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FUTURE BIOCLIMATE CONDITIONS FOR AUSTRIA BASED ON CLIMATE SCENARIOS

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Abstract
The IPCC quantifies Heat Stress as a combination of air temperature and air humidity. In order to describe the future bioclimatic conditions in a human-biometeorological manner the analysis of a modern thermal index has been chosen. The PET (Physiologically Equivalent Temperature) allows the assessment of the effect of the thermal environment based on the energy balance of humans including thermo-physiological information. The required meteorological data for the calculation of PET are air temperature, relative humidity, wind velocity and mean cloud cover.
Regarding future changes of the climate, PET calculations for the time slices 1961 and 1990 and also 2070 and 2100 have been run in 0.5 ° resolution. By the use of statistical regression for the 0.5 ° resolution the results have been downscaled to 1 km resolution in order to identify and quantify the areas in Austria, which will be affected bioclimatologically. The constructed maps present current and future climatic conditions and also differences for the different time slices and SRES-scenarios of the IPCC. Maps of the difference between the PET and air temperature have been constructed to show that the used thermal indices, which have been applied by the IPCC underestimate the expected thermal bioclimate conditions of the future climate.

Key words
Physiologically Equivalent Temperature, Scenarios for tourism, recreation and health issues

Introduction

The thermal bioclimate is of high interest for decision makers in the public health sector as well as for the population in general. The only existing description of the thermal human bioclimate, the "bioclimatic map of Austria" has been developed in 1983 (Rudel et al., 1983). It is based on two "simple complex parameters", with the equivalent temperature as the thermal load and the cooling power as a measure for cooling stress.

Throughout the 21st century, air temperature will continue to rise, according to computer simulations performed with global circulation models (GCMs). In addition to air temperature, the output of these GCMs includes a range of climate variables, such as air humidity, wind speed and cloud cover. Based on these variables, further analysis of thermal comfort and the impacts of extreme heat conditions on humans can be undertaken. The IPCC quantifies Heat Stress as a combination of air temperature and air humidity. In order to describe the future bioclimatic conditions in a human-biometeorological manner the analysis a modern thermal index has been chosen. The PET (Physiologically Equivalent Temperature) allows the assessment of the effect of the thermal environment based on the energy balance of humans including thermo-physiological information. The data for the calculation of the PET came from climate models. The required data are for the climatic parameters air temperature, relative humidity, wind velocity and mean cloud cover as the necessary inputs for Physiologically Equivalents Temperature.

Area of investigation

Due to steep slopes and its location in the core of Europe, Austria has an extremely differentiated climate, compared with its relatively small area. The diversity of the different climatic zones is caused by the various orographic characteristics and by the interaction of atlantic and continental climate influences. (Rudel et al., 1983). Its central geographical location in Europe increases additionally the attractiveness of the country for a broad population spectrum, so that numerous groups of interest have a high need of a bioclimatic zoning of Austria (Hammer et al., 1990a and b).

Geographically situated between 46.5° and 49° northern latitude, and 9.5° and 17° eastern longitude, Austria covers 83855 km². Since its 201 climate stations are well distributed over the country and measure extensive and almost complete series of meteorological data, Austria is the perfect country for (bio)climatic case studies.

Thermo-physiological assessment of Austria

Heat balance models of the human body have gained acceptance in the field of assessment the thermal comfort. The heat balance equation of the human body takes into account the metabolic rate (internal energy production by oxidation of food), the physical work output, the net radiation of the body, the convective heat flow, the latent heat flow to evaporate water into water vapour diffusing through the skin, the sum of heat flows for heating and humidifying the inspired air, the heat flow due to evaporation of sweat and the storage heat flow for heating or cooling the body mass. All the required components of the above equation can be calculated using synoptic/climatological and astronomical data (VDI, 1998, Matzarakis et al, 2000) plus physiological parameter. The necessary meteorological inputs are air temperature, air humidity, wind speed, short and long wave radiation fluxes as well as physiological parameters as sex, weight-height-skin surface, activity level, and clothing factor. From the meteorological input data the radiant fluxes are most difficult to deal with, because measuring data are more often than not available. In this work we used the physiologically equivalent Temperature (PET) (VDI, 1998). The advantage of PET compared to other thermal indices also obtained from the human energy balance is the widely known unit °C. Here the internal heat production was set to 80 W and the heat transfer resistance of the clothing to 0.9 clo (Matzarakis and Mayer, 1996).

Simulations and downscaling

Based on the IPCC SRES Scenarios (IPCC 2000), the PET values for the CLINO 1961 – 1990 and the period 2070 – 2100 have been calculated for expected future climate conditions. The existing data sets for climatological data (New et al. 2002) include all the relevant data for a human-biometeorological analysis. For the present analysis the IPCC scenarios A1F, A2A, B1A and B2A have been used.

Figures 1a and 2a shows the winter and summer (lower) spatial distribution for CNTRL conditions (1961 – 1990) of PET for the wider area of Austria in 1 km spatial resolution based on the Hastings et al. (1999) data. The b) and c) parts of the Figure 1 and 2 show the differences of the A1F rescp. B1A scenario minus the CNTRL conditions of the figures for winter and summer.

Results

The mean PET conditions during winter are ranging from less – 20.0 and –6 for the biggest area of Austria. Only low lying areas show PET conditions higher than –6 and can reach PET conditions near 0 °C (Figure 1a). For summer the PET conditions (Figure 2a) are ranging from lower than 0 °C in the higher elevated areas and reaching mean conditions higher than 20 °C in the low lying areas in the eastern, southern and western parts of the country.

Figure 1b and 2b show the expected conditions for the A1F scenario. It can be extracted that the thermal bioclimatic conditions are expected to change strongly based on the A1F scenario for summer, covering changes more than one to two stress levels for summer in the whole area, while in winter, the expected changes range one to two stress levels. For the more moderate scenario B1A the expected conditions are ranging about one thermal stress level.
Table 1 shows the maxima and minima PET-conditions for the area of Austria for the CLINO period and the Differences Scenario minus CLINO. The highest changes will occur during summer followed by autumn and spring. During winter the expected PET conditions are lying in the frame of one stress level for A1F and lower for the other scenarios.

Table 1: Seasonal maximum and minimum conditions for the CLINO and the differences Scenario – CLINO for the used scenarios

		Winter	Spring	Summer	Autumn
Base	Max	3.9	16.3	30.2	18
	Min	-14.9	-7.7	3.2	-4.6
A1F	Max	5.0	5.6	10.7	8.1
	Min	5.0	4.3	6.8	6.4
A2A	Max	3.1	4.7	9.5	6
	Min	4	3.4	5	5
B1A	Max	2.7	2.4	6.4	4
	Min	3	1.8	3.2	2.8
B2A	Max	2.6	3	6.7	4.3
	Min	2.5	2.5	3.5	3.5

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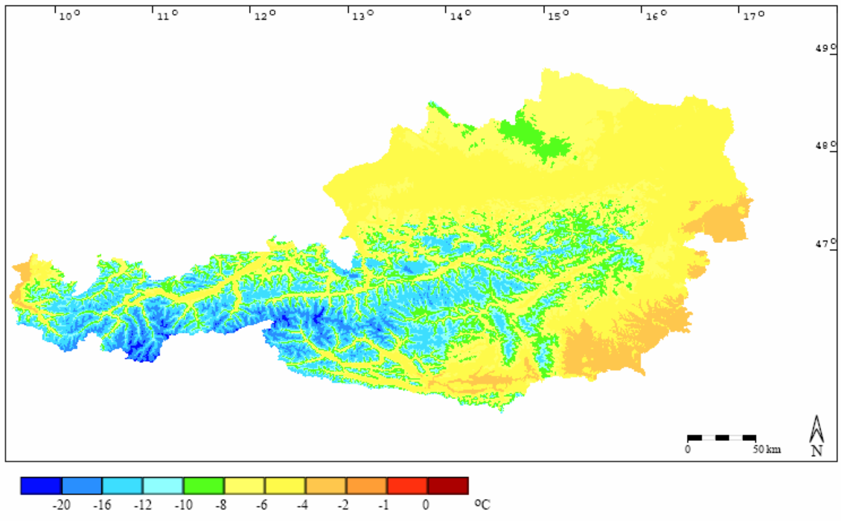
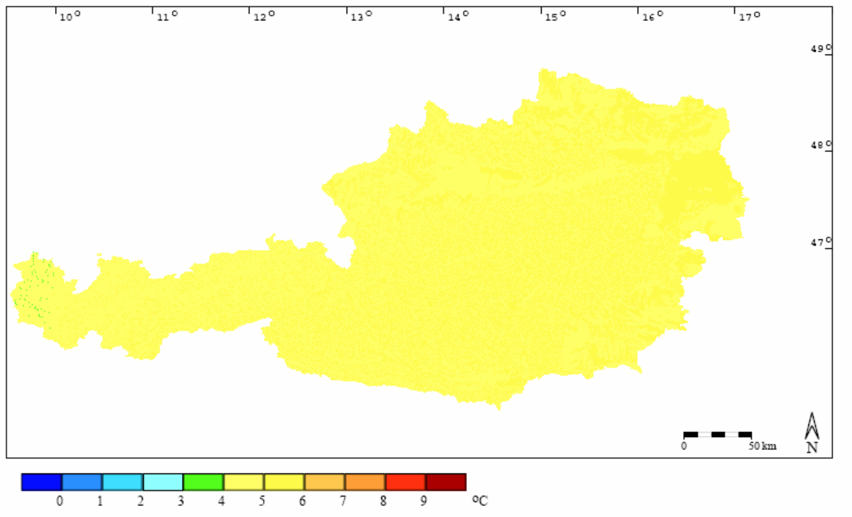
a)



b)



c)

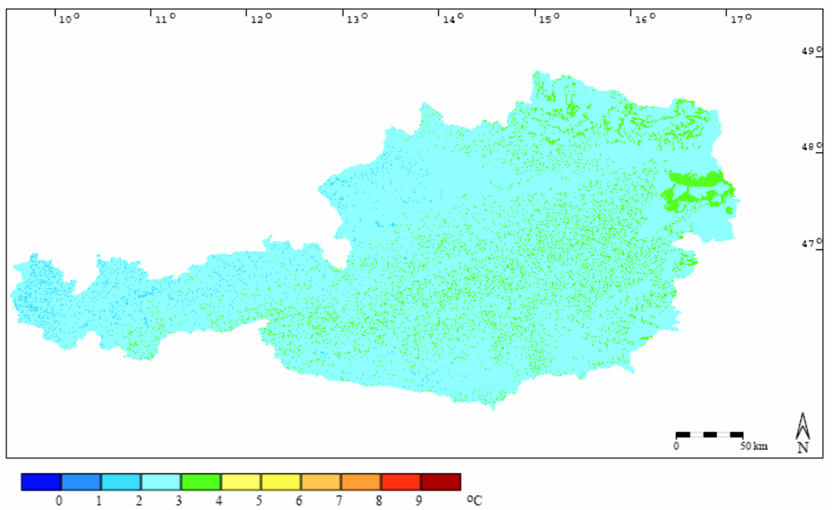


Figure 1: Geographical distribution of PET for a) CLINO, b) A1F - CLINO, c) B1A – CLINO in Austria in Winter (December, January, February)

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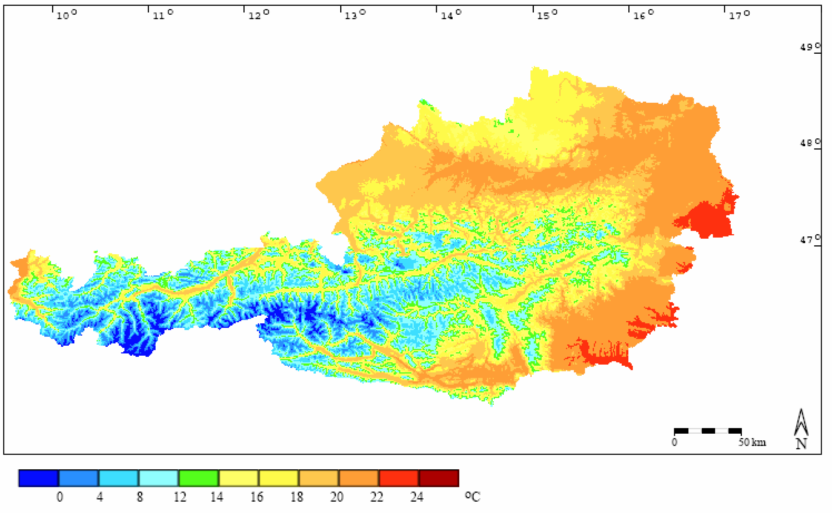
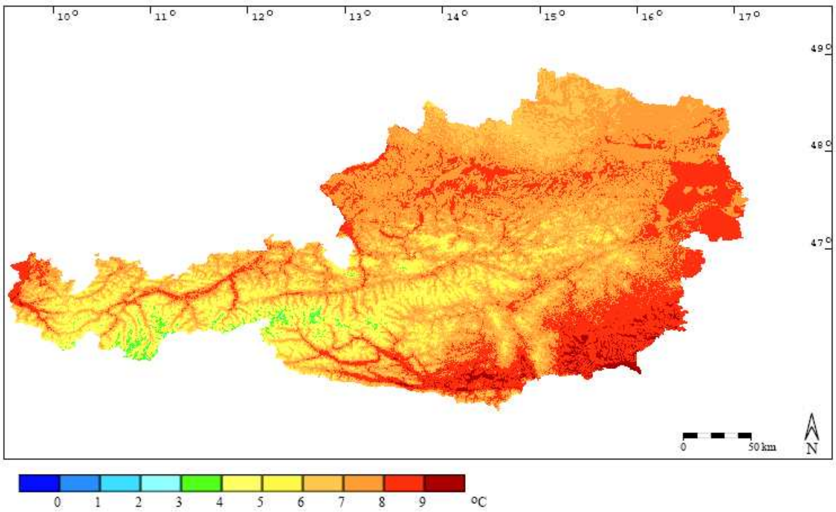
a)



b)



c)

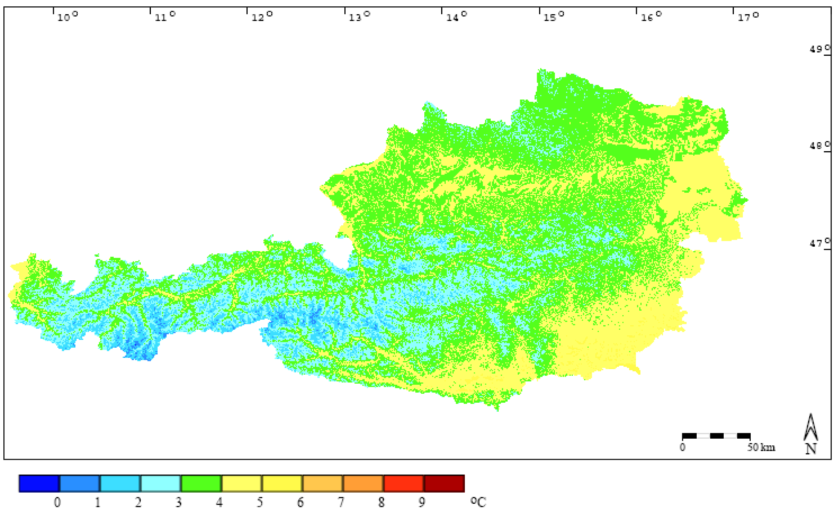


Figure 2 Geographical distribution of PET for a) CLINO, b) A1F - CLINO, c) B1A – CLINO in Austria in Summer (June, July, August)

Conclusions

The constructed maps present current and future climatic conditions and also the differences for the different time slices and SRES-scenarios of the IPCC. Maps of the difference between the Physiological Equivalent Temperature show expected changes of thermal bioclimatic conditions. The results presented here can be considered as a first approach because of the uncertainties of the climate data from the scenarios and the simple downscaling technique.

Nevertheless results offer fundamental information for different stakeholder and authorities for purposes like tourism/recreation and health issues for present and expected bioclimatic conditions. Future analysis and projections should include land use conditions and changes in order to quantify more precise future expected thermal bioclimatic conditions

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