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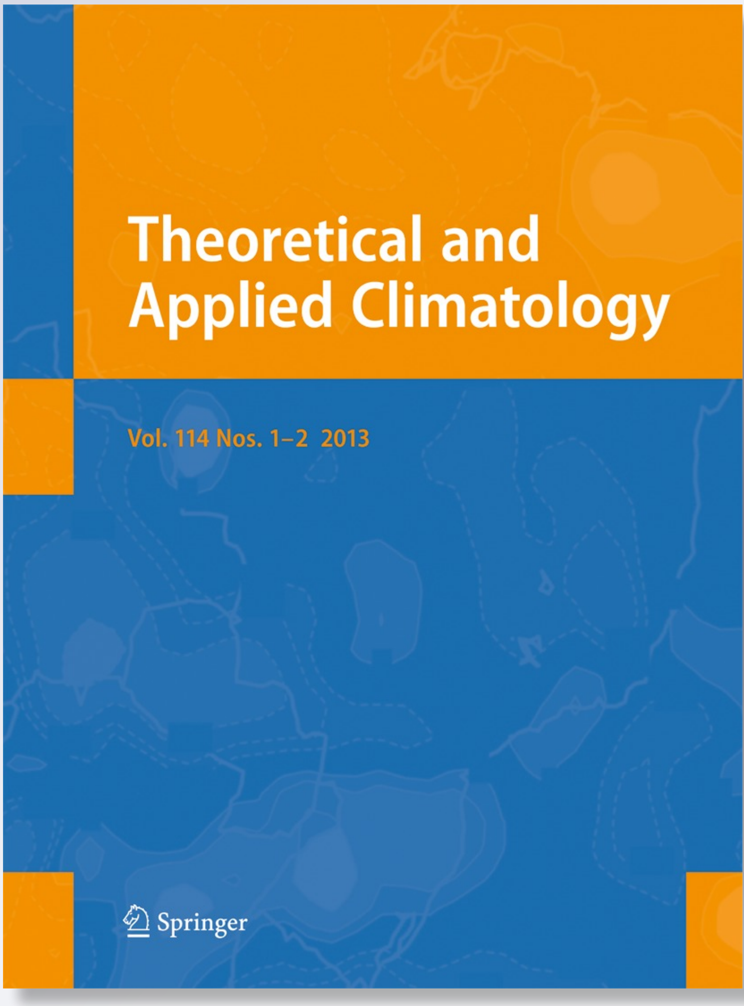

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ORIGINAL PAPER

Assessment of thermal bioclimate and tourism climate potential for central Europe—the example of Luxembourg

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Abstract Tourism destinations often require information about climate to assess their climate potential. This can be performed in terms of mean conditions of relevant climatological parameters. For a user-friendly analysis and visualization of climate data relevant for tourism application in Luxembourg, information is prepared based on the facets of climate in tourism. Information on thermal comfort/stress conditions as well as aesthetical and physical parameters is considered. In the present study, relevant and sensible factors were identified and presented. Therefore, physiologically equivalent temperature, precipitation patterns and the Climate-Tourism/Transfer-Information-Scheme are applied. In addition, extreme events relevant for heat stress are analysed based on existing data sets (i.e. heat waves of 2010). Expected climatic conditions for the future are investigated using the projections of two different regional climate models. The results concerning climate change conditions reveal increasing heat stress and sultriness but decreasing cold stress. This information is the basis for an adequate assessment to provide relevant information for different environmental planning issues as well as for the growing tourism sector of Luxembourg.

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1 Introduction

The bioclimate is of high interest for decision makers in the public health and recreation tourism sectors as well as for the general public. Many studies and working groups especially the 'Commission on Climate, Tourism and Recreation' of the 'International Society of Biometeorology' showed and emphasized the importance of weather and climate in the context of tourism and the need for adequate assessment possibilities (Matzarakis and de Freitas 2001; Matzarakis et al. 2004, 2007a; Scott et al. 2006; Amelung et al. 2007; UNWTO 2007). In addition, the importance of quantification of recent and projected climate conditions pushed studies to develop helpful assessment and adaptation strategies (Matzarakis 2007; IPCC 2007; Zaninovic and Matzarakis 2009; Scott 2011; Lin and Matzarakis 2011). Both recent climate and projected future climate conditions are important for the diverse kinds of tourism and recreation in Luxembourg.

Research of the last two decades has shown that the existing approaches do not cover all factors relevant in tourism climate (Matzarakis 2010). Currently used climate tourism indices are based upon the combination of meteorological variables, but some relevant aspects, e.g. aesthetical aspects, are missing. Weather and climate information for tourists, tourism organizers, agents, tourism planners and investors, especially in the period before and during the holidays, are very useful and vital. In this context, thermal aspects of climate are relevant for tourism planning process (de Freitas 2003; Matzarakis 2006). Thermal aspects comprise heat and cold stress, sultriness as well as thermal comfort issues. The aesthetical aspect includes fog and clouds, whereas conditions related to high wind speeds, precipitation patterns and sultriness can be implemented in physical ones.

In the past 30 years, many indices based on different aims and goals were developed to assess the suitability of climate for tourism activities and thermal comfort issues including adaptation factors (Morgan et al. 2000; Maddison 2001; Lise and Tol 2002; Gomez Martın 2004; Hamilton and Lau 2005; Nikolopoulou and Lykoudis 2006, 2007; de Freitas et al. 2008; Lin and Matzarakis 2008; Lin 2009; Kántor and Unger 2011; Lin et al. 2011). The most widely known and applied index is the 'Tourism Climate Index' proposed by Mieczkowski (1985) which combines seven parameters. The included thermal index is simple and only based on a combination of air temperature and air humidity. Other factors included in the Tourism Climate Index are wind speed, sunshine and precipitation. However, state of the art is the calculation of thermal comfort based on the human energy balance (Fanger 1972; VDI 1998).

The physiologically equivalent temperature (PET), a thermal index derived from the human energy balance (Mayer and Höppe 1987; Höppe 1993, 1999; Taffé 1997), has been used to quantify the thermal facet of tourism climate. PET is well suited to evaluate thermal components of different climates and different demands in applied sciences. Containing a detailed thermo-physiological basis and measured in degree Celsius (°C), PET is preferable to other thermal indices such as the predicted mean vote (Fanger 1972). Therefore, results are much more comprehensible to e.g. urban or regional planners, who are not familiar with human-biometeorological terminology. Results can be presented graphically or as bioclimatic maps. Graphs mostly display the temporal behaviour of PET, whereas spatial distribution is specified in bioclimatic maps (Matzarakis et al. 1999). Mapping of modern bioclimatic indices basing on the human energy balance presents an adequate method for the quantification of the human thermal bioclimate that can be applied for different uses and requirements. Additional factors and detailed implementation of climate relevant factors for tourism and recreation can be performed with new tourism climate quantification, e.g. Climate Tourism/Transfer Information Scheme (CTIS). This scheme is based on thresholds and frequencies of relevant factors and parameters from the climate facets in tourism (Lin and Matzarakis 2008; Çalışkan et al. 2011). CTIS can be visualized by freely available software (Matzarakis et al. 2007c; www.urbanclimate.net/climtour).

The study area of Luxembourg is attractive for diverse kinds of tourism including cultural, business and urban tourism. In the context of climate change, knowledge about the recent and future climatic conditions is requested because of the relevance of tourism and recreation (Matzarakis 2010). Results can serve as a tool in terms of long-term adaptation and re-structuring the tourism sector for Luxembourg according to the projected changes.

2 Methods

2.1 Study area

The Grand Duchy of Luxembourg situated in Western Europe between Belgium, France and Germany covers an area of 2,590 km^2 and is divided into two natural regions, the Oesling in the north (225–559 m above sea level) and the Gutland in the south (140–440 m above sea level). The Gutland region is characterized by a cuesta landscape where large gentile sloped valleys contrast with the deeply cut Luxembourg sandstone. Most residential areas and industries are located in the Gutland alternating with forest, agriculture and grassland. Dominating westerly atmospheric fluxes cause annual rainfall totals in Luxembourg exceeding 900 mm passing above the Ardennes massif. December, January and February are the wettest months (>100 mm), while April, August and September are the driest months (<70 mm) on average. The mean annual temperature at the Luxembourg Findel airport station (WMO ID=06590) is 8.7 °C for the reference period from 1971 until 2000. The warmest month is July with a long-term mean temperature of 17.5 °C. From 1971 until 2000, an increase of the annual mean air temperature of 0.5 °C per decade was observed. Potential effects of climate change for Luxembourg were currently investigated by Junk et al. (2012).

2.2 Data and thermal indices

From a climatological point of view, several climatic indices do not include the effects of short- and long-wave radiation fluxes since these fluxes are generally not included in standard climatic records (Matzarakis et al. 2004). In addition, the concept is only thought for summer tourism, and it does not include appropriate assessments for thermal facets based on the energy balance of the human body (Matzarakis et al. 2007c). Another point to mention is the lack of information about extreme events.

Modern thermal indices which quantify the effects of thermal environment on humans are the predicted mean vote and the standard effective temperature (Fanger 1972; Gagge et al. 1986; Mayer and Höppe 1987; Höppe 1999). These thermal indices have the advantage to evaluate thermal conditions for the whole year. They require meteorological variables (air temperature, air humidity, wind speed as well as short- and long-wave radiation fluxes) and can be calculated by free software packages, e.g. RayMan (Matzarakis et al. 2007b). In this study, PET is used due to its widely known temperature unit (°C) as an indicator of thermal stress or thermal comfort. Air temperature, vapour pressure (VP), average wind speed and global radiation were included to calculate PET values for Luxembourg using the RayMan model. PET is based on the MEMI model

(Munich energy balance model for individuals) and gives the possibility to assess a thermal-physiological perception due to thermal conditions. Therefore, meteorological parameters are combined with physiological aspects of the human body such as activity, clothing and age. To include the effects of wind conditions on humans, values for wind speed are reduced to 1.1 m since this height represents the centre of the human body (VDI 1998). The precipitation conditions in Luxembourg are assessed by an analysis of precipitation intensity classes and cover also aspects of rainy or dry conditions during the year.

Hourly values of air temperature, relative humidity, wind speed, wind direction, precipitation and cloud cover of the Findel airport station for the period from 1986 until 2010 were used. Air temperature, relative humidity, wind speed and cloud cover at 14 CET were selected for the calculations. This was because humans mostly stay outside at that time of the day. Vapour pressure and PET values have been taken from the RayMan output.

CTIS is a useful method for a graphical description of analysed tourism-related parameters and provides relative frequency classes and frequencies of extreme weather events on a 10-day (decas) or monthly time scale (Matzarakis 2007). The scheme is suitable for analysing climate stations or grid points and describes the corresponding frequency of single parameters. The used data refer to specific conditions during the late midday (14 LST for measured data), where people are often outside with pleasant conditions during winter and highest heat loads during summer. Only for precipitation data with a daily resolution were used. A frequency of 100 % indicates that each day in a month is characterized by the respective condition. The method combines climatological and tourism-related components and simplifies climate information for tourism. It has also to be mentioned that the parameters were selected according to their relevance to tourism activities. In some cases, factors or parameters can be negative or positive depending on the type of tourism.

In detail, the following factors are selected and included:

- Cold stress (PET <0 °C),
- Heat stress (PET >35 °C),
- Thermal comfort (18 °C<PET<29 °C),
- Sunshine/cloud cover conditions in terms of the number of days with a cloud cover <5 octas (sunny days),
- Vapour pressure >18 hPa (sultriness),
- Wind velocity >8 ms^{-1},
- Relative humidity >93 % (foggy days),
- Precipitation <1 mm (dry days) as well as
- Precipitation >5 mm (wet days).

In general, definitions of several thresholds (values) do not necessarily correspond to universal or standard meteorological threshold values and are adjusted to applied tourism climatology and human health applications. A stormy day (under meteorological aspects) is given by wind strength of at least 8 Bft which corresponds to a wind velocity greater than 17.2 ms^{-1}, while in tourism climatology, a wind velocity of 8 ms^{-1} (5 Bft, windy day) is perceived as unpleasant and uncomfortable. All mentioned factors above have been included in an information scheme in order to describe these factors in a high temporal resolution (Matzarakis 2007).

Climate change effects were assessed based on projections of the regional climate model REMO with a spatial resolution of approximately 10 km (Majewski 1991; Jacob et al. 2001, 2007) and COSMO-CLM of approximately 18 km (COSMO model in Climate Mode) (Steppeler et al. 2003; Böhm et al. 2006; Rockel et al. 2008) for the two SRES-emission-scenarios A1B and B1 (Nakicenovic and Swart 2000). For the assessment of projected changes, two periods, 2021–2050 (near future) and 2071–2100 (far future), were chosen. The model output for 13–14 CET was selected for REMO, whereas for CLM, only the output for 15 CET was available. A spatial average of nine grid points centred on the geographical coordinates of Findel, Luxembourg (49°37′36″N, 6°12′41″E) was applied.

Direct measurements of the Findel airport station will be used for analysing the frequency distribution of meteorological parameters. Therefore, the period from 1986 to 2010 has been chosen. Also, tourism potential was exemplarily analysed with a CTIS for summer 2010. At least climatic trends were assessed in order to compare the near and far future period (2021–2050 and 2071–2100) with the reference periods (1971–2000).

3 Results

Results are presented as:

- Bioclimate diagrams constructed to analyse climatic conditions in Luxembourg. Therefore, relevant meteorological parameters were analysed for the period 1986–2010. Bioclimate diagrams do not only contain mean PET values but also frequency classes of thermo-physiological stress levels for PET (Matzarakis and Mayer 1996). The bioclimatic diagrams are based on decas separating the months in three intervals of 10 days, except of the last decas, which varies from 8 to 11 days (Matzarakis and Endler 2010).
- Wind roses showing relative frequencies of wind direction and speed during the period 1986–2010.
- CTIS analysis for the same period to analyse bioclimatic and tourism climatic factors in decas.
- Temporal analysis for periods with heat and cold stress as well as thermal comfort. Therefore, frequency classes

of PET have been used. Analysis based on hourly values from May until September and results have been visualized.

3.1 Air temperature, humidity, vapour pressure and wind conditions

The frequency distribution of air temperature (T_a) for the period from 1986 until 2010 is shown in Fig. 1a. Hottest periods occur during summer months with approximately 5 % values >30 °C in the first 20 days of August. Coldest days can be observed from November until the beginning of March. In January, more than 30 % of days show temperatures between −10.0 and 0.0 °C. Days <−10 °C are rare and show the highest amount in the middle of January

The frequency diagram for the relative humidity (RH) values given in Fig. 1b shows a high variability with a typical annual cycle. In the meteorological winter months December, January and February more than 50 % of the values are in the range between >85.0 and 95.0 % RH or even higher, whereas values <45 % RH are rare. In the summer months, values RH >65 % occur in 20 % of the cases. For VP, the same kind of frequency diagram was calculated (Fig. 1c). Sultriness, defined as VP values >18 hPa, occurs on the average from May until October and shows highest amounts during July and August with approximately 10 % of cases. Sultry events occur only on very rare occasions from 1986 until 2010. The frequency distribution of precipitation (RR) for Luxembourg was analysed to characterize rainy periods (Fig. 1d) and covers the same period from 1986 until 2010. No rain (RR <1 mm) occurs on the long-term average on 236 days, whereas precipitation with more than 5 mm could be observed only on 58 days.

Wind direction distribution is visualized via different wind charts based on hourly mean values for the period from 1986 until 2010 (Fig. 2a–c). In Fig. 2a, all hourly values of the whole period >0.5 ms^{-1} were taken into account. The prevailing wind directions are south-west and north-east with higher wind speeds in the south-western sector. The average wind speed is 7.0 ms^{-1}, and wind speeds lower than 0.5 ms^{-1} could be observed in only 2.1 % of the hours at the Findel airport station. In general, wind speed is higher during daytime (Fig. 2b), whereas during night-time (Fig. 2c), the north-east sector is more pronounced.

The above described parameters are important for the calculation of the PET in order to describe the thermal bioclimate. Detailed information of air temperature, air humidity and wind speed are of relevance including their variability and the covered range. For human biometeorological purposes, vapour pressure instead of relative humidity is of higher relevance. In addition, information of

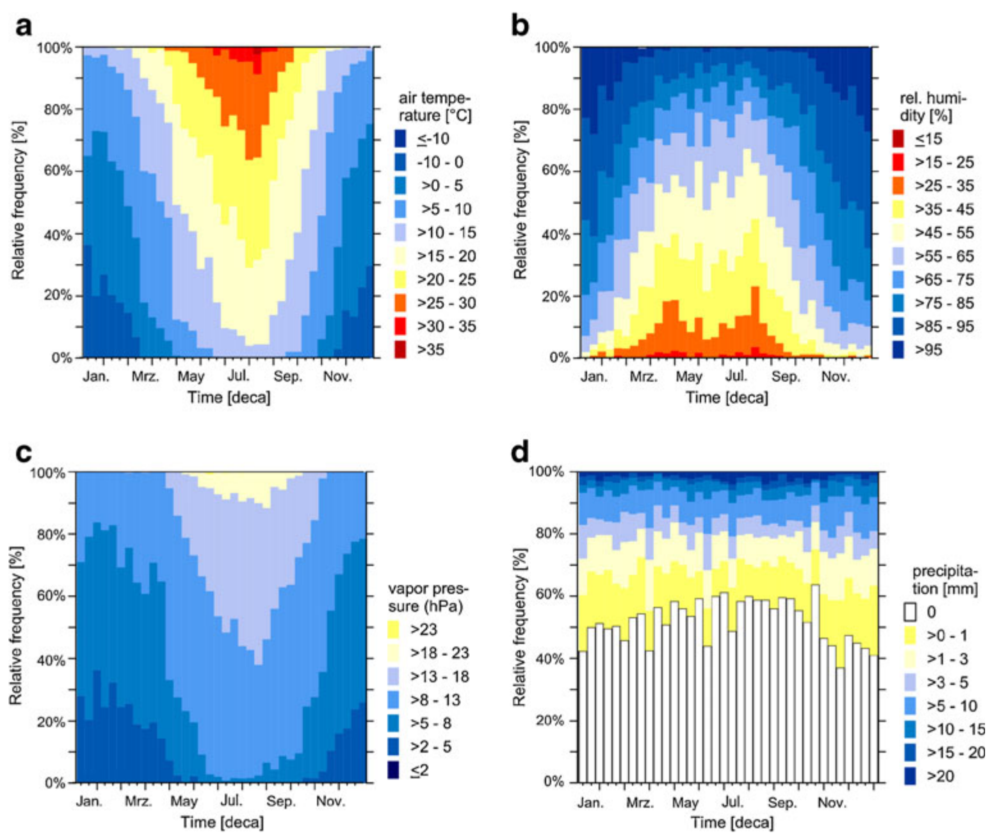


Fig. 1 Relative frequency diagrams of air temperature (**a**), relative humidity (**b**), vapour pressure (**c**) and precipitation (**d**) at 14 CET based on 10-day periods (decas) for Luxembourg, 1986–2010

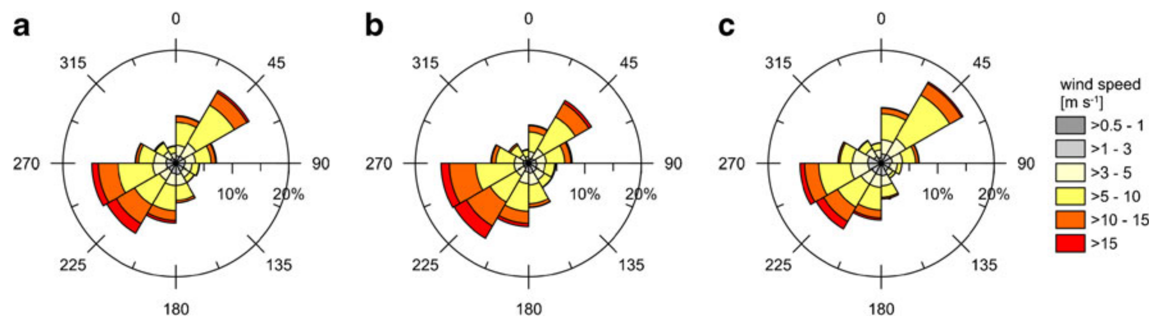


Fig. 2 Wind rose for the airport station Findel based on hourly values for the period from 1986 until 2010 (excluding calms with wind velocity <0.5 ms^{-1}). *Left* figure (**a**) all values (N=203,431/calms= 2.1 %), *middle* (**b**) only daytime hours between 0600 and 1700 hours MEZ (N=103,872/calms=1.3 %), and *right* (**c**) only night-time hours between 1800 and 0500 hours MEZ (N=100,905/calms=2.9 %)

precipitation characteristics is a main CTIS factor and so of basic importance.

3.2 Physiologically equivalent temperature

PET allows the evaluation of thermal conditions with regard to humans in a physiologically significant manner. Figure 3 presents the relative frequencies for PET values divided into 11 classes in order to evaluate the thermal stress for the period from 1986 until 2010 on an hourly basis. Every class indicates a special thermal condition, e.g. the PET-class >23–29 °C represents slightly warm conditions. Thermal comfort occurs from February to October, with highest probability (>15 %) in the summer months June and July and lower in February (~1 %). Cold stress (<0 °C) can be observed from October to the beginning of May with highest frequencies (~60 %) from December until February. Days with strong heat stress, defined as PET values >35 °C, can be observed from May to September with maximum frequencies during May until August.

The bioclimate diagram, based on relative frequencies, has the advantage that detailed information of several type of stress can be described in parallel. So, frequencies of cold stress or heat stress can be extracted and used for specific health issues or tourism activities.

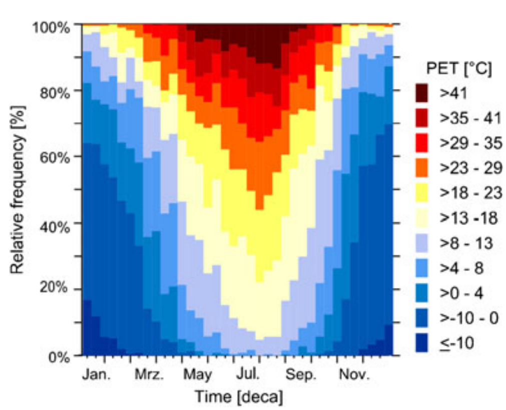


Fig. 3 Relative frequency diagram (percentage) of PET (degree Celsius) at 14 CET based on 10-day periods (decas) for Luxembourg, 1986–2010

3.3 Climate–Tourism/Transfer–Information–Scheme

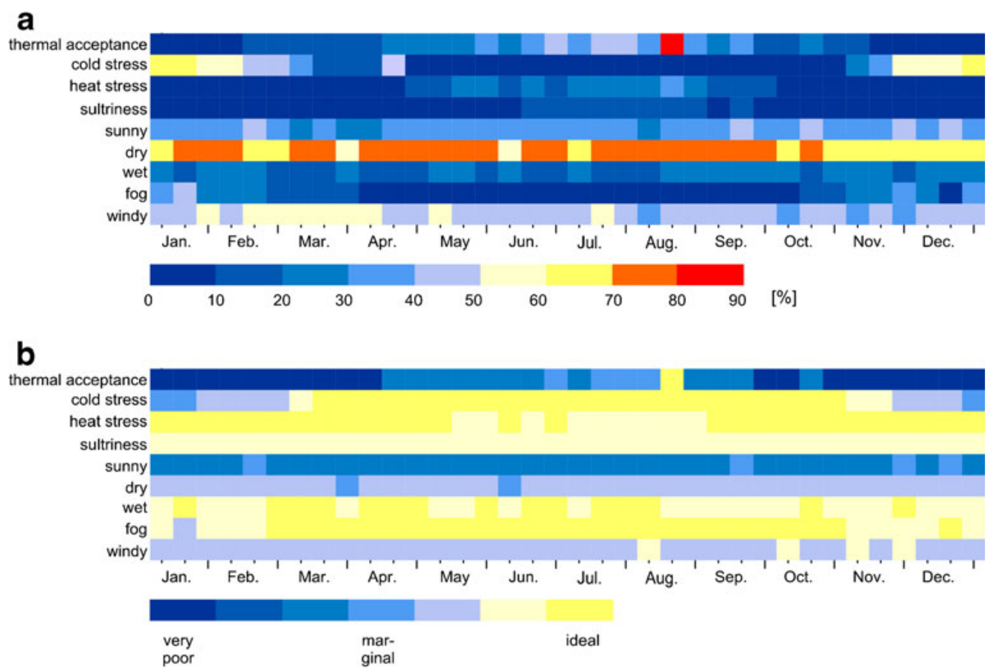
The Climate–Tourism–Information–Scheme (CTIS) is a tool for destination analysis of present or future climate conditions and combines meteorological and tourism-related components. To support the tourism sector, it is important for governmental agencies to offer detailed specific climate information to improve Luxembourg's tourism potential. A detailed description of the methodology is given by Matzarakis (2007), Lin and Matzarakis (2008) and Zaninovic and Matzarakis (2009).

Results are presented here in two different ways. Firstly, relative frequencies of the different biometeorological factors are calculated (Fig. 4a). Based on these results, Fig. 4b shows evaluated results in seven classes from very poor up to ideal conditions. The evaluation is based on the combination of thermal components like PET ranges and thresholds, aesthetic components like cloudiness and fog, and physical components like wind speed, precipitation and vapour pressure.

In order to make the CTIS diagrams easier to understand for non-experts in climatology, the comprehensive "Climate Index for Tourism" (De Freitas et al. 2008) is incorporated into the scheme. The probability CTIS scale is expressed in seven climate classes from "very poor" to "ideal", which gives about 14 % of probability to each class. For some parameters, greater probability means less favourable conditions, while for other parameters, greater probability means more favourable conditions. A particular colour is always associated with the same class of convenience of climate for tourists, making it is much easier to understand and use (Zaninovic and Matzarakis 2009). The diagram offers sufficient climate information for tourists, based on which they can choose their preferred travel period.

For the period from 1986 until 2010, thermal comfort/acceptance is given from the middle of April until the middle of September. Ideal conditions for thermal comfort can be

Fig. 4 Climate Tourism Information Scheme (CTIS) for Luxembourg, period 1986–2010, **a** in relative frequencies and **b** as evaluated



observed in the end of August. During June, July and August, thermal comfort/acceptance is given in 30 % up to 50 % of the cases, but highest amounts of heat stress also occur (up to 40 %). During these months, the highest amount of sultriness can be also detected. Cold stress occurs with more than 50 % during November and December until February. Frequencies of cold stress up to 50 % can be observed until April. Sunshine can be detected through the whole year with approximately 40 %. Foggy days occur during fall and winter until the end of March with amounts from 10–30 % showing highest amounts in January. With regard to the whole year, 63 days can be detected as windy days (>8 ms^{-1}), 77 days as cloudy days (>4 octas), 9 days as sultry days (>18 hPa) and 47 days as foggy days (>93 % RH).

CTIS combines different factors and parameters relevant for tourism and outdoor recreation. One of the advantages of CTIS is that the included factors give temporal information of specific occurrence of relevant (in some cases positive and negative) factors. These information and results are of basic interest for the most relevant kinds of tourism and recreation. In addition, CTIS is flexible in a way that those factors not relevant for a region can be excluded and factors with specific relevance can be considered.

3.4 Extreme events

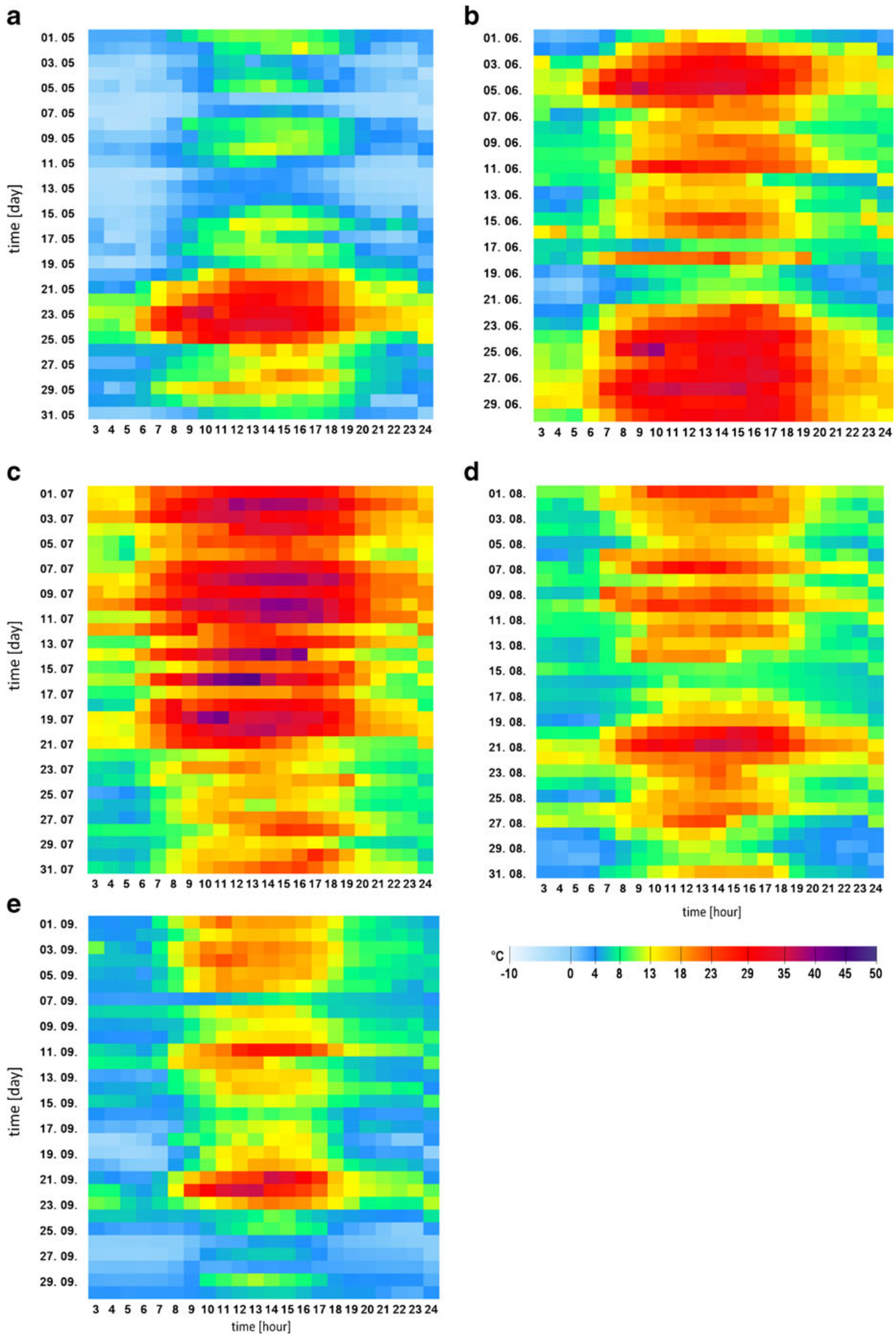
Diurnal courses of PET for May to June 2010 are shown in Fig. 5a–e, whereas PET classes from −10 to 50 are visualized. This way of presentation has the advantage to see which periods of the day especially during summer are mostly related to high heat stress. Because of missing wind data for the year 2003, no PET analyses for that strong heat wave were possible. We select 2010 as a typical recent year. Hot periods with PET values greater than 29 °C occur in the middle of May until mid of September. Cooler conditions, relevant for thermal comfort, are observed during May and also in June, but with lower frequencies. Especially during September night and morning hours show low values around 4 °C. Days with heat stress are detected at 2 days in May, at 7 days in June, at 11 days in July and at 2 days in August and September.

High temporal information during summer periods based on hourly data can deliver relevant information for prevention measures of selected population groups, e.g. older or ill people. This kind of information about the nocturnal pattern is of relevance for health and urban planning authorities.

3.5 Projected climate change conditions

To analyse projected future climate conditions, two periods have been chosen: the near future (2021–2050) and the far future (2071–2100). These periods were compared with the reference period (1971–2000). Data sets of the REMO and CLM regional climate models driven by the SRES-Scenarios A1B and B1 were chosen for analyses. The chosen data represent only a specific hour of the day, 14 and 15 LST for REMO and CLM, respectively. The spatial resolution of the regional climate data is 10 km for REMO and 18 km for CLM. In addition, not only one grid point has been chosen but also eight surrounded grid point (finally

Fig. 5 Diurnal courses (3 to 24 h) of PET (degree Celsius) for Luxembourg for the month of May (**a**) until September (**e**) 2010 ▶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nine) were averaged. Extracted data have been analysed with the RayMan model to calculate PET values.

In Table 1, the absolute frequency of different climate events (days above or below a certain threshold) derived from the CLM and REMO model results for the A1B and B1 scenarios was presented (mean values for a 30-year time period). The reference period (1971–2000) was compared with the near future (2021–2050) and the far future (2071–2100). In a first step, the Kolmogorov–Smirnov test was used to test normality of distribution (indicated with ND in the table). In case of normal distribution, an *F* test was used to test if the arithmetic mean values of the reference and the respective future period show statistically significant differences (indicated as bold values in Table 1). For not normally distributed data, the non-parametric Mann–Whitney *U* test was used to test the differences.

While the number of days with cold stress decreases statistical significantly for both emission scenarios and models in the near and far future, the number of days with heat stress increases only in four out of eight cases. The number of dry days (RR <1 mm) decreases according to both model results for the B1 scenario in the near future but increases for the projected results of the far future period (REMO A1B). The results for sultriness (VP >18 hPa) show a consistently substantial increase for all cases except for REMO near future A1B scenario where the increase is not statistically significant. Highest changes for both models occur for cold stress (PET <0 °C), vapour pressure and heat stress (PET >35 °C).

In general, the projected results for the climate events related to air temperature are more reliable than those for events related to precipitation. This is due to the fact that the precipitation projections are adhered with higher uncertainties than those of air temperature (Tebaldi and Sanso 2009).

4 Discussion and conclusion

Traditional methods describing climate variables relevant for tourism applications used to be visualized mostly as monthly means or sums. Methods and possibilities presented in this paper are an easy transferable way for applied sciences (Amelung et al. 2007). They base on frequency diagrams of thermal bioclimate (e.g. PET) and climatological factors based on thresholds and facets of climate in tourism with the application of CTIS. Therefore, an easy and understandable way for stakeholders and decision makers who may not have to be familiar with complex terminologies and methods from human biometeorology or applied climatology is created (Endler and Matzarakis 2011a, b). This method makes an integral description of the climatic tourism potential of a specific region possible.

Experiences made in the framework of past projects show that stakeholders and decision makers are open minded for more simple ways of description and visualization of complex and latest scientific findings (Matzarakis and Nastos 2011). Results in the present study are comparable to existing studies for similar climate regions, e.g. Austria, Germany and Greece (Endler and Matzarakis 2011a, b; Junk et al. 2003; Matzarakis et al. 2012). The integrated analysis based on PET, precipitation, CTIS for the two regional climate models (CLM and REMO) as well as different emission scenarios shows high similarities (Endler and Matzarakis 2011b, c). Regional climate change projections are afflicted by different kind of uncertainties due to e.g. initial or boundary conditions, emission scenarios, parameterisation effects, or ultimately by the fact that some physical processes are not fully understood or

Table 1 Comparison of the absolute frequency of different climatological events derived from the CLM and REMO model results for the A1B and B1 emission scenario

	Reference period 1971–2000		Near future 2021–2050				Far future 2071–2100			
			CLM		REMO		CLM		REMO	
	CLM	REMO	A1B	B1	A1B	B1	A1B	B1	A1B	B1
Cold stress	94	75	77* ND	82*	59* ND	60* ND	49* ND	65* ND	28*	44* ND
Thermal acceptance	51	80	53	48	77 ND	76	54 ND	54 ND	77 ND	77 ND
Heat stress	16	19	24*	18	16 ND	22 ND	41*	31*	40 ND	30* ND
Sunny	72	155	72	68 ND	147* ND	147* ND	80 ND	73 ND	155 ND	150 ND
Dry RR<1 mm	206	226	206 ND	195* ND	226 ND	215* ND	212 ND	206 ND	239*	228 ND
Wet RR >5 mm	63	47	66 ND	70* ND	48 ND	53* ND	68	68 ND	45	47 ND
VP>18 hPa	18	30	23	25*	34	38* ND	43*	34*	71* ND	56*

Results are shown for the reference period (1971–2000), the near future (2021–2050) and the far future (2071–2100)

ND normal distribution

*$P<0.05$, statistically significant

implemented until now (Knutti et al. 2010). Comparison of different emission scenarios and different regional models (multi model ensemble approach) will help to understand and deal with these uncertainties of the models.

In order to quantify these conditions, all measured data as well as output from regional climate models can be used (Matzarakis 2010). Results show that 10-day periods (deca) are closer to time spans typical for recreation. These results can be used as a basic climatological and bioclimate analysis of a specific destination—here Luxembourg. Nevertheless, a basic analysis about climate and tourism or bioclimate in general is an issue of environmental information and is in close relationship with many environmental issues like urban planning, public health and recreation or in general with life quality (Matzarakis 2010). In addition, most important influences are connected with extreme events which can be detected and quantified with the methods described for the past and the future. Results based on frequency diagrams and CTIS approach give the possibility to be informed about basic climate conditions and expected changes for near and far future time spans.

The quantification and the assessment of extreme conditions have to be performed by an appropriate way which does not only include air temperature. PET values are suitable for the biometeorological quantification of heat waves and can deliver important contributions for the development of adaptation strategies for the protection of human life especially in urban agglomerations (Matzarakis et al. 2009). Usage of climate change projections can be helpful to inform about trends of climate conditions for future periods and derive possible mitigation and adaptation strategies, e.g. planting of trees or modifying still existing urban spaces (Matzarakis and Endler 2010). Finally, issues of health, recreation and tourism, not only in urban areas, build in every country a non-negligible part of the gross domestic product indicating the importance of current and future weather and climate conditions for several economic sectors including the tourism sector.

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