The future bioclimatic conditions in Austria under the aspect of climate change scenarios

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1. INTRODUCTION

Austria - situated between 46° and 49° northern latitude - and its economy are strongly affected by climate change and its consequences (Koch et al., 2004). Two thirds of the GDP comes from the service sector, where Austria profits particularly from tourism (Matzarakis et al., 2007a). The effect of climate change on winter sports has been topic of many scientific studies but additionally also summer tourism will be affected. The outcome of most of these studies was that a shortening of the winter sports season will occur in the next decades (Abegg, 1996, OECD, 2007). The logical conclusion is an extension of the summer season. The climatic tourism potential determined with meteorological parameters will change in future. In the present investigation special attention is given on summer tourism (Rudel et al., 2005, Matzarakis, 2006).
But first of all one has to answer the question whether one can solve the problem just to apply simple climate parameters like e.g. air temperature, or snow cover, etc. to describe the present und future climatic tourism potential conditions or one has to use interdisciplinary approaches. In the context of the project “StartClim 2006” we decided to use an integral attempt based on climatological, human-biometeorological and climatic – tourism (leisure time and tourism) methods. This approach combines the thermal conditions with physical elements (rain, wind) and aesthetic factors (sunshine, clouds, visibility) and gives thus a comprehensive quantitative description of the climatic tourism potential. In addition, we focused our interest in the thermal facet of climate, which is important for tourism and recreation and health issues as well (Rudel et al., 2005, Matzarakis al., 2007c).

2. METHODS AND DATA

The physiologically equivalent temperature PET, which considers the influence of the complete thermal environment (i.e. air temperature, air humidity, and wind velocity as well as short and long-wave radiation) on humans, describes the thermal facet of the climate for tourism purposes (Höppe, 1999). The frequency of certain PET classes quantifies thermal suitable conditions for leisure and recreation and gives information about cold and heat stress. Additionally, the term „sultriness“ is calculated with the classical criterion of the excess of a certain water vapour pressure (de Freitas, 2003, Matzarakis, 2006).
The aesthetic facet covers factors such as duration of sunshine, cloudiness and fog, range of visibility and length of day. We integrated this aspect with the amount of cloudless or bright days as well as with the number of days with fog.
The physical facet, which comprises influences such as wind, rain, snow conditions, air quality and extreme weather situations, is described by the factors high wind velocity and precipitation (days with few or no rain as well as long lasting precipitation events).
Basis for the investigation are climate data of the Central Institute for Meteorology and Geodynamics (ZAMG) of the period 1950 - 2005 of eleven selected stations well distributed over the country to give a representative cross section of the different landscape – and climate regions.
The future climatic tourism potential of Austria is calculated by scenario runs of the REMO model of the Max-Planck Institute for Meteorology in Hamburg and covers the period 1961-2050. We used the A1B emission scenario (Jacob et al., 2001, UBA, 2005).

3. RESULTS

First, we focused on the thermal - bioclimate and on precipitation conditions, because these parameters represent the most important factors for tourism and recreation. Instead of the often used monthly average values the frequencies of these parameters are calculated in the high temporal

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resolution of 10 days - each month is divided into three time intervals (see figure 1 and 2).
In the next step we developed and applied a flexible Climatic Tourism Information Scheme (CTIS) to get an integral description of the climatic tourism potential. Flexible means one can select and include different climatic parameters that are relevant for a specific tourism-sector in a specific climate region. For summer tourism in Austria we chose CTIS factors as thermal suitability for recreation and leisure (like cold stress, heat stress, and sultriness), sunshine duration, precipitation poverty, fog situations, rain conditions as well as stormy days. Because the diagram covers the whole year it can be used also for winter tourism and ski potential. It is here described by the days with snow cover of more than 10 cm (Matzarakis, 2007, Matzarakis et al., 2007c). Figure 3 shows the CTIS diagram for 1961 to 1990 and figure 4 for the period 2021 to 2050 both for Vienna.

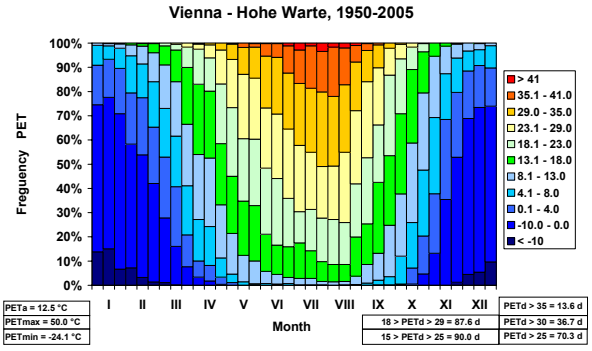

Fig. 1. Bioclimate diagram (PET-frequencies) for Vienna for 1950 - 2005 and amount of days with PET-threshold values.

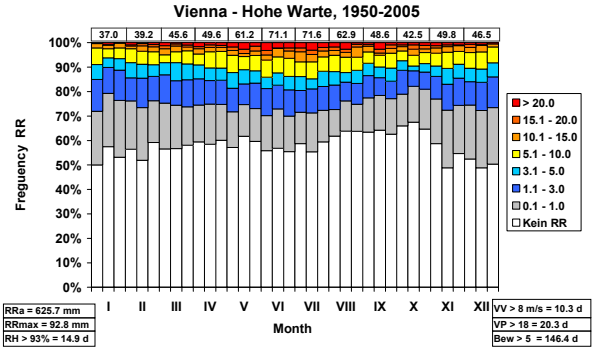

Fig. 2. Precipitation frequencies in Vienna for 1950 – 2005.

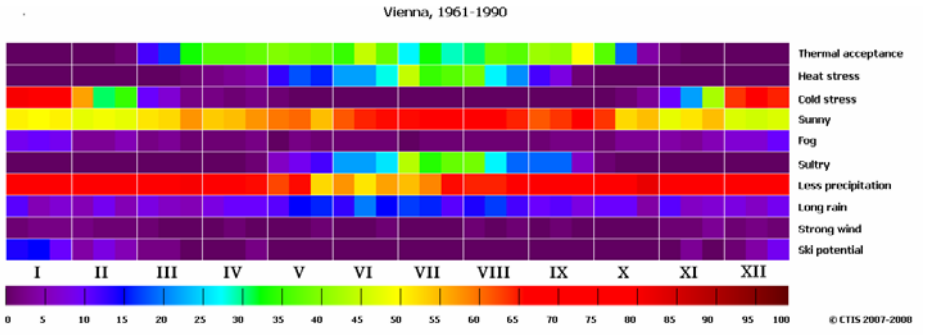

Fig. 3. CTIS-Diagram for Vienna based on the A1B-climate scenario for the period 1961 – 1990.

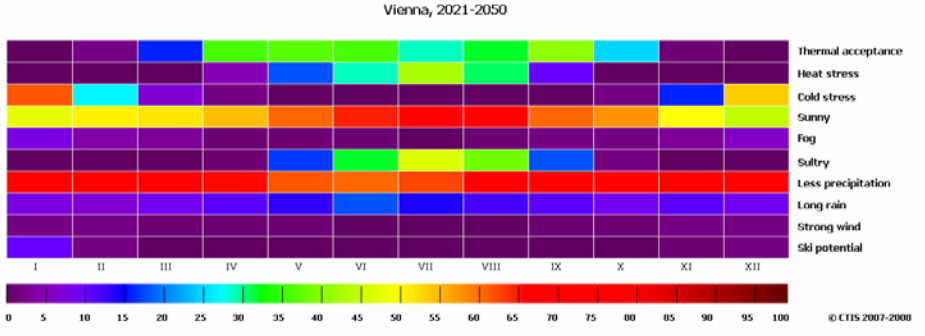

Fig. 4. CTIS-Diagram for Vienna based on the A1B-climate scenario for the period 2021 – 2050.

In addition, our interest was to quantify the thermal bioclimatic conditions (based on PET) for the middle and the end of the 21st century. Therefore, we produced maps for the periods 1961-1990, 2021-2050 and 2071-2100 for the A1B scenario based on the REMO data (Jacob et al., 2001, UBA, 2005) and related to PET conditions and to the thermal facet of CTIS (Matzarakis, 2007). Figure 5 shows the conditions of cold stress (PET < 0 °C) for the used periods. The conditions with thermal acceptable

conditions (18 °C < PET < 29 °C) are shown in the maps of figure 6. Finally, the conditions with PET > 35 °C (heat stress) are shown in Figure 7.
The amount of days with cold stress will decrease for the period 2010-2050 about 10 days and for the late three decades of the century more than 20 and up to 50 days especially in the low lying areas. Due to the elevation and geography of a region the conditions for thermal acceptable conditions will decrease and increase in some areas respectively.

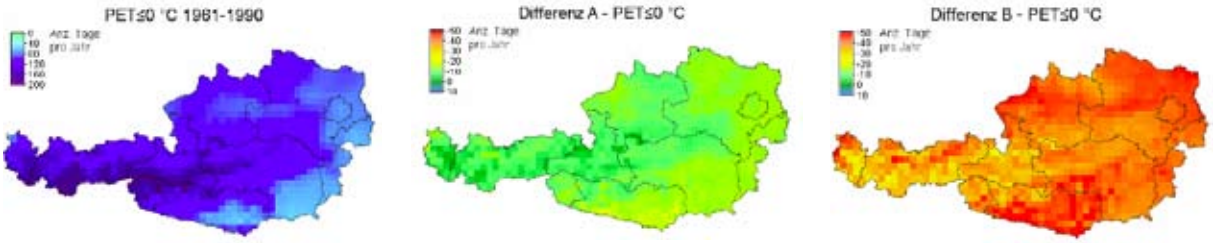

Fig. 5. Maps for cold stress (PET < 0 °C) in Austria for the periods 1961-1990, difference A (period (2021-2050)-(1990-1960)) and difference B (period (2071-2100)-(1990-1960)).

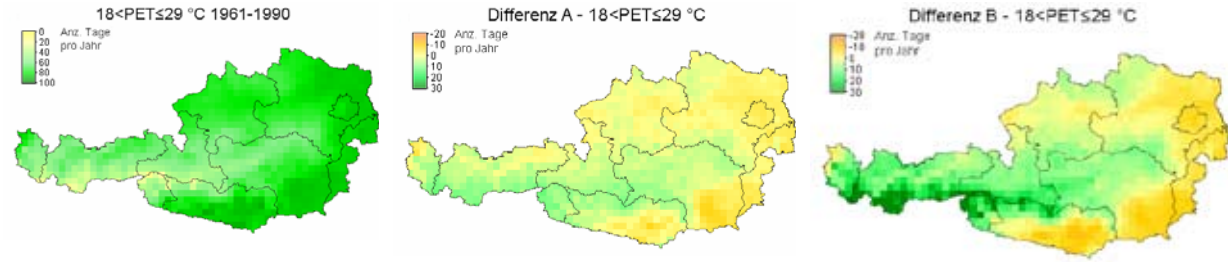

Fig. 6. Maps for thermal acceptable conditions (18 °C < PET < 29 °C) in Austria for the periods 1961-1990, difference A (period (2021-2050)-(1990-1960)) and difference B (period (2071-2100)-(1990-1960)).

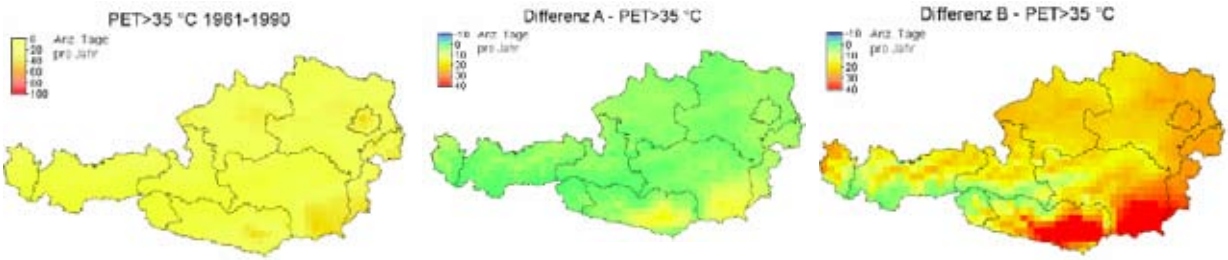

Fig. 7. Maps for heat stress conditions (PET > 35 °C) in Austria for the periods 1961-1990, difference A (period (2021-2050)-(1990-1960)) and difference B (period (2071-2100)-(1990-1960)).

The conditions with heat stress will generally increase for the 20121-2050 period less than 20 days but the situation will get worse for the period 2070-2100, with values lying more than 40 days in the south east part of Austria and less than 10 days in the higher elevations of the country.

4. DISCUSSION AND CONCLUSIONS

Summing up the climate simulations for the period for 2021-2050 we come to following results:

- The amount of the days with cold stress decreases up to 20 days. Especially in the south and southeast of Austria there is a tendency to a shortened period with cold stress.
- Thermal comfortable conditions will increase up to approx. 10 days. But the trends are ambiguous - urban areas show no trend. In the annual course the thermal suitability for recreation and leisure is extended into the late fall.
- According to the scenario the number of days with heat stress will rise in future. However, areas with an elevation above 1000 m are not affected. In the southeast of Austria more than 40 days with heat stress will occur and in generally the heat stress periods will extend. Also the days with sultry conditions will increase nearly in the same manner.

- The number of cloudless and bright days will increase especially in higher elevations. The number of foggy days generally decreases
- In general, there is a slight increasing trend for the days with high precipitation. The frequency of days with few or no precipitation as well as of days with long precipitation events will experience an increase in the summer.
- About the change of strong wind conditions (especially for recreation and leisure) no concrete statement can be made but it seems that there is a slight decreasing trend.
- The potential for ski sports decreases, however, in the higher elevations (above 1600 m) it is ensured.

For thermal bioclimatic conditions and for the period 2071-2100 the situation will change rapidly and the days with heat stress will have a strong increase in the lower lying areas.
The future bioclimatic conditions for the summer tourism in Austria show us an extension of the season with pleasant thermal conditions into the late fall. The increase of days with sultriness can be seen positively for the lake tourism in Austria. However, health and wellness tourism can be negatively affected by changes in sultry conditions. Last but not least the decrease of the summer precipitation events based on the used climate scenario will affect favourably almost all sectors of the summer tourism.

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