipitation data of all three temperature scenarios have been manipulated such that we have

(i) left precipitations without manipulations,

(ii) added 5%, 10%, 15%, or 20% of the daily precipitation,

(iii) subtracted 5%, 10%, 15%, or 20% of the daily precipitation,

(iv) increased daily winter precipitation (September to February) by adding 5%, 10%, 15%, or 20% and decreased daily summer precipitation (March to August) such that the annual precipitation sums remain unchanged, and

(v) increased daily summer precipitation by adding 5%, 10%, 15%, or 20% and decreased daily winter precipitation such that the annual precipitation sums remain unchanged.

The temperature and precipitation scenarios constitute our climate change spectrum for Austria and the period 2008-2040.

5. Constructing climatic conditions for the period 1975-2007

The original observed weather time series for the period 1975-2007 can be requested at ZAMG. To allow the user a comparison of the climate change spectrum for the period 2008-2040 to the climatic conditions in the period 1975-2007, we constructed three scenarios for the period 1975-2007 following the same procedure as described in section 4, but without considering the precipitation spectrum. In more detail, we have selected three out of 30 bootstrap re-allocations for the period 1975-2007 where the mean temperature (mean of minimum temperature and maximum temperature) for the period 1975-2007 is at its maximum (scenario 1), average (scenario 2), or minimum (scenario 3). These three temperature scenarios are available together with the corresponding data of solar radiation, precipitation, relative humidity and wind. Their statistics reproduce well the statistics of the weather observations. Thus the three scenarios out of 30 bootstrap re-allocations can be used as base run scenarios.

6. Discussion

Eitzinger *et al*. (2009) found no significant changes in the precipitation patterns in Central Europe. However, they estimate that precipitation sums are slightly increasing in winter whereas in summer they are rather decreasing. Moreover, small scale and regional differences have to be expected as precipitation is highly influenced by mountainous landscapes (e.g. windward side of a mountain in comparison to the lee side). The scenarios of REMO-UBA (Jacob *et al*., 2008) predict an increase of precipitation in Central Europe of about 10%. More than 10% increase of precipitation is modeled in parts of Lower Austria and in Sachsen-Anhalt (Germany). In the alpine region, the spectrum of precipitation changes in the 21st century constitutes of increases in Switzerland and decreases in Austria (Eitzinger *et al*., 2009). These results confirm that the uncertainty of regional scenarios on precipitation remains high as regional structures and model parameterizations can vary substantially between RCMs.

The GCMs identify two significant changes in precipitation patterns in Europe: Lower precipitation amounts are expected between the Mediterranean area and the Iberian Peninsula, and higher precipitation amounts are expected in the northern regions (Scandinavia and the north of Russia). These two spatially differing trends can lead to an increase of inter-annual

variability of seasonal precipitation in Austria (Seneviratne *et al.*, 2006, Heilig, 2008). In years with a greater impact of the anti-cyclone over the Azores, the weather conditions can be drier and hotter in summer than currently observed. In years with a greater weather impact from Scandinavia and from the North Sea, the summers can be more humid and also warmer.
An increase of precipitation intensity is likely due to the temperature increase (Böhm, 2008) as warmer air-mass can hold more humidity. The frequency of heavy rainfall events can increase in the Northern Alps, when the amount of the annual precipitation sum increases (Schönwiese, 2008). The GCMs and RCMs are not yet accurate enough for quantitative assessments of changes in heavy rainfall events and thunderstorms with or without hail. However, in our uncertainty spectrum of climate change data the effects of increasing temperatures can be considered in some respects even though we assume that the climate variabilities in the future are similar to the climate variabilities in the past.
The temperature scenarios by IPCC show global increases between 0.5 °C and 7.5 °C until the end of the century (Eitzinger *et al.*, 2009). The highest increase is expected in the Arctic region (North Pole). A pronounced East-west temperature gradient is discernible in Central Europe, with higher temperatures in the Eastern part of Europe. This trend is also valid for Austria. The climate change signal from our statistical climate change model is shown in Figure 4.

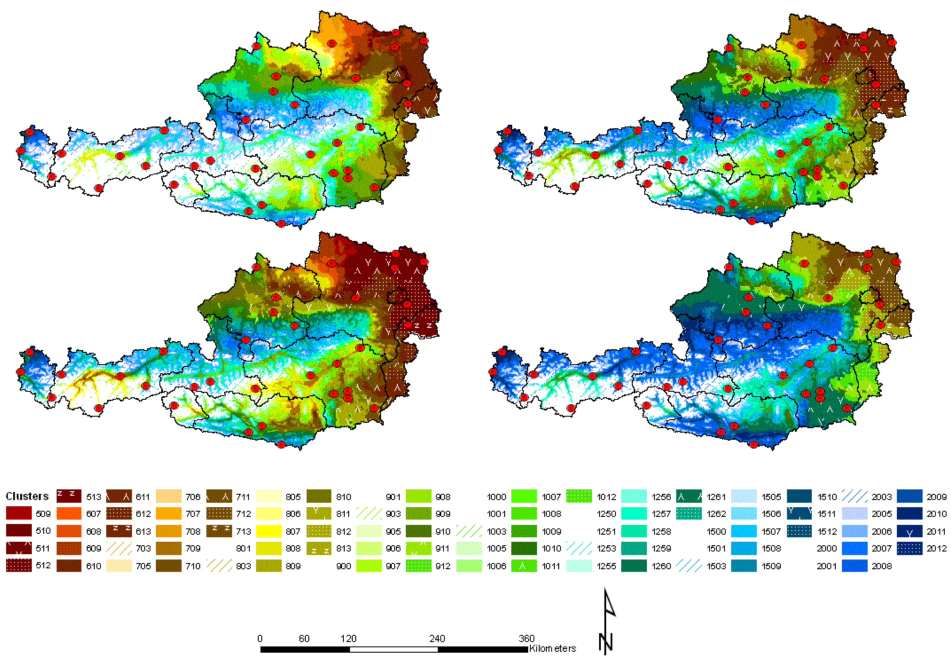

Figure 4. Climate clusters in Austria between 1975 and 2007 (upper left), and between 2008 and 2040 (upper right), as well as with 20% lower annual precipitation sums (lower left), and with 20% higher annual precipitation sums (lower right)

The figure shows climate clusters between 1975 and 2007 and between 2008 and 2040 for different precipitation scenarios (lower and higher precipitation sums of 20%). The darker colours in Figure 4 as compared to Figure 1 indicate a general shift to higher temperature classes. The period 2008-2040 shows two new temperature classes compared to the period 1975-2007 (mean annual temperature classes of 11 °C, 12 °C and 13 °C). More details to the developed dataset are available in Strauss *et al*. (2010).

7. Description of data structure, files and data availability

The complete dataset is freely available at: http://www.landnutzung.at/Ergebnisse.html. The datasets include:

- austria_cluster.mdb: Microsoft Office Access database giving the location of climate clusters in the Austrian territorial grid
- austria_cluster.*: location of climate clusters in the Austrian territorial grid in GIS-readable format
- *.zip: zipped daily climate data in the period 1975-2007 and 2008-2040 for climate clusters in ASCII format.

Identification of grids and appropriate cluster numbers are in austria_cluster.mdb. The grid projection is ETRS 1989 LAEA with one km² resolution. ObjectID gives a running identification number. Cellcode gives the grid code in meters and is unique. For example, 1kmE4285N2683 stands for X-coordinate (East of Origin) 4285000 meter, and Y-Coordinate (North of Origin) 2683000 meter. The grids are also given in the corresponding decimal degrees of latitude and longitude. PGNR is the index number of the respective municipality, GRIDCODE is the climate cluster number and ELEV is the sea level in meters per grid (latter is missing on the Austrian border).

Each one km² grid contains information on the municipality and climate clusters (Majority). The sea level is based on the Shuttle Radar Topography Mission (SRTM) 90 m digital elevation model (http://www.mapmart.com/DEM/InternationalDEMBundle.htm).

The same information is included in the file named austria_cluster.shp. This is the shape file (Polygon), which can directly be read into GIS. The file Austria_cluster.lyr is the respective layer file and represents the colored climate clusters.

The coding of data files of climatic conditions in the period 1975-2007 is xxxxyypa.zip, where xxxx is the number of the climate cluster as shown in Table II (a 0 is at the beginning, when the number has less than four digits), yy is the temperature scenario (01 = maximum, 02 = average, and 03 = minimum), and 'pa' stands for 'past'. In total, three zipped files (for each scenario one zipped file) are available, where each of them contains data of the 60 climate clusters.

For example, the file 070503pa.dly in the zipped file xxxx03pa.zip refers to:

xxxx= 0705 Cluster number 705,

yy = 03 temperature scenario 03 (minimum temperature scenario), and

pa = in the past.

The coding of data files of climate change scenarios for the period 2008-2040 is xxxxyyzz.zip, where xxxx is the number of the climate cluster as shown in Table II (a 0 is at the beginning, when the number has less than four digits), yy is the temperature scenario (01 = maximum, 02 = average, and 03 = minimum), and zz indicates the precipitation scenarios from 01 to 17:

01: unchanged precipitation of corresponding temperature scenario
02: + 5% of daily precipitation
03: +10% of daily precipitation
04: +15% of daily precipitation
05: +20% of daily precipitation
06: - 5% of daily precipitation
07: -10% of daily precipitation
08: -15% of daily precipitation
09: -20% of daily precipitation
10: + 5% of daily winter precipitation
11: +10% of daily winter precipitation
12: +15% of daily winter precipitation
13: +20% of daily winter precipitation
14: + 5% of daily summer precipitation
15: +10% of daily summer precipitation
16: +15% of daily summer precipitation
17: +20% of daily summer precipitation

In total, 51 zipped files (for each scenario one zipped file) are available for the period 2008-2040, where each of them contains data of the 60 climate clusters.
xxxx is the number of climate cluster based on the data in the period 1961-1990. The numbers of climate clusters are kept for the period 2008-2040 even if the climate conditions in the clusters change due to rising temperatures and different precipitation patterns.

For example, the file 07050306.dly in the zipped file xxxx0306.zip refers to:

xxxx = 0705	Cluster number 705,
yy = 03	temperature scenario 03 (minimum temperature scenario), and
zz = 06	precipitation scenario 06 (- 5% of daily precipitation).

The data content of *.dly files are:

year	column 1
month	column 2
day	column 3
solar radiation [MJ/m²]	column 4
maximum temperature [°C]	column 5
minimum temperature [°C]	column 6
precipitation [mm]	column 7
relative humidity [0-1]	column 8
wind speed [m/s]	column 9

The data should be cited as:
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Contact:
Franziska Strauss
University of Natural Resources and Applied Life Sciences Vienna
Department of Economics and Social Sciences
Institute for Sustainable Economic Development
Feistmantelstraße 4, 1180 Vienna, Austria
Tel: +43 (0)1 47654 3666, Email: franziska.strauss@boku.ac.at

8. Summary and Conclusions

A dataset of climate change for Austria with temporal and spatial resolution of one day and one km² has been developed based on historical daily weather data from 1975 to 2007. The mean annual temperatures in Austria are likely to rise by about 1.6 °C in the next 33 years. This estimated temperature trend is also confirmed in the literature (Eitzinger *et al*., 2009, Gobiet *et al*., 2009). We assume in our statistical climate change model that means and variances of the distributions of solar radiation, precipitation, relative humidity and wind do not change in the next three decades. This assumption is motivated by their constancy observed in the past 33 years on average. Consequently, the dataset may not be appropriate in conjunction with changing occurrence of extreme weather events. However, we have developed a climate change spectrum with three alternative temperature and 17 alternative precipitation scenarios reflecting climate uncertainties in the mountainous region Austria (compare to e.g. Gobiet *et al*., 2009). In addition, when comparing our approach to the downscaling methods in regions where uncertainties are high due to complex topographies (Schiermeier, 2010), we see an advantage of our approach, because the small regional effects are automatically included in our climate clusters.

Our new high resolution climate change dataset for Austria and until 2040 is useful for studies related to near-future adaptations and mitigations analysis in climate relevant sectors such as agriculture, energy, and tourism. Users of the dataset are kindly invited to apply and comment the dataset and should cite this document as reference. The digital datasets can be downloaded at: http://www.landnutzung.at/Ergebnisse.html.

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Bestelladresse:

Universität für Bodenkultur Wien
Department für Wirtschafts- und Sozialwissenschaften
Institut für nachhaltige Wirtschaftsentwicklung
Feistmantelstrasse 4, 1180 Wien
Tel: +43/1/47 654 – 3660
Fax: +43/1/47 654 – 3692
e-mail: Iris.Richter@boku.ac.at
Download unter: http://www.wiso.boku.ac.at/h731_publikationen.html