CLIMATE CHANGE AND CLIMATE–TOURISM RELATIONSHIPS IN GERMANY

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ABSTRACT Climate change, mitigation and adaptation are highly discussed research topics. Global warming, sea level rise and extreme weather events, e.g., heat waves and storms, are closely related to climate change. That results in both negative and positive consequences for tourism. The project *CAST ("climate trends and sustainable tourism development in coastal and mountain regions")* and its five sub-projects aim to answer the questions as to how the tourism potential will change and how the society will adapt to changing climate conditions. Therefore, the climatic tourism potential will be analysed under modified climate conditions by means of two different climatic sensitive regions in Germany: the North Sea and the Black Forest.

Human-biometeorological computations related to tourism, based on the IPCC scenarios A1B, A2 and B1, are carried out by use of the regional climate model REMO from the Max-Planck-Institute for Meteorology Hamburg. Human-biometeorological, physical, thermal and aesthetic facets are used for the validation of climate-tourism relationships. The aim is to quantify the climatic tourism potential for stakeholders. Frequency classes and frequencies of extreme weather events are generated based on 10-day-intervals. The derived results, in terms of so called climate tourism information schemata (CTIS), and maps are made available for the stakeholders.

KEYWORDS: *Climate change, tourism, CTIS, North Sea, Black Forest*

INTRODUCTION

Tourism is closely linked to weather and climate. Weather and climate are both limited and advantaged parameters. They influence summer and winter tourism, e.g. hiking, swimming, skiing and other activities related to tourism. Therefore, two different climate-sensitive regions will be analysed: a coastal and a mountain area. Many people choose the North Sea and the Black Forest for vacation. In comparison to urban areas, the North Sea and the Black Forest offer beneficial weather conditions, especially in the summer season. In the context of global

warming, these regions will exhibit several risks for the ecosystems and for tourism, but furthermore they remain climatic attractive, predominantly for summer tourism. Sea level rise due to thermal expansion is an enormous threat to coastal areas and low isles. The average rate of rise during the 21st century is very likely to exceed the 1961 to 2003 average rate (1.8 ± 0.5 mm yr^{-1}). In the period 2090 to 2099 under the IPCC scenario A1B, the central estimate of the rate of rise is 3.8 mm yr^{-1}. For an average model, the scenario spread in sea level rise is only 0.02 m by the middle of the century, and by the end of the century it is 0.15 m (IPCC, 2007). On the other hand, global warming influences the snow fall in mountainous regions. The snow season will be shortened and the snow cover will also be reduced. By the late 21st century a 50 to 100 per cent decrease in snow depth in most of Europe is expected (Räisänen et al., 2003; Rowell, 2005). For every °C increase in temperature, the snow line will rise by about 150 m. Therefore, reliable snow conditions are assured for elevations above 1500 m (Beniston, 2003). Because the highest mountain of the Black Forest has a height of 1493 m asl (Feldberg), winter tourism is highly vulnerable.

METHODS

The original data is based on the regional climate model REMO developed by the Max-Planck-Institute of Meteorology in Hamburg (Jacob, 2001; Jacob et al., 2007). The model region encompasses Germany and the Alps (Fig. 1).

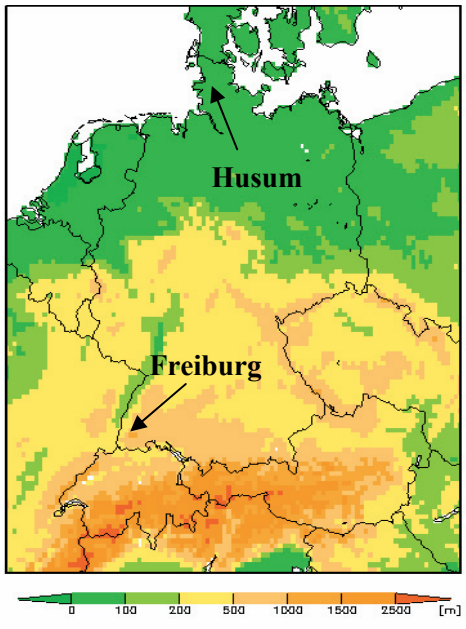

Figure 1: Model region of REMO

The data has a spatial resolution of 10 km and a temporal resolution of hours. The data is available from 1950 to 2100. Thereby, the period 1961-1990 of the A1B scenario is used as

the reference period for future climate change. Based on the daily values of the A1B scenario, human-biometeorological parameters are computed using RayMan (Matzarakis et al., 2007) until 2050. The main output of RayMan is the Physiologically Equivalent Temperature (PET). PET is the background for thermal comfort and discomfort (Höppe, 1999).

The following climatic parameters relevant for tourism are considered: thermal comfort, heat and cold stress, sunshine, fog, sultriness, precipitation, storm and ski potential. These analysed values refer to 14 CET, except for precipitation where the total annual precipitation amount is considered.

For the analysis of the climatic tourism potential particular thresholds are defined (Tab. 1) (Matzarakis, 2007). The extracted information is presented in terms of frequency classes and frequencies of extreme weather events based on 10-day-intervals. The derived results will be shown in so called climate tourism information schemata (CTIS).

Table 1: Parameters and their thresholds

Parameter	Threshold
Thermal comfort	18 °C < PET < 29 °C
Cold stress	PET < 0 °C
Heat stress	PET > 35 °C
Sunshine	Cloud cover < 5/8
Sultriness	Vapour pressure > 18 hPa
Fog	Relative humidity > 93 per cent
Dry day	Precipitation < 1 mm
Wet day	Precipitation > 5 mm
Stormy day	Wind velocity > 8 ms^{-1}
Ski potential	Snow cover > 10 cm

RESULTS

The analysis of human-biometeorological parameters relevant for tourism is introduced for Husum (North Sea) and Freiburg (Black Forest), exemplarily (Fig. 1). Husum is located close to the seaside. The North Sea climate exhibits a maritime character, i.e. mild winters and relativley warm summers. The mean air temperature (1961-1990) is 8.2 °C and the annual amount of precipitation is 864 mm (DWD, 2007). Freiburg is located between the Black Forest and the Upper Rhine Graben. Freiburg has a continental climate character. The winters are mild, heat stress periods often occur in the summer months. The mean air temperature (1961-1990) is 10.8 °C and the annual amount of precipitation is 954.8 mm (DWD, 2007).

The most significant changes in climatic conditions for Husum refer to cold stress. Cold stress will markedly decrease by about 16 days until 2021-2050. The thermal comfort will increase

from 1961-1990 to 2021-2050 by 4 days, whereas the changes in heat stress are insignificant. In general, heat stress is not important for Husum but sultriness gains more in importance. A strong increase in sultriness will be recongnised. The number of sultry days will rise from 23 days up to 39 days on average. In addition the number of wet days will increase, while the number of dry days will decrease. Stormy days are frequented in both periods 1961-1990 and 2021-2050 (> 70 days) (not shown).

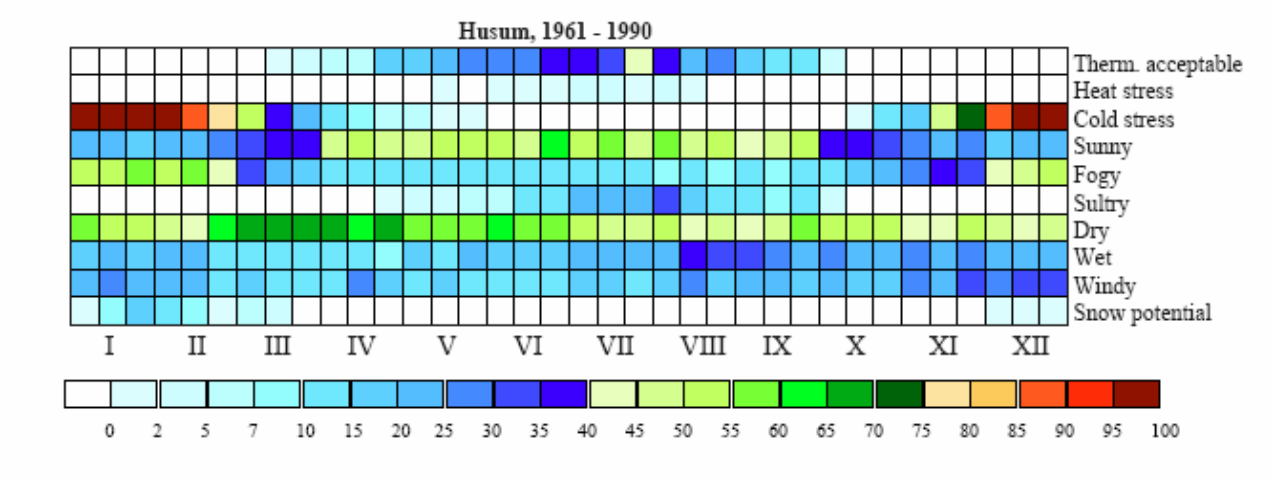

Figure 2: CTIS for Husum for the period 1961-1990

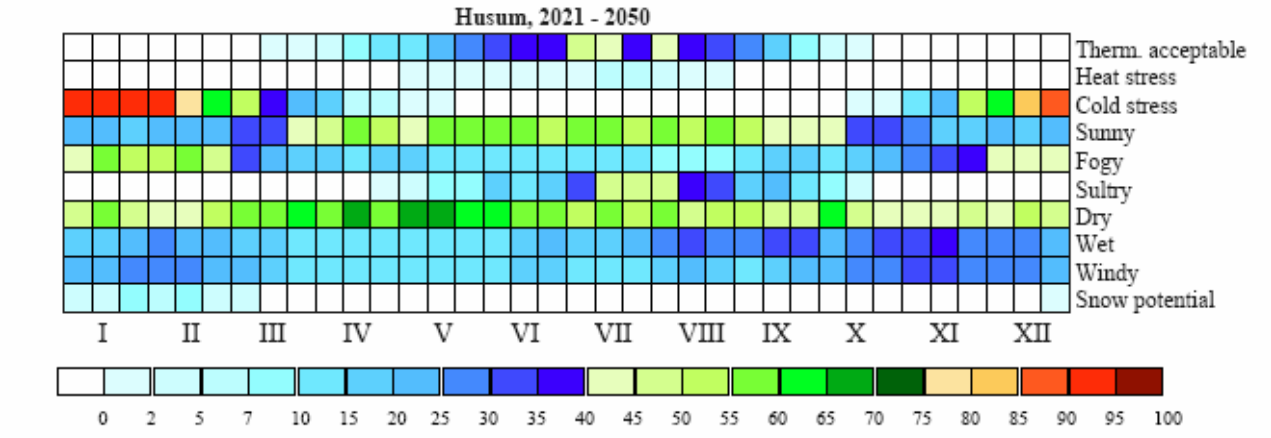

Figure 3: CTIS for Husum for the period 2021-2050

Figures 2 and 3 yield the following results: thermally indifferent conditions will arise in 5-10 per cent, especially in July. CTIS also exhibits marked changes in cold stress. The cold stress in the winter months (mid December – end of February) will decline down to 15 per cent. The frequency of fog will decrease marginally in the winter season. The occurrence of sultriness will considerably increase, especially in the summer months July and August. Furthermore, the time span will expand from mid May until the beginning of October for the period 2021-

2050. The precipitation rate will increase in spring and autumn, while a slight decrease will be noted in summer. In the winter season the frequency of stormy days will decline slightly.

The most significant changes in Freiburg will be cold and heat stress and sultriness. Whilst both cold stress and thermal comfort will decrease by 14 and 5 days, respectively, heat stress and sultriness will increase by 8 and 17 days, respectively. The number of dry days will increase slightly by about 3 days on average. Days with high precipitation rates and stormy days will not change (not shown).

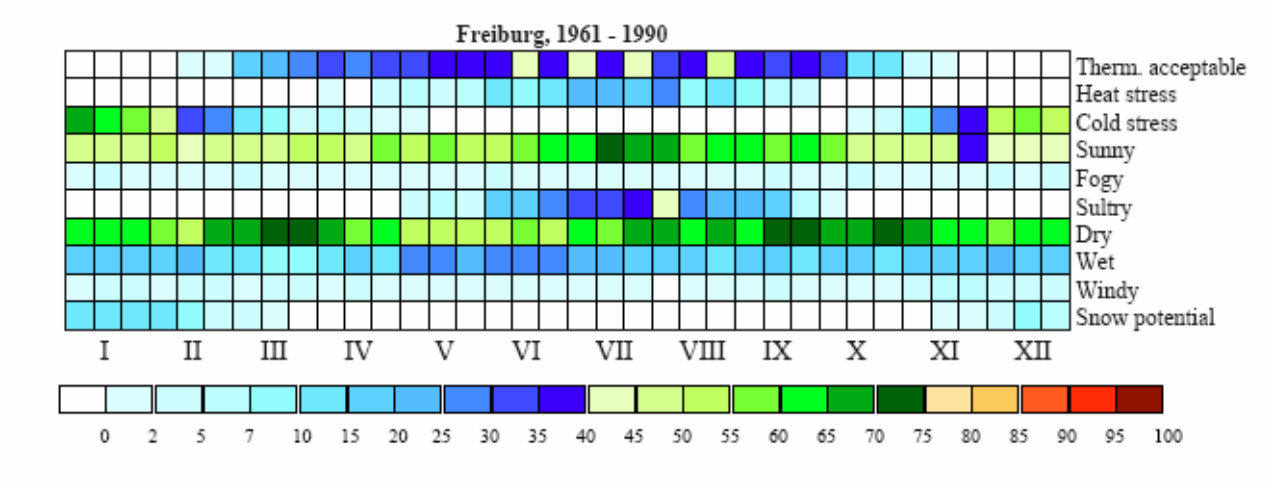

Figure 4: CTIS for Freiburg for the period 1961-1990

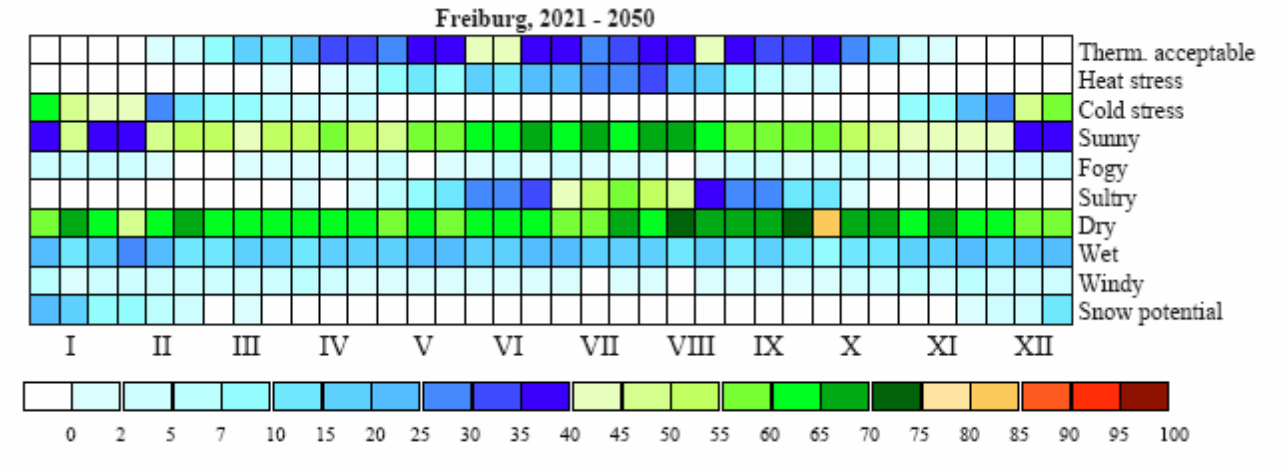

Figure 5: CTIS for Freiburg for the period 2021-2050

Figures 4 and 5 show that thermal comfort will decline, especially in spring and autumn, due to an increase in air temperatures. Therefore, heat stress will rise by about 10 per cent in July and August. A significant decline of 15 per cent in cold stress will be observed during the winter time. Furthermore, the occurrence of sultriness will increase to 20 per cent in July. The frequency of less precipitation will appear in spring (May/June) with a rise of 10 per cent. The

months February and March will be characterized by a higher precipitation rate. Changes in fog and wind can are marginally.

DISCUSSION AND CONCLUSION

Although the two researched stations exhibit different geographical locations, their climatic conditions are suitable for tourism on a moderate level. However the changes differ extremely in occurrence and intensity for the period 2021-2050 but the general climatic trends are similar. Thus the fluctuation and variability in bioclimatic parameters (e. g. PET) will increase. These fluctuations will impede the adaptation to current conditions in weather and climate.

The busy tourism season in Husum will become more pleasant because of an increase of thermal indifferent conditions. Heat stress is irrelevant and from this it follows that the climatic conditions will improve. Moreover, cold stress will also decline and allow an improved well-being of tourists. Nevertheless, the storm potential will continue to remain significant in all seasons.

Due to global warming, the thermal comfort in Freiburg will expand to the off-peak seasons in spring and autumn. People will less frequently be stressed by cold. This results in a positive feedback for the tourism industry. But the peak season is characterized by a strong increase in heat stress. From this it follows that there will be a shift of tourism from the peak season to the low season.

In conclusion, both Husum and Freiburg are affected by positive and negative climate change impact factors.

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