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on Climate, Tourism and Recreation.**

**Edited by A. Matzarakis and C. R. de Freitas**

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ΕΚΠΑΙΔΕΥΣΗΣ ΑΡΝΑΙΑΣ**



## Contents

	Page
PREFACE	1
THEORY, CONCEPTS AND METHODS IN CLIMATE TOURISM RESEARCH	3
Chris de Freitas	
EVALUATING DOMESTIC TOURISTS' ATTITUDES TO BRITISH WEATHER - A QUALITATIVE APPROACH	21
Melanie Limb and Greg Spellman	
MORE HEAT AND DROUGHT--- CAN MEDITERRANEAN TOURISM SURVIVE AND PROSPER?	35
Allen Perry	
CLIMATE IMPACTS ON THE DEMAND FOR TOURISM. Maureen Agnew and Jean P. Palutikof	41
THE BIOCLIMATIC DIVERSITY OF BULGARIA: A RESOURCE OR A LIMITING FACTOR OF RECREATION AND TOURISM?	51
Zoya Mateeva	
USING A MODIFIED 'TOURISM CLIMATE INDEX' TO EXAMINE THE IMPLICATIONS OF CLIMATE CHANGE FOR CLIMATE AS A NATURAL RESOURCE FOR TOURISM	69
Daniel Scott, Geoff McBoyle	
TOURISM IN THE LAND OF THE OZONE HOLE: A PERCEPTION STUDY	89
L. Michael Trapasso	
ASSESSING CLIMATE FOR TOURISM PURPOSES: EXISTING METHODS AND TOOLS FOR THE THERMAL COMPLEX	101
Andreas Matzarakis	
ANALYSIS OF A HEAT WAVE PHENOMENON OVER GREECE AND IT'S IMPLICATIONS FOR TOURISM AND RECREATION	113
Balafoutis, Ch. J. and Makrogiannis	
THE INFLUENCE OF THE WEATHER UPON THE RECREATIONAL USE OF THE DANUBE FLOOD PLAINS NATIONAL PARK, VIENNA, AUSTRIA	123
Christine Brandenburg	
ASSESSMENT OF RECREATIONAL POTENTIAL OF BIOCLIMATE BASED ON THE HUMAN HEAT BALANCE	133
Krzysztof Blazejczyk	
ASSESSING THE SENSITIVITY OF THE ALPINE SKIING INDUSTRY IN ONTARIO, CANADA TO CLIMATE VARIABILITY AND CHANGE	153
Daniel Scott, Geoff McBoyle, Brian Mills, Geoff Wall	
CLIMATE AND BIOCLIMATE INFORMATION FOR TOURISM IN GREECE	171
Andreas Matzarakis	
THE EFFECT OF CLIMATE ON THE USE OF OPEN SPACES IN THE URBAN ENVIRONMENT: RELATION TO TOURISM	185
Marialena Nikolopoulou	

LINKS AMONG CLIMATE, FOREST FIRE, AND RECREATION IN THE US SOUTHWEST	195
Barbara J. Morehouse	
CLIMATOLOGICAL BASIS FOR PLANNING IN MOUNTAIN RECREATION	227
Marjana Gajic-Capka	
CLIMATE AND TOURISM – AN AUSTRALIAN PERSPECTIVE	239
Carol J. Skinner and Richard J. de Dear	
BIOMETEOROLOGICAL POTENTIAL OF CROATIAN ADRIATIC COAST	257
Ksenija Zaninović	
RESULTS AND COMMENTS FROM THE WORKSHOP CLIMATE, TOURISM AND RECREATION	265
Participants of workshop	

## PREFACE

The aim of the Workshop was to: a) bring together a selection of scientists and tourism experts to review the current state of knowledge of tourism climate; and b) explore possibilities for future work and, in particular, the role of the ISBCCTR in this.

The Workshop was held in the well-known coastal resort of Porto Carras located two kilometres from the village of Neos Marmaras. The complex of hotels and recreational facilities is sited at the base of the Sithonia peninsular. Sithonia is the middle peninsular of three on the southern end of the picturesque Halkidiki area, the centre of one of the most important recreation and tourism regions in Greece. Sithonia is set between the Mount Athos peninsular to the east and the Kassandra peninsular to the west. Porto Carras is a large, well-established resort, built in the 1970s to cater for a broad range of activities, including swimming, boating, golf, coastal and inland touring.

A total of 25 delegates attended the Workshop. Their fields of expertise included biometeorology, bioclimatology, thermal comfort and heat balance modelling, UV-radiation, tourism marketing and planning, urban and landscape planning, architecture, and climate change impact assessment. Participants came from Australia, Austria, Bulgaria, Canada, Croatia, Germany, Greece, New Zealand, Poland, United Kingdom, USA and Switzerland.

Business conducted during the Workshop was divided in three parts:

- Approaches to Tourism Climate Research
- Methods and Applications
- Tourism Industry/Climate and Weather Information for Tourism

Each day of the Workshop had two separate sessions. The morning sessions comprised of oral presentations from 0830 to 1300 hours. This was followed by an extended break for rest and recreation through to 1700 hours, as is the custom in Greece. Evening sessions were held between 1700 to 1930 hours during which time the results of morning presentations were analysed, discussed and key points summarised. The results of this are summarised below.

The final day of the Workshop was dedicated to an extended field trip. Participants travelled by bus to the Petralona tourist cave and then through the mountain areas of Halkidiki including Holomontas mountain followed by visits to the traditional town of Arnea and the village Stagira, the birthplace of Aristotle.

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# Theory, Concepts and Methods in Tourism Climate Research

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## Abstract

It is generally accepted that climate is an important part of the region's tourism resource base, but its role in determining the suitability of a region for tourism is often assumed to be self evident and therefore to require no elaboration. Relatively little is known, other than in very general terms, about the effects of climate on tourism or the role it plays. And even less is known about the economic impact or significance of climate on commercial prospects for tourism. The whole area involving which climate related-criteria people use to make decisions about tourism and recreation choices is largely unresearched, but highly relevant to a variety of applications. Thus far, much of the research specifically on climate reported in the journal literature has been superficial in that relationships between climate and tourism are assumed rather than observed and seldom objectively tested. Moreover, the research is largely devoid of any clearly structured conceptual framework or frameworks that embrace important theory, paradigms, processes and interactions. These theoretical frameworks are important because they provide a basis for data generation, hypothesis testing and further theory generation. Without this, it is difficult to develop a coherent set of research methods; and perhaps more importantly, develop models that constitute a bridge between the observational and theoretical levels that can assist in building a coherent knowledge base for understanding, explanation and prediction. This paper reviews the work so far on climate and tourism with a view to identifying what concepts and theoretical frameworks may already exist and looks to ways these may be drawn together in future research.

## INTRODUCTION

Tourism is one of the world's biggest industries. It is also the fastest growing. For many regions tourism is the most important source of income, for others the potential economic returns from tourism development are enormous. In these places it is generally accepted that climate is an important part of the region's tourism resource base, but the role of climate in determining the suitability of a region for tourism or outdoor recreation is often assumed to be self evident and therefore to require no elaboration. Relatively little is known, other than in very general terms, about the effects of climate on tourism and outdoor recreation or the role it plays. And even less is known about the economic impact or significance of climate on commercial prospects for tourism.

The whole area involving which criteria, including climate related-criteria, people use to make decisions about tourism and recreation choices is largely unresearched, but highly

relevant to a variety of applications. Thus far, much of the research specifically on climate reported in the journal literature has been superficial, in that relationships between climate and tourism are assumed rather than observed and seldom objectively tested. Moreover, the research is largely devoid of any clearly structured conceptual framework or frameworks that embrace important theory, paradigms, processes and interactions. These theoretical frameworks are important because they provide a basis for data generation, hypothesis testing and further theory generation. Without this, it is difficult to develop a coherent set of research methods; and perhaps more importantly, develop models that constitute a bridge between the observational and theoretical levels that can assist in building a coherent knowledge base for understanding, explanation and prediction. This paper reviews the work so far on climate and tourism with a view to identifying what concepts and theoretical frameworks may already exist and looks to ways these may be drawn together in future research.

## **CONCEPTS AND TERMS**

### **Definitions**

The study area labelled *tourism climatology* deals with the concepts of “climate” and “tourism” in the broadest sense. Climate invokes the concept of “weather” in that it is defined as the accumulation of daily and seasonal weather events over a long period of time, where weather is the condition of the atmosphere at any particular time and place. “Tourism” embraces the concept of “recreation” in that it is the practice of travelling for recreation, where recreation is defined as an activity in which individuals voluntarily engage for personal satisfaction or pleasure. Thus, in broad terms, there are elements of equivalence in the dual terms *weather* and *climate* on the one hand, and *tourism* and *recreation* on the other. They are often used interchangeably in tourism climate research, which may be broadly defined as the study of interrelationships of tourism and recreation with climate and weather.

### **Weather and climate as a natural resource**

Together with geographical location, topography, landscape, flora and fauna, weather and climate constitute the natural resource-base of a place for recreation and tourism. The concept of tourism climate recognises a climatically controlled resource, which along with weather, according to Hibbs (1966), can be viewed as a recreational resource which at various times and locations may be classified along a favourable-to-unfavourable spectrum. Thus climate is a resource exploited by tourism, and the resource can be measured. In this way climate can be

treated as an economic asset for tourism. The asset can be measured and the resource is capable of being assessed. But there are numerous problems.

One major problem is selection of meteorological or climatological criteria. For example, what exactly are the criteria for *ideal*, *suitable*, *acceptable*, or *unacceptable* conditions? Only after appropriate climatological criteria have been clearly identified can key questions be answered. When is the best time to visit? What clothing equipment is needed? What are the weather hazards or climate extremes likely to be?

### **Weather and climate as limiting factors in tourism**

The characteristics of weather and climate are not necessarily determinants of tourism but constitute an important factor in both financial terms for tourism operators and the personal experiences of tourists. Various places in the world have a “tourism potential” and weather and climate set limits. For example, tourism administrators do not promote places with a little potential or appeal, as this would not be profitable. On the other hand, the tourist who chooses to visit such places would suffer inconvenience (e.g. transport costs) or discomfort (e.g. heat or cold stress). Financial losses can also result from weather variations and changes. Rainy summers or less snowy winters can have significant impacts on tourism.

### **Climate data**

The type of climatic data and manner it is presented in tourism climate research depends on the purpose of the work. Information can be used by 1) the tourist planner, 2) the tourist operator and 3) the individual tourist. For example, a ski facility planner needs information on the length of snow season, whereas skier wants seasonal distribution of probabilities that a skiable depth of snow will exist at a particular location and time. A planner for a tropical island resort needs to know the length period of acceptable weather for tourists. Prospective tourists need to know when and where conditions will be optimal, acceptable, tolerable, or unacceptable.

Climate data must be presented in a form that relates to the individuals response to weather or climate conditions. That is *events* rather than *averages*. Average have no physiological or psychological meaning. Data should give an impression of the likelihood of occurrence of the climate/weather conditions (events). Data should reflect the fact that individuals respond to the integrated, combined effects of weather elements (thermal, physical, aesthetic etc). Equal importance should be given to the nature and form of output data. It should be presented in a form that can be readily interpreted and understood by the

user. Often we have to rely on standard meteorological or climate station data, which may not be representative of the recreational area - valleys, peaks, hills, coast, beach etc. Climate station-data are intended to be representative of the bottom of atmospheric column rather than a particular microclimate or location such as beach, park or ski slope.

### **Weather and climate as factors in tourism and recreation ‘demand’**

Given that recreation is an activity in which individuals freely engage for personal satisfaction or pleasure, recreation is voluntary behaviour proceeding from one’s own free choice. As a result, participation will only occur if the potential participant perceives the climate condition to be suitable. The voluntary and discretionary nature of recreation means that participation will decrease as discomfort and dissatisfaction increase. Thus satisfaction affects participation, which can be taken as a measure of demand for the climatic resource, the called “demand factor.” Examples of indicators of demand in this context are visitation or attendance numbers (Paul, 1971; de Freitas, 1990) and hotel/motel occupancy or hotel “tourist nights” (Rense, 1974).

The climate or weather circumstances to which the recreationist or tourist may react or respond (i.e. those that affect decisions) are 1) conditions anticipated by the tourist (say, gleaned from weather\ climate forecasts, travel brochures etc) and 2) on-site weather. These are collectively referred to as human responses to weather and climate. They can be identified and assessed using “demand indicators”.

There are two categories of methods for assembling data on human response to climate and thus the demand for the climate resource. 1) Assess conditional behaviour, such as by using questionnaires and images (e.g. Adams, 1971) to determine how people may react or think, which includes assessing influence or role of weather or climate forecasts. 2) Examine on-site experience. Since individuals are experiencing conditions first hand, the latter is more reliable. Ideally, the approach must be activity specific. And it is best not to lump all tourism together, but deal with specific categories of activities, either a) *active* or b) *passive*. Sightseeing (touring) is regarded to be the most common tourist activity.

## **APPLICATIONS**

Potential applications of tourism climate research are diverse and sundry. They depend on what is required by planners, members of tourism industry and tourists themselves. Climatologists need to translate the technical work of researchers (climatologists) into simple

language and explain this in uncomplicated terms for use by planners, tourist operators etc. Methods used should be transparent as well as simply expressed and clearly explained. Above all, planners require climate data that is quality-checked, easy to use [i.e. well sorted]. Applications aimed directly at the tourist involve, among other things, the role of climate in considerations of destination choice - especially in relation to increasing use of the Internet.

Other applications include:

- Provide information on the length of period recreational facility will operate.
- Provide standardised climatic information to assist choice on where and when to go for a holiday, or basis for selecting an alternative activity
- Provide information for publicity campaigns to condition tourist expectations of climate at given locations.
- Describe changed opportunities because of climate change.
- Given an understanding of how weather/climate affect on-site behaviour, businesses can plan to meet demand for certain activities.
- Forecasting on-site conditions.
- Advisory services to inform travellers of what to expect (thermal conditions, cloud, rain, extremes etc).
- Provide climate information that can be used to affect the “climate image” of a destination ('destination image').
- To help tourists to bring together expectations of climate at a place and actual climate at that place.
- Guide how particular destinations are marketed to potential visitors.
- Provide information on period tourist facility will operate.

## APPROACHES TO TOURISM CLIMATOLOGY

Most research on tourism climate appears to be motivated by the potential usefulness of climatological information within planning processes for tourism and recreation. The research addresses the theme of tourism climate as an adjunct to a variety of decision making processes ranging from those related to such things as the development and location appropriate recreational facilities, or determining the length of the recreation season during which a facility will operate, to those as specific as planning future activities involving personal decisions of when and where to go for a holiday.

There has also been interest in the indirect effects of climate. For example, Perry (1972) suggested that people leave swimming pools and golf courses on wet days and converge on nearby towns in search of amusement indoors. Therefore, depending on the weather sensitivity of the recreational activity, climatic information can help in the planning, scheduling and promoting of alternative indoor entertainment facilities. Perry (1972) also describes the use of climatic information in publicity campaigns to condition tourists' expectations of climate at a certain locations.

In this context, considerable effort has gone into devising numerical indices of climate that summarise the significance of climate for tourism (Peguy, 1961; Poulter, 1962; Fergusson, 1964; Rackliff, 1965; Hughes, 1976; Davis, 1968; Murray, 1972; Mieczkowski, 1985; Harlfinger, 1991; Becker, 1998). This is because of the multivariable nature of climate and the complex way they come together to give meaning to a particular weather or climate condition in terms of recreation or tourism. These indices facilitate interpretation of the integrated effects of various atmospheric elements and permit places to be compared. The problem is all of these climate ratings are arbitrary as none have been empirically tested, with the exception of study by Harlfinger (1991).

It is clear, however, that if climatic information is to be useful in decision-making, it needs to be presented in a form appropriate to the problem. Tourists respond to the integrated effects of the atmospheric environment rather than to climatic averages. It is generally accepted, therefore, that standard weather data or even secondary climatic variables are not always reliable indicators of the significance of atmospheric conditions. At any given air temperature, for example, the thermal conditions experienced will vary depending on the relative influence and often offsetting effects of wind, humidity, solar radiation and level of a person's activity. Moreover, the design of a particular thermal assessment scheme will depend on the intended use as well as on the nature of the thermal climatic conditions to which the scheme is to be applied. For example, schemes have been devised for groups of runners (de Freitas *et al*, 1985), survival in climates of extreme cold (de Freitas and Symon, 1987) and for general purposes of human climate classification (Auliciems, de Freitas and Hare, 1973; Auliciems and Kalma, 1979; de Freitas, 1979, 1987). The importance of this has been recognised in climate-recreation research (Terjung, 1968; Bauer, 1976; Reifsnyder, 1983), but so far there have been few convincing studies aimed at to identify optimal or preferred conditions for various outdoor recreational activities. There have been even fewer that examine the sensitivity of tourism to atmospheric conditions generally.

Several writers have described tourism climate in terms of human response in preference to traditional taxonomic methods of portraying regional climates (Green, 1967; Davis, 1968; Murray, 1972; Maunder 1972; Crowe, McKay and Baker, 1973, 1977a, 1977b; Findlay, 1973; Crowe, 1976; Gates, 1975a, 1975b; Masterton, Crowe and Baker, 1976; Masterton and McNichol, 1981; Smith, 1985). In some cases, as in the work of Paul (1972), simple climatic indices such as the Thom Discomfort Index and the Wind Chill Index have been computed from climatological data and, in the case of Green (1967), generalised quantitative summations of weather variables arbitrarily weighted have been employed. Other researchers such as Terjung (1968), Danilova (1974), Bauer (1976) and Yapp and MacDonald (1978) have used more sophisticated measures of tourism climate based on the body's thermal exchanges with the environment. Mieczkowski (1985) has devised a broadly based climatic index for evaluating world climates for tourism. However, meaning attached to these measures has been secondarily derived and interpreted without field investigation.

It was with the above in mind that the work by de Freitas (1990) set out to examine, by way of a case study in Australia, methods capable of giving information that can be used to appraise and rate recreational climates in terms of user sensitivity and satisfaction. Ideally, given the complexity of the problem of addressing the amenity role of climate, the research should concentrate initially on a well-defined human activity; preferably one that is clearly linked with amenity resource attributes of the atmospheric environment. These requirements are fulfilled by a variety of outdoor recreational activities of which beach recreation appeared to be the most appropriate. There are several reasons for this. 1) Beach recreation is an activity in which the human body is usually lightly clad and therefore directly exposed to atmospheric elements. 2) Beach users in Australia are normally clustered in a relatively small area (patrolled by lifeguards). Therefore, sample populations can be readily observed, and the compact area facilitates on-site monitoring of atmospheric and associated environmental variables representative of ambient conditions. 3) For the beach user, individual recreational aims or objectives of the occasion are similar. From a research standpoint these characteristics offer a relatively controlled situation. 4) Beach use is among the most popular of outdoor recreational activities in Australia and elsewhere as measured by beach attendance figures. Thus, greater knowledge of the influence of climate on beach recreation is likely to be economically important to the coastal recreation industry.

Two broad categories of questions exist around which the investigation was built (de Freitas, 1990). Since the heat balance of the body is fundamental to assessments of human climates, the first category involves specification of the thermal environment.

- 1) Given methods of body-environment energy budgeting, how are outdoor thermal conditions best quantified?
- 2) How should thermal index values be interpreted?

The second category of questions centres on assessing the atmospheric resource generally in terms of recreation.

- 1) What thermal atmospheric conditions are those most preferred for (beach) recreation?
- 2) To what extent is the level of (beach) user satisfaction influenced by non-thermal atmospheric conditions?
- 3) What are the relationships between atmospheric conditions and participant satisfaction?

## **CONCEPTUAL FRAMEWORKS**

Human response to climate is largely a matter of perception, with the exception of the thermal component. Thus some climate variables are entirely *physical* (e.g. rain), some are *physiological* (e.g. air temperature), some are *psychological* (e.g. clear blue skies) and some are *combinations of all three*. Many writers on the subject of tourism climate single out the thermal component of climate as the most important element. But within a broad range of moderate or “non-extreme” thermal conditions, other factors assume relatively greater importance in determining the pleasantness rating of a given weather or climate condition.

The nature of the relationship between the atmospheric environment and the enjoyable pursuit of outdoor recreational activity may be seen to be a function of facets of on-site atmospheric conditions. A conceptual framework for this is shown schematically in Figure 1. The *facets of tourism climate* given at the top of Figure 1 are 1) *thermal*, 2) *physical*, and 3) *aesthetic*.

- 1) Treatment of the *thermal* characteristics of on-site conditions involves four steps.

- a) Integrate the physical factors influencing the body-atmosphere thermal state.

The method used must include both the attributes of those exposed and the functional attributes of the environment as well as the complete range of atmospheric variables. For the atmospheric environment these include air

temperature, humidity, wind, solar and longwave radiation and nature of the physical surroundings, and for the body, metabolic rate, posture and clothing.

- b) Provide a rational index with sound physiological bases that adequately describes the net thermal effect on the human body.
  - c) Identify relationships between the thermal state of the body and the condition of mind that expresses the thermal sensation associated with this state.
  - d) Provide a rating of the perceived thermal sensation and corresponding calorific index according to the level of satisfaction experienced. This means identifying subjective reaction classified on a favourable-to-unfavourable spectrum as a measure of desirability of conditions.
- 2) The *physical* category shown in Figure 1 is identified in recognition of the existence of specific meteorological elements such as rain and high wind that directly or indirectly affect participant satisfaction other than in a thermal sense. The occurrence of high wind, for example, can have either a direct mechanical effect on the vacationer, causing inconvenience (personal belongings having to be secured or weighted down) or an indirect effect such as blowing sand causing annoyance. Others things that fall into physical category are rain (duration), rain days (frequency), ice, snow, severe weather, air quality and ultraviolet radiation.
- 3) The aesthetic aspects relate to the climatically controlled resource attributes of the recreation environment, which Crowe, McKay and Baker (1973) have termed the atmospheric component of the 'aesthetic natural milieu'. Included within this category are 'weather' factors such as visibility, sunshine or cloud associated with the prevailing synoptic condition (for example, 'a nice, clear, sunny day'), day length and visibility.

The above factors are summarised in Table1.

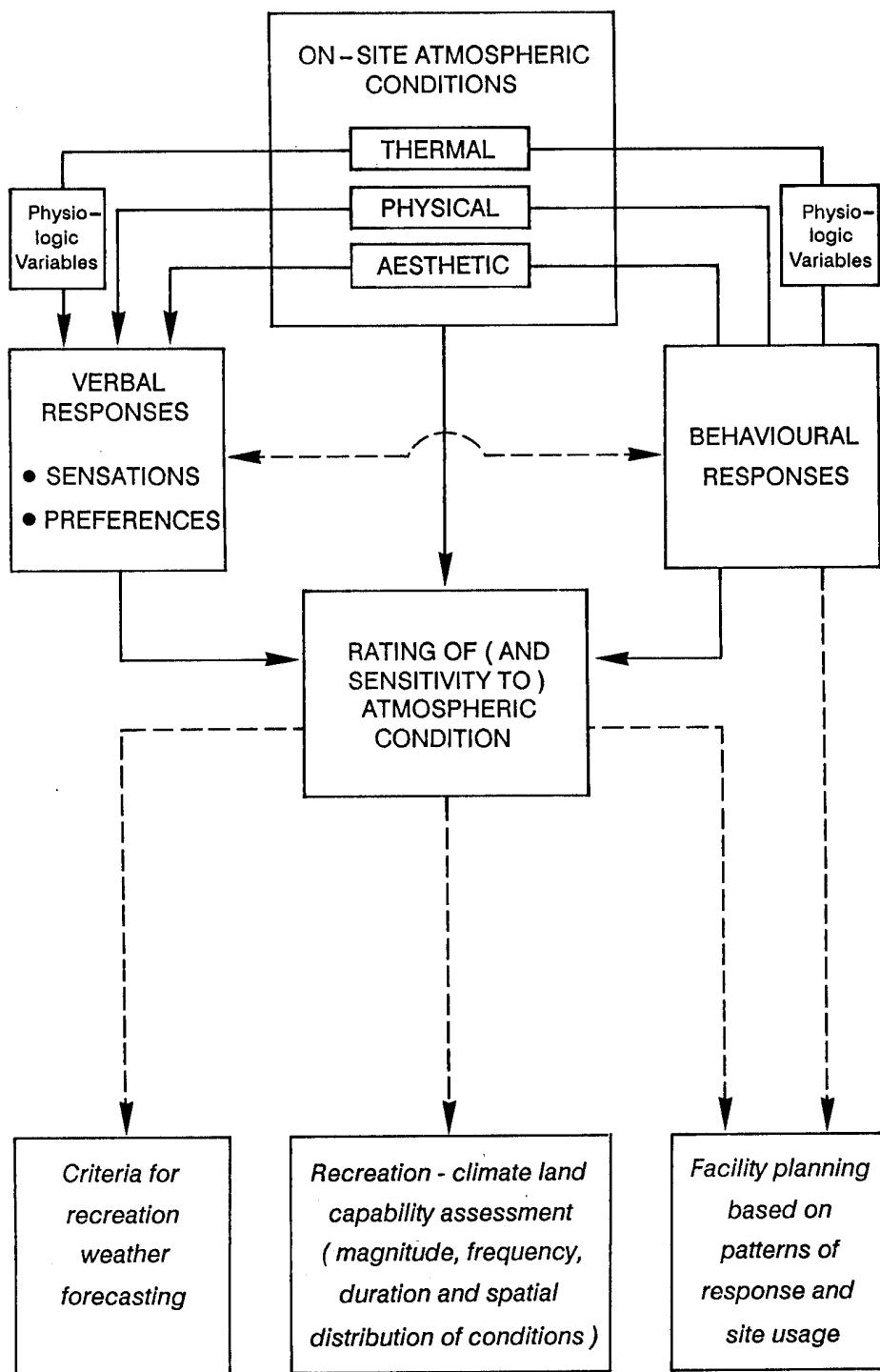


Figure 1. Conceptual framework for the study of tourism climate showing the make-up of on-site climate conditions and two independent methods for assessing human response or reaction. These can be used for rating weather and climate in terms participant sensitivity and satisfaction to conditions.

Table 1. Various facets of tourism climate and their significance and impact.

<b>Facet of climate</b>	<b>Significance</b>	<b>Impact</b>
Aesthetic		
Sunshine/cloudiness	Quality of experience	Enjoyment, attractiveness of site
Visibility	Quality of experience	Enjoyment, attractiveness of site
Day length	Convenience	Hours of daylight available
Physical		
Wind	Annoyance	Blown belongings, sand, dust...
Rain	Annoyance, charm	Wetting, reduced visibility, enjoyment
Snow	Winter sports/activities	Participation in sports/activities
Ice	Danger	Personal injury, damage to property
Severe weather	Annoyance, danger	All of above
Air quality	Annoyance, danger	Health, physical wellbeing, allergies
Ultraviolet radiation	Danger, attraction	Health, suntan, sunburn
Thermal		
Integrated effects of air temperature, wind, solar radiation, humidity, longwave radiation, metabolic rate.	Thermal comfort Therapeutic, restorative	Environmental stress Physiological strain Hypothermia Hyperthermia Potential for recuperation

To identify and describe the experience of on-site atmospheric conditions, de Freitas (1990) used two separate forms of user response, shown in Figure 1:

- 1) Sensory perception of the immediate atmospheric surrounds expressed verbally;
- 2) Behavioural responses that modify or enhance effects of the atmosphere.

By employing, independently, separate indicators of the on-site experience, the reliability of each was examined and interpreted by comparison and apparent threshold conditions verified.

Little is known about the effects of climate on human behaviour, but it is clear that in some cases behaviour is a response that modifies or enhances the effects of the atmosphere. Behaviour can be used as a measure of human sensitivity and satisfaction. Role and significance of behaviour is that an individual can adapt/adjust in five ways:

- 1) Passive acceptance;
- 2) Avoid of areas of unfavourable weather or climate determined condition (for example: move from sun to shade, or vice versa; select vacation destination according to climate condition etc);
- 3) Change activity to suit weather condition so as to maximise enjoyment of outdoor experience (for example: swim more\less, drive rather than walk, extend\reduce length of stay etc);
- 4) Use structural or mechanical aids (for example, use of: umbrellas, wind breaks, hats, shelters etc); and
- 5) Adjust thermal insulation of body (clothing).

The results of the research (de Freitas, 1990) showed that body-atmosphere energy balance indices are reliable indicators of on-site thermal conditions. Thermal component is main factor determining the desirability of weather. Behaviour is a reliable indicator of the significance of weather conditions. Use of shade and clothing are best indicators of heat and cold stress, respectively. Change of posture related to on-site conditions, to a greater degree than expected. Duration of visit is best behavioural indicator of overall significance of recreation climate.

Certain behavioural adjustments (use of shade umbrellas, windbreaks and possibly increased frequency of swims) serve to reduce the beach user's sensitivity to on-site atmospheric conditions, although stated preferences as regards beach weather remain the same. In the absence of ideal conditions, an individual can create, to a point, a personal microclimate that is acceptable. Surprisingly, attendance is a poor measure of demand (i.e. user response to varying on-site atmospheric conditions). Attendance only reflects the outer

limits of acceptability. The work suggested that time spent on site per visit (duration of visit) is a more accurate measure of user response and preferences. Furthermore the findings of the research indicated that atmospheric conditions within the broad zone of acceptability are those that the beach user can readily cope with or effectively modify. Optimum thermal conditions are those requiring no specific adjustment or behavioural fine-tuning.

## FUTURE DIRECTIONS

Thus far, most work in tourism climatology has been based on subjective criteria and unverified perceptions of tourists. More field studies are required along with work that assembles observational data to determine the actual responses, perceptions, needs, reactions and expectations of vacationers. Anderssen and Colberg (1973) have shown that of factors that affect tourism demand, the dominant attributes of a tourist destination are cost, climate and scenery. Research is needed to assess the relative importance and role of the climate attribute as a component of the tourist destination image.

There a number of studies are in the tourism climatology literature that identify potentially useful areas for future research. For example, Ross (1992) has shown that climate, as a component of destination image, does strongly influence tourist behaviour. Hunt (1975) pointed out that images and expectations of a destination may have as much as, or more, to do with an area's tourist image projection than the more tangible recreation resources. Publicity about climate to be expected in an area can also modify a tourist's expectations and thus their degree of satisfaction with the outcome of the experience. There is the often-quoted example of the Irish Tourist Board, which shrewdly promoted the delights of a cool and rainy Irish summer. It was thought to have influenced the expectations of tourists, thus reducing their disappointment.

Ross (1992) has also explored the influence of a variety of climatic conditions on both ideal holiday destinations and on perceptions of the wet tropics area of Far North Queensland. Given that distinct patterns were found, these results have implications for those involved in the tourism/hospitality industry, as it should influence the way the area is marketed to potential visitors to Far North Queensland as a holiday destination.

There is also the question of forecasting tourist travel overseas based on climate. Palutikof (1999) and Agnew and Palutikof (2001) have explored this area. They found that: a) outward and inward visitor movement is a response to both weather during the year and travel and weather the previous year; b) rainfall is a better indicator of outward travel than inward,

with wetter conditions encouraging more visits abroad; and c) autumn temperatures and sunshine have the greatest influence on inward travel. Predictions of tourist travel based on these findings could be important to the travel industry and justify further research.

There are costs to both tourists and tourism operators resulting from the occurrence of unexpected less than satisfactory climate. These need to be fully documented and methods and approaches to studying these require attention. Even now tourists and tourist operators can take out insurance on likelihood of “bad” weather conditions occurring while on vacation. The question arises as to how insurance companies define “bad weather” and the extent to which this is accurate or appropriate, and how this compares to perceptions of the “quality” of conditions experienced by tourists themselves on the one hand, and how it varies with different recreational activities on the other.

The popularity of Mieczkowski’s Tourism Climate Index (TCI) shows that there is demand for this type of unitary indicator of climate. What is now required is research that tests the accuracy of such an index or devises a similar index using systematic surveys to interpret it, rather than relying on arbitrary and subjective value judgements of the researcher, as in the case of TCI. An ideal tourism climate model would:

- Rely only on standard climate data.
- Minimise use of average values and maximises use of actual (real) observations.
- Use as input all attributes of the atmospheric environment.
- Use an integrated body-atmosphere energy balance assessment of the thermal component of climate
- Includes all three attributes of tourism climate: thermal, aesthetic and physical/mechanical
- As an added feature, recognise the notion of climate as a limiting factor, or climate limits to tourism, with focus on thresholds or limitations; for example, times when climate unsuitable or unappealing to the vacationer.

In all of this, the aim should be to adopt standard methods and indices as far as possible. There is also a need to provide potential tourists with probabilistic information on climate to be expected at various destinations. This will lead to improved information and improved choice. Clearly, much work remains to be done.

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# *Evaluating domestic tourists' attitudes to British weather. A qualitative approach*

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## *Abstract*

Previous research has attempted to develop and map quantitative measures of the climatic well being of tourists (eg Mieczowski's Tourism Climatic Index). These have been based on the assumption that a majority of tourists are entirely motivated by climatic conditions, of a certain and common nature. Mintel (1991) claimed that 73 percent of respondents to a UK survey cited 'good weather' as the main reason to go abroad. This study develops the idea that tourist decisions related to trips within the UK by UK residents has a far more sophisticated relationship with climatic conditions and these cannot be adequately captured by simple quantitative indices. The paper develops a qualitative methodology using in-depth discussion groups to investigate the importance of tourist memories and experiences in relation to climate. It is found that definitions of 'bad' and 'good' weather are more complex than quantitative indices suggest. Some people show ambivalence in their attitudes towards weather conditions and their decisions involve trade-offs between the risk of poor weather and other aspects of the holiday experience

## *Introduction*

For 46% of the British public '*having a good holiday*' is considered their highest spending priority (Mintel 2000) and the domestic market for tourism still accounts for 61% of all trips either to, from or within the United Kingdom (*table 1*). On the other hand, these trips account for a lesser percentage of total expenditure. Tourist-climate studies often seek to explain where climatic considerations are positioned amongst the set of factors that influence holiday location (and the timing of) decisions. According to many authors, for instance Perry (1997), climate constitutes an important part of the environmental context in which recreation and tourism takes place. However the influence of meteorological conditions will be dependent on the chosen activity and tourist expectations. Smith (1993) identified a distinction between 'weather-sensitive' tourism – where the climate is insufficiently reliable to draw mass participation and 'climate-dependent' tourism in which travel to a holiday destination is generated by the actual or perceived climatic attractiveness of the destination. The classification of any holiday into these broad types therefore relates to the tourist activity (eg beach tourism, mountaineering, sailing or sightseeing) and on local climatic conditions both in source and destination locations.

*Table 1 United Kingdom Tourism (Mintel 2000)*

	<b>Trips (millions/%)</b>	<b>Nights (millions/%)</b>	<b>Expenditure (millions UK Pounds/%)</b>
<b>Domestic Market</b>	123.5/61	435/36.3	14,875/26.5
<b>Outbound Market</b>	53.6/26.5	536/44.7	28,672/51.1
<b>Inbound Market</b>	25.5/12.6	228/19.0	12,605/22.4
<b>Total</b>	202.6/100	1199/100	56,112/100

It is proposed that domestic tourist decisions by United Kingdom residents can be viewed as 'weather-sensitive' and that actual climatic attractiveness exerts only a minor pull on

holidaymakers. Mintel (1991) claimed that 73 percent of respondents to a UK survey cited ‘good weather’ as the main reason to go abroad. In some instances, according to Mieczkowski (1985), many tourists are entirely motivated by climatic considerations. We assume that domestic tourists in the United Kingdom are unlikely to fall into this category.

Before making such an assumption it is necessary to determine which climatic factors, or combination of climatic factors are relevant. Writers, such as Davis (1968) and Mieczowski (1985), have identified temperature, sunshine and rainfall amounts as most important. Climatic means for United Kingdom resorts compare unfavourably with, for example, Mediterranean resorts. In efforts to capture combined effects of weather variables, indices have been developed to assess tourism climate. Mieczkowski’s Tourist Climatic Index (TCI), for instance, is based on a relatively sophisticated arithmetic formula which employs weighted measures of temperature, humidity, rainfall and sunshine to quantify the suitability of a location to tourism.

There exists a growing literature on the use of climatic indices to rate the climatic suitability of a location to tourist activity. However these have been based on the assumption that a majority of tourists are motivated by climatic conditions, of a certain and common nature. In the development of this index and similar quantitative measures there is little evidence relating to how preferences were assessed. In many cases this climate attractiveness is entirely derived from energy balance type equations based on sedentary individuals. Although these provide highly accurate and potentially useful information such positivist approaches fail to recognise the social contexts of individual decision-making. This study therefore employs an alternative qualitative approach to the investigation of climate resources.

### **Methodology**

In undertaking this piece of research we have adopted the epistemology of cultural geography. According to this perspective ‘society does not comprise an isolable, unitary, internally coherent whole’ (Amit-Talai, 1995, 223). There is in fact no common vision of the world. ‘Instead society is seen as multicultural, comprising a complex myriad of different socially defined (constructed) groups each with their own ‘ways of seeing’. (Matthews, Limb and Taylor, 1998, 311). These textual communities are not all equally represented in the decision-making of society. Rather, while some are insiders in positions of power, others are marginalised as outsiders. In conducting this study we have purposefully chosen examples of both insider and outsider groups.

The methodology adopted is qualitative and more specifically involves in-depth discussion groups. These are not focus groups which meet once and tend to deal with issues in a frenetic and superficial way. In-depth discussion groups meet more than once. They are run using principles of group analysis and allow a group identity and memory to be created. This approach has been found to be more sensitive to people’s expression of feelings, meanings and environmental values. Such a perspective is valuable because as long as the variety and richness of people’s environmental values go unexpressed they cannot be represented in the public domain.

In geography, groups were pioneered successfully (Burgess, Limb and Harrison, 1988) have become widely accepted (Special Issue of *Area* 1996) and have been recently and extensively used (Bedford and Burgess 2001, Kneale 2001, Jackson 2001and Crang 2001).

There are a number of key aspects of the research project. These include recruitment, conducting the groups, collecting the data and interpreting the data. In choosing who to include in our groups we were keen to have groups which traditionally have been seen as insiders (professional males and middle class walkers) and outsiders (children and mums with preschool children). The groups were run according to principles of best practice (Burgess,

Harrison and Limb 1988) by a conductor and an observer. The Conductor's responsibilities included listening, using silences, not asking direct questions, drawing in silent members, keeping "to task", handling conflict and protecting individuals. Data was recorded on tape (with the participants' permission) and were transcribed by either the conductor or observer. The group discussions generated 12-15,000 words of data per group. The interpretation of the data was started immediately after the discussion in the form of a debrief between the conductor and the observer. Thematic analysis of the transcripts was then undertaken generating *in vivo* (drawn from the discussions) and *meta* (drawn from the literature) codes. These themes were then written up under the following headings:

1. Placing weather in perspective  
 'Good' and 'bad' things about holidays  
 Favourite UK holiday memory  
 Most recent UK holiday
2. Deconstructing 'good' and 'bad' weather
3. The social context of holiday decision-making
4. Dimensions of the weather experience

### ***Findings***

The first part of the analysis seeks to place weather in perspective by examining the importance of weather in the context of people's discussions of 'good' and 'bad' things about holidays. The purpose of this exercise was to investigate the role of weather in people's evaluation. For mums and professional males there is a wide range of factors that affect their evaluation of a holiday (see *table 2 and 3*) Weather is mentioned by all three groups but is particularly important for the mums because of their concern about how their children would cope with hot weather. Interestingly they see hot weather as a problem rather than an advantage.

*Table 2 Responses to question: What's good about holidays?*

<i>What's good about holidays?</i>		
<b>Male Professionals</b>	<b>Mothers</b>	<b>Children</b>
Different cultures	Leaving everything behind	Weather
Different food	Getting outside more	Different scenery
Something worth photographing	Fewer toys, so children are more resourceful	Chance to relax
Escaping domestic tasks	Getting away from jobs	Away from it all
Natural history	Getting away from routine	Getting brown
Being active	Everybody is more relaxed	
Exploration	Change of scenery	
Restaurant and meals	Spending time with children	
Good weather	Extra money	
Drinking	Children enjoying being with both parents	
Trekking		
Relaxing		
Varies over lifecycle		

The next part of the analysis seeks to put weather in perspective by uncovering a favourite UK holiday memory. This was achieved by using a relaxation and retrospective exercise with the groups in which they went back to a favourite UK holiday memory using their imagination and then drew a picture of what they had remembered. Such exercises have been observed before to generate particularly vivid memories. The experiences which were described by the groups reflect a variety of elements. Weather is not mentioned by the professional males group (*figure 1*) but plays an important part in memories from the children's (*figure 2*) and mums' groups (*figure 3*).

The third and final part of the analysis seeks to put weather in perspective by examining people's memories of their most recent UK. Experiences again reflect a variety of elements. Weather features in 3-4 of children's descriptions (*figure 4*) and all of the mum's group descriptions (*figure 5*). There is no mention of weather by professional males (*figure 6*).

Our conclusions from these three analyses is that rather than being a distinct and isolated variable, weather is embedded in the fabric of holiday life. There are a wide variety of other factors which play a part in people's evaluation and memories of holiday experiences. There is variation within and between groups in the extent to which weather features. In particular the Professional Males group do not mention weather. It is therefore important to investigate why that may be the case.

*Table 3 Responses to the question: What's bad about holidays?*

What's bad about holidays?		
<b>Male Professionals</b>	<b>Mothers</b>	<b>Children</b>
Don't want to lie on beaches	Still hard work with children	Miss friends
Turbulence	Travelling time	Coming home is an anti-climax
Not sitting by the pool with kids screaming	Rain when camping	
Train breaking down	Entertaining the children when its raining	
Theme nights and lunches	Having to take so much 'kit'	
Lack of access to the landscape	High temperatures so children cannot sleep	
Rain and poor weather	Delays when flying	
Brits abroad		
Union Jack T-shirts		
Insects		
Litter		
Sewage		
Unfriendly natives		

We then moved on to try and deconstruct 'good' and 'bad' weather according to the groups. If we examine children's responses to 'good' and 'bad' weather we find quite a complex and ambivalent picture of their definitions (*table 4*). On the one hand there is a clear view among the children that bad weather can spoil a holiday and the elements of bad weather-cloud, rain and low temperatures are identified. On the other hand there is a recognition that hot weather presents a risk of burning and sunstroke. Although rain was seen as a threat to a good holiday, opportunities to spend time with the family indoors when it's raining were still welcomed.

The professional males give a very different response (*table 5*). They provide no clear definitions of what constitutes 'good' and 'bad' weather. Rather they see rain as a natural hazard when walking or exploring and argue that they enjoy it anyway. Much emphasis is placed by them on having realistic expectations and a positive attitude whatever the weather. Their indifference to the weather may explain why weather does not feature in their evaluations and experiences analysed earlier. There is however an acknowledgement that, at its extreme, poor weather (in the form of low cloud and rain) can be dangerous when hill walking. They also point out that they do seek to avoid very hot weather by choosing carefully where and when to go. They too therefore express some ambivalence in their attitudes to weather.

*Table 4 Children's attitudes to holiday weather*

<b>Good Weather</b>	<b>Bad Weather</b>	<b>Ambivalence</b>	<b>Irrelevance</b>
Hot, but not sticky	If abroad – more significant	Sunstroke and sunburn	Enjoyment whatever the weather
Sunny, but with a breeze	Brochures are inaccurate	Need to spend time in the shade	Importance of the 'family thing'
Relaxing	Ruins the day, Places close	Caught out by the English sun	Rain is irrelevant
Predictable	Can't go out, can't go on the beach	Enjoy rain – sit inside and drink cocoa	
Sunshine makes you feel bright and you want to do things	Not what you come on holiday to do	Clouds give you a headache	
Warmth is important	Sit indoors and watch TV		

*Table 4 Male Professionals attitudes to holiday weather*

<b>Good Weather</b>	<b>Bad Weather</b>	<b>Ambivalence</b>	<b>Irrelevance</b>
	Rain when outdoors	Too hot	Enjoy the outdoors anyway
	Expectations	Choice of when to go	
	Attitude	Weather and season are intertwined	
	Weather can be dangerous		

One of the things we were interested in examining was the extent to which social context figured in decision-making about weather and holiday locations. To that end we chose groups who might be seen to be very different in terms of their freedom of choice. Children and mums with young children have long since been recognised as less powerful groups within society. Whereas our professional males and middle class walkers might be seen as more privileged in this respect.

Our discussions with the children suggested that there was a difference in the group between a minority whose parents consulted them about holiday decisions (including likely weather conditions) and the majority for whom such decisions were out of their hands. In particular there were several examples of how a parental preference for hot weather took priority over the children's desire for cooler conditions.

For the group of mums with young children there was a constant compromise between what weather adults might prefer and what weather they would deem suitable for their children. '*since having the children...it's kind of been dictated by the children...the adults have had to make compromises with the children*' (Session 2:722-4). Compromising is not only restricted to children. When asked if holidaying with family involved compromises about desirable weather conditions one mum replied '*All the time, and I just go 'whatever'....I do think if everybody else is going to be happy then that makes me happy*' (Session 2: 719, 724-5)

Such compromises were not evident in discussions with professional males who seem able to exert a strong personal choice in their decision-making. Equally such compromises were also not evident among the ramblers with the exception of one male member whose wife's ill health made a hot weather holiday impossible. There seems to be a clear division between groups who are relatively less or more powerful in making choices about holiday weather conditions.

Part of our purpose in conducting this research project was to explore the diversity and richness of people's experience. We wanted to go beyond an objective analysis of weather, consisting of temperature, precipitation, wind and cloud, to examine our groups' intersubjective experiences of weather. There was no doubt that the children were tuned into the fact that weather affects moods and the emotions (cloudy weather makes you moody, warmth gives you the incentive to get up and do something). To illustrate this point further we have chosen the following extracts from the transcripts.

(Mum with pre-school children describing favourite UK holiday memory) '*It's just a particular day which was so brilliant...it was one day walking in Wales, in Snowdonia, walking up a mountain Cadre Iris and it was just a really baking hot sunny day and it was just clear blue skies and really exhilarating because we managed to walk up –and it wasn't that hard a walk-but it was a nice, you know, walk-really fresh and we got half way up and the lake was beautiful, clear lake and it just looked so inviting and we just dived in fully clothed and it was just lovely." It was the most refreshing swimming I've ever had and then carried on walking and we were dry within however long- not long because it was so sunny and hot and then sitting on the top we could just see the whole shape of Wales just about.... The sea and the coastline and just see for miles'* (Session 2: 147-156).

(Another mum describing a favourite UK holiday) '*The scenery and the place was fantastic and I just remember going dipping in and out of the rivers on horseback and drinking the water and stopping for picnics in really idyllic spots with the smell of the ferns and this dappled sunlight through the trees.*' (Session 2: 189-191)

(Another mum responding to a picture of a snow scene) '*I do actually love being in a ski resort because I just think that the scenery and the atmosphere and the snow and just the whole thing about it is really nice...and the sunset and the way that the sun usually streams down the valley at the end of the day*' (Session 2: 478-481).

(Male rambler) 'Yes I think obviously warmish-not too hot sort of weather. But I think that all of us would say that we've enjoyed the experience perhaps of-not necessarily of walking in the rain but walking in the cloud-walking in overcast weather because you often see the countryside in a quite different light and certainly when I'm doing sort of higher walks the sort of broody nature of the countryside can be enhanced by cloud cover and the occasional – you sort of get the feeling of remoteness and isolation when there's clouds over the sky and there's a bit of wind and the clouds are skudding'.

(Male rambler) '*I like to see-not continuous cloud cover but I like to see you know shower clouds, different cloud formations...I'd rather see different clouds...continuous blue sky after a while gets boring'*

(Male rambler) '*It can and it comes back to the point you made and it (weather) does change the lighting and you get shade and light, shade and if you're on high ground you can see these areas of shade and light around and it does give some enhancement'*

(Male rambler) '*I can remember seeing storm clouds and a dreadful storm building up over Kinder from Mam Tor and sort of looking across and seeing the clouds rolling up and seeing the lightening in the sky when we were staying quite nice and dry-those sorts of experiences are not to be missed.'*

(Female rambler) '*If you're walking in East Anglia out towards the East coast then that's what you have to rely on is actually the skyscape as opposed to undulating land...so you're looking at the sky so you do need cloud to give you interest. It's a whole different scene.'*

(Male rambler) '*A good point about light whoever made that –I think if you walk a lot different light at different times of the year and different surroundings are important.*'

Two further comments were made in responses to photographs

(Male rambler) '*It's not just the terrain as the whole picture. One the sky-it's the sort of day which I would enjoy walking in where it looks as if there is a movement-a moving sky so you've got changes of light, sky movement'*

(Female rambler) '*I like sort of lighting, misty...it's a landscape that will sort of hold me. It pulls you on-it's sort of tantalising. I can think that this will be changing because the mists will be swirling round and changing*'.

From these extracts we begin to see evidence for a more complex and intimate appreciation of weather. In particular weather has a role in lending light, colour, character, movement and atmosphere to scenery.

### **Conclusion**

We acknowledge that our study only begins to explore the values and meanings that people have towards weather. However, there are a number of conclusions which we tentatively make. First, weather is not a distinct and isolated variable, rather it is embedded in people's holiday experience. Second, it is clear that different groups of people evaluate and remember weather in different ways. Third, 'good' and 'bad' weather are not absolute concepts but vary with circumstances and individual's preferences. Indeed, people have ambivalent attitudes to weather. Fourth, we have found that responses to weather conditions are mediated by other factors such as company, activity and expectations. Decision-making about holiday locations and weather take place in a social context which involves negotiations between family and/or friends and constrains some people more than others. Finally we would suggest that the qualitative method illustrates that experiences of weather are rich and engage the emotions and senses in ways which are not readily evident through quantitative analysis.

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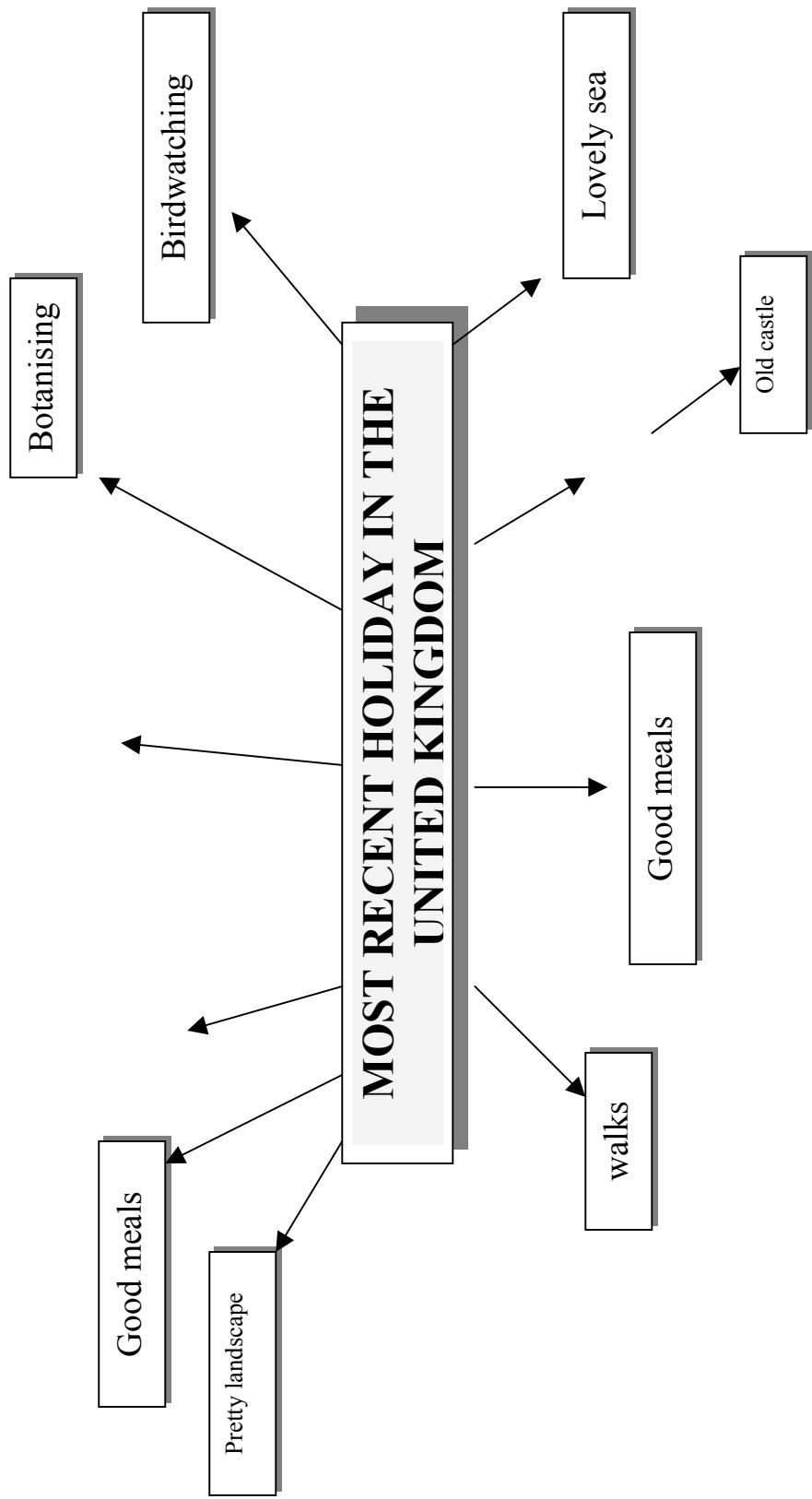
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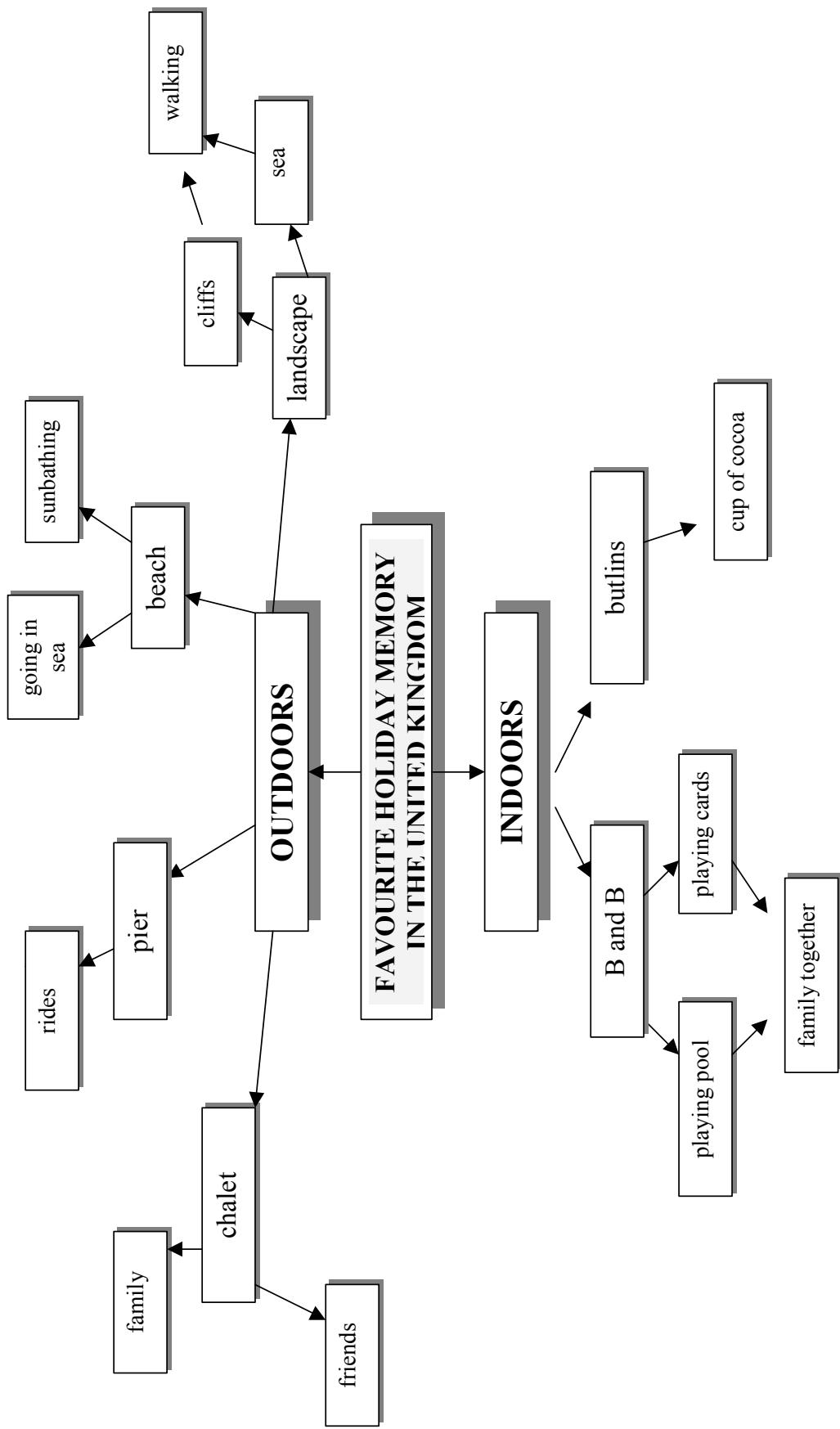
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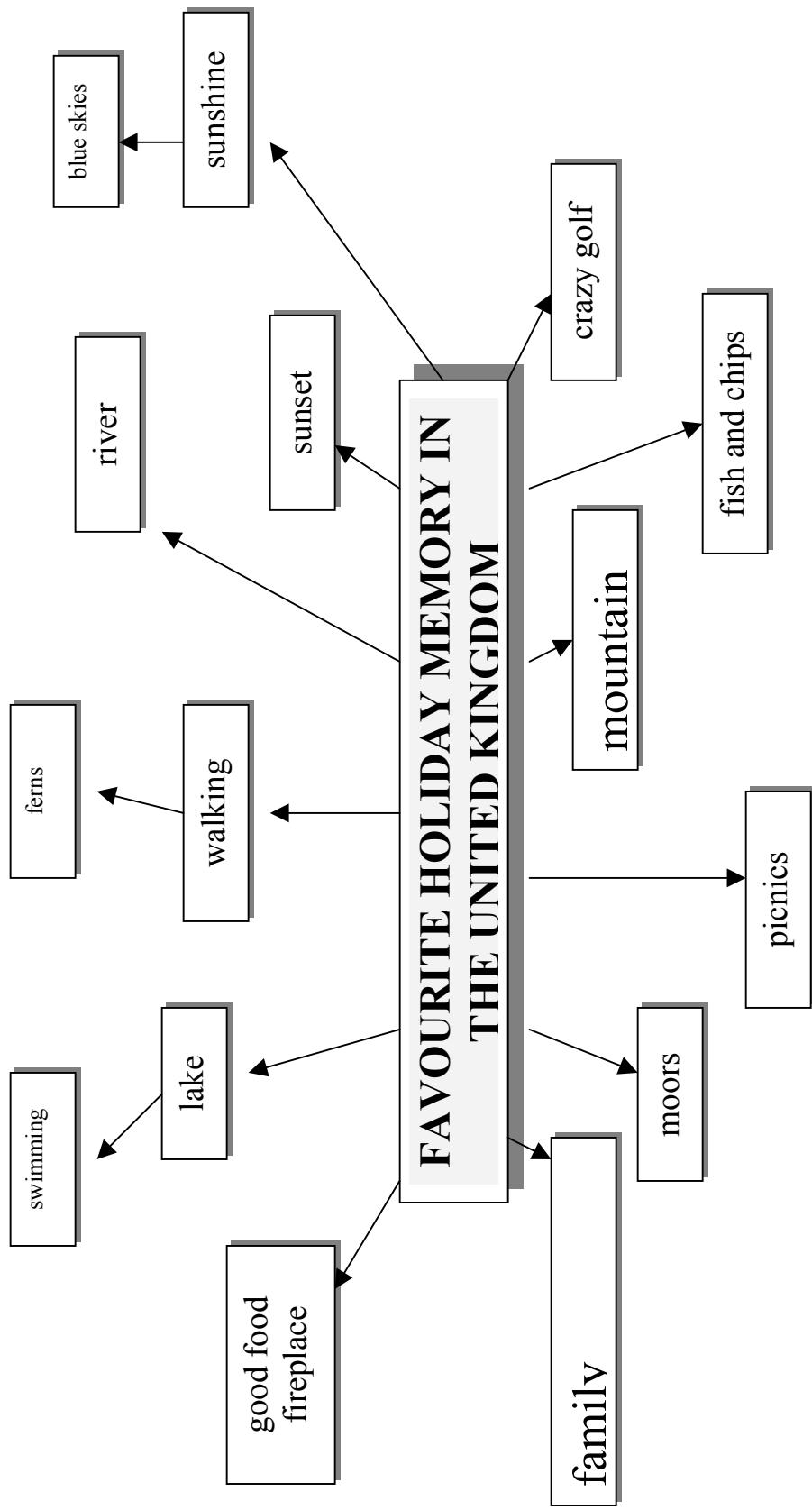
*Figure 1 Map of responses of male professionals – most recent holiday in the UK*



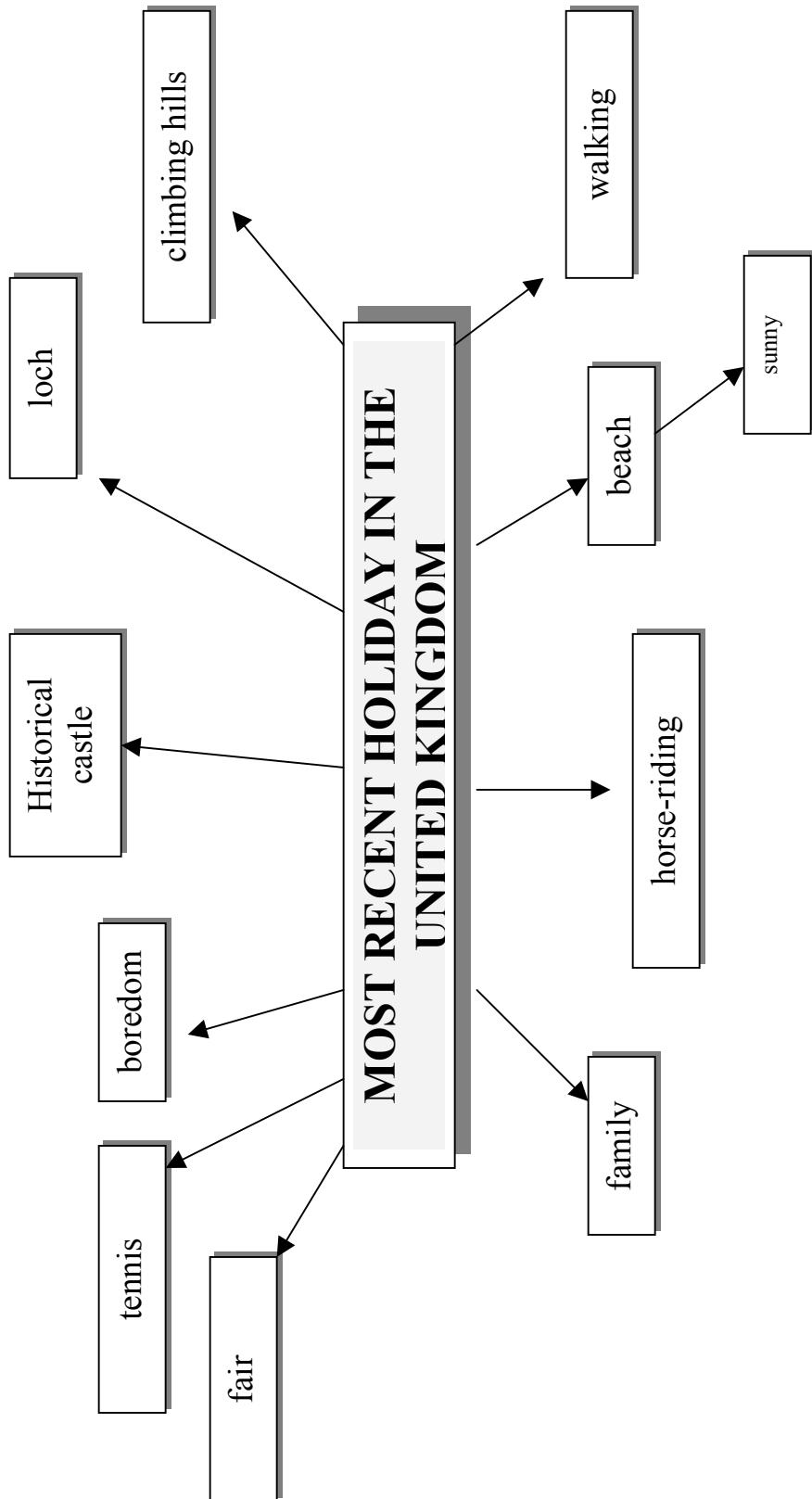
*Figure 2 Map of responses – Children – most favourite holiday memory in the UK*



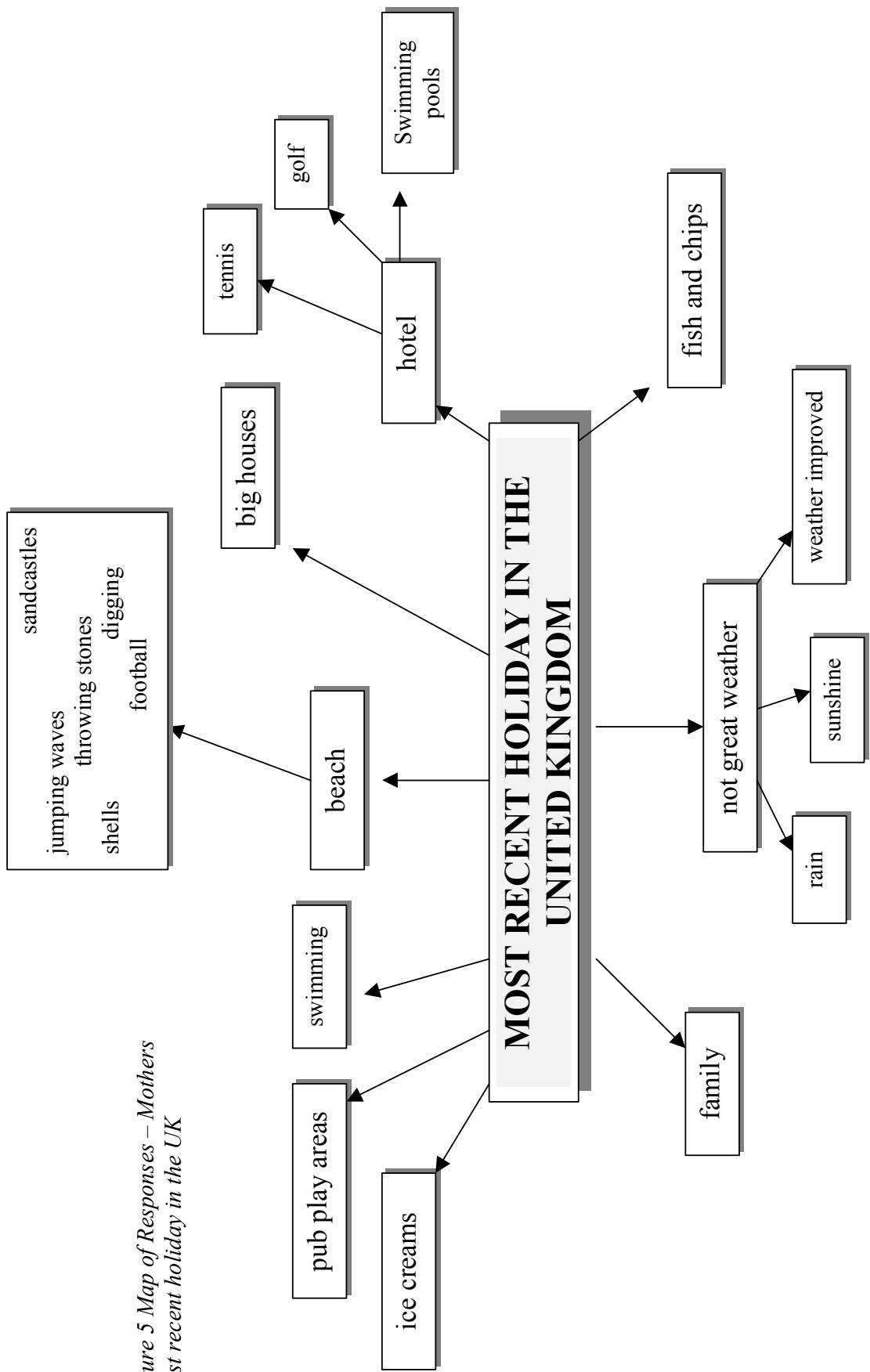
*Figure 3 Map of responses – mothers- most favourite holiday memory in the UK*



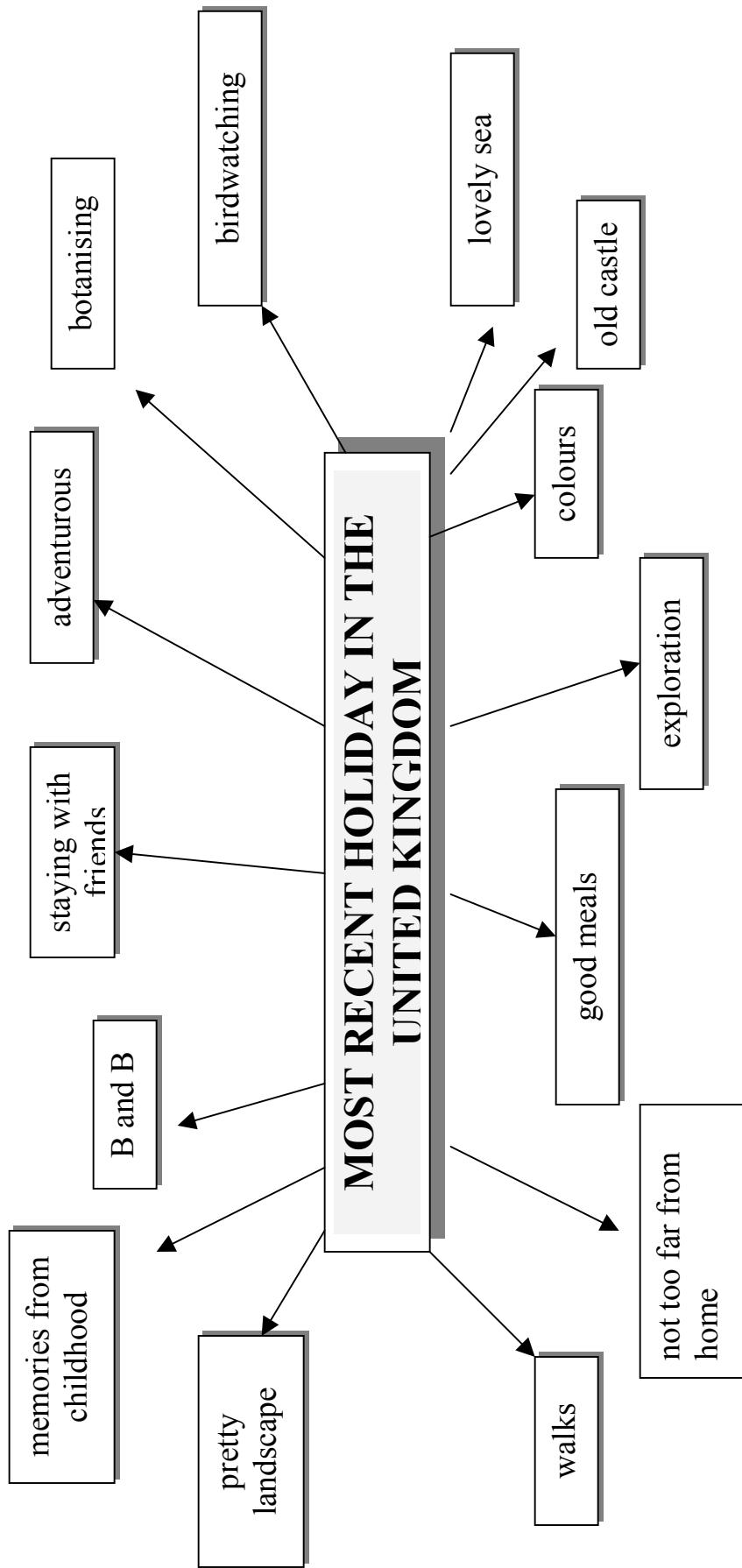
*Figure 4 Map of responses of children – most recent holiday in the UK*



*Figure 5 Map of Responses – Mothers  
Most recent holiday in the UK*



*Figure 6 Map of responses of professional males – most recent holiday in the UK*



## **MORE HEAT AND DROUGHT -- CAN MEDITERRANEAN TOURISM SURVIVE AND PROSPER?**

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### **Abstract**

Summer heat-waves in southern Europe have become more frequent. They are forecast to increase even more in frequency in association with projected climate change as a result of global warming. The impact of very hot weather on the tourism industry of the Mediterranean will be considered. The measures and responses that can be adopted to alleviate the impacts will be reviewed. Adaptive responses can be learnt from other areas that experience intense summer heat and from a consideration of the views of holidaymakers to the problems that can accompany excessive summer heat. The use of indices to measure the desirability of the Mediterranean in relation to other potential holiday destinations will be explored. Future tourism scenarios in the Mediterranean need to consider also changing demographic and economic conditions. Climate change will present new challenges but also lead to new opportunities for tourist investment to capitalise on the new environmental conditions.

**Keywords:** Heat, drought, tourism, Mediterranean

### **Introduction**

The climate of the Mediterranean is perceived, quite erroneously, by many tourists as idyllic, benign and delightful. It is the renowned radiance and clarity of light, rather than the heat-waves, droughts, storms and floods that can plague the region at times, that have made the area seductive to north Europeans for many centuries. The Mediterranean is currently the world's most popular and successful tourist destination with over 120 million visitors every year. Climate constitutes an important part of the environmental context in which recreation and tourism take place and because tourism is a voluntary and discretionary activity, participation will depend on perceived favourable conditions. For many activities there are critical threshold levels beyond which participation and enjoyment levels fall and safety or health may be endangered.

Whilst in the eighteenth and nineteenth centuries it was the winter that was "the season" with the aristocracy of northern Europe fleeing the cold and dark winters, today it is mass "sun-lust" package tourism that leads to a seasonal peak in high summer. A UK survey suggested that for over 80% of overseas holiday-makers better weather than can normally be found in the UK in summer was the primary reason for choosing an overseas holiday. Concern about skin cancer and worries about UV-B radiation has so far tended merely to modify behaviour (e.g. the use of more effective sunscreen treatments), rather than cause a change in destination preference. It is still the case that for many the acquisition of a sun tan and the purchase of a holiday is as important as buying consumer durables for the home. The beach has become a fun place of ease, entertainment and relaxation.

### **KEY SENSITIVITIES TO WEATHER AND CLIMATE**

Major holiday decisions within many of the "tourist exporting" countries of Northern Europe are subject to a push and pull effect. The higher temperatures and settled weather of the Mediterranean summer exerts a big attraction, but better summers at home will reduce overseas holiday bookings. Giles and Perry (1998) have shown that the exceptional summer

of 1995 in the UK led to a drop in outbound tourism and a big reduction in demand in the peak summer season for Mediterranean package holidays. In hot years there is a suggestion that Dutch tourists too prefer domestic to foreign beach holidays (WISE 1999). Large numbers of people indulge in short-term opportunistic decision-making and switch their normal holiday preferences to take account of the unusually favourable conditions at home. Such limited evidence does suggest that climate warming might alter the competitive balance of holiday destinations with adverse effects on high season tourism in the Mediterranean. A limited survey of UK travel agents revealed that their customers most of all wanted guaranteed fine warm weather. Press reports about adverse health conditions, terrorism threats and devastating forest fires was more likely to concern customers than reports of very high temperatures.

## THE FUTURE CLIMATE

IPCC3 (2001) has shown that higher maximum temperatures and more hot days are very likely to increase in frequency during the 21<sup>st</sup> century. The Mediterranean is likely to become less attractive for health reasons in the summer. Apart from the dangers increasingly associated with skin cancer, many Mediterranean beach resorts may simply be too hot for comfort in the peak season, with a much higher frequency of severe heat waves (Perry, 1987). Carter (1991) has used an approximate index of climatic favourability to investigate changes of seasonal climate in Europe under possible future climate change. Results suggested that a climate warming of 4 degrees C would lead to a shift in the optimum summertime climate from the traditional southern coastal resorts northwards to currently less fashionable regions. This result holds true regardless of whether the warming is associated with moderate decreases or increases of precipitation. Mieczkowski (1985) proposed a tourism climate index (TCI) as a means of evaluating world climates for tourism. Whilst he used 5 climate variables in the TCI formulae thermal comfort was considered the most important and given a 50% weighting in the formulae. Using the ACACIA A2 High scenarios (2000) the index was calculated for the recent good summer of 1995 and an average summer 1999, together with the expected index value in 2020, 2050 and 2080 for the UK resort of Bournemouth. From Fig 1 it can be clearly seen that in the 21<sup>st</sup> century most summers are likely to have a preponderance of very good, excellent or ideal days for the holiday-maker in the UK. However the attractiveness of the Mediterranean coastal zone in spring and autumn would be enhanced relative to the present. It is in the months of October-November that the lingering warmth and sunshine of the Mediterranean provides the biggest contrast with the weather in northern Europe. At this season maximum temperatures at present are 8-10C higher than in London whilst in April this difference is only 5-7C. Rotmans, Hulme and Downing (1994) suggest that the area suitable for sun-related tourism will decline in much of Italy and Greece as summer temperatures make beach tourism too uncomfortable. It is single-product destinations that are most vulnerable. A few destinations (e.g. Cyprus and Corsica) offer the potential to commute from hot beaches to cooler mountains but the Mediterranean area is likely to face other climate-related problems, such as marine water pollution and the scarcity of fresh water supplies. The availability of water supply could become a major constraint and the quantity and quality of water available may not be sufficient to satisfy future tourist demands. Large scale expenditure on desalination plants will be needed, especially in some island resorts if water supplies are to be guaranteed.

## DROUGHT

The Spanish drought of the early 1990's showed how island resorts like Majorca could

become dependent on water being transported from the mainland with attendant political tensions (Wheeler 1995). In the last three decades there has been a decrease in spring rainfall in southern Spain and Portugal with the rainy season ending earlier and the dry season onset also occurring earlier. Small islands, for example in the Aegean, could be particularly affected if tourism is allowed to continue to grow. Nicholls and Hoozemans (1996) have shown that in the Mediterranean there are 162 islands exceeding 10 square km in size. Most have a low resource base but significant tourist development. Decline in rainfall and water supply availability, together with beach erosion could undermine their tourist industries and hence their local economies. It has been suggested (Karas 1997) that Crete could experience serious water shortages in 5 years out of 6 by 2010. There is likely to be an increase in friction, with a conflict of interest between local people and tourist authorities on the use of scarce water. It has been calculated that a luxury hotel consumes around 600 litres of fresh water per guest per night. Water-hungry land uses like golf courses and water parks will be seen as water-stealers by local people. Projected decreases in runoff will exacerbate the problem of salinisation of water resources. Increased degradation of the environment and spreading desertification is likely to make some areas less scenically attractive to tourists.

## HEATWAVES

Two major factors have interacted to impede the development of a definition of what a heatwave is, namely, the absence of a simple meteorological measure representing the complex interaction between the human body and the thermal environment, and the lack of suitable homogeneous time series of the meteorological variables likely to be involved (Robinson 2001). Should we use exceedance of fixed absolute values, or deviation from the normal local climate as the basis for a definition? There are clearly several dimensions to very hot weather that need to be considered and examples of three hot weather variables are shown in Fig 2-5. These are taken from the European Climate assessment web-site. Extended heat waves, defined as 10 days or more, appear to be becoming more frequent in the Mediterranean. In the 15 years to 1994 Italy endured 8 such heatwaves. In addition short-duration heat waves of 3-5 days with temperatures 7 degrees C or more above normal have occurred on 33 occasions in the central Mediterranean between 1950-95. Individual heat wave days have increased from 52 days in the decade 1950-1959 to 230 in the decade 1980-1989. (Conte, Sorani and Piervitali 1999) Heat waves cause rises in the death rate, especially in urban areas, for example in one episode from 13 July – 2<sup>nd</sup> August 1983 in Rome 450 deaths above the normal average occurred. In 1987 more than 1100 residents died in Greece between 20-31<sup>st</sup> July (Katsouyanni et al 1988) with a combination of temperatures above 40C and poor air quality. In 1998 in Cyprus 45 deaths attributable to heat were noted when the maximum temperature exceeded 40C on 8 successive days. In Athens the National Weather Service of Greece forecasts heat wave emergencies and warnings are disseminated to the public. Extreme heatwaves and the deaths involved frequently get reported in the media of foreign countries and give a negative image to potential holiday-makers. Emotive phrases like “killer heatwave” have been used. Even reports by reputable organizations can use hyperbole to get their message across. The World Wild Fund For Nature reported that some tourist destinations could be turned into “holiday horror stories”. It has to be remembered that holiday-makers from northern Europe will be unused to temperatures as high as 40C and may be more at risk than local people, who are used to long hot summers. Gawith, Downing and Karacotas (1999) have shown that at Thessaloniki in northern Greece the temperature-humidity index (THI) which assesses the impact of high temperatures and humidity will rise above a value of 84 (when nearly everyone feels uncomfortable) for more than twice as long as at present by 2050. In addition there will be significant increases in the shoulder warm periods suggesting a lengthening of the summer season. Forest fires, such as were very widespread in August 1994

in Tuscany ,Corsica ,Sardinia and France can lead to evacuation from tourist facilities such as camp sites. Pinol, Terradas and Lloret (1998) found that in coastal eastern Spain there has been increased fire activity and the number of days of very high fire risk is likely to increase further since there is a correlation between summer heat and fire occurrence. In Italy a strong association has been found between the number of forest fires and both higher summer temperatures and lower summer precipitation. Measures such as the closure of forest and parkland in summer may become increasingly necessary.

The tourist industry is very vulnerable to natural disasters. The publicity given to heat wave deaths in Greece in summer 1998, if repeated regularly, could act as a deterrent to tourism. In that year there were stories in the UK press of holidaymakers staying in their hotel rooms to try to escape the intense heat on the beaches. Queues of Britons were reported at hospitals and pharmacies suffering from heatstroke and burns while others cut short their holidays and returned home early. Rising mean summer temperatures will inevitably be accompanied by more occasions of extreme maximum temperatures. Extreme weather episodes are likely to have a stronger impact than average weather changes. Heat wave conditions are also implicated in the development and proliferation of algal blooms which can lead to closure of beaches, disfigurement of the coastal environment, and kills of fish as has happened in the Adriatic.

## DISEASE

Higher temperatures could lead to some Mediterranean holiday areas becoming a suitable habitat for malaria-bearing mosquitos. Spain, for example, is currently seen as a friendly easily accessible no risk destination not requiring immunisation, or courses of treatment against exotic diseases. It is anticipated that by the 2020s suitable habitats for malaria will have spread northward from North Africa into Spain. Increases in the incidence of food poisoning and food related diseases related to enhanced microbiological activity e.g. salmonella are likely to increase as temperatures rise. There will be a higher risk of epidemics of cholera and typhoid as well as infectious diseases. Adverse publicity would follow such public health scares and frighten tourists away, as happened at Salou, Spain a few years ago. Extra costs will be involved in maintaining and strengthening public health defences and in health and hygiene education programmes.

## TOURISTS REACTIONS TO THE CHANGING CLIMATE AND ADAPTIVE RESPONSES

Considerably more research has been done on the likely changes that Mediterranean climates may experience than on the possible impact of those changes on tourists in the future. It is not always easy to tease out the impact of climate from the many other factors influencing holiday choice (Perry 2000).

Tourism is a continuously adapting industry, responding to changing demographic and economic conditions as well as to new demands and technologies. Climate change will present new challenges but also lead to opportunities for tourist investment to capitalise on the new environmental conditions. Work has only just begun on “translating” the suggested future climate scenarios into their impacts on tourism but already some interesting adaptations are emerging:-

- 1 Higher air and sea temperatures are likely to encourage a longer tourist season. If the summer becomes widely perceived as too hot the season could become “doughnut

shaped”, with peaks in spring and autumn months and a hole in high summer. Such a pattern might resemble the current profile of visitor demand for a resort like Dubai. Recently Maddison (2001) has indicated that a lengthening and flattening of the tourist season is likely in Greece although with overall tourist numbers almost unchanged. With this in mind, resorts need to discourage a “closing down” attitude at the end of summer. Higher temperatures will allow a prolongation of the season and if possible added cultural and sporting attractions such as arts festivals ,regattas, food or drink events and local fiestas can help this process. Breaking the traditional seasonal patters has as much to do with changing consumer attitudes as with developing new attractions and more targeted advertising could help in this respect. A longer tourist season would allow quicker returns on investment with more intensive utilization of facilities over a longer period. What in the UK is called the short-haul beach package has almost certainly peaked, but beach holidays will still be popular. They will be price-sensitive and probably booked later and we are likely to see greater segregation between resorts who continue to cater for this market and those who choose to chase other markets and become more diversified.. Some parts particularly of the Spanish coasts, have an inheritance of many 30 year old hotels, devoid of modern amenities and catering for a declining number of holiday-makers, many of whom will be low-spending ,low-yielding Eastern European tourists The demand will be for more individual “bespoke packages” offering a little more excitement than the “identikit” traditional IT. (Middleton 1991)

- 2 The larger numbers of older people in the population will still wish to escape the dark, dreary winters of northern Europe. More are likely to consider moving permanently to, or buying second homes in ,Mediterranean areas. King, Warnes and Williams (1998) have shown that in several retirement destinations. including the Costa del Sol and Malta the most important reason given for moving to the chosen destination was climate. Thus the climate of the receiving region for these migrants has been considered to be the most important pull factor.. There are considerable planning implications if the growth of new apartments, villas and bungalows is not to cause environmental blight in some of these coastal areas. Along with this development will come increased demand for leisure pursuits e.g golf courses, marinas
- 3 Tourists will increasingly expect holiday accommodation to be air conditioned. Such accommodation will attract a premium price, whilst poorer quality self-catering apartments and rooms without air conditioning will be much less attractive in the summer. At present only a fifth of rooms in hotels in Mediterranean countries are in the 4 and 5 star categories .Increased demands will be made on electricity supplies from the demand for additional cooling systems

## **CONCLUSIONS**

We can use an economic principle that leisure time is a scarce resource and tourists resent interference or curtailment of their holiday enjoyment by adverse meteorological events like heat-waves. They will thus seek to minimise the likelihood that their holiday will be affected by circumstances perceived as adverse. by destination swopping. More research is needed to quantify the climatic wellbeing of tourists by developing and extending tourism climatic indices and beach comfort indices. Past growth and attractiveness are not necessarily a guide to the future and the Mediterranean tourist industry cannot assume an untroubled and

guaranteed future. The primary resources of sun, sea and beaches are likely to be re-evaluated in the light of expected climate change.

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## CLIMATE IMPACTS ON THE DEMAND FOR TOURISM

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**Abstract:** Climate impacts on international and domestic tourism are examined using: (1) a quantitative approach of regression modelling, supplemented by (2) a qualitative approach using surveys of the perception of climate impacts and in particular of climate extremes. Four countries were involved in the study: UK, The Netherlands, Germany and Italy. Temperature has the greatest influence on international tourism. The optimal summer temperature for attracting tourists to a country is estimated to be 21°C, with little deviation from country to country. In hot years, tourists tend to prefer domestic to foreign beach holidays. For domestic tourism, the relationship with temperature is usually positive in the same month, except in winter sports regions. A summer warming of 1°C is estimated to increase domestic holidays by 0.8-4.7%. The climate impact depends on destination type; for example, coastal resorts in Italy respond more favourably to summer temperature increases than inland resorts. There is some indication that weather in the intermediate seasons (spring and autumn) has a greater influence on tourist behaviour than is the case in winter and summer.

The public perception survey suggests that during an unusually hot summer, people are more likely to change their plans for day trips and short breaks than for their main holiday. Those that do change their holiday plans stay either at home or in their own country. The importance of weather/climate for short holiday trips, domestic trips and spontaneous trips is generally understood by management in the tourism industry. However, tour operators and managers plan their marketing strategies with very short time horizons and claim not to incorporate climate considerations. Nevertheless, tourism suppliers have shown some attempts to weatherproof the industry and tourism managers have a tendency to use bad weather as an excuse for poor tourism figures.

**Keywords:** Tourism demand, climate impact, UK

### Introduction

Tourism has become the largest and most rapidly expanding economic activity in the world. In 1999, travel and tourism involved 663 million people internationally and generated US\$ 450 million in tourist receipts (TTI, 2000). Weather and climate do not figure prominently in the academic tourism literature, yet it is clear that the climate of many countries is an important asset for tourism. Although the tourist industry is accustomed to rapid change, climate variability and change could have major implications for the tourist industry. In this paper we investigate the climate sensitivity of domestic and international tourism.

This research forms part of a project that examined Weather Impacts on Natural, Social and Economic systems (WISE) in Europe (Palutikof *et al.*, 1999). Four countries were involved: UK, the Netherlands, Germany and Italy. For the tourism sector, we examined climate impacts on international and domestic tourism, using two different approaches: (1) a quantitative approach using regression modelling, supplemented by (2) a qualitative approach using surveys of the perception of climate impacts and in particular of climate extremes.

## Methods

The general impact model used in the WISE project was as follows:

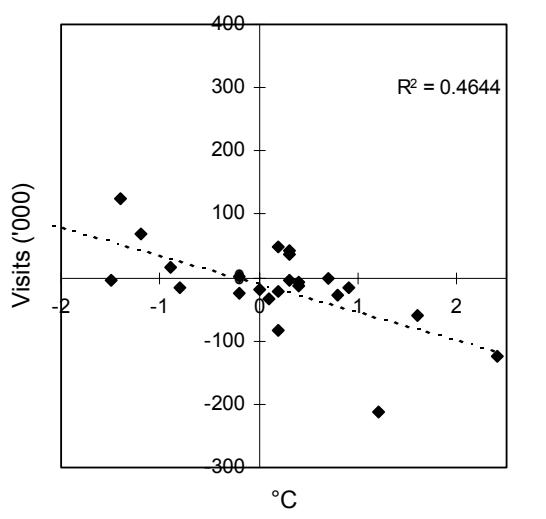
$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 y + \alpha_3 W_t + \alpha_4 W_{t-1} + u_t$$

For an annual series,  $X$  denotes the index of interest (e.g., international tourist arrivals) and depends on its value in the previous year. A time variable  $y$  is used to capture all unexplained trends, for annual observations,  $y=t$ .  $W$  represents the climate variable that is hypothesised to influence  $X$  and may be a vector. Since the climate of a previous time step may influence current behaviour, a one-year-lagged value of  $W$  is also included, and  $u$  denotes the error term. The intercept term is given by  $\alpha_0$  and  $\alpha_1 \dots \alpha_4$  are parameters estimated from the observations using either conditional maximum likelihood or ordinary least squares.

Quarterly observations were modelled as follows:

$$X_t = \alpha_0 + \delta_2 Q_2 + \delta_3 Q_3 + \delta_4 Q_4 + \alpha_1 X_{t-1} + \alpha_2 X_{t-4} + \alpha_3 y + \alpha_4 W_t + \alpha_5 W_{t-1} + \alpha_6 W_{t-4} + u_t$$

The variables  $Q_i$  are dummy variables for quarters 1 to 3, and the dummy parameters  $\delta_i$  measure the difference in level of that quarter with the first. The lag-structure for the quarterly model includes the influence of the previous quarter and the influence of the same quarter in the previous year. Monthly variables were modelled in a similar manner, with 11 monthly dummies, and 1-month and 12-month lags in the climate and impact domains.



**Fig. 1** UK tourist visits to Germany (residuals) and April central England temperature.

Deviations on this basic model were used in certain instances; for example, in the tourism analyses socio-economic variables (such as GDP and exchange rates) were offered as candidate predictors alongside the climate and trend variables.

### Impacts of climate on international tourism

Two aspects of international tourism are considered, arrivals (inward flows) and departures (outward flows).

#### *Departures*

Relative to other climate variables, temperature was generally regarded as having the greatest influence on international departures. For example, a 1°C increase in summer temperature in the Netherlands increased outward tourism in the following year by 3.1%. The association between annual visits from the UK to Germany and the April central England temperature (CET) series was negative (see Figure 1). However, the direction of impact (i.e., positive or negative) was not always clear.

In general, wetter weather seems to encourage holidays abroad in both the current and following year. For the UK, precipitation was a more useful indicator of international departures than arrivals. Climate sensitivities seem to vary from season to season. For the

UK international departures, spring and autumn climate predictors were more commonly included in the regression models than winter or summer predictors. The previous year's weather was clearly more important for all-holiday tourism from the UK abroad, this was sometimes but not always true for departures to specific destinations.

### ***Arrivals***

Temperature seems to be of overriding importance in explaining the variation in tourist arrivals. Although sunshine variables were included in the UK model of international arrivals, they were generally of secondary importance to temperature. Warm conditions in the previous year increase summer (June to August) arrivals to West Germany (86% of the variance in international arrivals were explained by temperature, trend, and arrivals in the previous month and year). Annual arrivals to the UK were also positively associated with temperature. The results suggest that warmer conditions in spring were especially important in attracting visitors to the UK in the following year. In the regression models developed the coefficient of determination varies between 0.79 and 0.96 for arrivals to the UK from Austria, Spain, France, Germany, Italy, the Netherlands and the US. In the Netherlands, the number of foreign arrivals were found to be significantly higher when summer temperatures were warmer, with 96% of the variance explained by the trend, arrivals in the previous year and summer temperature.

Although of secondary importance, precipitation was also included in the models for international arrivals to the UK and West Germany. In the UK, drier and sunnier conditions were generally associated with an increase in annual tourist arrivals. In West Germany, international arrivals in winter (January to March) increased with drier conditions in the same season (70% of the variance was explained by the trend, winter precipitation in the same month and winter precipitation in the previous month).

A global tourist destination model was developed by the Dutch research team. Annual arrivals (the global aggregate) were estimated using the following destination variables: year, the land-surface area of the country, GDP per capita, temperature and temperature squared. The estimates of the parameters for temperature were found to be plausible, stable over the sample, and robust to variations in the model specification. The inclusion of both temperature and temperature-squared implies that there is an optimal summer temperature for tourism.

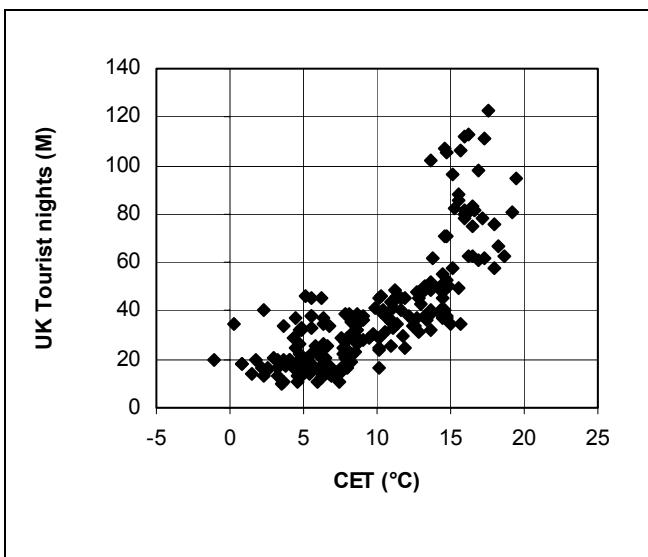
Globally, the optimal summer temperature for the destination country was estimated to be 21°C, and individual countries shown little deviation from the global value (Table 1).

**Table 1** Optimal holiday temperatures for all international tourists, and for tourist arrivals to selected countries.

	Optimal temperature °C (standard deviation is given in brackets)	# obs.	R <sup>2</sup>
World	20.88 (1.73)	1730	0.43
Netherlands	21.21 (4.34)	414	0.31
Japan	21.70 (2.24)	145	0.51
France	21.73 (1.60)	156	0.80
Germany	21.53 (1.60)	170	0.75
Canada	21.94 (1.94)	158	0.62
Italy	21.18 (1.61)	140	0.77
USA	20.43 (1.44)	159	0.62
UK	21.50 (1.63)	157	0.68

## Impacts of climate on domestic tourism

Temperature was generally the strongest indicator of domestic tourism. The relationship was usually positive in the same month (e.g., Figure 2) except for winter sports destinations and for situations in which summer temperatures become uncomfortably hot. In regression modelling, temperature squared was the most important climate predictor of UK domestic tourism. An annual lag in tourism nights, temperature squared, sunshine in the same month, a trend variable and dummy variables for August, December, and July explain 96% of the variability in annual numbers of tourist nights. For all the countries considered, a summer warming of 1°C was estimated to increase domestic holidays by between 1 and 5%. In countries with a significant winter sports market, a negative association was shown between winter tourism and temperature. For example, the regional number of Italian domestic bed nights in winter was strongly negatively correlated with the monthly regional temperature in the previous month. This may be due to the negative influence of unusually mild temperatures on the skiing season in the Italian Alps and Apennines.



**Fig. 2** UK Domestic tourist nights and same-month CET (central England temperature).

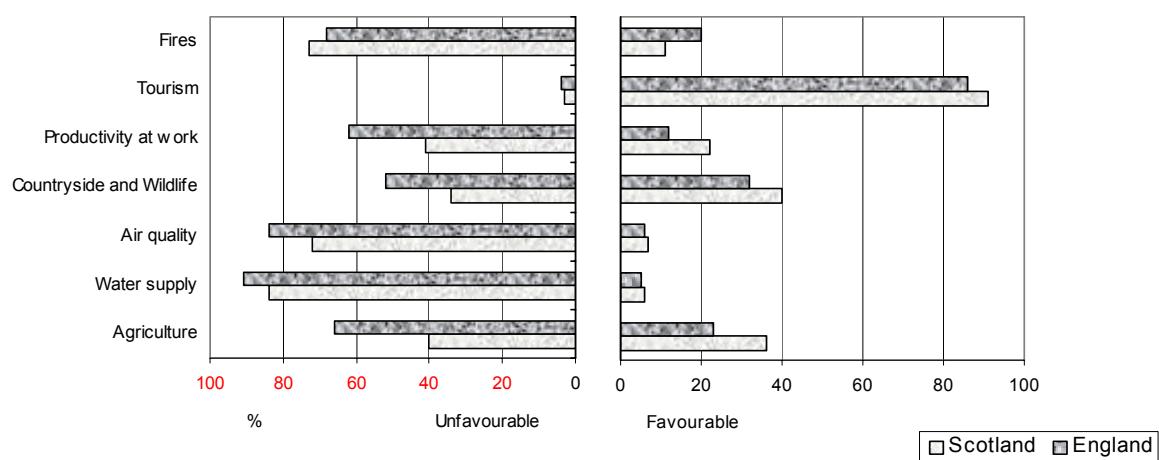
Precipitation was a significant predictor of domestic tourism in the regression models for domestic tourism in Germany; the association was generally negative in the same month. In the UK, June rainfall has the most significant impact on domestic holidays taken in August and October. In Italy, rainfall in the same month in the previous year appeared to act as a deterrent for domestic tourism, particularly in July. In July, 88% of domestic tourism in Italy

can be accounted for by bed nights in June, bednights in July of the previous year, a time trend and July precipitation.

There is some indication that weather in the intermediate seasons (spring and autumn) has a greater influence on tourist behaviour than in the case of winter and summer. For example, in Niedersachsen, Germany, a strong association has been found between March temperature and domestic bed nights in the same month, in the following summer (June to August) and in the same month of the following year. In Italy, higher temperatures in May and October seem particularly important at triggering domestic tourism flows. The nature of the climate impact depends on destination type. For example, coastal resorts in Italy respond more favourable to summer temperature increases than inland resorts.

### **Public perception of the impacts of climate extremes**

In a postal survey undertaken of the public perception of climate extremes (hot summers; mild winters), it is interesting to note that of the impact areas considered, UK residents identify the tourism industry as the only clear ‘winner’ during unusually hot summers (see Figure 3). A similar result was also found in the Netherlands and Germany.



**Fig. 3** Percentage of UK respondents who believe the sector impacts for the country as a whole, were unfavourable or favourable during an unusually hot summer.

Sensitivity to climate extremes appears to depend on the length of trip. In an unusually hot summer, most people do not alter plans for their main vacation. Those that do change their

holiday plans stay either at home or in their own country. During anomalously hot summer weather, people are more likely to change their plans for day trips than they are for short breaks, and are more likely to change their plans for short breaks than for their main holiday. For example, during a hot summer in the UK, we found that 52% of respondents took more day trips, while 33% of respondents took more weekend or short breaks, and less than 15% changed plans for their main vacation. This result is not surprising, since main holiday bookings are usually taken well in advance of the date of departure, and the ability to change plans for the main vacation is therefore considerably less flexible than for short breaks or day trips. Of those respondents who changed their main holiday plans, the majority decided to remain at home or to take a domestic holiday rather than to holiday abroad. This substitution effect (substituting a domestic holiday for a holiday abroad in an unusually hot summer) has also been noticed in the Netherlands and Germany. The responses to the hypothetical future state in which such hot summers become more common, suggest that the substitution of domestic for foreign holidays will become more popular, particularly in the UK and the Netherlands. In addition, the results suggest that unusually hot summers would favour the UK short-break tourist market relative to the other European countries considered.

Even within a nation, there are regional differences in the response to climate extremes. For example, of those who altered their main holiday in response to the unusually hot summer, we find large differences in the actions of Scottish and English residents. In particular, 80% of those who lived in Scotland stayed in the UK instead of going abroad for their holiday (compared to 47% who lived in England) and more people who lived in Scotland stayed at home instead of going away for a holiday (53% compared to 24% of those living in England). Regional differences in response were also noted in Italy, where Sicilians were more likely to visit the beach in hot weather, while Lombardians are more likely to enjoy country pursuits.

### **Managerial perception of the impacts of climate extremes**

Telephone interviews were conducted with managers in the tourist industry. The results complement those of the statistical analyses and the public-perception survey. The importance of weather/climate for short holiday trips, domestic trips and spontaneous trips was generally recognised by tourist operators. It was acknowledged that weather conditions (actual and anticipated) are important for determining the attractiveness of a holiday destination. In hot summers, some interviewees note a 2-10% increase in bed nights. Mild

winters were considered to be less important except in winter sport regions, such as the Harz mountain range in Germany.

However, while recognising the importance of weather and climate, tourist agents do not plan for it. Tour operators and managers plan their marketing strategies with very short time horizons and claim not to incorporate climate considerations. However, tourism suppliers have shown some attempts to ‘weatherproof’ the industry and tourism managers have a tendency to use bad weather as an excuse for poor tourism figures. In recent years, ‘weatherproofing’ has involved the development of indoor tropical holiday parks and artificial snow slopes for skiing and snow-boarding.

The flexibility in response to climate variability and change varies between sub-sectors of the tourist industry. Tourists have the greatest freedom of destination choice and have a certain degree of timing flexibility. Tourist operators also have considerable flexibility, if conditions are unfavourable in one area of the world, holidays can be targeted in a more favourable area. Although tourist suppliers and local managers have the least flexibility, as noted above, they have shown attempts to reduce the sensitivity to climatic variations by introducing weather-independent tourist attractions.

## **Conclusions**

Tourism is a highly volatile and rapidly growing industry. There are extremely complex processes at work in tourism decision-making and it is not always easy to tease out the impact of climate from the many other factors influencing holiday choice. Ideally, to understand the influence of climate more clearly we would have data differentiating between pre-booked and spontaneous trips, between destination type (coastal, urban, winter sports regions), and information on the differences in climate between the source and destinations regions. Nevertheless, broad patterns in the relationship with climate have been identified and we have highlighted the aspects of tourism which have greater climate sensitivity and for which further research is required.

## **Acknowledgements**

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## **Bioclimatic diversity of Bulgaria: a resource or a limiting factor of the recreation & tourism?**

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### **Abstract**

Placed along the middle latitudes, the territory of Bulgaria combines climatic features of far more northern and southern placed areas. The general influence of the solar and circulatory factors on the climate of this small territory is combined with the specific impact of the local physical-geographical factors, represented by the high mountain systems as Rila, Pirin, Rhodopy, Balkan, etc., as well as the basin of Black sea too. The influence of these factors induces considerable seasonal and space climatic differences, varying from tropical to arctic climates. What is the role of the corresponding bioclimatic diversity for the recreation and tourism? This paper seeks for an answer of this question, basing on the method of the heat balance of the human body. On this base it is established, by indexes like "a heat load of an organism" or "a space bioclimatic contrast", etc., that the bioclimatic diversity on the territory of Bulgaria varies from "thermal-neutral conditions" to "extreme heat stress" (both a stress from overcooling and overheating). However from the point of view of recreation-and-tourism the next fact is of an importance: in any given period of the yearly climatic cycle there are places of the territory of Bulgaria which are distinguished by favourable bioclimatic conditions. But the planning of an optimal recreational&tourist activity requires a close preliminary bioclimatic reference, both in macro- and in mezo-/micro-scale. In other case a risk to fall in a discomfort bioclimatic situation is quite possible here any time at given place, and any place at given time.

**Keywords:** Bioclimatic diversity, Human heat balance, Bioclimatic confort/discomfort, Bioclimatic "identity card", Bioclimatic network.

### **Introduction**

The geographical location of Bulgaria on the edge between the mid-latitudes and the subtropics determines significant climatic diversity of its territory. As a rule the climate of Bulgaria is formed mainly under the influences of the mid-latitude air masses, in the system of the West-East zonal air transfers. However this rule quite often gets broken by the meridional forms of an atmospheric circulation, which provide a North-South direction of an air exchange. Within the frame of this exchange the territory of Bulgaria very often gets affected both by tropical and by arctic air masses. That is why, at the

typical for these latitudes solar radiation conditions, the climate of Bulgaria combines features which are specific for far more northern and more southern climates.

An additional factor which reinforces the climatic diversity of Bulgaria is the physical-geographical characteristic of it's territory, which possesses quite specific peculiarities (fig.1).



**Fig. 1** Physical-geographical map of Bulgaria

The broadly-opened territory to the north - north-east, as well as the orientation of the big river valleys of Maritza, Struma, Mesta, etc., to the South - South-east, foster the North-South air access. The high mountain systems of Rila, Pirin, Rhodopy and the Balkan disrupt the natural horizontal climatic zonality, generating vertical climatic belts. The highest elevations of these mountains are characterized by specific climatic features similar to the features of the high latitudes of the planet. The lowlands, the hollows and the valleys closed between the mountains, enhance the climatic continentality of Bulgaria, and the Black sea basin moderates it's climate.

For examples, about 10% of the days in summer at places along the Southern Black sea coast, or along the big rivers/lakes from the internal parts of the country, are known by wet-tropical type of weather, according to the Choubukov classification (Tishkov 1968). This type of weather is described by average diurnal air temperatures above  $27.4^{\circ}$  C, in combination with a relative humidity of an air above 81%. On the other hand about 70% of the days in winter at the high mountain levels in Bulgaria are described as "ice days", i.e. they show negative diurnal temperatures, and this is valid for the average values, as

well as for the minimal and the maximal values too (Tishkov 1972). These mountain places are specific by “very high” degree of Bodman’s weather severity index (Mateeva 2001). However, in the same time, many parts of the country keep “neutral” bioclimatic conditions in different periods of the year.

This quite motley climatic picture of Bulgaria appears as some more motley bioclimatic picture, grading from indifferent to extreme extents of the bioclimatic scales (as at an overheating so at an overcooling of the human organism).

What is the extent to which the bioclimatic diversity of Bulgaria stimulates the recreation&tourism and what is the share of it's limiting role?

This study is trying to give an answer of this question by making a specific assessment of the bioclimatic conditions in Bulgaria, differentiating them by space, and by seasons.

## **Methods**

In this work the influence of the climate on the human biocomfort is studied by the method of the human heat balance. The method concerns the heat equilibrium of the human organism “which is a basic requirement for keeping constant core temperature and preconditions good physical and mental health” (Blazejczyk, Krawczyk 1994). The adaptation of the method to the open air conditions creates possibilities of it's use to investigate the climatic influence on the human activity in the open, including on the recreation&tourism.

We have used the following model of a heat exchange between the human body and it's surroundings (Licht, Sidney 1964), (Blazejczyk 1994):

$$\text{BMR} + \text{WL} + \text{R} + \text{C} + \text{E} + \text{L} + \text{Res} = \text{S}$$

where:

BMR	Basal metabolic rate
WL	Metabolic heat production due to physical activity
R	Solar radiation absorbed by a clothed man
C	Heat exchange by convection (i.e. turbulent exchange of sensible heat)
E	Heat loss by evaporation (i.e. turbulent exchange of latent heat)
L	Heat exchange by long-wave radiation
Res	Heat loss by respiration
S	Net heat storage

The BMR, WL and R are the import heat sources to the human organism whereas the C, E, L and Res are the sources of a heat export from the organism. In specific meteorological situations when the air temperature is higher than the skin temperature, a slight income of a heat by C or by L is observed (Blazejczyk 1993). Heat losses due to conduction, or by the excretory system of the organism are insignificant, so they are not considered in this model.

The calculations are made by the algorithmic system of the MENEX model (Blazejczyk 1994). The following indices, calculated mostly by this model are used in this paper :

- Thermal sensation (TS)
- Heat load (HL)
- Bioclimatic contrast (BD)
- Optimal clothing (ICL)
- Maximal time of exposure (MTE)
- Optimal work load (OWL)

The above indices are calculated at a standard insulation of a clothing of 1 clo and at a work load (physical activity) of  $70 \text{ W.m}^{-2}$ . As the recreation&tourism activities take place mainly in the day hours, the indexes are calculated by mean momentary values of the initial meteorological data (at the mid-day term of observation), 1941-1980. These indices, excluding ICL and OWL, are calculated at corresponding momentary skin temperature. The index of TS, as an index for general bioclimatic assessment, as well as a micro-bioclimatic index, is calculated both by the mean diurnal values of the initial meteorological data (at a constant skin temperature of  $33^0 \text{ C}$ ), as by mean momentary data (at an inconstant skin temperature) too.

The results shown in this paper refer to representative months (January, April, July and October), and to representative meteorological stations from different types of the physical-geographical conditions in Bulgaria (table 1).

**Table 1** Meteorological stations from different physical-geographical areas of Bulgaria, used in this study

Meteorolog. Stations	Altitude (m)	Latitude	Longitude	Physical-geographical conditions
peak Botev	2376	42°43'	24°55'	High mountains
Vezen	1800	42°46'	24°21'	Middle mountains
Samokov	1000	42°19'	23°34'	Low mountains
Sandanski	191	41°34'	23°17'	Valley opened to the Mediterranean
Plovdiv	160	42°09'	24°45'	Lowlands
Burgas	2	42°29'	27°29'	Seaside

## Results

According to the de Freitas classification (Blazejczyk 1994), based on the net heat storage of the human body, the heat bioclimatic conditions, respectively the thermal sensations (TS) vary in the following scale: *very cold*  $\Rightarrow$  *cold*  $\Rightarrow$  *cool*  $\Rightarrow$  *temperate cool*  $\Rightarrow$  *comfortable*  $\Rightarrow$  *temperate warm*  $\Rightarrow$  *warm*  $\Rightarrow$  *hot*  $\Rightarrow$  *very hot*.

The bioclimatic conditions in Bulgaria, according to this classification, represent more narrow spectrum: *very cold*  $\Rightarrow$  *cold*  $\Rightarrow$  *cool*  $\Rightarrow$  *temperate cool*  $\Rightarrow$  *comfortable*  $\Rightarrow$  *temperate warm* (table 2).

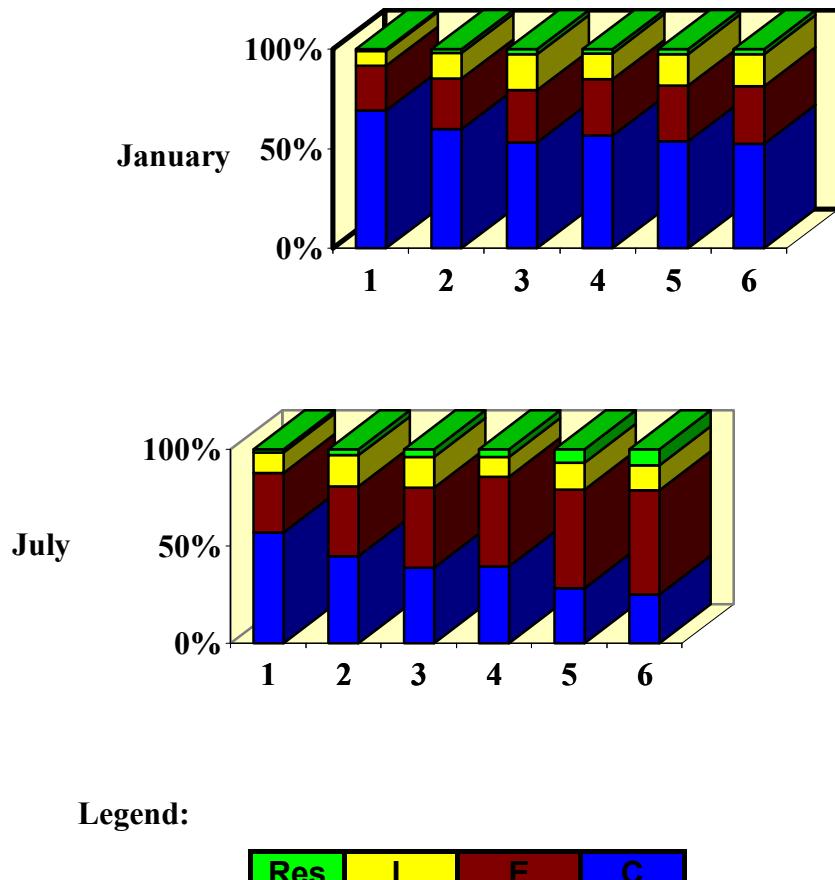
This generalized bioclimatic picture of Bulgaria is based on average diurnal meteorological values. However, if we would consider the average mid-day meteorological values, when man usually realizes his activity in the open, we would find a quite more variegated picture of the bioclimatic conditions in Bulgaria. It's spectrum widens, crossing nearly all bioclimatic degrees, including the extreme ends of the bioclimatic scale: *very cold*  $\Rightarrow$  *cold*  $\Rightarrow$  *cool*  $\Rightarrow$  *comfortable*  $\Rightarrow$  *warm*  $\Rightarrow$  *very hot*. Based on the Blazejczyk classification (Blazejczyk 2001), this scale is applicable to the unstationary model of calculations, related to the momentary observations.

**Table 2** Mean diurnal heat conditions (very cold, cold, cool, temperate cool, comfortable, temperate warm, warm, hot, very hot), at clothing insulation of 1 clo, at physical activity of  $70 \text{ W.m}^{-2}$

Months	Meteorological Stations					
	p. Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
Jan	-748	-320	-206	-236	-212	-187
Apr	-498	-201	-98	-143	-69	-50
Jul	-257	-47	8	21	44	61
Oct	-383	-141	-79	-88	-46	-27
<hr/>						
Legend:	v. cold	cold	cool	t. cool	com-fortab.	t. warm
		warm	hot	v. hot		

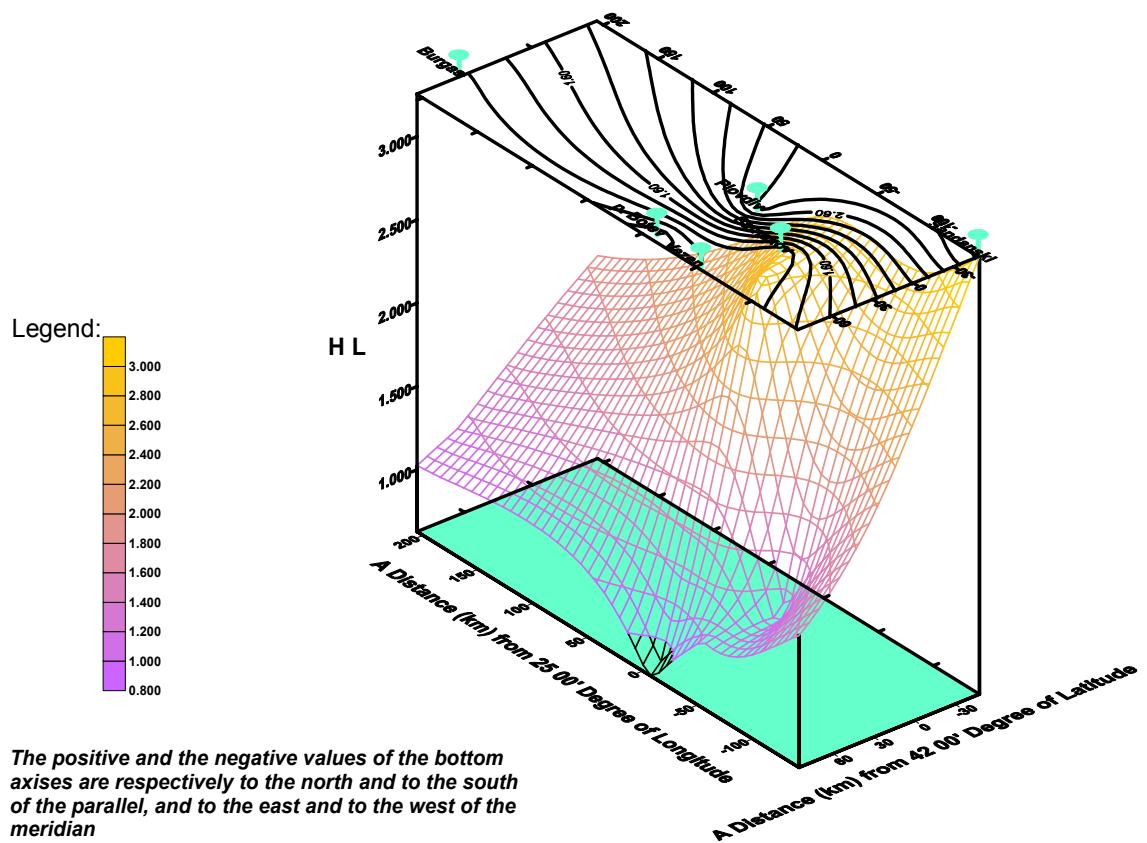
The diversity of bioclimatic conditions in Bulgaria, represented by the values of the net heat storage, respectively by TS, appears also by the structure of the heat exchange between human body and its surroundings. Specific differences of this structure emerge both seasonally and by space (fig.2). The main export share of the heat exchange in average annually has the heat lost by convection (C). In summer an increase of heat losses by evaporation (E) are observed though, and they become a main share of the heat export from the human body for the lowlands/hollows in Bulgaria. However in the mountains even in summer C remains the main export heat flux.

What is the heat load (HL) (Blazejczyk 2001) of an organism induced under the influence of the various heat conditions in Bulgaria? The results show that the HL differences in Bulgaria reach the maximal extent: from “an extreme stress of an overcooling” through “a comfort” up to “an extreme stress of overheating”, and this appears both territorially and seasonally. For example, in the summer on the highest mountain peaks of Bulgaria “extreme stress of overcooling” is observed (at a clothing insulation of 1 clo and a work load of  $70 \text{ W.m}^{-2}$ , at mid-day term of observation). At the same time, the middle- and the low mountain areas are characterized by “neutral” thermal conditions, the sea coast - by a “very small stress of overheating”, the lowlands from the internal country areas - by “an extreme stress of overheating” (fig.3).

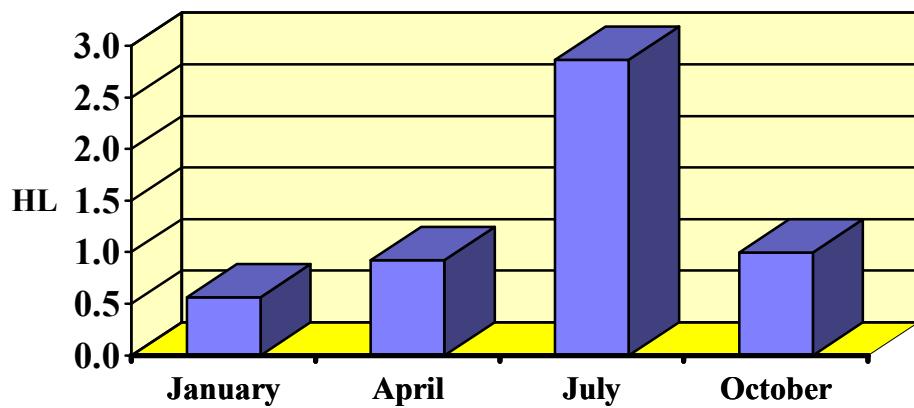


**Fig. 2** A structure of the human heat balance: a share (%) of the lost heat fluxes (C-heat exchange by convection, E-heat loss by evaporation, L-heat exchange by long-wave radiation, Res-heat loss by respiration), compared to the total heat loss from the human body, for: 1-p.Botev; 2-Vezen; 3-Samokov; 4-Burgas; 5-Plovdiv; 6-Sandanski

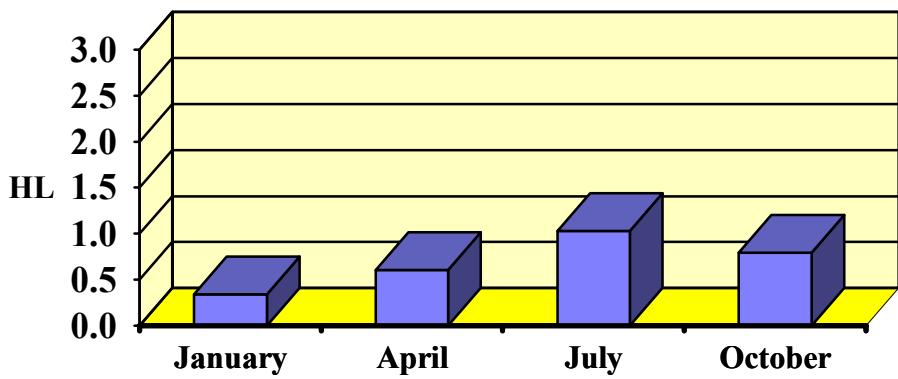
Such significant variations of HL are observed also seasonally, but they are representative mainly for the lowlands/hollows of the country (for an example Plovdiv) (fig. 4). The sea coast areas and especially the mountains have considerably smaller seasonal fluctuations (fig.4a).



**Fig. 3** Heat load (HL) of the human organism in July, at clothing insulation of 1 clo, at physical activity of  $70 \text{ W.m}^{-2}$



**Fig.4** Heat load (HL) of a human organism in Plovdiv, at clothing insulation of 1 clo, at physical activity of  $70 \text{ W.m}^{-2}$



**Fig.4a** Heat load (HL) of a human organism at Vezen, at clothing insulation of 1 clo, at physical activity of  $70 \text{ W.m}^{-2}$

The space and the seasonal bioclimatic differences in Bulgaria are illustrated by the index of a weather/climatic contrast (BD) (Rusanov 1996), (Mateeva 1997), (Mateeva, Filipov 2000), which shows the bioclimatic distances in the space (SBD), and by time (in this study by seasons) (CBD). Both SBD and CBD have the following grades: *optimal* (0.0 - 7.6)  $\Rightarrow$  *slight* (7.7 - 15.3)  $\Rightarrow$  *temperate* (15.4 - 30.7)  $\Rightarrow$  *sharp* (30.8 - 45.2)  $\Rightarrow$  *super-sharp* ( $>45.2$ ). Table 3 indicates that on the territory of Bulgaria SBD varies from an “optimal” to a “super-sharp” extent. The seasonal bioclimatic distances (CBD) are also almost that expressive as the spatial ones. This is illustrated by table 4, for a meteorological station Plovdiv, representing conditions which are typical for a large part of the non-mountain territory of the country.

The considerable bioclimatic diversity of Bulgaria, illustrated by the results represented above, is a background for the following summary: any time of the year there are places on the territory of Bulgaria with extreme bioclimatic conditions, which limit the recreation&tourism. But in the same time there are any time places with mild bioclimatic conditions, stimulating the recreation&tourism. Examples for limitations are the highest parts of the mountains – almost during the whole year, and also the lowlands/hollows - in the summer and in the winter. Examples for stimulating conditions are both the Black-sea coast and the low/middle-mountain regions - in the summer, the southern valley areas opened to the Mediterranean basin - in the winter, and the whole territory of the country, excluding the high mountains - in the spring and in the autumn. However this general limits&stimuli bioclimatic picture is quite more diverse in terms of each

particular recreational&tourist site where a specific micro-bioclimatic situation exists on the background of the macroclimatic one. A detailed and precise bioclimatic studies in mezo- and micro-bioclimatic scale are needed to answer the concrete applied question: which is the right place and when is the right time for a recreation&tourism from the bioclimatic comfort point of view.

**Table 3** Space bioclimatic distances in January and July

**Legend:**

July	January
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Met. Stations	P. Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
p. Botev		52	62	59	63	65
Vezen	30		13	9	14	17
Samokov	40	19		5	1	4
Burgas	28	24	9		6	10
Plovdiv	46	30	17	9		3
Sandanski	46	30	17	9	0	

**Table 4** Seasonal bioclimatic distances in Plovdiv

Months	January	April	July	October
January		27	43	25
April	27		32	3
July	43	32		35
October	25	3	35	

### Discussion matters

This study brings up at least two groups of questions:

1. Methodical
2. Applied

The methodical questions are related to the human heat balance algorithmic system, used in this work. There are some problems which concern the unstationary approach of calculations, i.e. at inconstant conditions of a heat exchange between the human body

and its surroundings. The most significant of these problems is related to the calculation of the heat loss by an evaporation (E). The nonrealistic values of E at a very high skin temperatures have an effect on the net heat storage (S) values, and this reflects on the derivative indices, as well as on the relevant bioclimatic assessments. We have proposed some corrections of the formula of E (Mateeva 1997), which have reduced the problem to a certain extent, but we still consider this question remains as an open one.

The second discussion matter in this study has an applied character seeking for an answer of the question: How to conform the recreation&tourism by time and by space to the bioclimatic comfort, and how to reduce the bioclimatic discomfort in the cases when it inescapably appears? For countries with a considerable bioclimatic diversity like Bulgaria, this question takes a major importance. The optimization and planning of the recreational&tourist activity in the quite wide range between the extreme ends of the bioclimatic scales requires to know the means of the intentional thermal regulation for a reduction of a bioclimatic risk.

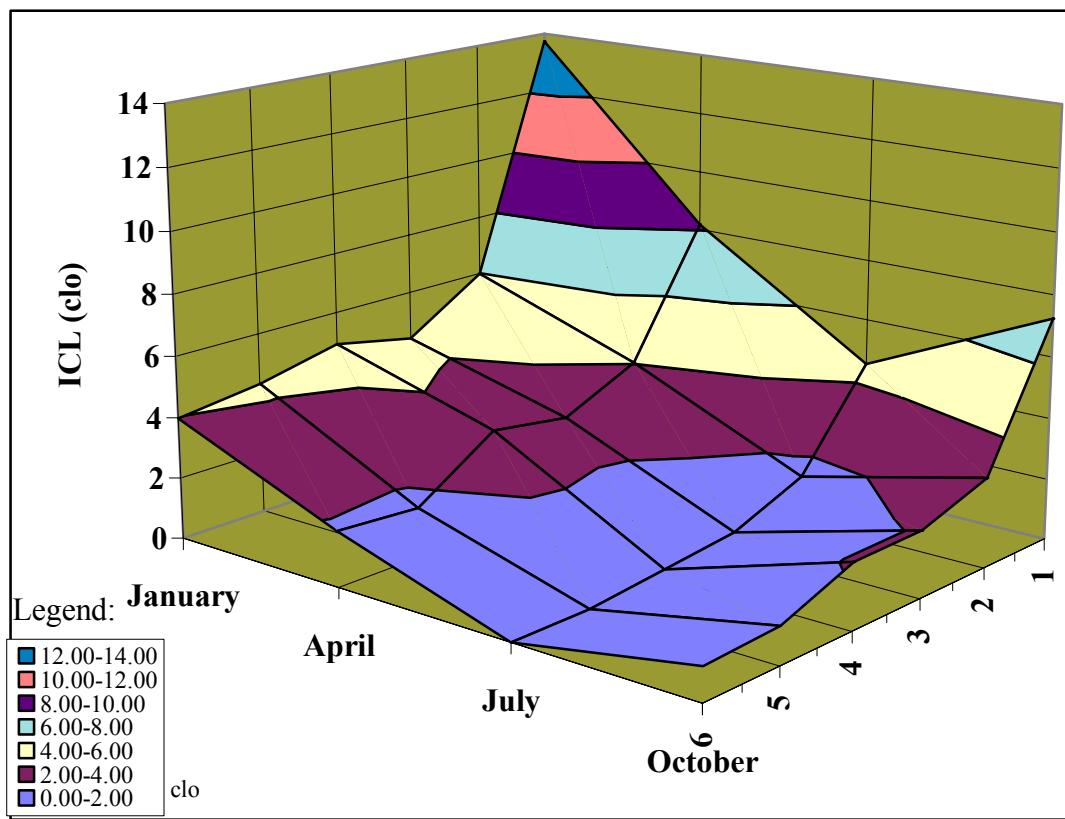
One of the most important regulators of the man's bioclimatic comfort is the clothing. By the clothing the perimeter of bioclimatic comfort may become considerably wider. This is shown on table 5, which presents the bioclimatic conditions in Bulgaria at a standard seasonal clothing (in comparison to a clothing of 1 clo on table 2). According to the International standards (ISO/DIS 9920) it is accepted in Bulgaria as a standard clothing insulation of 2 clo both in spring and in autumn, 1 clo in summer, and 3.3-3.5 clo in winter. By the index of ICL (Liopo, Tsitsenko 1971), (Blazejczyk 1994), (Mateeva 1996) we may calculate the values of the clothing insulation which reduce the bioclimatic discomfort to a comfort. So the index of ICL may be used both as a criterion for bioclimatic assessments, and also as a measure for the optimal clothing insulation at concrete weather/climatic conditions. Figure 5 indicates some places in Bulgaria where the values of ICL deviate from the standard values for each season, i.e. the places with an increased bioclimatic risk as well as the comfort places.

**Table 5** Mean diurnal heat conditions (very cold, cold, cool, temperate cool, comfortable, temperate warm) at clothing insulation suitable to the season (compared to mean diurnal heat conditions at clothing insulation of 1 clo on table 2)

Moths	Meteorological Stations					
	p. Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
Jan	-228	-62	-25	-32	-25	-15
Apr	-260	-83	-23	-48	-5	5
Jul	-257	-47	8	20	44	61
Oct	-191	-48	-13	-15	7	18



Another index of an applied importance for a reduction of the bioclimatic discomfort is an optimal work load (OWL) (Blazejczyk (1994), (Mateeva (1999)). It shows the optimal parameters of the physical activity at respective weather/climatic conditions, and at concrete parameters of a clothing insulation. This index gives various possibilities for a practical application, for example to project tourist trails with a definite optimal load of activity, depending on the preferences of the walking tourists, at a correspondent weather/climate. Table 6 shows that on the high mountains of Bulgaria a heavy physical activity is required during the whole year in order to maintain heat comfort (at a standard seasonal clothing). These are places appropriate for projecting of heavy tourist trails and activities, for example high mountain skiing, etc. On the other hand in the non-mountain areas of the country even the smallest physical work in summer causes a heat discomfort.



**Fig.5** Optimal insulation of clothing (Icl), at physical activity of 70W.m-2, for: 1-p.Botev, 2-Vezen, 3-Samokov, 4-Burgas, 5-Plovdiv, 6-Sandanski

**Table 6** Optimal work load (W.m-2), at clothing insulation of 1 clo

Months	Meteorological Stations					
	p.Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
January	478	177	113	136	111	97
April	450	196	127	153	46	58
July	445	120	20	0	0	0
October	395	126	79	79	21	13

An index for reduction of the bioclimatic risk is also the maximal time of exposure in the open (MTE) (Blazejczyk (1994), (Mateeva (1997). The results show that in Bulgaria the possibilities for non-risk stay of man in the open have an exceptionally high diversity. At clothing of 1 clo and work load of  $70 \text{ W.m}^{-2}$  MTE varies, depending on the season and on the place, from 14 min in winter (on peak Botev) to above a twenty-four-hour period in the autumn (in the lowlands) (fig.6).

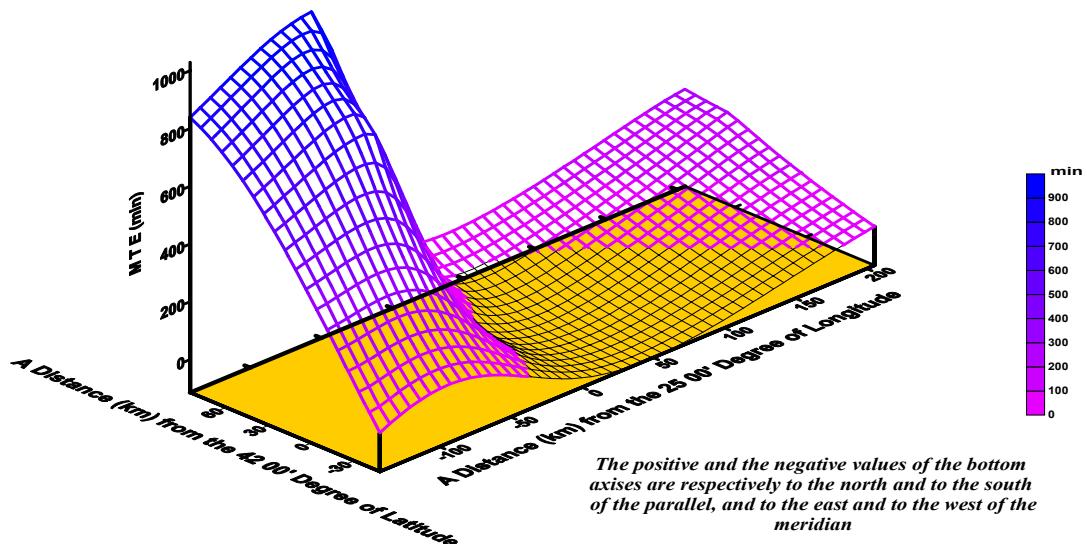


Fig. 6 Maximal time of exposure (MTE) in July, at clothing insulation of 1 clo, at physical activity of  $70 \text{ W.m}^{-2}$

There are also a lot of other indices, based on the human heat balance which are of a great applied importance, especially for the recreation&tourism. Their calculation and use depends on the requirements of every particular recreation&tourism activity.

### Recommendations

1. We would like to focus the attention of the scientific community to the algorithmic system of the human heat balance. We would focus our attention more to the problem of calculating the flux of the heat loss by evaporation (E), especially at an unstationary conditions of a heat exchange between the human body and its surroundings.

2. It would also be useful the development of an unified, complex bioclimatic index which to integrate the different types of bioclimatic assessments: physical, physiological, psychological, etc. Such an index should has a multiple character, compound by multifarious criteria: for heat conditions; for physical limitations of the weather in open air, like rains, fogs, storms, etc.; for weather fluctuations (incl.assessments of it's contrasts and steadiness), etc.

We expect with a great scientific interest the results of the ISB commissions work, both the commission of "Development of a Universal Thermal Climate Index" and the commission of "Climate, Tourism and Recreation", which would combine the research efforts and achievements in this field by now, and would further develop them .

Based on such an unified index a bioclimatic "identity card" ("passport") should be developed for every recreational&tourist object. Bioclimatic "passportization" may has both climatic and meteorological aspect. The first one should be based on long standing climatic data, while the second requires an establishment of an operative bioclimatic monitoring ( may be on the base of the meteorological network), providing current bioclimatic information, incl. the ways for a reduction of a bioclimatic discomfort (thus the bioclimatic limits may turn even into stimuluses).

On the base of the bioclimatic "passports" of the tourist&recreational objects a bioclimatic network may be built, both in national and in international scale, or by bioclimatic transects across the world physical-geographical regions.

The help and the encouragement of the international scientific community in establishment of a bioclimatic network may be a promising condition for an optimizing the recreational & tourist activities.

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My deep gratitude to the researchers of human heat balance, whose works serves as a baseline for future studies.

Accepting the main knowledge of the human heat balance by Prof. K.Blażejczyk I regard him as a co-author of all my works in the field by now.

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## **Using a ‘tourism climate index’ to examine the implications of climate change for climate as a tourism resource**

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### **Abstract**

Climate has a strong influence on the tourism and recreation sector and in some regions represents the natural resource on which the tourism industry is predicated. There has been little consideration of how climate change might affect the tourism climate resource or how such changes could alter the competitive relationships between tourism destinations. This study used a modified version of Mieczkowski’s (1985) ‘tourism climate index’ (TCI) to explore the impact of projected climate change on the tourism climate resource of a sample of tourism destinations in North America. Conceptual seasonal tourism climate distributions are defined and the current tourism climate index scores of 17 North American cities calculated. All Canadian cities had a ‘summer-peak’ distribution. Cities in the southern US displayed either a ‘winter-peak’ or bimodal spring-autumn peak distribution. Los Angeles was the only city examined to approximate a year-round optimal tourism climate distribution. Seasonal tourism climate index scores are then compared with seasonal accommodation costs at five locations, in order to determine whether the tourism climate index reflects tourism demand. Results at each location were positive. Climate change scenarios were constructed from two general circulation models (CGCM2 and HadCM2) for the 2050s and 2080s and integrated into the tourism climate index of eight Canadian cities. The cumulative annual TCI score improved for all of the cities. Seasonally, the impact of climate change varied by location. Seasonal TCI rating improved in each season for cities in western Canada (Calgary, Vancouver and Yellowknife), while the TCI rating declined in the key summer tourism months of July and August in eastern Canada (Toronto and Montreal). As the first empirical assessment of the implications of climate change for the tourism climate resource, this investigation also raises questions for future inquiry.

**Keywords** Tourism Climate Index, Climate Change, Tourism

### **Introduction**

Tourism is a major sector of the global economy, with international tourism receipts of US\$439 billion in 1998 (World Tourism Organization 1999). It is projected that by 2020, there will be 1.6 billion international tourist arrivals, spending over US\$2 trillion worldwide (World Tourism Organization 1998). Canada and the United States were among the top 10 tourism destinations in

1998, in terms of international tourist arrivals and related economic receipts. Domestic tourism in both nations is estimated to be many times larger in terms of economic activity.

Climate has a strong influence on the tourism and recreation sector and in some regions of the world constitutes the resource on which the tourism sector is predicated. Inter-annual climate variability influences the length and quality of recreation seasons and the profitability of the tourism industry. In Canada Wilton and Wirjanto (1998) estimated that a  $1^{\circ}\text{C}$  above normal summer temperature increases domestic tourism expenditures by approximately 4%. Studies by Agnew (1995) and Benson (1996) in the UK also found that tourism spending was partially determined by climatic conditions. In both analyses, tourism spending abroad increased following a cold winter. Benson (1996) and Giles and Perry (1998) also found that domestic tourism spending in the UK increased during and following a warm summer.

Yet despite the importance of climate to tourism, Smith (1993:389) indicated that, “There have been comparatively few investigations into the relationships between climate and tourism.” Consequently, the vulnerability of the tourism sector to current climate variability and long-term climate change has not been adequately assessed.

The tourism climate index (TCI) was originally conceptualized by Mieczkowski (1985) as a composite measure that would systematically assess the climatic elements most relevant to the quality of the tourism experience for the ‘average’ tourist (i.e., the most common tourism activity of sight-seeing and shopping). The TCI developed by Mieczkowski (1985) was based on previous research related to climate classifications for tourism and recreation (Heurtier 1968, Crowe 1976) and theoretical considerations from the biometeorological literature related to human comfort, particularly with reference to tourism activities (Burnet 1963, Dammann 1964, Hofer 1967, Heurtier 1968, Danilova 1973, and Kandror et al. 1974). Initially, 12 monthly climate variables were identified from the literature as pertinent to the TCI. Meteorological data limitations reduced number of climate variables that were integrated into the TCI to seven (monthly means for maximum daily temperature, mean daily temperature, minimum daily relative humidity, mean daily relative humidity, total precipitation, total hours of sunshine, and average wind speed). These seven climate variables were combined into five sub-indices that comprised the TCI. A standardized rating system, ranging from 5 (optional) to -3 (extremely unfavourable), was devised to provide a

common basis of measurement for each of the sub-indices. The five sub-indices and their relative contribution to the TCI are outlined in Table 1. Although devised on the basis of available biometeorological literature, the rating systems of the five sub-indices and their relative weightings within the TCI are ultimately subjective. The biometeorological literature, upon which the weighting of the five climatic variables that comprise the TCI and the thresholds used to devise the rating systems for each of the five variables, has been described at length in Mieczkowski (1985) and the reader is referred to the original paper for additional details pertaining to the conceptual and methodological development of the TCI.

**Table 1** Sub-indices within the tourism climate index

Sub-Index	Monthly Variables	Climate	Influence on TCI	Weighting in TCI
Daytime Comfort Index (CID)	maximum temperature & minimum relative humidity	daily & daily	Represents thermal comfort when maximum tourist activity occurs	40%
Daily Comfort Index (CIA)	mean temperature & daily relative humidity	daily & mean daily	represents thermal comfort over the full 24 hour period, including sleeping hours	10%
Precipitation (P)	total precipitation		reflects the negative impact that this element has on outdoor activities and holiday enjoyment	20%
Sunshine (S)	total hours of sunshine		rated as positive for tourism, but acknowledged can be negative because of the risk of sunburn and added discomfort on hot days	20%
Wind (W)	average wind speed		variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while ‘wind chill’ in cold climates rated negatively)	10%

The TCI provides a method to systematically rate the tourism climate resource for locations around the world, using an easily interpretable scale (-20 to 100) that is divided into 11 categories, where 50-59 is ‘acceptable’ as a tourism climate, 80-89 is ‘excellent,’ and 90-100 is ‘ideal.’ Though not designed for climate change research, the TCI also represents a potentially useful empirical tool for exploring the impact of climate change on the tourism climate resource.

The purpose of this paper is to investigate the relationship between climate and tourism by using a modified version of the tourism climatic index developed by Mieczkowski (1985) to explore the spatial and temporal patterns of the tourism climate resource in North America. The study will also attempt to validate the TCI in the tourism marketplace and examine how climate change scenarios may impact the tourism climate resource in Canada.

## Methods

### Study Sites and Data

A total of 17 cities were selected for this study (Table 2), roughly forming three latitudinal transects of North American (one across the US south, a second across the center of the US, and a third across southern Canada) and one longitudinal transect in western North America, extending from Denver in the south to Yellowknife in the north. For the Canadian cities all of the climate data are 30-year monthly normals for the period 1961-90 and were provided by the Meteorological Service of Canada. Climate data for the US cities were obtained from the National Climate Data Center of National Oceanic and Atmospheric Administration. Temperature and precipitation data were 30-year normals for 1961-90, while wind, relative humidity and sunshine were monthly averages for at least 20 years from the observed record. Sites with less than 20 years of climate data were removed from the analysis.

The climate change scenarios used in this analysis were obtained from the Canadian Climate Impact Scenarios (CCIS) project. The scenarios provided by CCIS (2001) have been constructed using recognized methodologies and in accordance with the recommendations of the Intergovernmental

**Table 2** North American cities included in analysis of current TCI rating

<b>Canadian Cities</b>	Latitude	Longitude	<b>US Cities</b>	Latitude	Longitude
Vancouver	49.25°N	123°W	Seattle	47.5°N	122.25°W
Calgary	51°N	114°W	Los Angeles	34°N	118°W
Edmonton	53.5°N	113.5°W	Phoenix	33.5°N	112°W
Yellowknife	62°N	114°W	Denver	39.75°N	105°W
Winnipeg	50°N	97.5°W	St. Louis	38.75°N	90.25°W
Toronto	43.75°N	79.5°W	New Orleans	30°N	90°W
Montreal	45.5°N	73.5°W	Miami	25.75°N	80.25°W
Summerside (PEI)	46°N	64°W	Charleston	32.75°N	80°W
			New York	40.5°N	74°W

Panel on Climate Change's (IPCC) Task Group on Scenarios for Climate Impact Assessment (TGCIA). The scenarios available from CCIS are derived from climate change experiments undertaken at six international climate modeling centers that meet the criteria established by TGCIA. The scenarios are derived from 30-year means (2040 – 2069 to the 2050s scenario and 2070 – 2099 to the 2080s scenario) and represent change with respect to the 1961-1990 base-line period. The wide range of variables required for this analysis restricted the use of scenarios to the greenhouse gas plus aerosol runs from the Canadian Centre for Climatic Modelling and Analysis (CGCM2) and the UK Hadley Centre (HadCM2). In both cases, ensemble scenarios were used (gax). The HadCM2 scenarios represent the lower bounds of climate change projections in Canada (both 2050s and 2080s), while the CGCM2 scenarios represent the mid-range. The climate change scenarios are developed from the values of GCM grid boxes that are within 2.5° lat/long of the geocentroid of each city. The number of grid boxes included depends on the GCM resolution and to some extent on where the geocentroid lies within the grid box, but generally the change fields are calculated from the average of 4 to 6 GCM grid boxes. Table 3 indicates the annual temperature and precipitation change projections (2050s and 2080s) for the Canadian cities included in this study.

Data for a range of tourism demand indicators were sought to test the validity of the TCI in the tourism marketplace. Only hotel/resort accommodation rates were available at the temporal and spatial resolution required (monthly data for individual cities). Accommodation rates for randomly selected hotel/resorts covering different price ranges, but excluding those near airports and

**Table 3** Annual climate change scenarios for Canadian cities

City	CGCM2-gax				HadCM2-gax			
	2050s	2080s	Tmean	Precip	2050s	2080s	Tmean	Precip
Vancouver	+2.3°C	+4.0%	+3.6°C	+8.8%	+2.5°C	+5.6%	+3.6°C	+7.1%
Calgary	+3.0°C	+4.8%	+4.8°C	+9.0%	+2.2°C	+10.8%	+3.3°C	+13.0%
Edmonton	+3.0°C	+4.8%	+4.7°C	+8.3%	+2.1°C	+10.3%	+3.3°C	+12.2%
Yellowknife	+3.3°C	+0.1%	+5.3°C	-0.6%	+2.5°C	+5.7%	+4.0°C	+6.0%
Winnipeg	+3.6°C	+5.0%	+5.7°C	+6.6%	+2.0°C	+7.6%	+3.1°C	+14.4%
Toronto	+3.1°C	+1.5%	+4.9°C	+4.8%	+1.5°C	+7.3%	+2.4°C	+17.9%
Montreal	+2.6°C	+2.6%	+4.2°C	+2.8%	+1.7°C	+6.4%	+2.7°C	+14.3%
Summerside (PEI)	+2.5°C	+4.7%	+3.9°C	+3.1%	+1.8°C	+3.8%	+2.8°C	+10.7%

downtown locations catering mainly to the business community, were obtained for six North American cities (Calgary, Toronto, Los Angeles, Miami, New Orleans and Charleston) that represented different tourism climate index distributions. Monthly accommodation rates were compiled from web sites and/or by telephone for hotels/resorts within or near to these cities.

### Modification and Implementation of the TCI

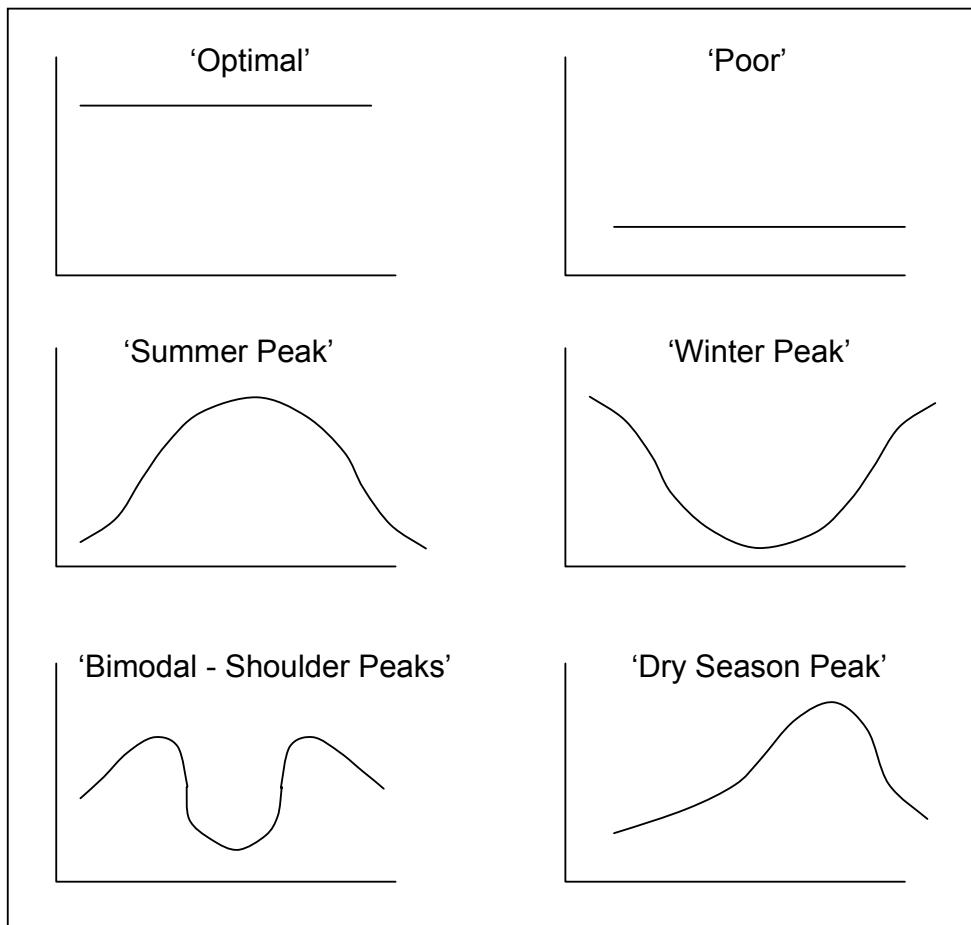
The main modification to the original TCI in this analysis was the replacement of ‘Effective Temperature’ (ET) with a more recent ‘Apparent Temperature’ (Steadman 1984) or ‘Heat Index’ as it is referred to in applied use in the United States, as the measure of thermal comfort in the index. Although a range of other modifications were considered (see Discussion), the other difference relative to the original TCI analysis was related to the period of record for climate data. Though not specified, it is presumed that Mieczkowski (1985) used climate data or climate normals from 1951-80. The climate data used in this study are from the 1961-90 period. Both the rating systems for the five sub-indices and their weighting within the TCI were retained for this analysis.

## Results

### Current Tourism Climate Index Patterns

Theoretically, the tourism climate resource of every location can be classified into one of six annual TCI distributions (Figure 1). The spectrum runs from the ‘optimal’ year-round tourism climate

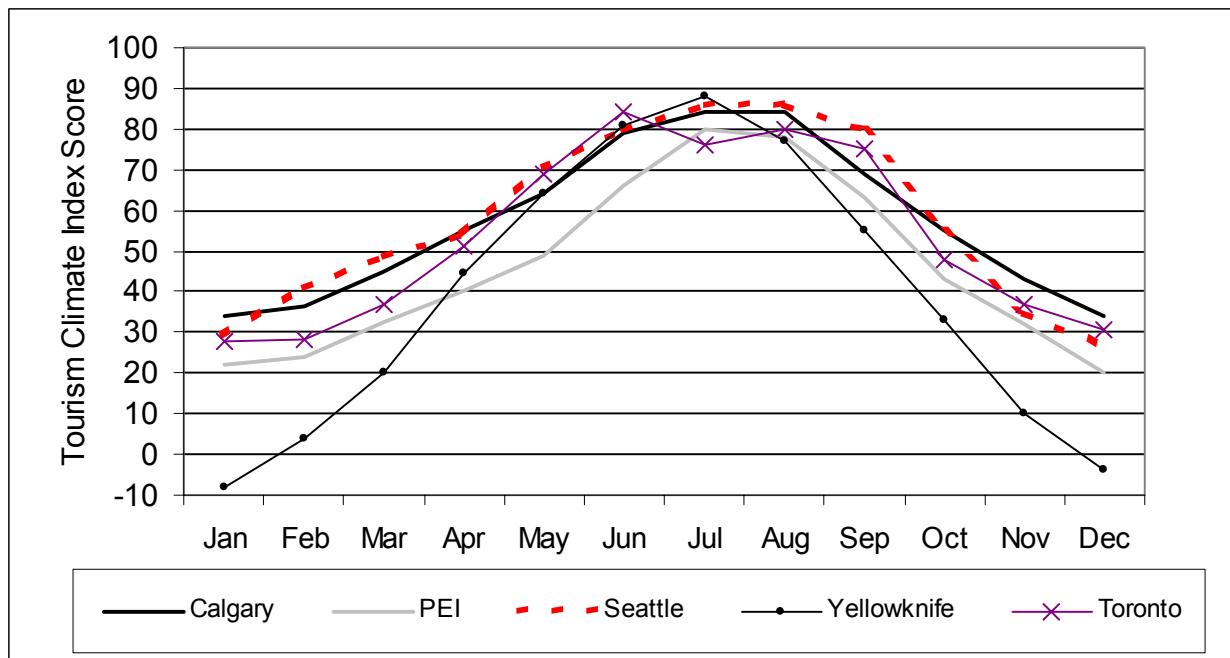
(TCI rating of 80 or above for each month of the year) through to a ‘poor’ year-round tourism climate (TCI rating under 40 throughout the year). The ‘summer’ and ‘winter peak’ curves have similar distributions, but are distinguished by the season in which the higher TCI scores occur. The ‘summer peak’ curve is indicative of many mid- to high-latitude locations where summer is the most pleasant period of the year for tourism. On the other hand, the ‘winter peak’ curve represents more equatorial and mid-latitude locations where cooler and/or lower humidity conditions in winter are more comfortable for tourists compared to hot and/or humid summer conditions. Where spring and fall periods are more acceptable to the tourist a ‘bimodal’ or ‘shoulder peak’ distribution is obtained. The tourism climate resource in regions with distinct wet and dry seasons will be determined to a large extent by precipitation. The TCI in these regions will display a dry season peak, when the climate is most conducive to tourism activity.



**Fig. 1** Conceptual tourism climate distributions

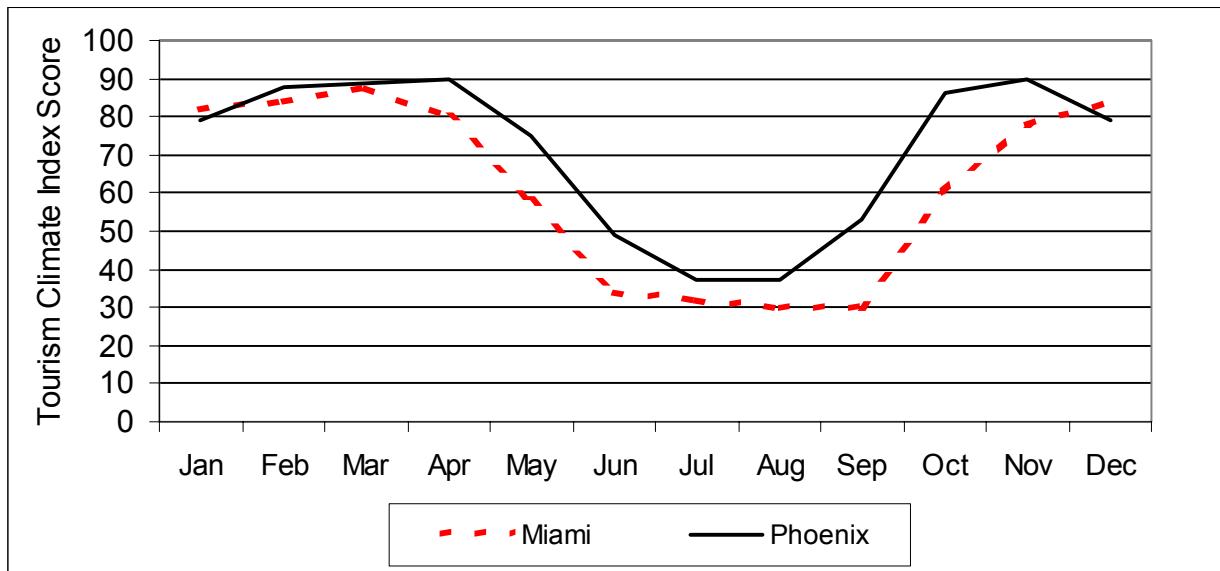
Using the sample of 17 North American cities, four of the six conceptual TCI distributions were represented. All of the Canadian cities, regardless of latitude or coastal location, had a summer

peak distribution (Figure 2 - Vancouver, Edmonton, Winnipeg and Toronto are not shown). Each of these locations has at least one month with a TCI score above 80, the level judged to be an ‘excellent’ tourism climate. The major difference in the TCI curves for these cities is the range of scores throughout the year. On the one hand, Yellowknife (lat 62°N) is rated ‘impossible’ throughout the winter with TCI scores in the negative, while Calgary is only ‘unfavourable’ with TCI scores in the 30-39 range.



**Fig. 2** Cities with summer peak TCI distribution

The TCI distributions in the US cities examined were much more varied. Like the aforementioned Canadian cities, Seattle and Denver displayed a summer peak (Seattle shown in Figure 2). Denver, like Toronto, had a slightly lower TCI in July than June and August, suggesting these cities are located in the transitional area between summer peak and bimodal-shoulder peak regions. The conceptual winter peak TCI distribution is represented by two popular North American winter tourism destinations, Phoenix and Miami (Figure 3). Both cities have six months with a TCI over 80 thereby classifying them as having ‘excellent’ tourism climates. Furthermore, Phoenix has an ‘ideal’ tourism climate (TCI scores of over 90) for half of the winter months. Summer TCI scores in Phoenix are lower because of the human discomfort caused by temperatures that often exceed

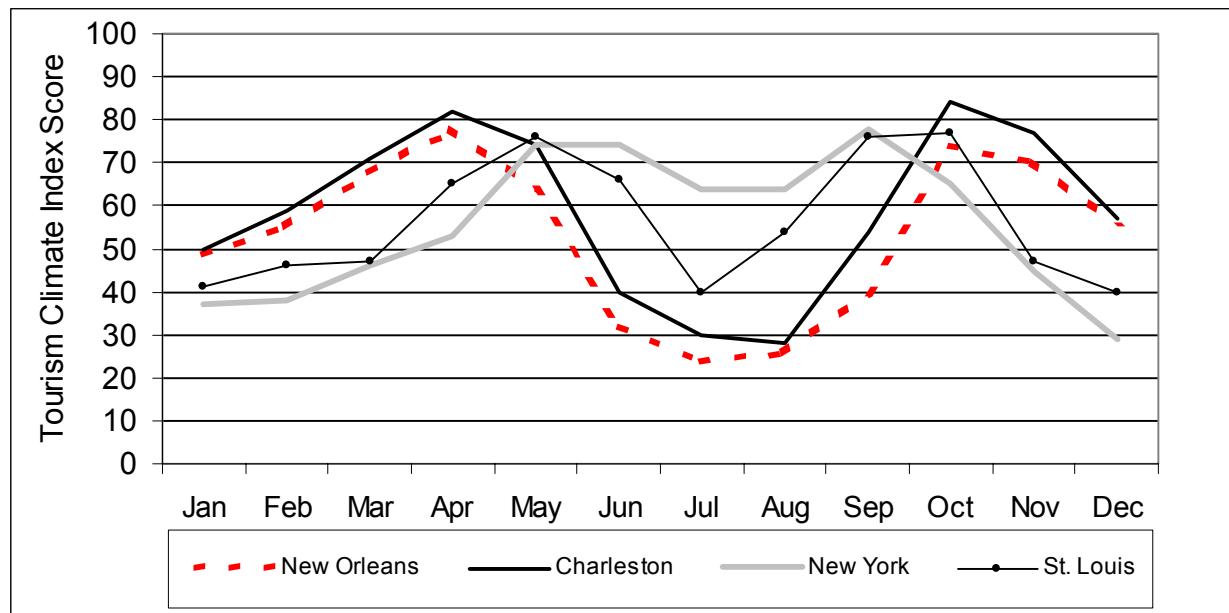


**Fig. 3** Cities with winter peak TCI distribution

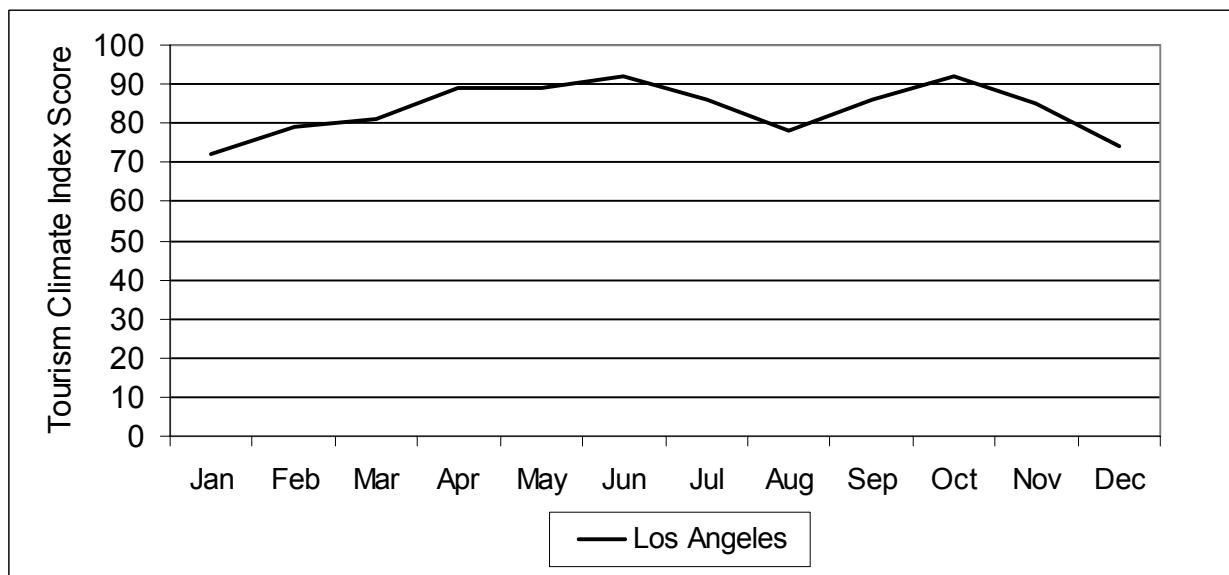
35°C. On the other hand, the summer months in Miami have low TCI scores as a result of the combination of high temperatures and high humidity.

New Orleans, St. Louis, Charleston and New York, known for their pleasant spring and fall weather, represent the bimodal TCI curve (Figure 4). In these cities the heat and humidity make the summer climatically uncomfortable for the tourist while the winters are too cool. In contrast to the summer and winter peak regions, Charleston is the only city with a bimodal distribution to achieve a TCI score of 80. The ‘optimal’ curve is represented by Los Angeles, which has only two months below the ‘excellent’ TCI rating of 80 (Figure 5). The coastal location reduces the impact of the summer heat, typical of Phoenix, while the discomfort of the winter cold is reduced by its southerly location.

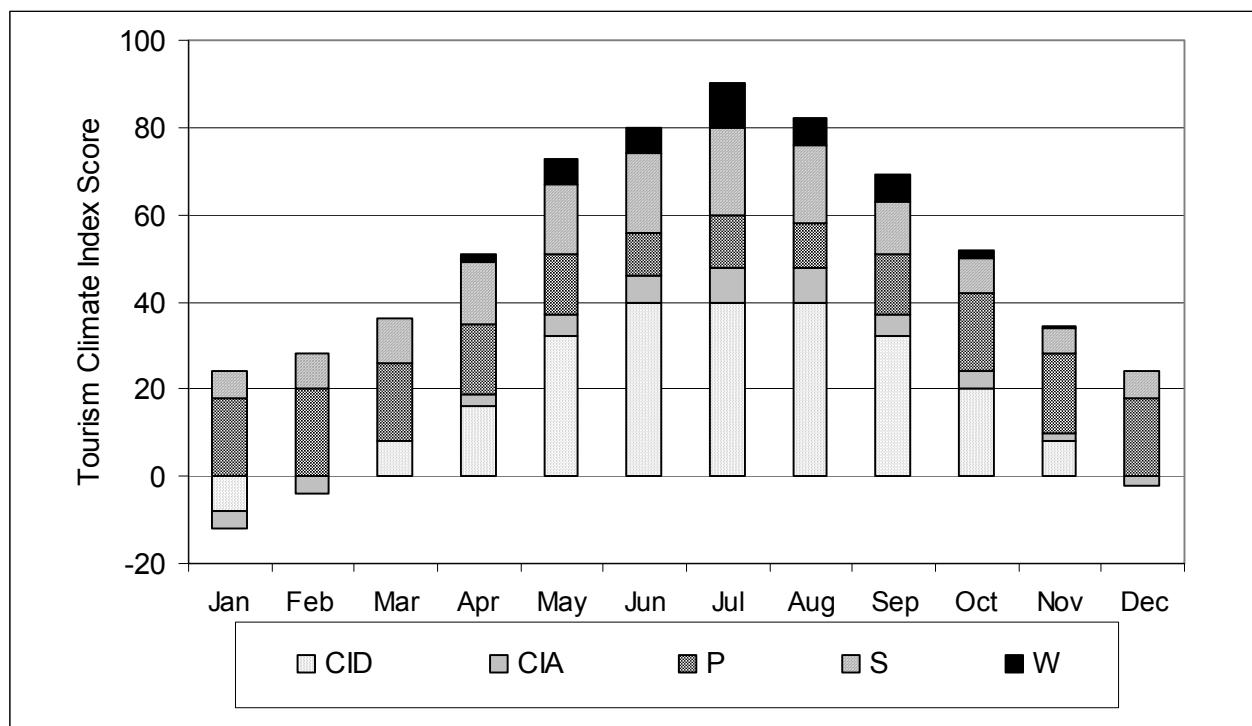
The five sub-indices of the TCI contribute differently to the TCI score at each location and in different seasons. Figures 6 and 7 illustrate how the contributions of the sub-indices change from season to season at Winnipeg and New Orleans and the disparate climatic strengths of the two cities. In Winnipeg, the cold winter temperatures produce negative TCI values. Low precipitation and abundant sunshine are climatic assets year-round, although the latter is diminished in winter by



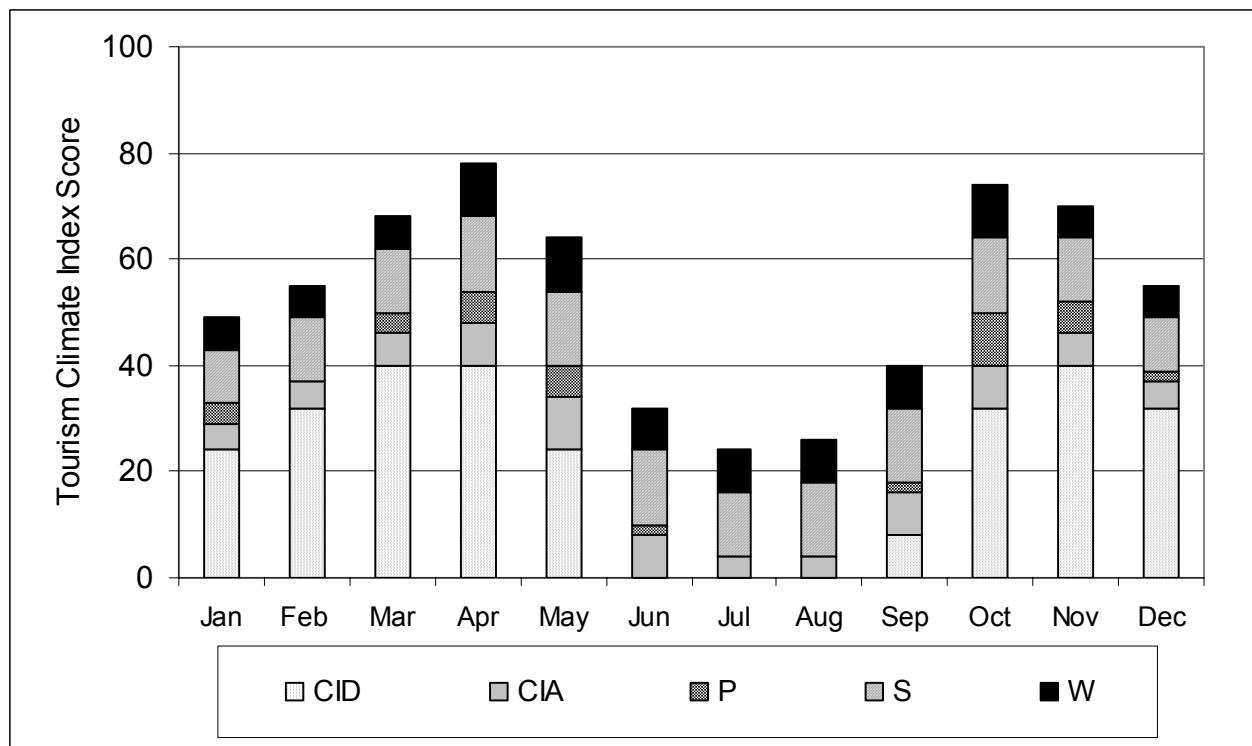
**Fig. 4** Cities with bimodal-shoulder peak TCI distribution



**Fig. 5** Cities with optimal year-round TCI distribution



**Fig. 6** Seasonal TCI sub-index ratings in Winnipeg (see Table 1 for description of sub-indices)



**Fig. 7** Seasonal TCI sub-index ratings in New Orleans (see Table 1 for description of sub-indices)

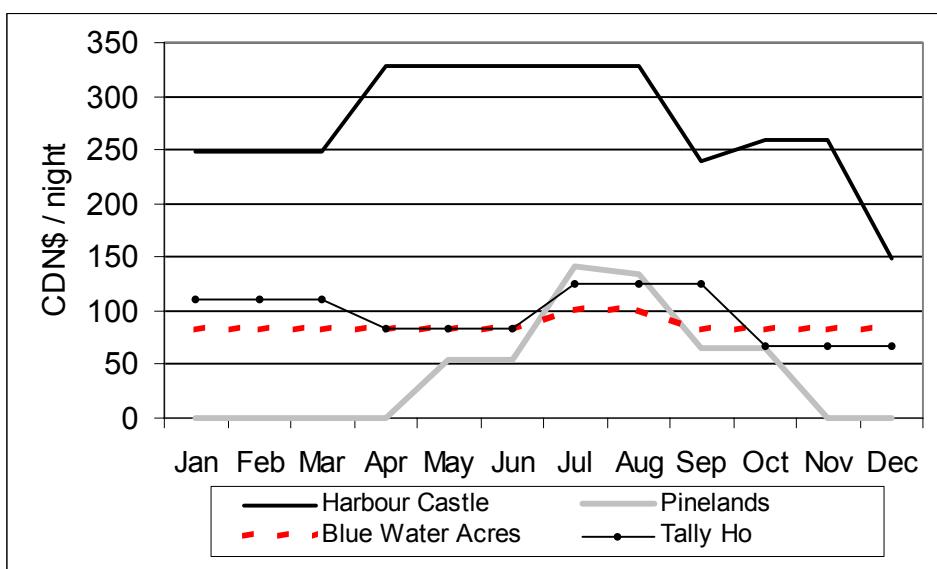
shorter daylight hours. While the cooling effect of wind is an asset during the warm summer months and contributes to TCI score, it is detrimental to Winnipeg's TCI score in the winter when it causes high wind chills values and thus is absent from the TCI score.

New Orleans has a bimodal TCI distribution. Here the thermal sub-indices contribute maximum values in March, April and November and very little during the summer months because of the high heat index. Precipitation follows a similar pattern, with higher precipitation contributing to lower TCI scores in the summer months. Unlike Winnipeg, wind is a climatic asset in New Orleans year-round. Similarly, sunshine has a relatively stable positive contribution to the TCI throughout the year.

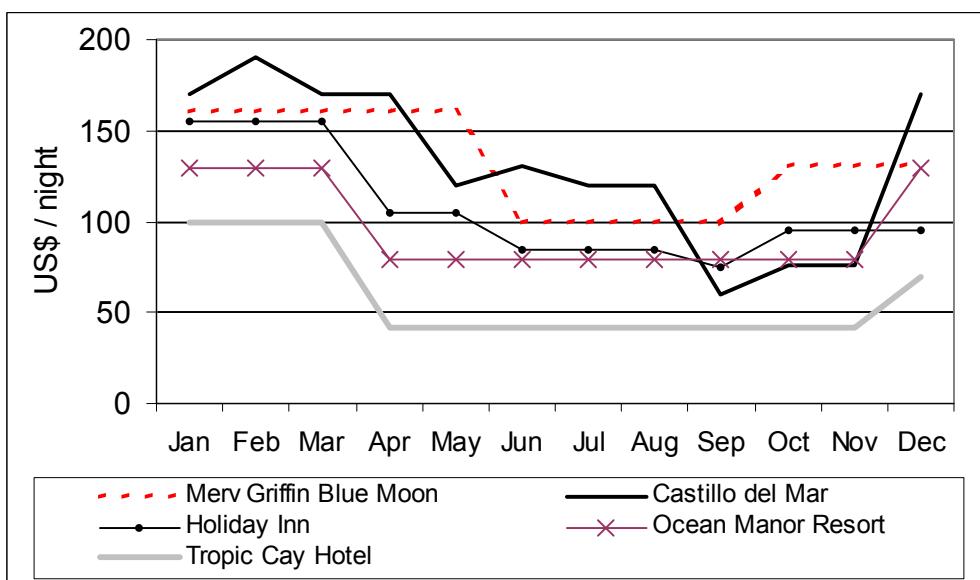
### Validation of the Tourism Climate Index in the Tourism Marketplace

If the climate resource is a determinant of tourism demand at a location, then theoretically measures of tourism demand should follow similar seasonal patterns as the TCI scores described previously. A range of tourism demand indicators were considered to explore this question, including: number of flight arrivals, number of visitors, visitor expenditures, hotel/resort occupancy rates and hotel/resort accommodation costs. A lengthy data research revealed that none of these variables is readily available at the temporal and spatial resolution required (monthly data for individual cities), except for hotel/resort accommodation rates.

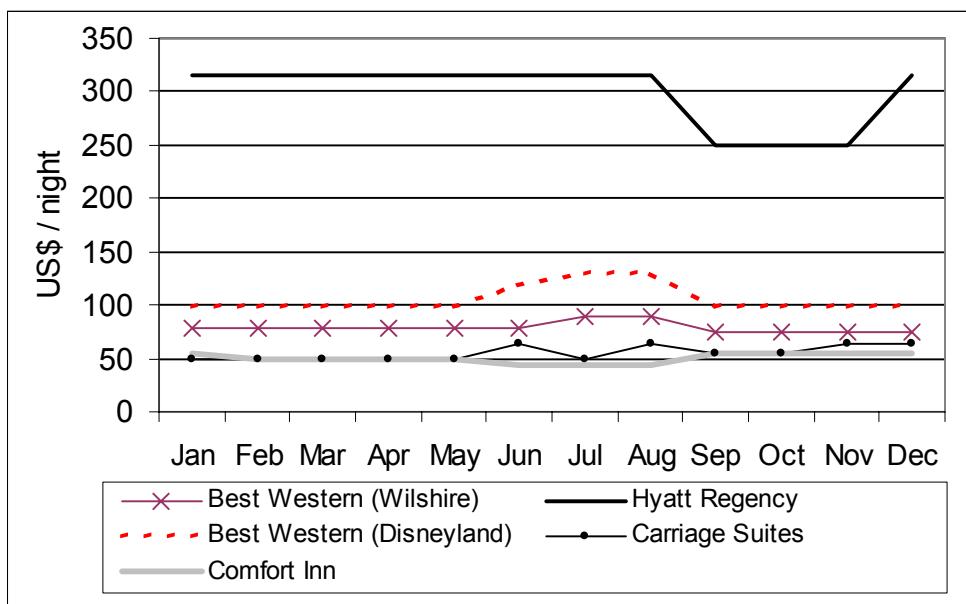
Overall, the accommodation cost curves, regardless of the price per night, resembled the TCI curves for each of the cities examined (Figures 8 to 10). Minor variations occur. For example, the increase in winter accommodation costs (Jan-March) at Muskoka resorts (Figure 8), near Toronto, can be attributed to increased demand during the alpine skiing season. The 'low season' troughs in the accommodation cost curves near Miami (Figure 9) are offset slightly from the TCI curve, extending up to two months longer in the fall season when TCI curves have already begun to rise. The slight rise in summer accommodation rates at most of the Los Angeles hotel/resorts (Figure 10), despite a concurrent drop in TCI scores, can be attributed to increased demand during the school holiday period in July and August.



**Fig. 8** Seasonal hotel/resort accommodation costs near Toronto-Muskoka (see Figure 2 for the seasonal TCI ratings of this area)



**Fig. 9** Seasonal hotel/resort accommodation costs near Miami-Fort Lauderdale (see Figure 3 for the seasonal TCI ratings of this area)



**Fig. 10** Seasonal hotel/resort accommodation costs in Los Angeles (see Figure 5 for the seasonal TCI ratings of this area)

Two important caveats must accompany this analysis. First, data limitations meant the TCI could only be validated against one indicator of tourism demand. Second, the sample size of hotel/resorts at each location was small and cannot be assumed to be representative of the entire accommodation sector at any of the selected cities. Nonetheless, the results appear to suggest that the TCI provides a useful measure of the relationship between climate and tourism.

#### Tourism Climate Index and Climate Change

One important dimension of the tourism sector that will be sensitive to climate change is the length and quality of tourism season. Here the TCI is used to explore how the tourism climate resource is expected to change seasonally and how the length of the tourism season might be affected. Any such changes would have considerable implications for the long-term viability of tourism enterprises and competitive relationships between destinations.

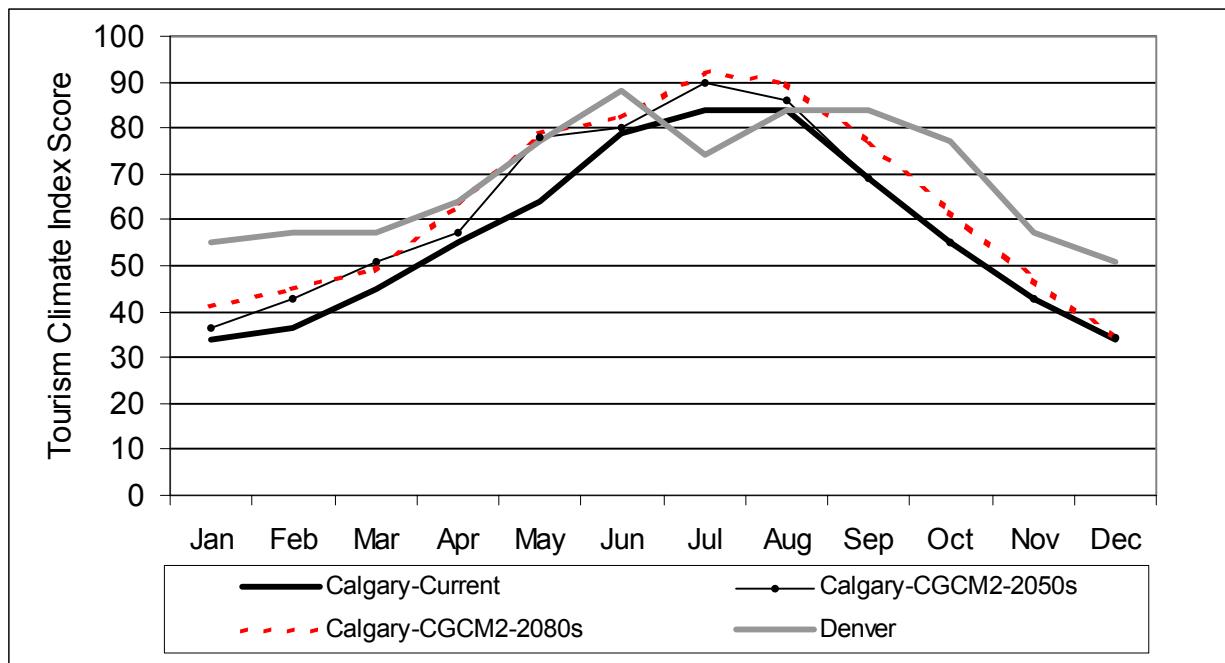
Analysis of the impact of climate change on the TCI of the eight Canadian cities indicated the annual tourism climate resource improved at each location in both the 2050s and 2080s. Under both the climate change scenarios, Vancouver was the largest benefactor in the 2050s with an average

monthly improvement of between 4.4 (HadCM2) and 5.3 (CGCM2) points on the TCI scale. Yellowknife experienced the largest improvement in the 2080s, with an average monthly increase of 6.3 (HadCM2) to 8.4 (CGCM2). Montreal and Toronto had the least net improvement.

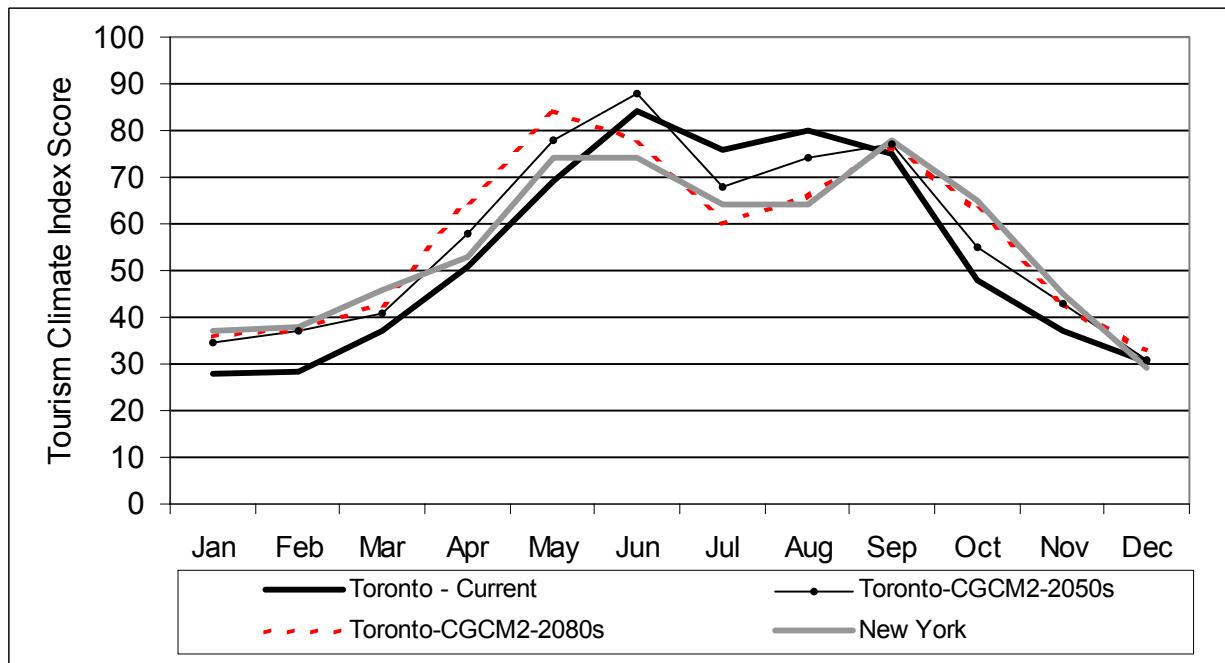
Seasonally, the impact of climate change on the tourism climate resource of the eight cities was much more varied. Calgary was the only city where the TCI went up in every month under all of the climate change scenarios. Particularly strong improvements occurred in the spring, with the TCI in May increasing 7 (HadCM2) to 14 (CGCM2) points in the 2050s. The number of months with an ‘excellent’ rating ( $TCI > 80$ ) increased from two to four in both Calgary and Edmonton to the north. For comparative purposes, the TCI curve for Calgary under the CGCM2 scenarios is presented with the current TCI curve for Denver (~1500km to the south) (Figure 11). While the TCI in Calgary remains below that of Denver in the fall and winter, it becomes equal to or better than Denver in the spring and summer.

Vancouver retains the summer peak distribution and improved in all months except August and October under the HadCM2 scenario, where increased precipitation negates improved thermal comfort. The number of months in the ‘excellent’ category ( $TCI > 80$ ) increased from two to three in both 2050s scenarios and up to four in the CGCM2 2080s scenario. By the 2080s, Vancouver’s tourism climate resource improves beyond that which Seattle enjoys currently.

In contrast to the improvements in the tourism climate resource in western Canada, the number of months with an ‘excellent’ rating in Toronto and Montreal declines from two to one and the month with the maximum TCI score shifts from June and July respectively to May under the CGCM2 2080s scenario. Both cities also experience notable declines (-6 to -16 points) in TCI ratings during the important summer holiday period (July and August). As Figure 12 illustrates, the negative impact of climate change on the summer tourism climate in Toronto, alters the TCI distribution from a summer peak to a bimodal-shoulder peak, very similar to that of New York currently. The decline in the summer TCI scores in Toronto is related to changes in thermal comfort. Specifically, under the CGCM2 climate change scenario, the number of days where the maximum temperature exceeds  $32^{\circ}\text{C}$  increases from four (1961-90) to 19 in the 2050s and 32 in the 2080s. Under the same scenario, the maximum daily temperature extreme in August increases from  $35^{\circ}\text{C}$  (1961-90) to approximately  $46^{\circ}\text{C}$  in the 2050s.



**Fig. 11** Calgary TCI under CGCM2 climate change scenarios



**Fig. 12** Toronto TCI under CGCM2 climate change scenarios

## **Discussion**

The findings of this study have implications for both domestic tourism in Canada and the nation's international tourism trade balance. Tourism in Canada is highly concentrated in warm-weather seasons. The third quarter (summer), when TCI scores in all of the Canadian cities examined are in the 'excellent' rating, accounts for 38% of annual domestic and 62% of the international tourism expenditures in Canada. There is also evidence to suggest that warmer summer temperatures contribute to increased tourism expenditures in Canada. Wilton and Wirjanto (1998) have estimated that  $1^{\circ}\text{C}$  above normal summer temperatures increases domestic tourism expenditures by 4%. Consequently, increased peak TCI scores and additional months in the 'excellent' category for several Canadian cities would be expected to have a positive impact on the domestic tourism economy.

Canada's international tourism trade deficit was estimated to be CDN\$2.1 billion in 2000 (Canadian Tourism Commission, 2001). The TCI analysis suggests that from a climatological perspective, Canada's tourism trade deficit could diminish under climate change. First, changes in TCI scores indicate that the tourism climate resource in Canada will improve, thus enhancing the competitive position of most Canadian regions in the international tourism marketplace (an increased tourism 'pull' factor). In particular, locations in western Canada were found to experience strong improvements in the tourism climate resource in the spring and summer. Additional research into the impacts of climate change for the tourism climate resource in the US is required to better understand how the competitive position of Canadian destinations may change. Second, Canadians spent CDN\$4.9 billion traveling to warm-weather destinations (Arizona, Australia, California, Cuba, Dominican Republic, Florida, Hawaii, Mexico and Texas) in 1997. Approximately one million Canadian 'snowbirds' seasonally migrate to the US sunbelt for the winter months. Shorter and less severe winters may reduce the impetus for Canadians to travel to warm-weather destinations as a winter escape (a decreased tourism 'push' factor).

Although improvements in the tourism climate resource in Canada under climate change, as estimated by changes in the TCI, suggest a net positive impact on Canada's international tourism trade balance, this optimism must be tempered by the range of potential negative impacts climate

change could have on Canadian tourism resources. Nature-based tourism is a major component of Canada's tourism industry (CDN\$11.7 billion in 1996 – Environment Canada 1999). A growing body of evidence (Wall 1998, Scott and Suffling 2000, Scott et al. 2002) suggests that important elements of the environmental resource base that supports nature-based tourism in Canada is vulnerable to climate change. The critical uncertainties regarding climate change impacts on the full range of tourism resources in Canada preclude a definitive statement regarding the net impact of climate change on this economic sector.

In conclusion, the TCI is a useful index not only because it combines climatic variables based on biometeorological studies into a single index that is readily interpretable by the traveling public, but also because it is designed to measure suitability of the climate resource for the most popular tourism activities in cities – sightseeing and shopping (Jansen-Verbeke, 2001). An additional strength of the TCI is its widespread applicability, as the climatological data required for the TCI are generally available for most locations. Furthermore, TCI curves appear to reflect tourism demand, at least as measure by one tourism indicator for a sample of North American cities.

There are, however, aspects of the TCI that require further refinement and analysis. The monthly period used in the TCI needs to be replaced by a timeframe that better resembles the length of most people's vacation period (7 to 10 days). In addition to climate means, the TCI would be strengthened if additional measures of climate variability were incorporated. The thermal comfort sub-index could be upgraded to make use of more sophisticated thermal indexes, such as the Physiological Equivalent Temperature (PET) (Höppe 1999). Testing the TCI with travelers is another important area of future inquiry. This would include determining whether travelers want an 'objective' measure of the quality of the climate at tourism destinations, how easily they interpret the TCI, if the TCI provides a sufficient measure of the climate for the average traveler, and perhaps evaluating the appropriateness of the sub-index rating systems and weightings in the TCI against stated traveler preferences. Additional validation of the TCI against other tourism indicators is also needed in order to further assess the value of the TCI as a tool for tourism climatology research.

Building on the initial work of Mieczkowski (1985), this is the first empirical study of how the tourism climate resource could be impacted by projected global climate change in the coming century. The findings and methods used are a positive step in addressing Wall's (1998: 614)

concern that “Although the implications for tourism are likely to be profound, very few researcher have begun to formulate relevant questions, let alone develop methodologies which will further understanding of the nature and magnitude of the challenges that lie ahead.”

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## **TOURISM IN THE “LAND OF THE OZONE HOLE”: A PERCEPTION STUDY**

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**Abstract:** The Ozone Hole has been perceived as anything from a serious threat to human existence, to a scare tactic by fantasists. Like with other environmental issues, this is a matter of perception. Regardless of the scientific facts, people perceive what they will. The perception of an issue is reality to those who take that view. People in various regions of Argentina and the Antarctic Peninsula were interviewed to gather perspectives within the Land of the Ozone Hole. Several viewpoints are included in this study: a scientific perception, a government perception, a mass media perception, and a perception of tourists. It was discovered that each perception differed, at least somewhat, from the others. Tourists offered the widest range of perspectives on this issue. Argentine tourists were nonchalant about wearing sun block or protective headgear in the sun, despite repeated warnings by tourism professionals, whose perspective was much more serious. American and British visitors comprised the foreign group of tourists. The views expressed by the foreign tourists spanned the range of total ignorance of the ozone hole, to concerned opinions, to over zealous caution. A recommendation to the Argentine/Antarctic tourism industry is included.

Key Words: Human Bioclimatology · Ozone Hole · Environmental Perception.

### **Introduction**

The Ozone hole has been perceived as anything from, a serious threat to humankind to, a scare tactic by environmental interest groups. In past studies (Trapasso 1982, 1992; 1994) it was found that the perception of people dealing with an environmental issue is as real as the scientific facts regarding that issue. A perception IS reality to those who take that view. The research

question then becomes, how is this phenomenon perceived by the people who live and work in that region, and by others wanting to visit the ‘Land of the Ozone Hole’?

Field work was conducted during January and February 1998, which included visits to various locations in Argentina and the Antarctic Peninsula to seek the existing perspectives on this controversial topic. Interviews with scientists, and data in the form of maps, charts, and satellite imagery were obtained from scientific stations, institutes, and university campuses. These primary sources, coupled with recent scientific literature constituted a *scientific perception*. Interviews with public officials comprised a *governmental perception*. Talks with news media professionals helped to form both a *popular*, and to some extent an *economic perception*. Discussions with both tourists and tourism professionals added to the *popular*, and *economic perceptions* as well. As expected, multifaceted views of this environmental problem focused on the interests of those interviewed.

### **The Scientific Perception**

It is vital to review the science first. Thus it is fitting to begin with a *scientific perception*. This perspective is discussed on several different levels: 1) science on the international project level, 2) science on the national or regional level, 3) science at the Antarctic research stations, and 4) health-related science.

The ozone hole by its very name reflects a certain perception. For the ozone hole is not a hole at all, but rather an area of ozone depletion resembling a dynamic circular/elliptical expanse surrounding the South Pole. As science has revealed so far; both natural meteorological processes and human-induced pollutants act together to diminish the ozone layer in this region during the austral spring. The depleted region reaches its maximum during late September through mid-October in any given year.

As news reported by the American Meteorological Society (1998), that year’s ozone hole was the largest observed since the early 1980s. Measured at more than 26 million square kilometers, it was an area larger than North America.

#### **International Project Level**

To investigate the perceptions of this issue required an extensive stay in Argentina. This country and the Antarctic Peninsula constitute the land of the ozone hole used in this study. Dr.

Susana B. Diaz is a resident scientist at CADIC (Austral Center for Scientific Research) located in the Port City of Ushuaia, Argentina. This is the southernmost city in the world and can be found within the boundary of the yearly ozone hole.

Her laboratory at CADIC is an integral part of the U. S. National Science Foundation Polar Network for Monitoring Ultraviolet Radiation, and represents the official UV monitoring station for Ushuaia. Dr. Diaz' cooperative research efforts have resulted in an impressive list of publications. Reviewing these and other literature, augmented by in-depth conversations with her, indicated that there is less of a danger to human life than one might assume. "It all pertains to basic radiation physics; as it relates to sun angles, and cloud cover," Diaz stated. Her data have shown that the maximum UVB radiation received at Ushuaia does not necessarily coincide with the maximum extent of the ozone hole. She elaborated "It is possible to have a greater exposure to UVB during a calm, clear, sunny day in summer, than a cloudy and hazy day during the ozone hole (Diaz et al. 1994, 1996, Diaz, personal communication 1998).

Climatologically, humans at high latitudes find protection by two basic radiation laws, working in concert: Lambert's Cosine Law and Beer's Law.

#### Lambert's Cosine Law

$$I = I_0 \cos V$$

where:  $I$  = Intensity of solar radiation reaching the surface.

$I_0$  = Intensity of solar radiation maximum (i.e., when the sun is 90 degrees).

$\cos V$  = Cosine of the Zenith Angle  $V$  (i.e., the angular departure from the vertical).

Thus, the lower the zenith angle the less intense the incoming solar radiation.

#### Beer's Law

$$-(arx)$$

$$I = I_0 e^{-(arx)}$$

where:  $I$  = Intensity of solar radiation reaching the surface.

$I_0$  = Intensity of solar radiation maximum (i.e., at the outer edge of the atmosphere).

$e$  = The Natural Logarithm (2.718...)

$-(arx)$  = Extinction Coefficient ( $a$  and  $r$  = absorption and reflection, respectively, by atmospheric gases and  $x$  = thickness of the gases)

Sun angles become more oblique with increasing latitude. Thus, solar radiation must pass through more of the atmosphere before striking the surface. Again, weaker radiation reaches Ushuaia than locations at lower latitudes with higher sun angles. These two basic radiation laws are work in tandem to help protect the human population from excessive incoming ultraviolet radiation, in essence, it is the geography of the location that is critical here.

The Estacion VAG (Global Atmospheric Watch) Station in Ushuaia, is the official ozone monitoring station for the region. This United Nations Environmental Program (UNEP)/ World Meteorological Organization (WMO) network contains 6 locations, Ushuaia being the southernmost. There I met with Ingeniero Sergio Luppo. This former Argentine Air Force meteorologist, agreed that he felt no danger of living in Ushuaia. The sun angles are too weak," he said, "and people cover up with clothing in the early spring. Luppo echoed a response I had heard at CADIC: "It is much more dangerous to go to the beaches near Buenos Aires in summer than to be here during the ozone hole" (Luppo, personal communication 1998).

#### National or Regional Project Level

To view the issue from a national standpoint, a number of research facilities were visited. At the headquarters of the Argentine Antarctic Institute in Buenos Aires, a meeting with Licenciado Alberto Cazeneuve, Chief of the Atmospheric Sciences added another view. According to Cazeneuve (Personal communication 1998), the ozone hole expands to include Ushuaia only a few days per year and therefore is not a constant danger to the people living there. He went on to explain, the scientists working at Argentina Antarctic research bases are safe because these bases only operate during the summer and thus are not inhabited during the ozone minimum. Cazeneuve did state that the Argentine researchers in the Antarctic are finding the effects of UV radiation on plankton density and biodiversity. That is their major concern.

#### Antarctic Research Stations

Farther within the land of the ozone hole, three research bases in the Antarctic were visited. Taken chronologically, the first was the Admiral Brown Science Station, an Argentine facility in Paradise Bay. There, marine biologist, Dr. Rufino Comes granted an interview. He stated that their major research interest concerns marine plankton. Their findings indicate that these minute sea creatures are indeed showing the effects of increasing UV radiation. The plankton

populations have decreased with increasing UV radiation, and its role as the base of the marine food web, causes great concern at this time (Comes personal communication, 1998).

The next visit was to the American research station at the Palmer, which deals with terrestrial plants, phytoplankton, and other marine life forms to a depth of 10 m, (the depth of penetration into the sea of UVB radiation). These researchers have also found delicate marine fauna and terrestrial flora are adversely affected by increased UVB radiation (Arens and Pineda personal communication 1998). These marine biologists felt they had little to worry about since they are not actively working during the greatest extent of the ozone hole.

However Kevin Bliss, who operated the official UV radiation monitoring station for the US National Science Foundation Polar Network, expressed a different concern. According to Bliss (Personal communication 1998) people experience a distinct difference between doing inside analysis work and doing outside fieldwork. There is concern about bad sunburns and cataracts among those who work upon the highly reflective snow and ice surfaces. Usually, sun block, hats, and protective clothing become the standard procedure, after the first severe sunburn is experienced.

The last of the Antarctic Stations was Port Lockroy, a British Station in Dorian Bay. The two staff members, also seasonal inhabitants, were involved with little else than maintenance duties and monitoring the local penguin population. When asked about the ozone hole they graciously handed me an official pamphlet published by the British Antarctic Survey Office in Cambridge, England, and offered no other comments.

### Health Related Research

According to the Ministry of Health and Social Action Offices in Ushuaia, there has only been one research study dealing with humans and the incidence of skin disorders in the Tierra Del Fuego (deCalot et al.1995). When comparing their results to the general Argentine population they found no significant increase in dermatological disorders for the inhabitants of Ushuaia. The authors of the study pointed out however, that the average age of the people in Ushuaia, a relatively new and growing city, is only 27 years old. This is generally too young an age group for melanoma and other tumors to manifest. The youthful sample, coupled with the protection by the cold weather clothing, were reasons for the low incidence of skin tumors.

## **The Perceptions of the Mass Media**

Professionals in the mass media often render valuable insight into *environmental issues* and how they affect the *perception of the populace*. While in Buenos Aires, interviews were sought with professionals working in: television, newspapers, and newsmagazines.

### **The Argentine Mass Media**

In trying to establish the stance of the Argentine television media, I visited the offices of Cronica TV, the main all-news cable station in Buenos Aires. One of the news directors, Ms. Elena Sambeca stated that the station would not cover any stories unless it comes directly from the SMN. The National Meteorological Service Headquarters is also located in Buenos Aires. This national television network relies totally on what is given to them by official sources and does not tend to initiate environmental stories (Sambeca personal communication 1998).

During field investigations in Ushuaia, a visit to the local newspaper, El Diario de Tierra del Fuego, found the editor, Licenciado Fulvio Baschera available for an interview. While agreeing that the ozone hole was an important issue, he relies upon CADIC to send any relevant data. He waits for the local scientists to decide whether or not a story concerning the hazards of ultraviolet radiation is newsworthy (Baschera personal communication 1998).

The lack of media involvement was also noticed in other parts of the country. While visiting the National University of the Patagonia in Trelew, Ingeniero Jorge Pedroni, Department Head of Physics within the Faculty of Engineering was available for an interview. Pedroni monitors incoming UV radiation in Trelew (independent of the NSF Polar Monitoring Network), and reports the data to the local newspapers. His department publishes a health advisory informing the public of the danger levels of UV radiation (Pedroni and Massoni 1996). Pedroni stated that the newspapers in Patagonia do not always print the advisories at all (Pedroni personal communication 1998).

### **American Mass Media in Argentina**

At the National Desk of the Buenos Aires Herald, the English language newspaper of the capital city, Editor Joseph Schneider offered an interesting view. He explained that news stories concerning environmental issues were rarely found in newspapers. "We used to have an environmental page in our paper, but we had to drop it due to lack of advertising dollars,"

Schneider said. Furthermore, he was unaware of any major stories concerning the ozone hole in recent years in Argentine print media (Schneider personal communication 1998).

While at the Buenos Aires Herald, I also met with Mr. Joe Goldman a correspondent for ABC TV News in Argentina. According to Goldman, "Few if any, environmental magazines can take-off in Argentina, because of the lack of advertising from big business sponsors. Environmental issues are downplayed, rarely can you find articles written about these topics" (Goldman personal communication 1998). Goldman mentioned a story written by his colleague and correspondent, for Time Magazine Uki Goni, as the last he recalled concerning the ozone hole.

An interview with Uki Goni (Personal communication 1998) and a subsequent reading of his article (Goni 1997) revealed a rare occurrence, during mid-May 1997, when an area of ozone depletion was found outside the Antarctic region. This area centered over the southern middle latitudes and encompassed the cities of Buenos Aires, Argentina and Santiago, Chile. Goni asserted that the National Meteorological Service downplayed the episode, and did not release data until well after the fact. The Chilean government, in contrast did release data and warnings to the general public especially in and around Santiago. The Goni article was highly critical of Argentina's failure to warn its people of possible danger.

#### Economic Pressures Affecting the Media

Discussions with news media professionals, confirmed one of my thoughts at the outset of this study. The Argentine economy relies heavily upon two large industries. The ozone depletion issue affects both. The first is cattle ranching and the exportation of beef. This activity involves the process of meatpacking and requires refrigeration, which relies heavily upon ozone-destroying Freon (commercial name for some chlorofluorocarbons). Any issues real or perceived that interfere with the use of this vital chemical coolant is bad for business.

The second vital economic activity is tourism. Any fear, real or perceived, strongly affects this highly competitive industry. When people are afraid to visit a country; it becomes bad for business. It was suggested by these media contacts, because of these 2 reasons, the Argentine government and mass media, seem reluctant to cover this environmental issue.

## **The Government Perception**

In an attempt to gain the *government perception*, the offices of the Department of Natural Resources and Sustainable Development, in Buenos Aires was visited. There, Secretary Roberto H. Kurtz was available for interview. Secretary Kurtz was the representative for Argentina at the Montreal Protocol, during the summer of 1987. The Montreal Protocol was an international conference where the curtailment of ozone destroying chemicals was outlined and negotiated. Kurtz was able to supply a written copy of the official Argentine stance presented at Montreal. In addition, he also rendered a copy of, Chemical Compound Law 24.040, which defines national legislation concerning the manufacture, restrictions and handling of ozone-destroying compounds.

Secretary Kurtz stated that the ozone issue is taken seriously by the Argentine government, especially with respect to terrestrial and marine flora and fauna. However, he did not extend that fear to the human population. "People in places like Ushuaia, run no more of a risk than people smoking a pack of cigarettes every day," he said (Kurtz personal communication 1998).

## **Perceptions of Tourists and Tourism Professionals**

As a visitor to the land of the ozone hole, I was particularly interested in the attitude of tourists. The opportunity to speak with people about this issue often came about while on various tours around the country. Two such interviews with tourism professionals seemed to tell an interesting story with remarkable similarity. These professionals live in two different parts of the country and work in two different types of tourism.

### **Argentine Tourists**

The first interview took place at the Nahuel Huapi National Park, in the Lake District of the Andes Mountains near San Carlos De Bariloche. There, National Park Ranger Silvina Arrido was adamant in her comments. "The sun is killing us! ... It gets worse each year," she stated. "The Park Rangers used to apply creams with SPF 45 or 50 as protection; now we use total Sun block if we can get it." When asked about how the tourists react to this environmental issue, she replied, "They don't! ... They act as if the sun cannot hurt them. They ignore my warnings and advice" (Arrido personal communication 1998).

Some of these statements were echoed at a later time during a visit to the Valdez Peninsula on the East Coast of the Argentine Patagonia. Rogelio Rhys, certified guide for NaturaTur of Chubut, a private tour company in Patagonia. He called the ozone hole "a very, very serious problem, both for the quality and quantity of life... I never leave the house without applying sun cremes with SPF of 45." According to Rhys, the incidence of both sunburn and sunstroke among his tour groups has risen in recent years. When asked about the attitudes of the tourists themselves he replied, "People don't care...they don't listen. To them, it is too silly to wear a hat or to put on sun block. The local Wildlife Rangers have only recently started to protect themselves, but the general public does not care" (Rhys personal communication 1998).

Ingeniero Jorge Pedroni of the National University of the Patagonia, who reports UV radiation data to the local newspapers, made similar comments. "People live for today. They don't care about skin protection. If the problem is not immediately life-threatening, Argentine people will not react," he asserted (Pedroni personal communication 1998).

#### Foreign Tourists

Foreign visitors to the land of the ozone hole, were encountered onboard the M.S. Explorer while sailing to the Antarctic Peninsula. This ship is owned by Explorer Shipping, Inc., an American company but subcontracted by Abercrombie and Kent, Ltd., a British concern. In addition to American and British, there were also French, Italian, and Brazilian tourists on board. Explorer Shipping allowed me onboard as a scientist needing transportation for Antarctic research with full passage in exchange for guest lectures and help with weather forecasting. The ship's administrators were adamant about interviewing the passengers. I was not to interrogate them, or bother them with written questionnaires. When learning that I was a climatologist, the tourists on board spoke freely about their ideas about the ozone hole. During casual conversations, I asked 3 questions. The first, have you ever heard of the ozone hole? Second, if so, do you know what it is? Third, how do you feel about visiting this area? From a total of 34 respondents I identified 4 categories: Ignorant, Informed, Defiant, and Over-compliant. The 34 people were composed of couples thus making 17 each male and female. The youngest respondent was 33 years old the oldest was 82. These 34 were chosen from the American and British passengers so that the conversations could proceed in English.

Total ignorance of the issue was rare, and at times comical. One woman had never heard of the ozone hole. Another thought that the ozone hole occurred in the ocean. The second question

was added to determine the level of familiarity with the issue. Other comments included "I've heard about the ozone hole, does it happen around here?" Fortunately those who lacked of knowledge of the issue constituted only about 18%, or 6 of the tourists interviewed. The level of defiance was about the same at 5 people or about 15%. This category was found among senior citizens. Their comments included, "At my age! I couldn't care less about dangerous radiation," ... "Everything gives you cancer. Smoking gets your lungs, drinking kills your liver; now the sun gives you skin cancer."... "I'm going to live my life the way I want!"

The "Informed" category increased to around 56% or 19 of the tourists with comments like, "We're only here for a week or two, I think a short exposure would be O.K.," and "I think the ozone hole is not too bad in February."

Only about 4 of the tourists (about 12%) were classed as Over-compliant. Those who appeared on deck, even on warm days totally clothed from head to foot. Others always applying sun block and offering protection to anyone, they thought, was not sufficiently protected.

## Conclusions

As with any perception study, one set of conclusions is replaced by several sets of conclusions. Here, people expressed their own views and established levels of perception. From a *scientific perception*, the ozone hole poses little danger to human life in high latitudes. The low sun angles do not yield high intensities, and cloud cover plays a more important role than originally hypothesized. High latitude geography also produces colder climates where people protect themselves with warm clothing. Keeping warm, and protection from UVB radiation both occur with a winter/spring wardrobe. The scientists studying in the Antarctic often conduct their experimentation only during the summer months, after the ozone hole reaches its yearly recovery.

*Government* agencies, while writing legislation to deal with the issue. The enforcement of those laws may be a different story.

The news media is split between two perceptions. The *Argentine media* rely totally on the initiative of scientists and government officials to initiate a news story, while *American journalists* insist that there is a resistance to this issue. The *economic pressures* of the meat packing industry and the travel industry may be the cause of the seemingly disinterested views of

the Argentine businesses, and their reluctance to advertise in the media projects which focus upon environmental issues.

Tourists in southern Argentina exhibit the widest variety of perceptions of this issue. The *Argentine tourists* seem to take a devil-may-care attitude towards the concept of harmful UVB radiation and seem resistant to self-protection. While Argentine tourism professionals, were adamant about their fears of the ozone hole. *Foreign tourist*, span the range from total ignorance of the issue to a very guarded attitude toward self-protection.

Recommendations to the tourism industry are quite simple in this particular case. Unlike some environmental perceptions where people act against the advice of scientific fact, here, science permits the defiance, and nonchalance towards the perceived fear. It could be recommended to the Argentine Tourism Industry to create a short, simple, colorful, reader-friendly, science report. This document (perhaps a brochure) could state why humans have little to fear in the ‘Land of the Ozone Hole’. Such a report, coupled with a colorful brochure showing the spectacular sites found around the Antarctic Peninsula should promote tourism. From there an intensive advertising campaign highlighting the science can and dispel any fears.

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## **Assessing climate for tourism purposes: Existing methods and tools for the thermal complex**

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### **Abstract**

The most important direct effects of climate on tourism occur at the micro scale. These effects are significant for both the tourism industry and the holiday makers themselves, but they are also of importance to the planning and design of tourism buildings, recreation facilities and a variety of other issues. With some modification, existing methods for assessing climate in human biometeorology can be used for the tourism climatology. For example, thermal indices that are derived from the energy balance of the human body can be useful here. The problem is that input environmental data required for these schemes rather specialized and usually not available. Standard climate data are air temperature, air humidity and wind speed. However, the most important environmental parameters for deriving modern thermal indices are the short and long wave radiation (and the derived mean radiant temperature). These can be determined using special techniques. The RayMan model that has been developed for urban climate studies is presented here. It is shown that this can be a helpful tool for the assessment of tourism and climate related questions. Sample analysis are presented and discussed.

**Keywords:** Human energy balance, Physiological Equivalent Temperature, Mean radiant temperature, RayMan

### **Introduction**

Humans have been aware that weather and climate affect health and well being. Hippocrates, 2.500 years ago, wrote about regional differences of climate and their relationship to states of health. Folklore anywhere is rich in belief about the effect of seasons and weather fluctuations on physical and mental health. Fevers vary seasonally, so do mood and various psychological disorders, aches and pains in joints flare up in winter and heat waves can debilitate and kill (WMO, 1999).

The apparent increased instability of weather patterns in many parts of the world in recent years, new insights into cyclical phenomena such as El Nino, and the evidence suggesting that the global climate is beginning to change in response to greenhouse gas emissions, have focused new attention on health consequences of the climate (WMO,

1999). Another point is that most people live in cities and spend the major part of their time there.

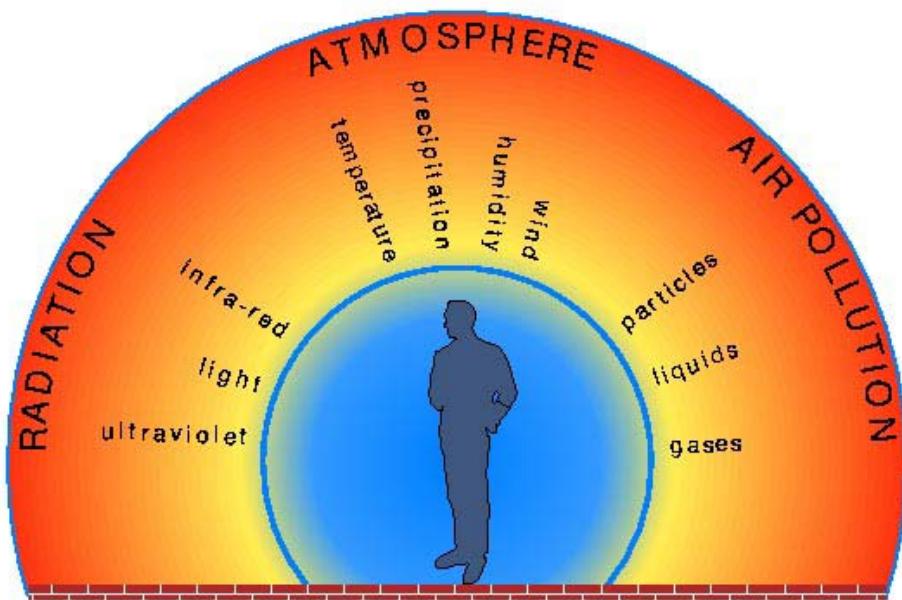
## Methods

### Atmospheric environment

Cause and effect relations between the atmospheric environment and human health or human comfort can be analyzed by a humanbiometeorological classification (Jendritzky et al. 1990, Matzarakis and Mayer 1996, VDI, 1998) that distinguishes (Fig. 1):

- thermal complex,
- air pollution complex,
- actinic complex
- and biotropy.

The thermal complex comprises the meteorological factors air temperature, air humidity and wind velocity, and also contains the short and long wave radiation that thermophysiological affects humans in indoor and outdoor climate. This complex is relevant to human health because of a close relationship between the thermoregulatory mechanism and the circulatory system.



**Fig. 1** Atmospheric environment and human (WMO, 1999)

The air pollution complex includes solid, liquid and gaseous natural and anthropogenic compounds that cause adverse health effects in humans, indoors as well as outdoors.

The relevance of air quality conditions to human health depends on the emission sources and the transmission conditions (dispersion, dilution, possible chemical reactions, wash out and rain out of air pollutants). These factors are determined by atmospheric layers (grade of turbulence), wind, precipitation, and possibly air humidity and solar radiation.

The actinic complex comprises the visible and ultraviolet range of the solar radiation that shows – apart from mere thermal effects – direct biological effects.

Biotropy deals with the biological effects of the weather. There are three possible reactions of the human organism to the weather: body reactions, slight and intense meteorosensitivity.

The fact that air pollution can seriously affect human health has long been acknowledged and resulted in numerous limiting values, guidelines and threshold values for air pollutants. Its importance is not only due to the fact that air pollution occurs throughout the whole. Different pollutants occur at different levels and hardly any individual protection can be taken against air pollution.

The thermal complex, however, is often underestimated, especially in the Central European climate region, although long-term data statistics show increased mortality rates at extreme thermal conditions (heat or cold stress) (Jendritzky 1992).

### **Assessment of the thermal complex**

Human biometeorological studies have already been carried out for some time. In the past thermal indices were frequently used to estimate the thermal environment. These indices were based on single or composite meteorological parameters, such as wet bulb temperature or equivalent temperature.

In the seventies of the 20<sup>th</sup> century, some scientists began to use physiologically relevant indices that were derived from the human energy balance for the assessment of the thermal complex (Höppe 1993 and 1999). A model for the human energy balance is MEMI (Munich Energy Balance for Individuals) which uses the assessment index PET (Physiologically Equivalent Temperature). This model is described in VDI-Guideline 3787, Part 2 “Methods for the Human-Biometeorological Assessment of Climate and Air Hygiene for Urban and Regional Planning” (VDI 1998).

**Table 1** Threshold values of the thermal indexes Predicted Mean Vote PMV and Physiologically Equivalent Temperature (PET) for different grades of thermal sensitivity of human beings and physiological stress on human beings, internal heat production: 80 W, heat transfer resistance of clothing: 0.9 clo (according to Matzarakis and Mayer 1996)

PMV	PET	Thermal Sensivity	Grade of Physiologic Stress
-3.5	4 °C	very cold	extreme cold stress
-2.5	8 °C	cold	strong cold stress
-1.5	13 °C	cool	moderate cold stress
-0.5	18 °C	slightly cool	slight cold stress
0.5	23 °C	comfortable	no thermal stress
1.5	29 °C	slightly warm	slight heat stress
2.5	35 °C	warm	moderate heat stress
3.5	41 °C	hot	strong heat stress
		very hot	extreme heat stress

The following meteorological parameters were taken into account in MEMI:

- air temperature,
- vapour pressure,
- wind velocity,
- mean radiation temperature.

Body parameters used in MEMI are:

- human activity and body heat production,
- heat transfer resistance of clothing.

Like the frequently used PMV index (Predicted Mean Vote), PET makes it possible to access thermo-physiologically (see Table 1) the thermal conditions of surrounding indoor and outdoor air, as point calculations or in form of maps (Matzarakis 1995, VDI 1998).

### **Importance of radiation fluxes in human-biometeorological studies**

For the estimation of thermal indices it is easy to obtain meteorological data like air temperature, air humidity and wind speed. The mean radiant temperature  $T_{mrt}$  is the most important meteorological input parameter for obtaining the human energy balance during summer weather conditions. Therefore,  $T_{mrt}$  has the strongest influence on thermophysiological significant indices like PET (Physiologically Equivalent Temperature) or PMV (Predicted Mean Vote) which are derived from models for the human energy balance (Mayer 1993, VDI 1998).

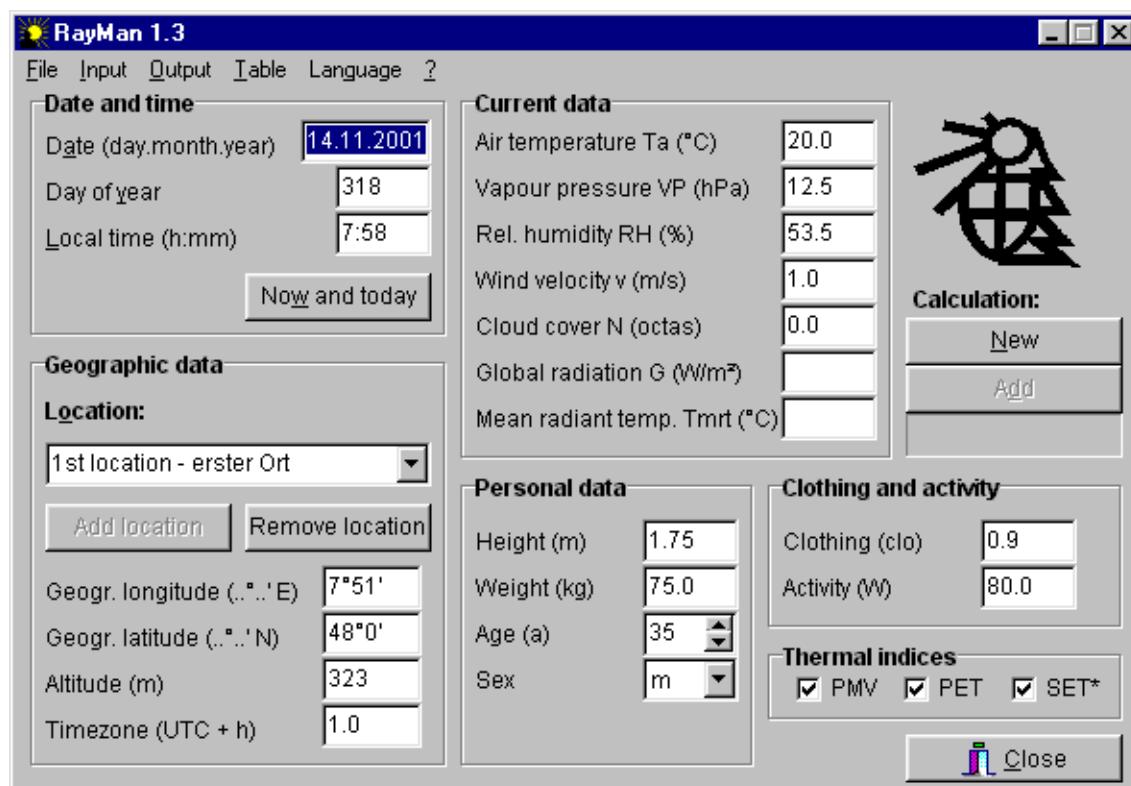
$T_{mrt}$  is defined as the uniform temperature of a surrounding surface giving of blackbody radiation ( $\varepsilon = 1$ ), which results in the same radiation energy gain of a human body as the prevailing radiation fluxes. The latter are usually very varied under open space conditions. The procedure for the measurement of  $T_{mrt}$  is very complex and needs much time (Höppe 1992, Matzarakis and Mayer 1998).

In literature, methods to estimate radiation fluxes based on parameters including air temperature, air humidity, degree of cloud cover, air transparency and time of the day of the year are recommended (Jendritzky et al. 1990, Matzarakis 1995). But the albedo of the surrounding surfaces and their solid angle proportions must also be specified. Additionally other factors like the geometrical properties of buildings, vegetation, etc. have to be known and to be taken into consideration (Matzarakis et al. 2000).

The model *RayMan* which is presented here is well suited for the calculation of the radiation fluxes especially within urban structures, because it considers various complex horizons (Matzarakis et al. 2000).

Working with *RayMan* (Fig. 2) at a PC, an input window for urban structures (buildings, deciduous and coniferous trees) is provided. The possibility of free drawing and output of the horizon (natural or artificial) are included for the estimation of sky view factors. Also possible is the input of fish-eye-photographs for the calculation of

sky view factors. The amount of clouds covering the sky can be included by free drawing while their impact on the radiation fluxes can be estimated (Matzarakis 2001).



**Fig. 2** Input window of *RayMan* 1.3 and the relevant values for the calculation of mean radiant temperature and thermal indices

In the field of applied climatology and humanbiometeorology the most important question about radiation properties in the micro scale is, if an object of interest is shaded or not. Hence, in the presented model shading by artificial and natural obstacles is included.

Horizon information need to be known to obtain sun paths. Calculation of hourly, daily and monthly averages of sunshine duration, short wave and long wave radiation fluxes with and without topography and obstacles in urban structures can be carried out with *RayMan*. These can be with meteorological input of manual data or files. The output is given in form of graphs and text data.

The final output of the model is, however, the calculated mean radiant temperature which is required in the energy balance model for humans, and thus for the assessment

of urban bioclimate and such thermal indices as Predicted Mean Vote (PMV), Physiologically Equivalent Temperature (PET) and Standard Effective Temperature (SET\*). The model is developed based on the German VDI-Guidelines 3789, Part II (VDI 1994), Part III (VDI 2001) and VDI-Guideline 3787 Part I (VDI 1998).

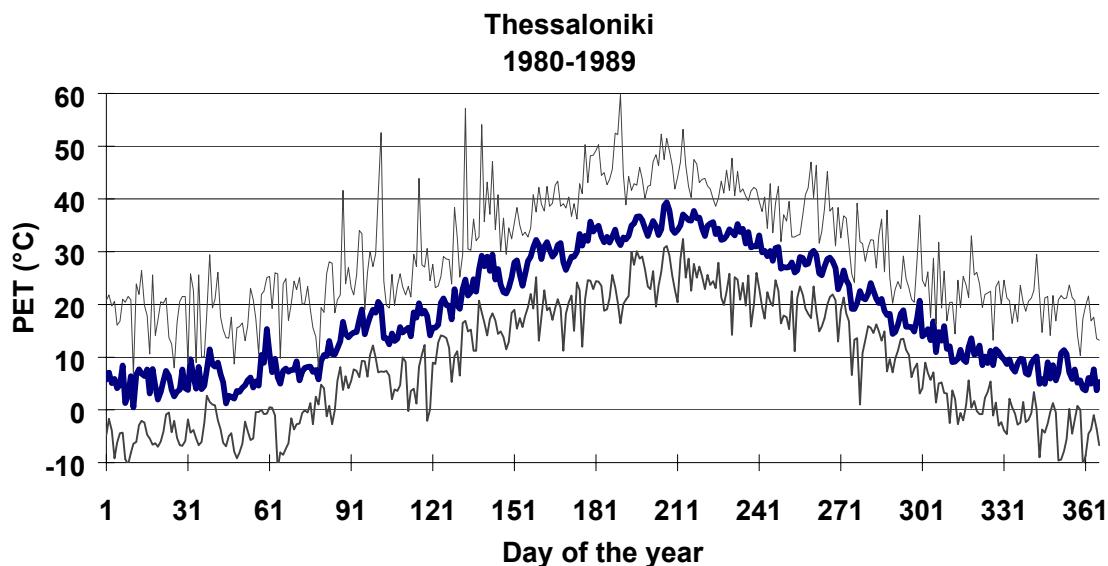
## Results

### Example for tourism areas

PET, which can be calculated by *RayMan*, is suitable for the evaluation of the thermal environment not only in summer, but also throughout the whole year. As an example of such an application in a Mediterranean climate, Fig. 3 shows mean, highest and lowest PET values at 12 UTC per day at Thessaloniki (at Mikra Airport) in Greece for the period 1980 - 1989. This kind of illustration provides good information on the variability of PET for individual days of the year within the investigation period. The results of Fig. 3 show that different grades of cold stress ( $\text{PET} < 18^\circ\text{C}$ ) occurs mostly from October to April. Mean PET values over  $30^\circ\text{C}$ , indicating at least moderate heat stress, can be found from June to September which is a period of 4 months. On some hot summer days from May to September, PET at 12 UTC was over  $40^\circ\text{C}$  representing a pronounced thermal stress level in Thessaloniki.

### Examples of climate manipulation

On the other hand the urban structures in urban areas are very complex and the variability of the meteorological parameters is very high (Matzarakis and Mayer 1998). As a typical example, Table 2 show an example of climate manipulation owing to the influence of trees in urban areas. Table 2 compares results from *RayMan* and measurements that were carried out on July 19<sup>th</sup> 1999 in Freiburg, southwest Germany. The latter refers to measurement site 4 (MP 4) marked out as one of the measurement sites for humanbiometeorological evaluations of urban structures. The MP 4 site is situated under a tree crown on a small green area in the northern area of the city. The selected day July 19<sup>th</sup>, 1999 was a beautiful summer day with recorded cumulus cloud cover about midday. The sky-view factor amounted to 0.07 on the basis of an appraised fish-eye photograph in the opposite MP6 in a nearby street canyon with a sky view factor of 0.61.



**Fig. 3** Mean, highest and lowest values per day of Physiologically Equivalent Temperature (PET) at 12 UTC at Thessaloniki for the years 1980-1989

In Table 2 are listed the mean and maximum differences between the “site street canyon north” and the site “below some tree crowns” for air temperature  $T_a$ , global radiation  $G$ , long wave radiation  $A$  from the upper hemisphere, long wave radiation  $E$  from the lower hemisphere, mean radiant temperature  $T_{mrt}$  and Physiologically Equivalent Temperature PET. The results in Table 2 show that there are existing differences which express the quantitative effects of trees in urban areas and explain the relevance of trees for urban climate and human beings (Matzarakis 2001).

**Table 2** Mean and maximum differences between the site “street canyon north” and the site “below some tree crowns” for air temperature  $T_a$ , global radiation G, long wave radiation A from the upper hemisphere, long wave radiation E from the lower hemisphere, mean radiant temperature  $T_{mrt}$  and Physiologically Equivalent Temperature PET.

	Site “street canyon, north” - Site “below some tree crowns”			
	Mean		Max	
$T_a$	0.4 °C	1.5 %	1.7 °C	6.1 %
G	323 W/m <sup>2</sup>	94.9 %	935 W/m <sup>2</sup>	99.0 %
A	-47 W/m <sup>2</sup>	-10.8 %	-59 W/m <sup>2</sup>	-13.3 %
E	66 W/m <sup>2</sup>	12.6 %	121 W/m <sup>2</sup>	20.5 %
$T_{mrt}$	14.7 °C	32.0 %	32.4 °C	49.7 %
PET	9.0 °C	26.5 %	19.8 °C	41.2 %

## Conclusion

Results of humanbiometerological analysis of different spaces are of interest because of their possible application in:

- urban and landscape planning (regarding investigation of impacts of big constructional projects),
- tourism (for the selection of holiday or the duration of holidays),
- giving advice concerning the location of residential areas,
- climate change and relation to humanbiometeorology and
- climate and health (for the analysis of thermal stress situations).

For the evaluation of the thermal component of urban and regional climate precise and high resolution radiation data of the whole surrounding is necessary. This data can be either measured or calculated using a radiation model. *RayMan* is able to do the latter and is available for general use under (<http://www.mif.uni-freiburg.de/rayman>).

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# **ANALYSIS OF A HEAT WAVE PHENOMENON OVER GREECE AND IT'S IMPLICATIONS FOR TOURISM AND RECREATION.**

By

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## **ABSTRACT**

As it is known the climatic conditions is a very important one when someone planning a holiday in a certain country. Especially the analysis of extreme weather events helps the tourism ,in general , very much. In this paper the heat wave phenomenon over the mainland of Greece, during the days 18 to 21 August 1999, has been studied mainly from a synoptic point of view. The predominant synoptic conditions at the surface was an anticyclonic flow contributing positively to transfer Tc air masses from Sahara desert to Greece. SW flux was predominating into layers of the middle troposphere. This type of circulation gives an intensive negative vorticity in the middle troposphere and a warm advection in the lower troposphere, over the studied area. Meanwhile the main axis of the Subtropical Jet Stream, at 200-hPa level, was displaced far north from the Balkans with a maximum wind speed of 100 Knots. Beneath the jet stream and south of its axis, was taking place a large-scale subsidence. This downward flow of troposphere air contributes in a warmer advection, because of the adiabatic heating. That was actually, the 'key' synoptic system for the heat wave phenomenon, during these days, which is a very important element for the heat wave prediction over Greece.

## **INTRODUCTION**

As it is known the heat wave is a meteorological phenomenon that consists from an abnormally hot and usually humid weather. This phenomenon belongs to the atmosphere's synoptic scale circulation.

During the period 18 to 21 in August 1999, over the hinterland of Greece the weather was very hot, a phenomenon that usually is called Heat Wave. This was a front-page title in many Greek newspapers and the Public Authorities had taken preventative measures. According to the international literature there is not a strict definition of the term "Heat Wave". In the Greek literature, Metaxas and Kallos (1980), refer to this term when the following criteria take place:

- a) The maximum temperature in Athens Observatory must be at least 37 °C.
- b) The average daily temperature must be at least 31 °C, at the same station.
- c) The maximum temperature at Larissa station must be at least 38°C on that day.

In USA, the Weather Channel uses the following criteria in order to specify a Heat Wave invasion:

- a) A minimum of ten States with maximum temperatures greater than 32°C and
- b) The temperatures must be at least five degrees above normal in parts of that area for at least two days or more.

In order to study this phenomenon we have used a combination of the above definitions.

The main target of this paper is to give the Synoptic Situation, as well as the Physical processes during this period over the major Greek area.

Only a few scientists, Giles and Balafoutis (1990), Metaxas and Kallos (1980), Prezerakos (1989, 1998), Karakostas and Gavith(1994), Karakostas et al (1996) have been studied this heat wave phenomenon over Greece.

## **DATA AND METHOD USED**

In order to have a detail information about the Synoptic Structure and an Analysis of the atmospheric circulation, we have used a lot of information given by the NOAA Air Resources Laboratory in the web site:

<http://www.arl.noaa.gov/ready/disclaim.html>

More specifically, from this web site the following maps and graphs have been used:

Maps of temperature values at the surface and at the level of 850 hPa, weather maps with wind speed values (Knots) at 200 hPa level, weather maps of wind flags at the levels of 500 and 850 hPa, the w-wind component weather maps at 700 hPa level and the Potential Temperature graphs.

## **SYNOPTIC SITUATION AND ATMOSPHERIC CIRCULATION ANALYSIS**

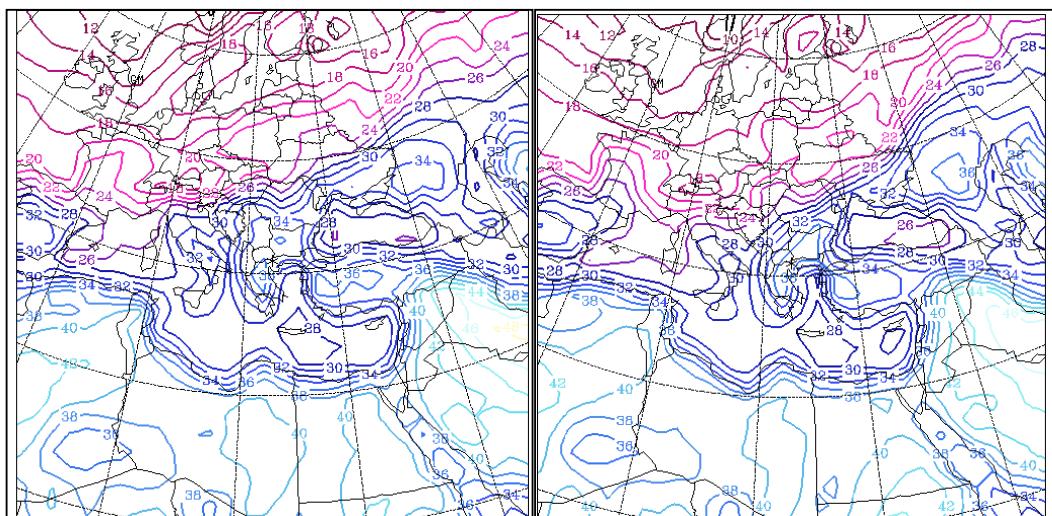
The synoptic experience for the heat waves indicates that the “Key” for their appearance is the position of the Subtropical Jet Stream (STJ) in the upper troposphere.

When the meteorological conditions during the summer over the Mediterranean and especially over the Greek area are normal, the main position of the STJ is observed over the following areas: SW Spain, Sicily, South of the Greek peninsula, Central

Aegean Sea and SW Turkey (Prezerakos, 1978). The axis of the maximum wind speed is located at the 200-hPa level.

The synoptic experience also indicates that: when this STJ moves north of the Greek area, the meteorological conditions in Greece are abnormal and their main characteristic is the very high values of the surface air temperatures. That is the Heat Wave phenomenon. The northern of Greece the STJ is located the more intense is the heat wave strike.

In Figure 1, the geographical distribution of the air temperature, at a level of 2 m above the ground is portrayed. As we can see from these isotherms, during the days of the phenomenon, the temperature values at 12 UTC (15 LT) were more than 32 °C over the whole Greek peninsula and also over Turkish hinterland.

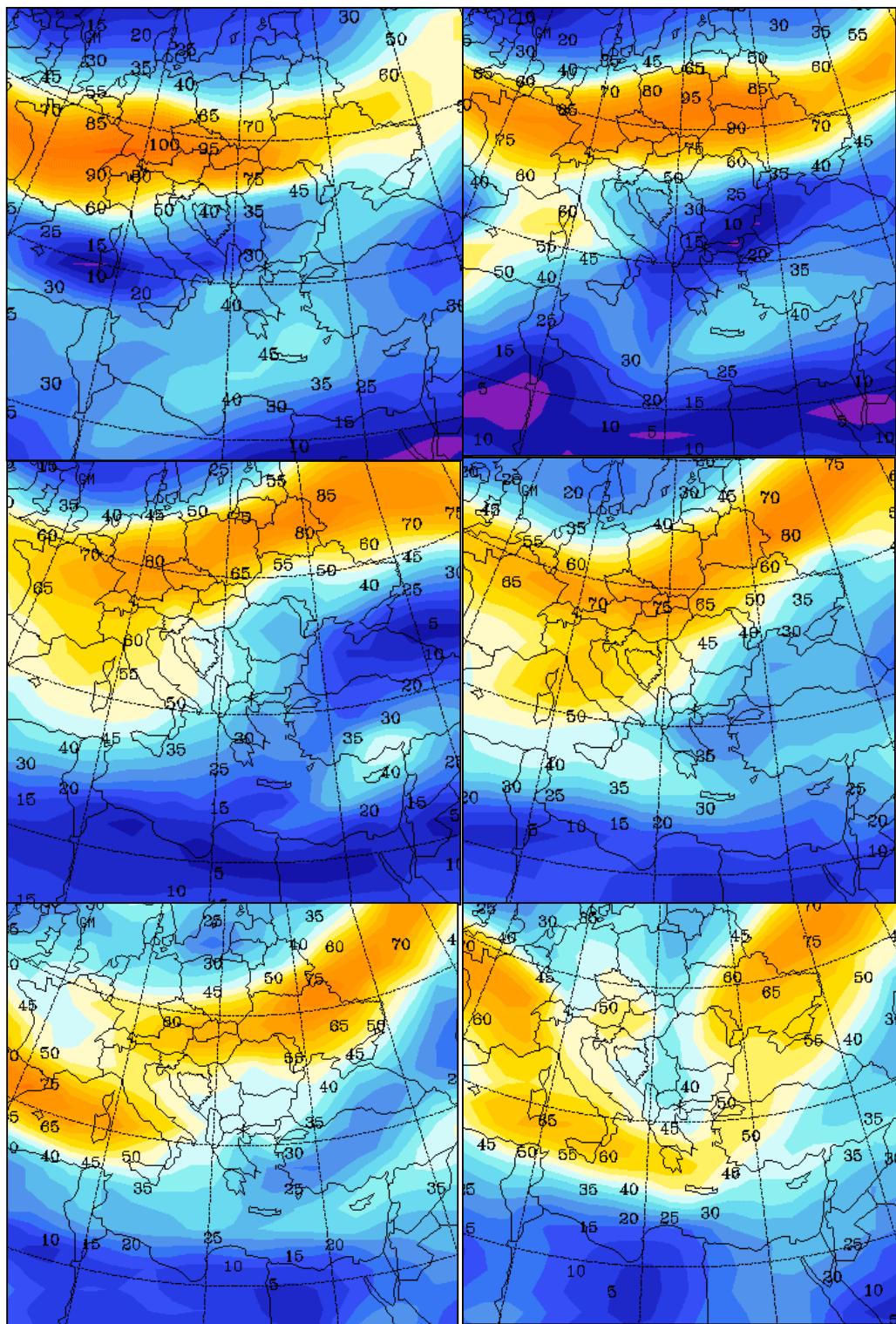


**Fig. 1** Air temperature distribution (at 2 m ) on 20 and 21-08-99 (12 UTC)

Meanwhile, the maxima of air temperatures in the main cities of Greece were:

City\Date	18	19	20	21	22	23
Athens	36.7	37.2	40.8	39.4	39.9	34.6
Larissa	37.4	38.8	39.6	40.6	35.8	36.1
Thessaloniki	34.5	35.4	37.8	36.6	35.5	33.0

According to the above mentioned criteria these days can be characterized as Heat Wave days over the continental area of Greece.



**Fig. 2** The wind speed field and the positions of the Subtropical Jet during the period 18 to 23, August, 1999, at 200 hPa level (from top left to right down).

In Figure 2, the positions of the STJ, during the period 18 to 23 of August 1999 at 00 TC, are portrayed with a maximum wind speed of 100 knots. As we can see, during the main days of the appearance of the phenomenon (18-21 August) the axis of the STJ is actually far northward of the Greek area, but after the end of the phenomenon this axis moves southward and on 23<sup>rd</sup> of August it returns, as far as it concerns the Greek area, in the main position that it usually holds during the summer season and which characterizes normal weather conditions in that area.

Moreover the physical process that takes place under these synoptic conditions is the large-scale subsidence within the tropospheric air down and south of the STJ which leads to the following results:

- a) raise of the air temperature due to the adiabatic compression,
- b) surface horizontal divergence of the vertical flux, and
- c) Increase of the Sea Level Pressure enchanting the anticyclonic circulation and hot weather.

According to the above statements, with such physical processes, the three terms of the right hand side of the thermodynamic equation (Wiin – Nilsen, 1973) bellow,

$$\angle T / \angle t = (1/c_p) \cdot (\overrightarrow{dq/dt}) - (\overrightarrow{V} \cdot \nabla T) o + \overrightarrow{\omega} (\Gamma_d - \Gamma)$$

finally contribute positively, giving a positive value in this equation, i.e.  $\angle T / \angle t > 0$ .

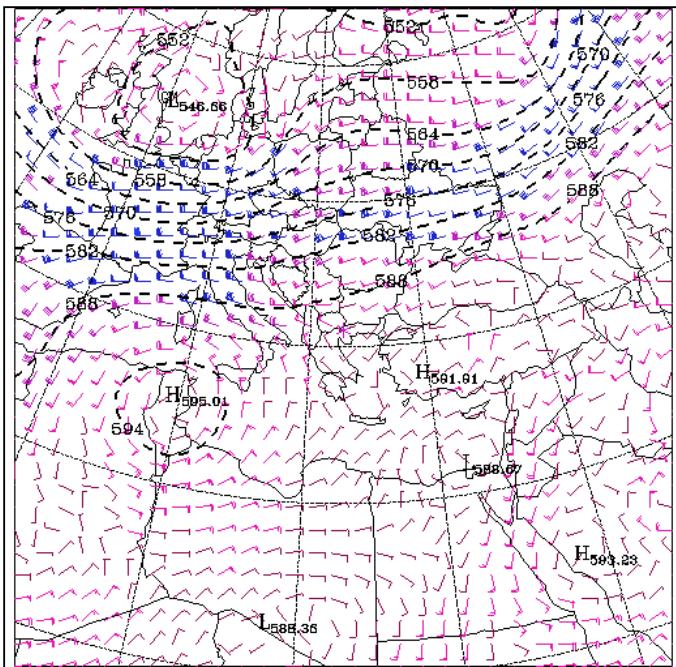
In other words, this procedure of the large scale subsidence in relation to the horizontal movements from South sectors are responsible for the Heat Wave phenomenon.

In this point it is reminded that the STJ commonly is located at the northern edge of the Hadley Cell (Chandler, 1979) where, as it is well known, the large scale subsidence of the air is observed. This subsidence contributes also to the formation of the Subtropical High Pressure Systems.

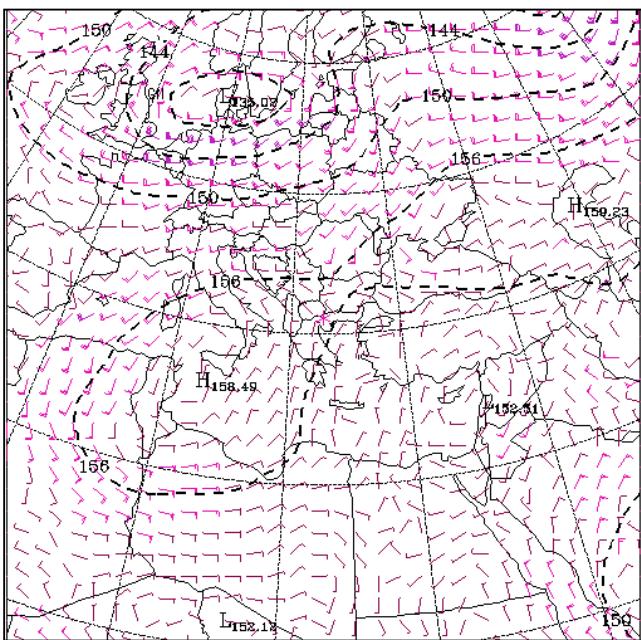
The northwards shift of the STJ contributes to the simultaneous movement of the Hadley Cell to the same direction. This means that the axis of the descending movements in the tropospheric air, is now observed over geographical areas with latitudes 35° - 40° N, instead of the usual position located over the parallel of 30°N.

Analyzing the type of the circulation at 500 hPa level (Figure 3) it is observed that a maximum of heights (5950 g.p.m.), centered over Tunisia, results to a SW flux over the

west Mediterranean, W flux over Italy and NW or N fluxes over the major Greek area. This type of circulation gives an intensive negative advection of relative vorticity in the middle troposphere and warm advection in the lower one over the studied area.

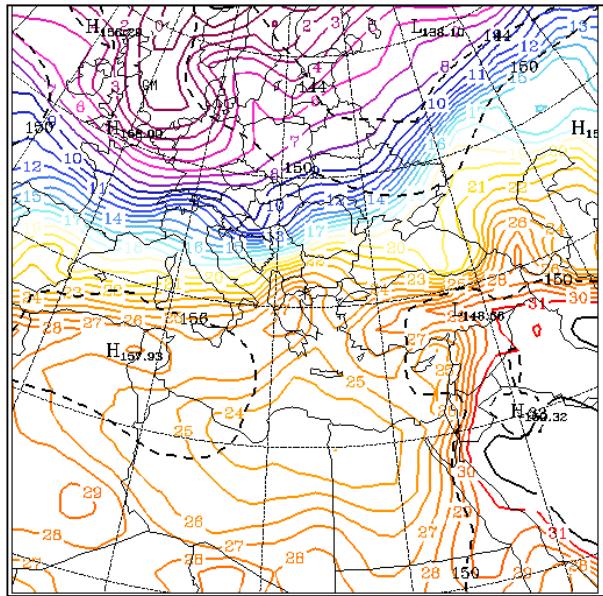


**Fig. 3** The wind flags and height contours at 500 hPa level, on 19-08 -99 (00 UTC)



**Fig. 4** The wind flags and height contours, at 850 hPa level, on 19-08 -99 (12 UTC)

This warm advection has been seen more clearly in the circulation type at 850 hPa level (Figure 4). This anticyclonic flow transfers very warm and very dry air from Sahara, towards the studied area. So the isotherm of 27° C covers the major part of Greece on the 21<sup>st</sup> of August (Figure 5).



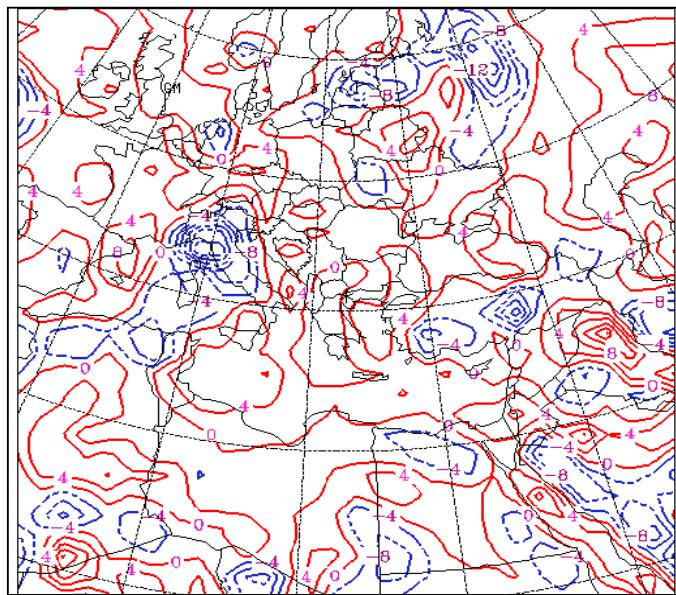
**Fig. 5** The air temperature field, at 850 hPa level, on 21-08-99 (12 UTC)

Meanwhile, large scale downward vertical velocities (maximum value +4 hPa/hr) dominate over central Mediterranean and Balkan peninsula (Figure 6). This subsidence, as was mentioned above, contributes to the observed intensive temperature rise at the surface and the absolute stability in the troposphere. This can be seen from Figure 7, where the Potential Temperature ( $\theta$ ) versus height is plotted. A line sloping to the right ( $d\theta/dz > 0$ ) indicates absolute stability or an inversion (Heffer, 1983).

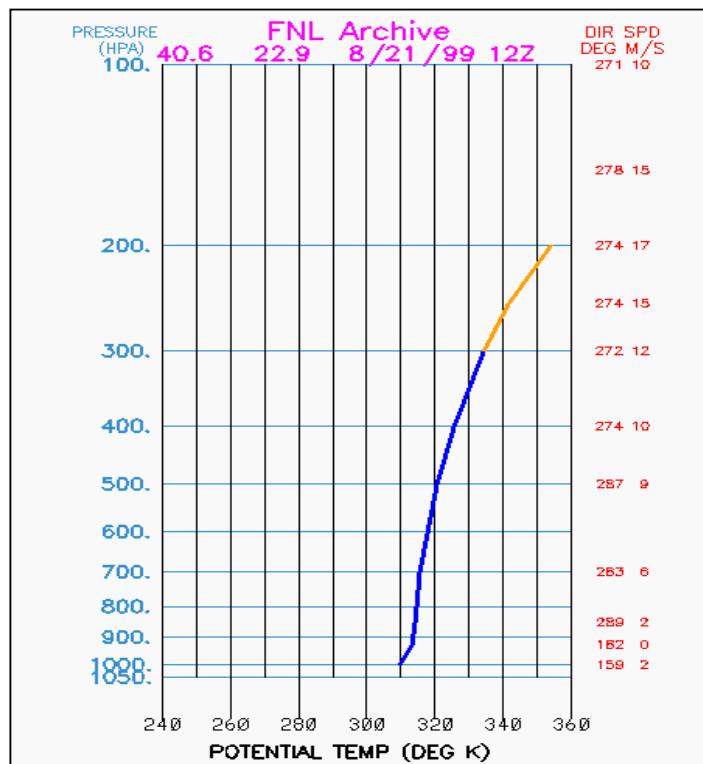
## CONCLUSIONS

The type of circulation in the middle and lower troposphere, described above, and the corresponding physical processes lead to the following results:

The Heat Wave phenomenon, appearing over the major Greek area, during the period 18 - 21 of August 1999, has been created by the following physical processes. The main axis of the STJ (at 200 hPa level) was located far north of Greece, with maximum wind speed



**Fig. 6** Vertical velocities (w), at 700 hPa level, on 20-08-99, in hPa/hr (12 UTC)



**Fig. 7** Graph of the Potential Temperature versus height, on 21-08-99 (12 UTC)

of 100 Knots. It is obvious that this northward shift of the STJ is the “Key” of this special phenomenon, because: It is followed by a simultaneous northward sifting of the Hadley Cell, the upper branch of which is characterized by a broad scale subsidence during these days and is located over areas with a latitude of 35-40° N.

The tropospheric air, above these areas, is warmed up significantly, due to the adiabatic compression. Simultaneously, the circulation type in the middle troposphere ensures a SW flux with negative relative vorticity and warm advection over the studied area.

The synoptic conditions at the surface contribute to the transportation of Tc air masses from Sahara direct to the Greek area. Thus the thermal field over Greece increases significantly, leading finally to the Heat Wave phenomenon.

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## The influence of the weather upon recreation activities

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**Abstract** The day of the week, as well as the weather, have an important influence on the kind and degree of use of an area for recreational purposes. One might expect a higher number of visitors over the weekend and whenever the weather is fine, than on rainy workdays. But the degree of influence of the respective factors, i.e. of the weather and day of the week, and their interaction is unknown. Only knowledge of existing relationships between the numbers of visitors and weather, as well as the weekday, permits a detailed description of recreational attendance levels in a certain area. Such knowledge is essential for an efficient visitor management of protected areas and tourism regions. For one year, video-monitoring was used at several entrance points to the Danube Flood Plains National Park to continuously register visitors. Data related to visitors, such as daily totals of all visitors and daily totals of separate user categories were correlated with meteorological data and the day of the week. The influence of certain meteorological elements, such as air temperature, clouds, precipitation, ..., and thermal comfort indices such as the Physiological Equivalent Temperature (PET), on the use of the National Park for recreational purposes was identified and evaluated with the help of statistical modeling. Reliable models can be obtained for the daily totals of visitors, as well as for specific user groups with high attendance levels (i.e. hikers and bikers). The day of the week has the greatest influence on the number of visitors. The Physiological Equivalent Temperature also plays a substantial role concerning the frequency of visitors per day, in particular for bikers and hikers. The usage patterns of joggers and dog walkers were difficult to model as they show less dependence on weather and week-day related factors. Among other findings, one result of the study is a model for the prognosis of attendance levels and the presence or absence of separate user categories depending on the factors weather and day of the week.

**Keywords:** Recreation • Visitor monitoring • Prognosis of attendance levels • Thermal comfort index

## **Introduction**

The problems caused by leisure activities in protected areas have been a subject of particular interest in recent times. The comprehensive understanding of recreational use is absolutely necessary for the sustainable and effective management of protected areas (Coch et al. 1998, Eagles et al. 1999). If the results of meteorological research are included in the prognosis of the number of visitors and the user categories, these must be subject to the criteria of being suitable for planning and practicable. Climatic or weather data can only be included as a planning factor when both the planner and practitioner are capable of completely understanding and implementing the information provided by these data (Höppe et al. 1987).

Although thermal comfort can be achieved in the research area on most days of the year by adjusting one's clothing and activities accordingly, the weather still has a major influence on leisure and recreational behavior. There has been widespread research into the relationship between recreational activities and the weather (De Freitas 1999, Gibbs 1973, Hunziker 1997, McCalla et al. 1987, McColl et al 1990). The dependence of human well-being on the weather and climate is a well-known phenomenon. In particular the thermic component of the atmospheric effects, which consists of air temperature, wind velocity, humidity and radiation, has the major influence on the behavioural fine-tuning (Auer et al. 1990, Höppe et al. 1997, Jendritzky et al. 1999, Höppe 1999). In order to avoid misinterpretation of the effect of the magnitude of these influences coupling of meteorological parameters is to take into consideration (Jendritzky et al 1979). The individuals perceive weather as a combination of temperature, humidity, cloudiness and wind, sunshine, solar radiation and complex values for human hygro-thermic sensitivity (Hoffmann 1980, Blüthgen 1980, de Freitas 1999, Hammer et al. 1990). Harlfinger (1978) showed, using the subjective evaluation of sultriness, just how greatly the preceding weather character could effect one's subjective wellbeing.

Biometeorological research in connection with thermic comfort has resulted in a considerable increase in knowledge for applied research and the implementation in everyday planning and management. In this connection the Physiologic Equivalent Temperature must be mentioned. This enables the layperson to compare the thermic conditions felt in the open air with his experience gained indoors. (Jendritzky et al. 1979, Höppe 1997, 1999).

Also the threshold of heat stress is measured using the Equivalent Temperature. The Equivalent Temperature is the measure of the total content of tangible and latent heat in the

air. The surrounding air temperature can be evaluated using the Equivalent Temperature threshold value. An additional complex value is the Effective Temperature (Auer et al. 1990, Hammer et al. 1986). It is the temperature that a seated, appropriately dressed person feels in a wind-still, saturated environment. Becker 1972, based on numerous test series, allocated the human sense of temperature to the chill value and classified these values.

## **Materials and methods**

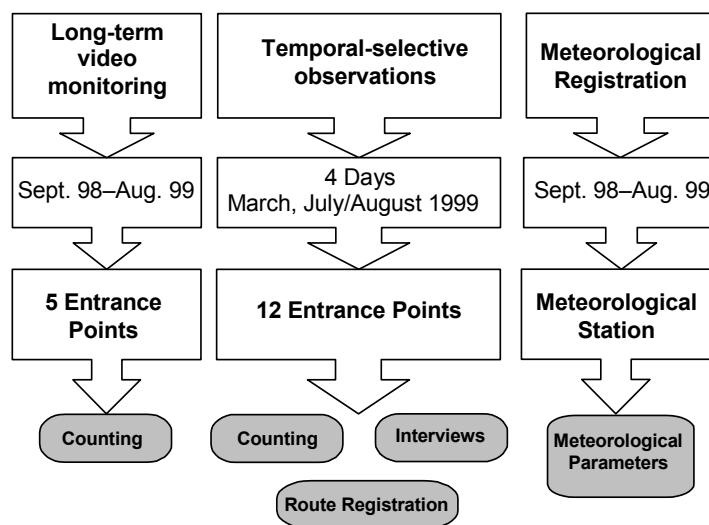
The Danube Floodplains National Park is situated to the east of Vienna, the capital city of Austria, with a population of 1.6 million. A portion of about 2.400 ha of this zone – the research area and so called Lobau - actually lies within the Vienna city boundaries and is a traditional local recreation area. In 1996 the Danube Floodplains were declared a National Park. This resulted in the protection of the floodplains gaining in importance compared to their use as a recreational area, which had been the major focus for many decades. The park management now has the task of fulfilling both the demands posed by intensive daily recreational use and by the need to protect the floodplains' forest ecosystem. In order to deal effectively with the high number of visitors, the park management needs in-depth information on the leisure and recreational usage of the area. Therefore, the Institute for Landscape Architecture and Landscape Management, commissioned by the Viennese City Council, investigated certain components of recreation activities i.e. data on the number and structure of the visitors to the area as well as their spatial and temporal distribution.

Permanent time-lapse video recording systems were installed at five entrance-points to monitor recreational activities (Leatherberry & Lime 1981, Vander Stoep 1986), the whole year round, from dawn to dusk. Data on the recreational use, collected over one year, were available. (The type of video system installed made it impossible to identify individual persons, thus guaranteeing anonymity.) For the analysis of the video tapes only 15 minutes per hour of observations were taken into account. This had no negative impact upon the significance of the results (Brandenburg et al. 1996, Brandenburg 2001, Muhar et al. 1995). The data based on 15-minute evaluations were verified with data of an analysis of a whole hour by using linear regression with a  $R^2$  value of 0.9 (Brandenburg 2001). The daily number of visitors to the Lobau were used for modeling. Days, when there was a loss of data of more than three hours at one of the video stations, were not included in the model. Therefore, 206 complete data sets of daily totals obtained when all cameras operated without failure, were available. A portion of the remaining data sets were used to verify the model. When

analysing the video tapes the following data were registered: date, day of the week, time, videostation, number of persons in a group, direction of movement, user group (bikers, hikers, jogger, ....) and the number of dogs.

In addition, on four days and at 12 entrance points to the park, visitors were counted and interviewed about their motives, activities, duration of visits and needs, etc.. The survey took place on a Thursday and the immediately following Sunday, once in spring and once in summer. To collect as much data as possible the survey was conducted on days with fine weather. The total sample size was 780 interviews.

Meteorological data such as air temperature, precipitation, wind velocity, vapor pressure, relative humidity and cloud coverage and global radiation were provided by a nearby meteorological registration station of the Central Institute of Meteorology and Geodynamics in Vienna (ZAMG). Depending on the meteorological parameters 2 p.m. data, the day mean or categorized factors were used for individual stages of the visitor modeling. In addition, using meteorological parameters thermal comfort indices such as the Equivalent Temperature, the Effective Temperature, the Cooling Factor (Becker 1972) and the Physiological Equivalent Temperature (PET) were calculated by 2 p.m. data of the meteorological elements. The calculation of the Physiological Equivalent Temperature was done by the RayMan Program (Matzarakis et al. 2000).



**Fig. 1** Methods of data gathering

As a tool for studying the interaction between recreational use and external influences the univariate analysis of variance was used. The contribution of each variable factor in explaining the total variation of the dependent variables can be investigated independently. It is also possible to investigate their specific interaction. Using categorized factors with a variance analysis it is possible to depict non-linear connections.

**Table 1** Description of the main input variables

number of the visitors	daily totals
number of the separate user	daily totals
separate user categories	biker, hiker, joggers, dog walkers
day of the week	workday (Monday to Friday), weekend or holiday (Saturday, Sunday, Holiday)
precipitation	occurrence (> 1 mm), non-occurrence (0-1 mm) at main activity time
cloud cover	categorized according to 10 th degrees of cloud coverage (Auer, 1990) bright (< 2/10), fine weather (> 2/10 - 5/10), cloudy (> 5/10 - 8/10), dull weather (> 8/10)
cloud cover of the last seven days	mean of the 10 th degrees of the last seven days
air temperature	days' mean
air temperature of the last seven days	mean of the days' mean of the last seven days
Equivalent Temperature (Teq)	categorized according to Robitzsch-Leistner (Auer et al. 1990) $Teq = Ta + 1,5e$ , Ta = Air Temperature, e = Vapour pressure (hPa) humid (> 56 °C), slightly humid (56 – 49,1 °C), comfortable (49 – 35,1 °C), cool (< 35,1 °C)
Effective Temperature (Teff)	categorized according to Auer et al (1990) $Teff = Ta - 0,4 * (Ta - 10) * (1 - RF/100)$ Ta = Air Temperature, RF = Rel. Humidity humid (> 24 °C), slightly humid (24 – 20,1 °C), comfortable(20 – 16,1 °C), cool (< 16,1 °C)
Chill Factor	calculated and categorized according to Becker (1972) $A = (0,26 + 0,34 * v 0,622) * (36,5 - Ta)$ mcal/cm <sup>2</sup> *s, v = Wind Velocity, Ta = Air Temperature hot-sultry-uncomfortable (0 - 4), warm-comfortable (5 - 9), mild-pleasant (10 - 19), cool (20 - 29), cold – slightly uncomfortable (30 - 39), moderately – very uncomfortable (40 - 49), unpleasantly – extremely cold (50 - 59), unbearably cold (60 - 70)
Physiologic Equivalent Temperature	categorized according the Ashrae scale very cold (< 4 °C), cold (4 – 8 °C), cool (> 8 – 13 °C), coolish (> 13 – 18 °C), comfortable (>18 – 23 °C), mild (>23 – 29 °C), warm (>29 – 35 °C), hot (>35 – 41 °C), very hot (> 41°C)

## **Results**

In order to better understand the visitor structure and, therefore, to interpret the results accordingly, a short overview of the recreational use of the study area is given.

More than 90 percent of the visitors interviewed came from Vienna and more than 60 percent of the interviewees visited the Lobau at least once a week and stayed for up to two hours. The Lobau can therefore be called the "Green Living Room" of a large number of the visitors (Arnberger et al. 2001). The Lobau is visited by about 600,000 people per year. The main visiting period is between March and October, highest frequencies could be observed in May and on Sunday afternoons, when all categories of visitors can be found in the Lobau. The main year-round users of the Lobau are bikers with 58 % and hikers with 37 %. The main visiting period for bikers is the summer, for hikers it is spring. Joggers can be mainly observed between March and September. Considering the average number of visits per week for the whole year covered by the survey, a considerable increase in the number of visitors over the weekend can be observed; the highest number of visitors was registered on Sundays and public holidays. On workdays, the number of visitors is fairly even, independent of the user categories.

In the first modeling experiments for predicting the attendance levels using the variable day of the week and only meteorological parameters such as cloud cover, cloud cover over the last seven days, precipitation during the day, wind velocity during the day, the day's mean air temperature and air temperature over the last seven days, no satisfactory results were obtained, particularly in interactive areas.

In the final model for the daily visitor totals - without any distinction between the various user groups such as bikers, hikers etc. - the differentiation between workday and weekend, the PET value according to the Ashare scale, occurrence or non-occurrence of precipitation at the principle activity times as well as the type of cloud cover, were all included. Even though cloudiness is used in the calculation of PET, it is also necessary as a main effect for explaining visitor numbers. This can be substantiated by the theory that, among other factors, the brightness of the sky is decisive for a person's psychological feeling.

It is necessary to develop an individual model, using partially different parameters, for each user group. This can be based on the greatly differing demands of these individual groups.

Reliable models can be obtained for the total number of visitors per day as well as for specific, large user groups (i.e. hikers and bikers).

**Table 2** Explanatory value of the total number of visitors per day and the user categories

Extent of interference	Total number of visitors	Bikers	Hikers	Joggers	Dog Walkers
Workday, weekend and holiday	high	high	high	small	moderate
Precipitation	moderate	moderate	small	existent	existent
PET	high	high	moderate		existent
Cloud Cover	moderate	moderate	small		small
Interaction between weekday and PET	moderate		small		existent
Cloud coverage of the last 7 days			very small	existent	existent
Air Temperature of the last 7 days		moderate	very small		
Value of model	adj. R <sup>2</sup> =.834	adj. R <sup>2</sup> =.844	adj. R <sup>2</sup> =.744	adj. R <sup>2</sup> =.291	adj. R <sup>2</sup> =.440

To summarize, it can be said that the day of the week has the greatest influence on the number of visitors. The Physiological Equivalent Temperature (PET) also has a major impact on the number of visitors per day, in particular on cyclists and walkers. Precipitation and cloud cover have a moderate influence on the number of visitors. The current modeling experiments show that the weather over the previous 7 days does not play an important role on the number of visitors. But it is assumed that, among other things, the weather of the previous days has an effect on very high attendance levels.

To evaluate the model, data records, not included in the model creation, were used to test these models. The control of the correlation between the observed daily totals and the predicted totals - using a linear regression - results in a determinacy of almost 90% for the model of the daily totals of all visitors.

## Discussion

The availability of the discussed data on visitor monitoring permits a statistical evaluation on the correlation between the total daily number of visitors, as well as for specific user categories, and the day of the week, meteorological parameters and comfort indices. The fact that it is difficult to predict the daily number of visitors of a specific category, such as joggers, is partially due to the fact that different decision-making patterns are decisive in the considerations of whether to jog or not.

Another problem arises from the size of the sampling. One specific group - swimmers - was not dealt with in this article because the sample size was too small to be used in an analysis using the univariate analysis of variance. In order to model low-frequency user groups it is necessary to incorporate sophisticated statistical methods such as regression trees (Ploner et al., submitted). Another possibility would be to increase the sample size by carrying out the survey over an extended period of time.

The demonstrative power of the model for days with peak loads, which means very high attendance levels, is not yet satisfactory. Particular emphasis must, however, be placed on these days because they are of importance for the supervision of the park and its ecological system management.

Along with other aspects, the weather reports influence the behavior of visitors planning a brief vacation. Tourism experts repeatedly reported that guests failed to appear as soon as bad weather was forecast. This was also true in those cases where the actual weather situation completely varied from the forecast. Weather forecasts play a less important role in the leisure activities of those people living in the proximity of the recreational area. The importance of the weather forecast on those travelling more than one hour in order to reach the area will be of major significance (Ammer et al. 1991). It must also be assumed that certain users react more strongly to these reports than others. Therefore the weather prognoses are absolutely necessary when estimating the number of visitors.

Relevant, practice oriented and reproducible data is required to enable leisure and recreational planning. This data must: be easily interpretable, permit simple further digital processing; be principally quantitative and result from continuous and simple data collection. This applies to the archiving of the current weather data, data from weather forecasts and visitor data.

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# **Assessment of recreational potential of bioclimate based on the human heat balance**

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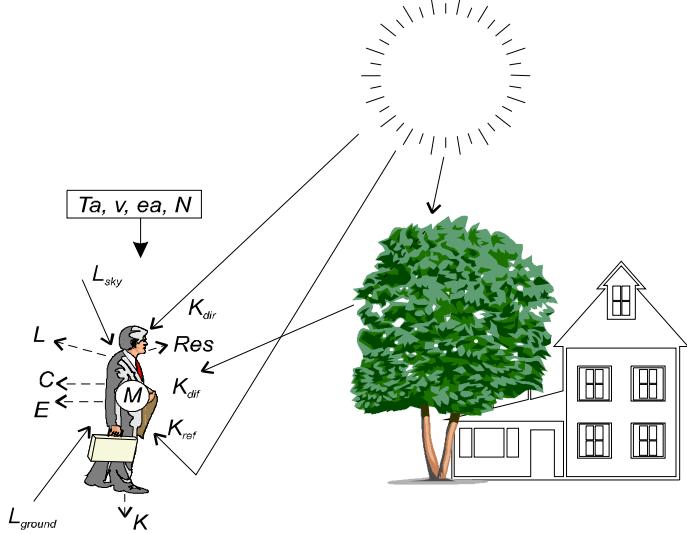
**Abstract:** Recreation outdoors strongly depends on actual weather conditions. To assess recreational potential of bioclimate new weather classification was used. It bases on the human heat balance. Bio-thermal features of weather as well as physiological response in man are the base to characterise the weather types. It also includes information dealing with daily precipitation, snow cover, daily amplitude of air temperature and sultriness. The classification was used for day-by-day analysis of weather as well as for evaluation of seasonal and regional differentiation of bioclimate.

**Key words:** Recreation, Bioclimate, Human heat balance, Weather classification

## **1. Introduction**

Recreation is a way of spending leisure time, i.e. it is any particular activity which is done for amusement and enjoyment. Many forms of recreational activity are related to the outdoor climate. Actual weather conditions are one of the main factors that limit recreational activity outdoors. They influence the form of recreation, its duration as well as its effectiveness. In assessment of bioclimatic recreational potential not only precipitation and others meteorological phenomena (e.g. fogs, storms etc.) are very important but also thermal conditions (intensity of warm/cold stress, daily amplitude) (de Freitas 1985, 1990, Matzarakis, Mayer 1994).

Most of existing methods of weather evaluation for recreation based on simple thermal characteristics (e.g. maximal and minimal temperature, its amplitude and temporal changes) as well as on simple biometeorological or climatic indices, e.g. Wind Chill Index, Equivalent and Effective Temperature - (Kozlowska-Szczesna et al. 1997, Lee 1980, Maarouf, Bitzos 2001), Tourism Climatic Index (Mieczkowski 1985). To assess thermal conditions we should consider not only physical parameters of the air but also physiological response of the human organism (Beaumont, Bullard 1965, Blanc 1975, Blazejczyk. 1997, 1998, 1999, Blazejczyk et al. 1999, Fanger 1970, de Freitas 1990, Mitchell 1977). Its intensity and heat state of man depend on the full complex of atmospheric stimuli: temperature, humidity, solar and thermal radiation, air movement, cloudiness (Fig. 1).



**Fig. 1** Man in a complex thermal environment

$T_a$  - air temperature,  $ea$  - vapour pressure,  $N$  - cloudiness,  $v$  - wind speed,

Solar radiation:  $K_{glob}$  - global,  $K_{dir}$  - direct,  $K_{dif}$  - diffuse,  $K_{ref}$  - reflected, Thermal radiation:  $L_{ground}$  - ground,  $L_{sky}$  - sky,

Heat fluxes:  $M$  - metabolism,

$C$  - convection,  $E$  - evaporation,

$L$  - long-wave radiation,

$Res$  - respiration,  $K$  - conduction

Complex of meteorological elements influences both, particular fluxes of man-environment heat exchange and also physiological parameters: skin temperature, metabolism, peripheral blood flow etc. (Blanc 1975, Blazejczyk 1997, 1999, Clark, Edholm 1985, Mitchell 1977, Nielsen et al. 1988, Yoshimura, Morimoto 1974). The resultant value of man-environment heat exchange at actual weather conditions is net heat storage (Fig. 2).

There are two principal considerations of climate-recreation relationships. The first one bases on the analysis of separated meteorological elements or simple biometeorological indices. The second one try to evaluate full complex of weather from the point of view of recreation. The aim of the paper is to present new weather classification for recreation based on the human heat balance outdoors and some examples of its applications in climate-recreation research at the Polish health resorts.

## 2. Method

### 2.1. Principles of the human heat balance

Various models estimated human heat balance indoors exist (Bligh, Johnson 1973, Fanger 1970, Holmér 1988, ISO/DIS 7933, ISO/DC 11079, Parsons 1993). However for outdoor conditions only few models can assess physiologically significant components of man-environment heat exchange: Brown, Gillespie (1986), Budyko's model (Budyko, Cicenko 1960), HEBIDEX and STEBIDEX (de Freitas 1985, 1990), Klima-Michel-Model (Jendritzky 1990), MEMI (Höppe 1984), MENEX (Blazejczyk 1994), Nielsen et al. (1988).

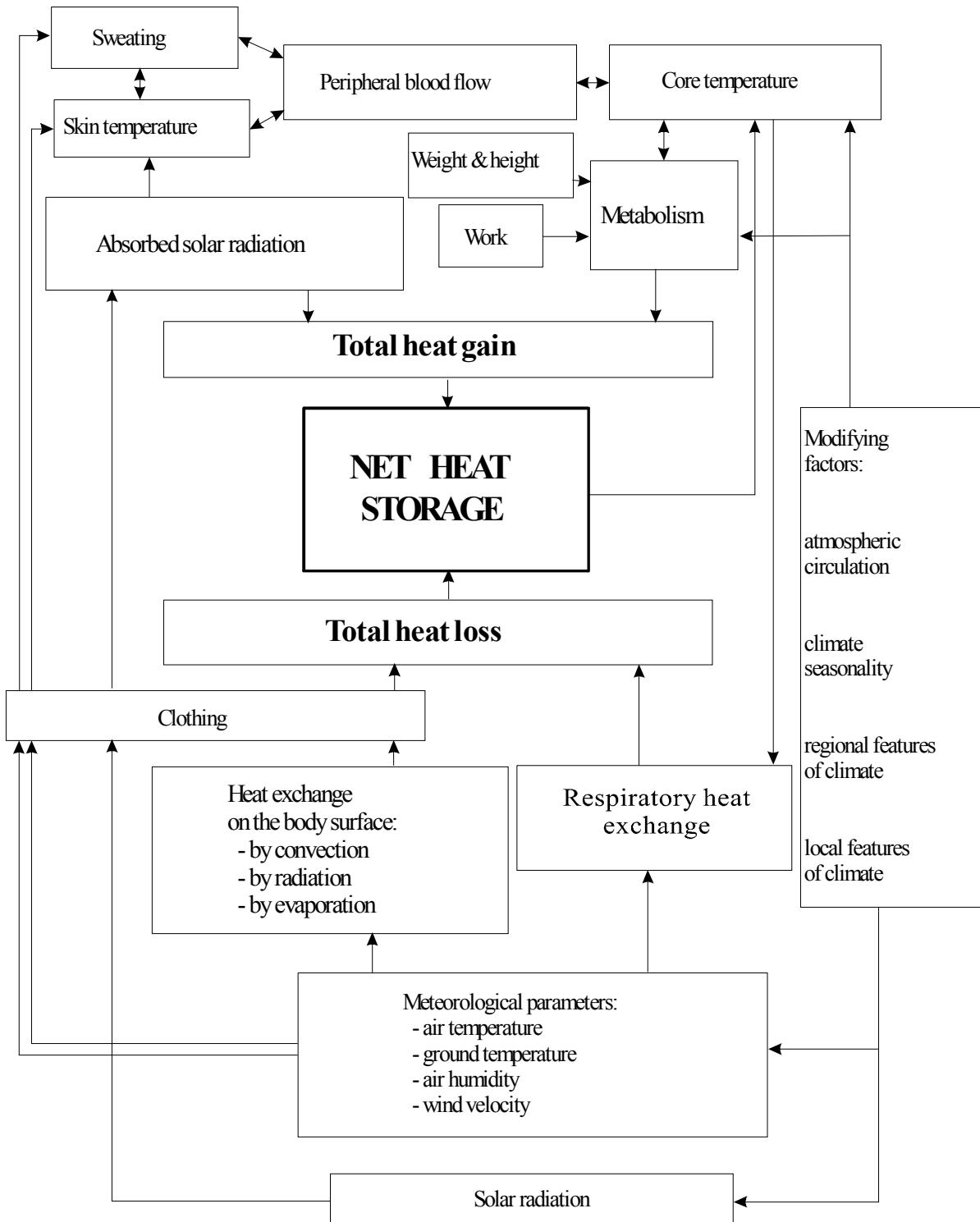


Fig. 2. Relationships between physiological and meteorological parameters considered in man-environment heat exchange model MENEX (Blazejczyk 1994).

According to the MENEX model the general equation of the human heat balance has the following form:

$$M + R + E + C + L + Res = S \quad (1)$$

where:  $M$  is metabolic heat production ( $\text{W m}^{-2}$ ),

$R$  – solar radiation absorbed by man ( $\text{W m}^{-2}$ ),  
 $E$  – evaporative heat loss ( $\text{W m}^{-2}$ ),  
 $C$  – heat exchange by convection ( $\text{W m}^{-2}$ ),  
 $L$  – heat exchange by long wave radiation ( $\text{W m}^{-2}$ ),  
 $Res$  – respiratory heat loss ( $\text{W m}^{-2}$ ),  
 $S$  – net heat storage, i.e. changes in body heat content ( $\text{W m}^{-2}$ ).

The  $S$  is resultant value of heat exchange between man and his surrounding. For long periods (24 hours or longer)  $S$  can be considered as equal to zero, i.e. heat gains are equilibrated by heat losses. However, in particular moments the  $S$  has positive or negative values. Positive  $S$  value points out the accumulation of heat in the body. However at negative values of net heat storage the cooling of body core occurs.

Metabolic heat is produced in the internal cell processes and by the work of mussels. It depends on human activity, body posture, age, sex, weight and height as well as on thermal conditions and climatic seasonality (Schofield 1985, Yoshimura, Morimoto 1974).  $M$  volume is assessed according to ISO 8996.

Evaporative heat loss depends on the difference in vapour pressure in the atmospheric air and at the skin surface. Some physical and physiological coefficients are taken into account as well:

$$E = \{he (e_a - e_{sk}) w Ie - [0.42 (M - 58) - 5.04]\} sex \quad (2)$$

where:  $e_a$  – air vapour pressure (hPa),

$e_{sk}$  – vapour pressure at the skin surface (hPa),

$he$  – coefficient of evaporative heat transfer ( $\text{W m}^{-2} \text{ hPa}^{-1}$ ),

$w$  – skin wetness coefficient (dimensionless),

$Ie$  – reduction coefficient of heat transfer through clothing (for evaporation) (dimensionless),

$sex$  – coefficient depended on sex (1.0 – for man, 0.8 for woman) (dimensionless).

Vapour pressure at the skin surface and the wetedness coefficient are the functions of skin temperature ( $T_{sk}$  in  $^{\circ}\text{C}$ ):

$$e_{sk} = \text{EXP}(0.058T_{sk} + 2.003) \quad (2.1.)$$

$$w = 1.031/(37.5 - T_{sk}) - 0.065 \quad (2.2.)$$

(at  $T_{sk} > 36.5^{\circ}\text{C}$   $w = 1.0$ )

Another coefficients are calculated as follows:

$$he = [Ta (0.00006Ta - 0.00002ap + 0.011) + 0.02ap - 0.773] \text{ SQRT}(v + v') \quad (2.3.)$$

where:  $Ta$  – air temperature ( $^{\circ}\text{C}$ ),

$ap$  – air pressure (hPa),

$v$  – wind speed ( $\text{m s}^{-1}$ ),

$v'$  – velocity of man ( $\text{m s}^{-1}$ ).

$$Ie = hc' / (hc' + hc) \quad (2.4.)$$

where:  $hc$  – coefficient of convective heat transfer ( $\text{W m}^{-2} \text{ K}^{-1}$ )

$hc'$  – coefficient of conductive heat transfer through clothing ( $\text{W m}^{-2} \text{ K}^{-1}$ ),

$$hc = (0.013ap - 0.04Ta - 0.503) \text{ SQRT}(v + v') \quad (2.5.)$$

$$hc' = (0.013ap - 0.04Ta - 0.503) 0.53 / \{Icl [1 - 0.27(v + v')^{0.4}]\} \quad (2.6.)$$

where:  $Icl$  – clothing insulation (clo)

Convective heat loss depends on temperature difference between the air and the skin surface as well as on heat transfer coefficients:

$$C = hc (Ta - Tsk) Irc, \quad (3)$$

where:  $hc$  is the same as (2.5.),

$Irc$  – reduction coefficient of heat transfer through clothing (for convection and radiation) (dimensionless).

$$Irc = hc' / (hc' + hc + 4s\sigma T^3) \quad (3.1.)$$

where:  $hc'$  – is the same as (2.6.),

$s$  – emissivity coefficient (=0.95),

$\sigma$  - Stefan-Boltzman constant ( $=5.67 \cdot 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ ),

$T$  – air temperature (K)

Heat loss by long-wave radiation is an effect of heat transfer by thermal radiation which occurs - according to the Stefan-Boltzman law - between any surfaces with the temperature  $>0 \text{ K}$ . Its resultant value depends on the temperature differences between the skin, the air and the ground as well as on emissivity coefficient:

$$L = [2s\sigma T^3 (Tg - Ta) - 0.5s\sigma T^4 (0.254 - 0.005e_a) (1 - 0.01cN) + 4s\sigma T^3 (Ta - Tsk)] Irc \quad (4)$$

where:  $Tg$  – ground temperature ( $^{\circ}\text{C}$ ),

$Irc$  – the same as (3.1.),

$N$  – cloudiness (%),

$c$  – coefficient depended on clouds type: 0.2 for  $Ci$ ,  $Cc$ , 0.3 for  $Cs$ , 0.4 for  $Ac$ ,  $As$ , 0.5 for  $Cu$ , 0.6 for  $Cb$ , 0.7 for  $Sc$ ,  $St$ , 0.8 for  $Ns$

Respiratory heat loss consists of two components: convective and evaporative heat loss. The first one depends on temperature differences between the atmosphere and exhaled air (assumed as 35°C). The second component depends on difference between air vapour pressure and vapour pressure of exhaled air (assumed as 56,2 hPa).

$$Res = 0.0014 M (Ta - 35) + 0.00173 M (e_a - 56.2) \quad (5)$$

Skin temperature can be taken from direct measurements, assumed as a constant value or estimated according to the empirical equations derived from experimental research. They regard the relationship between skin temperature and various meteorological elements (Blazejczyk 1994):

$$Tsk = (0.004K_{glob} + 0.09Ta + 0.08e_a - 0.1v + 26.4) + [(Icl - 1) 0.6] + 0.00128M \quad (6.1)$$

or

$$Tsk = [0.29Ta + 0.001f - 0.08v + 26.0] + [(Icl - 1) 0.6] + 0.00128M \quad (6.2)$$

or

$$Tsk = [0.29Ta + 0.001f + 1.12 (1 - 0.01N) - 0.08v + 26.03] + [(Icl - 1) 0.6] + 0.00128M \quad (6.3.)$$

Absorbed solar radiation can be calculated with the use of the one of the following models: **SolDir**, **SolGlob** or **SolAlt**. The models were derived from the experimental research carried out both, on the mannequin and on the human subjects (Blazejczyk 1998, 2000 b).

**SolDir** model may be used when we have in our disposal data of all solar radiation fluxes (direct –  $K_{dir}$ , diffuse –  $K_{dif}$  and reflected –  $K_{ref}$ ). Depending on Sun altitude absorbed solar radiation is calculated as follows:

- for  $h \leq 5^\circ$

$$R = 1.4 [K_{dir} \text{EXP}(-0.51 + 0.368h) + (K_{dif} + K_{ref}) (0.0013 + 0.033 \text{LN } h)] (1 - 0.01a_c) Irc \quad (7.1.)$$

- for  $h > 5^\circ$

$$R = 1.4 [K_{dir} (18.816/h - 0.235) + (K_{dif} + K_{ref}) (0.0013 + 0.033 \text{LN } h)] (1 - 0.01a_c) Irc \quad (7.2.)$$

where:  $a_c$  – albedo of skin and/or clothing (%),

$h$  – Sun altitude (degree),

$Irc$  – the same as (3.1.).

When we have only data of global radiation ( $K_{glob}$ ) then absorbed solar radiation can be calculated using **SolGlob** model as follows:

- for  $h \leq 10^\circ$ ,

$$R = 1.4 K_{glob} (0.546 - 0.224 \ln h) (1 - 0.01a_c) Irc \quad (8.1.)$$

- for  $h > 10^\circ$  and  $N = 0\text{-}20\%$

$$R = 1.4 K_{glob} (2.764 h^{-0.694}) (1 - 0.01a_c) Irc \quad (8.2.)$$

- for  $h > 10^\circ$  and  $N = 21\text{-}90\%$

$$R = 1.4 K_{glob} (0.04 + 5.166/h) (1 - 0.01a_c) Irc \quad (8.3.)$$

- for  $h > 10^\circ$  and  $N > 90\%$

$$R = 1.4 K_{glob} (0.0013 + 0.033 \ln h) (1 - 0.01a_c) Irc \quad (8.4.)$$

- for  $h > 10^\circ$ ,  $N = 21\text{-}90\%$  at the shaded place

$$R = 1.4 K_{glob} \exp(-1.86 - 12.702/h) (1 - 0.01a_c) Irc \quad (8.5.)$$

Very often we did not have in our disposal any data of solar radiation. In this case we can estimate (with an error up to 20%) absorbed solar radiation using **SolAlt** model:

- for  $h \leq 4^\circ$

$$R = 1.4 (1.388 + 0.215h)^2 (1 - 0.01a_c) Irc \quad (9.1.)$$

- for  $h > 4^\circ$  and  $N = 0\text{-}20\%$

$$R = 1.4 (-100.428 + 73.981 \ln h) (1 - 0.01a_c) Irc \quad (9.2.)$$

- for  $h > 4^\circ$  and  $N = 21\text{-}50\%$

$$R = 1.4 \exp(5.383 - 16.072/h) (1 - 0.01a_c) Irc \quad (9.3.)$$

- for  $h > 4^\circ$  and  $N = 51\text{-}80\%$

$$R = 1.4 \exp(5.012 - 11.805/h) (1 - 0.01a_c) Irc \quad (9.4.)$$

- for  $h > 4^\circ$  and  $N > 80\%$  or for  $h > 4^\circ$  and  $N = 21\text{-}80\%$  (at the shaded places)

$$R = 1.4 0.679h^{1.039} (1 - 0.01a_c) Irc \quad (9.5.)$$

Heat load of an organism both, warm and cold stress, is evaluated as a combination of the three principal heat fluxes: net heat storage ( $S$ ), absorbed solar radiation ( $R$ ) and evaporative heat loss ( $E$ ). Heat Load index ( $HL$ ) is calculated as follows:

- for  $S \leq 0 \text{ W m}^{-2}$  and  $E \geq -50 \text{ W m}^{-2}$

$$HL = [(S+360)/360]^{[2-1/(1+R)]} \quad (10.1.)$$

- for  $S > 0 \text{ W m}^{-2}$  and  $E \geq -50 \text{ W m}^{-2}$

$$HL = [(S+360)/360]^{[2+1/(1+R)]} \quad (10.2.)$$

- for  $S \leq 0 \text{ W m}^{-2}$  and  $E \leq -50 \text{ W m}^{-2}$

$$HL = (E/-50) [(S+360)/360]^{[2-1/(1+R)]} \quad (10.3.)$$

- for  $S > 0 \text{ W m}^{-2}$  and  $E \leq -50 \text{ W m}^{-2}$

$$HL = (E/-50) [(S+360)/360]^{[2+1/(1+R)]} \quad (10.4.)$$

All the calculations can be very easy made with the use of BioKlima<sup>©</sup> v. 1.61 software package (Blazejczyk K, Blazejczyk M 1997). The software may be downloaded from:  
[www.igipz.pan.pl/klimat/blaz/bioklima.htm](http://www.igipz.pan.pl/klimat/blaz/bioklima.htm)

## 2.2. Principles of thermophysiological weather classification

According to C R de Freitas (personal communication) climate evaluation should consists of three elements: aesthetic (e.g. Sun, clouds, visibility, day length), physical (e.g. rain, wind, snow, UV, pollution), thermal (common effect of climate and physiology). Actual weather is one of the basic demand indicators of recreational potential of any time, season and/or region. The weather classification presented in this paper includes most of the components considered by de Freitas.

### 2.2.1. Weather types

Recreational activity should bring the people rest, joy and amusement. When recreation is going outdoors the heat state of an organism must be considered as a main indicator of enjoyment. Thus the weather type should give the people information about actual bio-thermal conditions (Blazejczyk 2000 b). They depend both, on meteorological conditions and on physiological parameters of an organism (Tab. 1). Description of weather consists of three elements: heat load (HL), intensity of radiation stimuli (R') and physiological strain in man (PS).

The first element of digital description tells about heat load in man which occurs at actual weather and actual man's activity as follows:

$HL \leq 0.810$	- great cold stress,
$0.811 - 0.930$	- moderate cold stress,
$0.931 - 1.185$	- thermoneutral,
$1.186 - 1.600$	- moderate warm stress,
$> 1.600$	- great warm stress.

The next meteorological factor influencing humans outdoor is solar radiation (Blazejczyk 1997, 1998, Blazejczyk et al. 1993, Brown, Gillespie, 1986, Nielsen et al. 1988). Thus the second digit in the classification brings the message regarded the intensity of solar radiation

stimuli. In this purpose the value of solar radiation absorbed by nude man (according to one of the 7.1. - 9.5. formulas, without  $I_{rc}$  coefficient) was applied as follows:

- |                                 |            |
|---------------------------------|------------|
| $R' \leq 60.0 \text{ W m}^{-2}$ | - weak,    |
| $60.1 - 120.0 \text{ W m}^{-2}$ | - average, |
| $> 120.0 \text{ W m}^{-2}$      | - great.   |

The third element of description deals with physiological strain (PS) of an organism. It is define by the main way of heat elimination from the body as follows:

- $C$  - heat loss by convection = cold strain,  
 $E$  - heat loss by evaporation = warm strain.

Cold physiological strain is manifested by (Blanc 1975, Clark, Edholm 1985, Holmér 1988, ISO/DC 11079):

- decrease in skin temperature,
- reduction of peripheral blood flow,
- increase in blood pressure,
- increase in thermal insulation of skin tissue,
- shivering.

Warm physiological strain leads to (Kenney 1985, Clark, Edholm 1985, Mitchell 1977):

- increase in peripheral blood flow,
- decrease in blood pressure,
- increase in heart rate (Blazejczyk et al. 1999),
- intensive sweating (Beaumont, Bullard 1965)
- dehydration,
- temporal changes in skin temperature, from very high during warming the skin to low, during sweating phase Blazejczyk 1997, 1998, Malchaire 1991)

Finally, 30 weather types can be distinguished. They represent various combinations of heat load, intensity of solar stimuli and physiological strain of an organism during recreation.

## 2.2.2. Weather classes

As was mentioned some general features of weather influence the possibility of recreation outdoors. There are: daily precipitation, daily amplitude of air temperature, snow cover and sultriness.

**Table 1** Thermophysiological weather types

Heat load	Intensity of solar radiation stimuli		
	weak (1)	average (2)	great (3)
great cold stress (-2)	<b>C</b>	<b>C</b>	<b>C</b>
moderate cold stress (-1)	<b>E</b>	<b>E</b>	<b>E</b>
Thermoneutral (0)	<b>C</b>	<b>C</b>	<b>C</b>
moderate warm stress (1)	<b>C</b>	<b>C</b>	<b>C</b>
great warm stress (2)	<b>E</b>	<b>E</b>	<b>E</b>

Physiological strain: **C** – cold, **E** – warm

Recreation can be strongly limited by precipitation. The great importance has the duration of rain- or snow-falls during the daytime hours. However, this information are not commonly putted into meteorological data bases. Hence, daily totals of precipitation (RR) were applied in classification (at  $RR \geq 1$  mm the day was assumed as rainy).

Daily amplitude of air temperature ( $dt = t_{max} - t_{min}$ ) illustrates the range of temperature fluctuations which gains importance while recreation lasts for many hours a day. Two classes of daily changes in air temperature were assessed: at  $dt \leq 8$  deg weather was assessed as neutral and at  $dt > 8$  deg - as stimulative.

Snow cover (SC) is very important for winter recreation. It can be effectively used when its depth is  $\geq 10$  cm, i.e. a snowy day.

At summer recreation sultriness intensity (SI) limits its active forms at several groups of people (Steadman 1979). To assess sultriness intensity Heat Stress Index (*HSI*) of Belding and Hatch (1955) was adapted. 3 classes of weather were distinguished: no-sultry (at  $HSI < 40$ ), moderate sultriness (at  $HSI$  of 40-70) and great sultriness (at  $HSI > 70$ ). Finally, 20 classes of weather can be defined (tab. 2).

**Table 2** Weather classes

Daily precipitation	Daily amplitude of air temperature			
	0-8 deg		> 8 deg	
	(0) neutral		(1) stimulative	
< 1 mm <b>(0) non rainy</b>	0 1	0 1 2	0 1	0 1 2
≥ 1 mm <b>(1) rainy</b>	0 1	0 1 2	0 1	0 1 2

Snow cover: 0 – non snowy, 1 – snowy

Sultriness intensity: 0 – no-sultry, 1 – moderate sultriness, 2 – great sultriness

Digital description of the thermophysiological weather types and classes can be applied. Every digit contains information dealing with the considered weather characteristics as follows:

Heat load	Solar radiation	Physiological strain	Daily precipitation	Air temperature amplitude	Snow cover	Sultriness intensity
1	2	3	4	5	6	7
-2						
-1	1	E	0	0	0	0
0	2	C	1	1	1	1
1	3					2
2						

First three digits bring information regarded weather type. First one tells about the intensity of heat load in man, the second – about the intensity of radiation stimuli, the third – about main way of heat elimination. Other digits, in lower case, get message dealing with: the fourth – daily precipitation, the fifth – daily amplitude of air temperature, the sixth – the occurrence of snow cover, the seventh – the sultriness intensity. If information about any weather component is not available its place in digital pattern must be filled by x.

For example the record 12E0102 means the weather: with moderate warm stress, average radiation stimuli and with warm physiological strain. There is no precipitation but stimulative temperature amplitude; with no snow cover but with great sultriness observed.

### 3. Results



**Fig. 3** Location of selected recreation resorts

The calculations of the human heat balance were made using BioKlima<sup>©</sup> v. 1.61 software package for walking man (metabolism of  $135 \text{ W m}^{-2}$ ), wearing clothing with insulation of 1 clo in the warm half-year (May-October) and 2 clo in the cold half-year (November-April).

#### 3.1. Weather evaluation at particular days

Weather evaluation at particular days for the needs of recreation is an essential application of the human heat balance analysis. Tables 3 and 4 present day by day digital description of weather conditions in Krynica. Two months were chosen: January and July 1990. We can see that in January 1990 almost every day great cold stress occurs; only in the last decade thermoneutral weather was registered. Radiation stimuli were weak or average. Thermal conditions of the ambient air led to cold physiological strain. There were some days with precipitation. Only on few days stimulative amplitudes of air temperature were noted. Snow cover was observed in the first and in the third decades.

In July 1990 weather conditions were very differentiated. Days with great warm stress predominated, however days with moderate warm stress occurred as well. Radiation stimuli were great or average. Most days warm physiological strain was observed. 11 rainy days and 23 days with stimulative temperature amplitudes were noted. Only on 7 days no-sultry weather occurred and on 12 days great sultriness was observed.

Day by day weather analysis for the period of 1971-1990 was made for three Polish health resorts and recreational centres: Kolobrzeg – situated in the central part of the Polish shore of the Baltic Sea, Polanica – located in the south-west part of Poland, in Sudety Mts. and Krynica – in south-east Poland, in Beskydy Mts. (Fig. 3).

Similar analysis can be made in the weather forecasts. Information about predicted bio-thermal conditions may be very useful in planning of recreation activity outdoors to eliminate the risk of organism overcooling or overheating.

**Table 3** Weather conditions in Krynica,  
January 1990

day	HL	R'	PS	RR	dt	SC	SI
1	-2	1	C	0	0	1	0
2	-2	1	C	0	0	1	0
3	-2	1	C	0	0	1	0
4	-2	2	C	0	0	1	0
5	-2	2	C	0	0	1	0
6	-2	2	C	0	0	1	0
7	-2	2	C	0	1	1	0
8	-2	2	C	1	0	1	0
9	-2	1	C	0	0	1	0
10	-2	1	C	0	0	0	0
11	-2	2	C	0	0	0	0
12	-2	1	C	0	0	0	0
13	-2	1	C	0	0	0	0
14	-2	1	C	0	0	0	0
15	-2	1	C	1	0	0	0
16	-2	1	C	0	0	0	0
17	-2	1	C	0	0	0	0
18	-1	2	C	0	0	0	0
19	-2	1	C	1	0	0	0
20	-2	1	C	0	0	0	0
21	-2	1	C	1	0	1	0
22	-2	1	C	1	0	1	0
23	-2	1	C	0	0	1	0
24	-2	1	C	0	0	1	0
25	-1	2	C	0	1	1	0
26	-2	1	C	0	0	1	0
27	0	2	C	0	0	1	0
28	-2	1	C	0	0	1	0
29	-2	1	C	1	0	1	0
30	0	3	C	0	1	1	0
31	0	3	C	0	1	1	0

**Table 4** Weather conditions in Krynica,  
July 1990

day	HL	R'	PS	RR	dt	SC	SI
1	2	3	E	1	1	0	2
2	2	2	E	1	1	0	1
3	2	2	E	1	0	0	1
4	2	2	E	1	1	0	2
5	2	3	E	0	0	0	2
6	0	2	C	1	0	0	1
7	1	2	C	0	0	0	0
8	2	3	E	0	1	0	2
9	1	2	E	1	1	0	0
10	1	2	C	1	0	0	1
11	1	3	C	0	0	0	0
12	2	3	E	0	1	0	0
13	2	3	E	1	1	0	2
14	1	2	C	0	1	0	1
15	2	3	E	0	1	0	2
16	2	3	E	0	1	0	2
17	2	3	E	1	1	0	2
18	2	3	E	1	0	0	1
19	2	3	C	0	0	0	0
20	2	3	E	0	1	0	2
21	2	3	E	0	1	0	2
22	2	3	E	0	1	0	1
23	2	3	E	0	1	0	1
24	2	3	E	0	1	0	1
25	2	3	C	1	1	0	0
26	2	3	E	0	1	0	0
27	2	3	E	0	1	0	1
28	2	3	E	0	1	0	1
29	2	3	E	0	1	0	1
30	2	3	E	0	1	0	2
31	2	3	E	0	1	0	2

### 3.2. Seasonal differentiation of bioclimate

We can use day-by-day weather evaluation for the seasonal analysis of recreational potential of bioclimate. In this purpose we should calculate the frequency of particular weather types and classes. Figure 4 gives an example of the annual course of the frequency of

some weather types and classes in Krynica. Ten weather situations the most frequently observed in this resort were chosen.

In general in Krynica the most frequent is the weather with great cold stress, weak radiation stimuli and cold physiological strain (about 18% of days: 9% rainy – -21C<sub>1000</sub> – and 9% non rainy days – -21C<sub>0000</sub>). It is observed mainly in the cold half-year with culmination in December (25% and 24%, respectively). About 11% of days have the weather with great warm stress, great radiation stimuli and warm physiological strain. At 4% of days stimulative daily temperature amplitudes occurred also (23E<sub>0100</sub>) and at 7% of days great sultriness was noted as well (23E<sub>0102</sub>). The maximal frequency of sultry weather is observed in August (22%). The thermoneutral weather (13C<sub>0100</sub>) as well as the moderate warm stress weather (03C<sub>0100</sub>) with stimulative temperature amplitudes are noted in the Spring (March-April) and in the Autumn (October). During the Summer there are not observed.

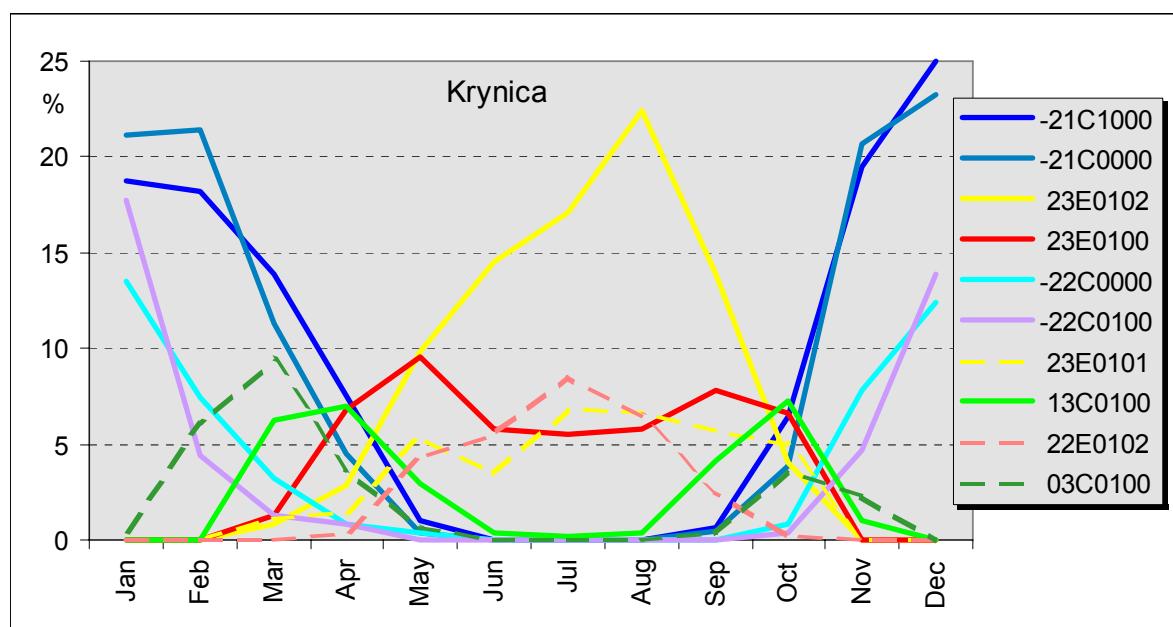


Fig. 4 Annual course of the frequencies of some weather types in Krynica, 1971-1990.

### 3.3. Spatial variability of bioclimate

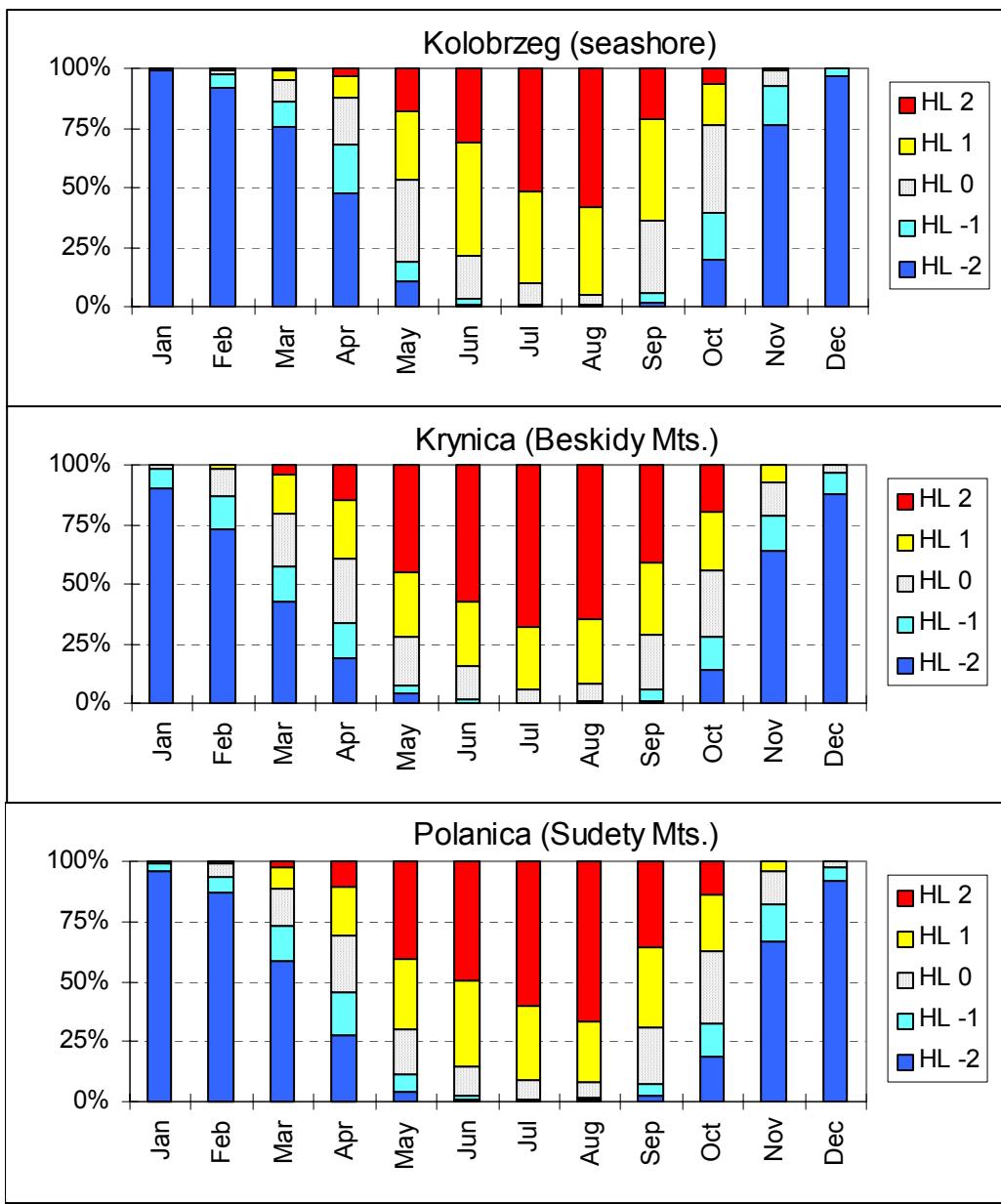
The territory of Poland is about 312,000 km<sup>2</sup>. The maximal difference in the longitude is 10° and in the latitude - about 6°. Geographical environment of Poland is relatively differentiated. The landscapes varies from the seashore up to alpine. The Polish recreational resorts are located in every region. However, most of them are situated at the seashore, in the mountains as well as in the lakeland regions.

When analysing weather types frequency some patterns were found. The most sensitive for the regional climate variability are the following weather components: heat load in man, daily amplitudes of air temperature, snow cover and intensity of sultriness.

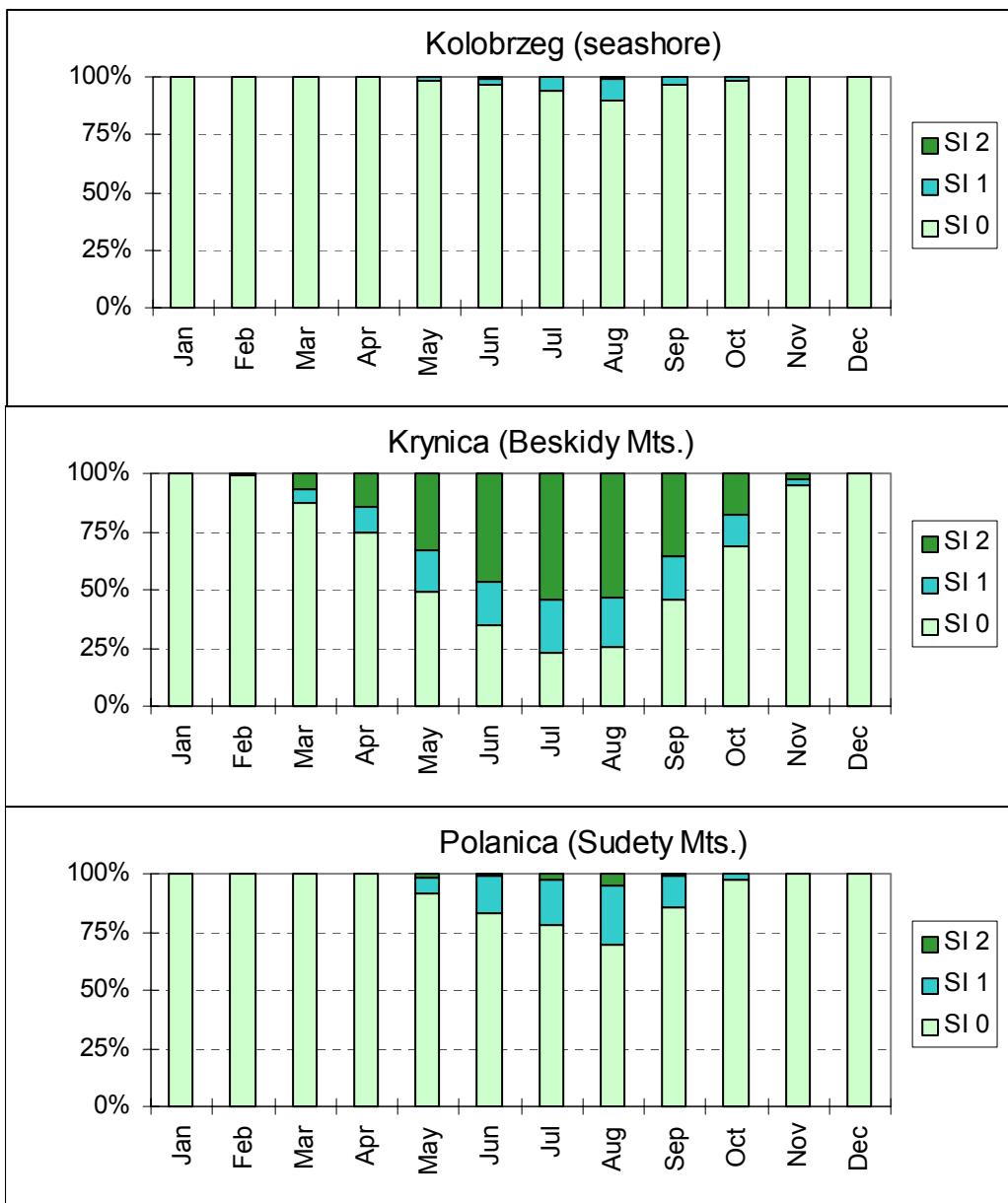
Comparing HL patterns in selected stations we can note significant differences in the frequency of heat load extremes. At the seashore (Kolobrzeg) in the period of November-March great cold stress weather predominates. At the same time in the mountain relatively often is thermoneutral weather. Some differences are also observed between Sudety and Beskid Mts. In Beskid (Krynica) the frequency of thermoneutral and moderate warm stress weather is greater than in Sudety (Polanica). In the summer, the most unpleasant weather (the great warm stress) is very frequent in Krynica (Beskid Mts.), and relatively rare - in Kolobrzeg (seashore) (Fig. 5).

The regional differences in weather conditions are very well seen when comparing frequency of sultry conditions. In the seashore resort (Kolobrzeg) sultry weather appears only during few summer days. In Sudety Mts. (Polanica) sultry conditions are observed relatively often, up to 27% of days in August. Great intensity of sultriness appears very seldom. However, in Beskid Mts. (Krynica), sultry weather appears from March up to November. In the Summer its frequency is 70-75%. The great intensity sultriness can be found every second day (Fig. 6).

The annual patterns of snowy weather and stimulative temperature amplitude weather are differentiated between seashore and mountains resorts. These weather components are considerably less frequent in Kolobrzeg than in Polanica and Krynica. There are no significant differences in SC and  $dt$  annual patterns between west (Sudety) and east (Beskid) mountain regions.



**Fig. 5** Frequency of weather with different heat load



**Fig. 6** Frequency of weather with various sultriness intensities

## Discussion

Recreation very strongly depends on actual weather conditions. The weather classification based on the human heat balance seems to be an useful tool in research of climate-recreation relationships.

Day-by-day weather analysis gives detail information regarded actual outdoor conditions. It can be very useful for planning of recreational activity, its intensity and duration. The examples given in the paper shows great risk of cold stress in relation to insufficient radiation stimuli and to intensive body cooling by convection, leading to cold strain, in January 1990 in Krynica. On the other hand in July 1990 the warm stress, sultry

weather occurred; it resulted in considerable evaporative heat loss and great warm strain of an organism. We can of course to consider not only archival data. Very important is also the possibility to predict thermophysiological strain in man based on traditional weather forecasts.

Bioclimatic characteristics of weather, i.e. the frequency of various weather types and classes, can be used in the studies dealing both, with seasonal and regional differentiation of bioclimatic conditions, from the point of view of recreation. The temporal analysis points to specific features of weather that can be found in particular seasons. They give the possibility for recreation planners and for decision makers to propose to the public the most adequate and safety forms of recreation for particular seasons. In Krynica, the most favourable weather conditions occur in the Spring and in the Autumn. Summer weather is too warm and too sultry.

Similar analysis of weather frequency in the spatial perspective points out the regions or resorts with the most favourable bioclimatic conditions. Taking into consideration three selected station it seems that Polanica has better bioclimatic characteristics then Krynica and Kolobrzeg.

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## **Assessing the vulnerability of the alpine skiing industry in Lakelands Tourism Region of Ontario, Canada to climate variability and change**

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### **Abstract**

The vulnerability of the alpine ski industry to climate variability and projected climate change is assessed in the Lakeland Tourism Region of south-central Ontario, Canada. A 17-year record of daily ski conditions at five ski areas was used to examine sensitivity to climate variability and the impact of snowmaking as a climate adaptation. Historical ski data were also used to calibrate a model to simulate the length of ski season under climate change scenarios (2020s, 2050s, 2080s) from the CGCM1 and HadCM3 general circulation models (GCMs). The LARS weather generator was parameterized to local climate stations and used to temporally downscale climate variables from the GCMs for input into a daily snow cover simulation model. A snowmaking module was developed using decision rules and capacities from the study area and integrated with the snow cover model. Analysis was also undertaken with improved snowmaking capacities, in order to account for the potential of further technological advances. The increased development of snowmaking throughout the 1980s and 1990s was found to have reduced the vulnerability of the ski industry. Under climate change scenarios and current snowmaking technology, the average ski season at the five ski areas was reduced by 8-30% in the 2020s, 16-52% in the 2050s and 30-66% in the 2080s. Concurrent with the ski season losses, the estimated amount of snowmaking required doubled at most locations by the 2050s. With improved snowmaking technology and additional snowmaking, ski season losses could be reduced to 3-17% in the 2020s, 10-32% in the 2050s and 22-49% in the 2080s. The climate change analysis

revealed the differential vulnerability of the five ski areas, how snowmaking costs are expected to increase at each location, and the relative benefits of improved snowmaking. The ability of individual ski areas to absorb additional snowmaking costs and remain economically viable remains an important avenue of further research.

Key Words Climate Change, Winter Tourism, Skiing

## **Introduction**

Weather and climate have a strong influence on the tourism and recreation sector (Paul 1972, Perry 1997), including the physical resources that are the foundation of many recreation activities (e.g., water levels for boating and snow cover for skiing) and the length and quality of tourism and recreation seasons. Nonetheless, Smith (1993:389) indicated that, “There have been comparatively few investigations into the relationships between climate and tourism. ... meteorologists and leisure specialists rarely communicate with each other.” Consequently, the vulnerability of individual recreation industries and the tourism sector to climate variability has not been adequately assessed. Despite the growing significance of the tourism industry to the global economy (World Tourism Organization 1998), Wall (1992) and Smith (1990) expressed concern that current understanding of the potentially profound impacts of global climate change on this sector remained equally limited.

The winter tourism industry in particular has been repeatedly identified as potentially vulnerable to climate change (ACACIA 2000, IPCC 2001, Agnew and Viner 2001) and has received greater research attention. Climate change impact assessments of ski areas in a number of nations (Australia – Galloway 1988, Konig 1998; Austria – Breiling et al. 1997; Canada – McBoyle and Wall 1992; Scotland – Harrison et al. 1999; Switzerland – Konig and Abegg 1997) all project negative consequences for the industry. One limitation of these studies has been the incomplete consideration of snowmaking as a climate adaptation strategy. Snowmaking is an integral component of the ski industry (Konig 1998, Scott et al. 2002) and must be incorporated into climate change impact assessments.

The objectives of this study are (1) to assess the current climate sensitivity and adaptation of the ski industry in the Lakelands Tourism Region of Ontario, Canada, and (2) to develop and apply a research methodology capable of integrating both current and improved snowmaking capabilities into a climate change impact assessment of the industry (2020s, 2050s, and 2080s).

## **Material and Methods**

### Study Area

The Lakelands Tourism Region in south-central Ontario, Canada was selected as the case study because of the importance of the tourism sector to the local economy (the direct and indirect economic contribution of tourism was CDN\$814 million and over 26,000 full-time equivalent jobs in 1999), its importance as a key recreation destination for Canada's largest urban centre (the Greater Toronto Area) and the concentration of winter recreation infrastructure. Southern Ontario is home to 30% of Canada's active alpine skiers (Canadian Ski Council 2000) and the ski areas in the region function as a nursery for the more challenging vacation ski resorts of North America and beyond (McBoyle and Wall, 1992). The estimated economic impact of the ski industry in the study area ranges from CDN\$62 to \$93 million (Scott et al. 2002) and in part represents what is at risk to climate change.

### Data

The analysis focused on five ski areas in the study area (Table 1). Data on the daily ski conditions (including whether the ski area was in operation, snow depth, snow conditions, ski runs open, and snow making activities) for the winters of 1981-82 to 1999-2000 was provided by the Ontario Ministry of Tourism, Culture and Recreation. The selection of climate stations for this study was based on two considerations, the proximity to ski areas and the length of record and data quality at individual climate stations. Table 1 identifies the climate stations used in this study and the nearby ski areas they represent. Daily temperature (maximum, minimum and

**Table 1** Ski areas and corresponding climate stations in the study area

Ski Area	Skiable Hectares	Number of Runs	Nearest Climate Station	Lat	Long	Elevation (masl)	T & P Record	Snow Depth Record
Hidden Valley	18	11	Huntsville	45.2°	79.13°	286	1961-99	1961-96
Sir Sam's	16	12	Haliburton	45°	78.35°	320	1965-92	1961-92
Horseshoe	25	22	Orillia	44.37°	79.25°	220	1961-99	1961-96
Blue Mountain	102	34	Collingwood-Owen Sound	44.29°	80.13°	221	1961-99	1961-96
Talisman	202	18	Chatsworth	44.24°	80.54°	305	1961-99	1961-96

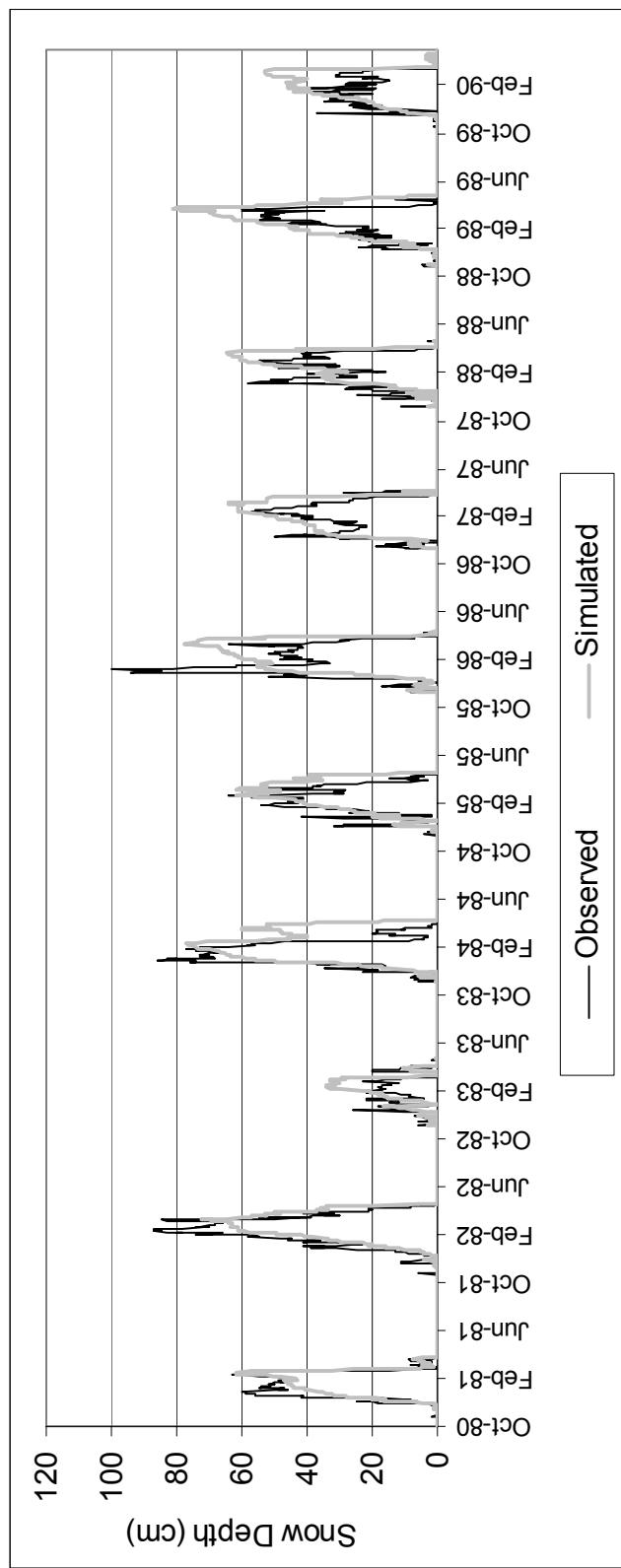
mean), precipitation (rain and snowfall) and snow depth data were obtained from the Meteorological Service of Canada. In all cases, a complete record for 1961 to 1996 (the last year the rehabilitated snow depth data set was available) was developed. The climate change scenarios used in this analysis were obtained from the Canadian Climate Impact Scenarios (CCIS) project. The scenarios provided by CCIS have been constructed using recognised methodologies and in accordance with the recommendations of the Intergovernmental Panel on Climate Change's (IPCC) Task Group on Scenarios for Climate Impact Assessment. The scenarios are derived from thirty-year means (2010-2039 corresponding to the 2020s scenario, 2040-2069 to the 2050s scenario and 2070-2099 to the 2080s scenario), and represent change with respect to the 1961-1990 modelled baseline period. Data from six modelling centres were obtained for the area 43-46°N by 79-82°W (including between 4 and 6 GCM grid boxes). The CGCM1 scenario from the Canadian Centre for Climate Modelling and Analysis and the HadCM3 scenario from the United Kingdom's Hadley Centre were selected for this analysis, as they represented close to the upper and lower bounds of climate change scenario for the study area (Scott et al. 2002). The IS92a greenhouse gas plus aerosol ensemble scenarios (gax) were used in each case.

## Methods

The climate data set at each of the five locations consisted of five variables (maximum, minimum and mean daily temperature, precipitation, and snow depth) and was constructed in several stages. Temperature and precipitation data for the baseline period (1961-90) were compiled from climate station data. To produce daily temperature and precipitation data for each of the climate change time series (2010-2039, 2040-2069 and 2070-2099), monthly climate change scenarios from CGCM1 and HadCM3 were temporally downscaled using the LARS stochastic weather generator (Semenov et al. 1998), parameterized to each of the five local climate stations. Temperature and precipitation variables were used to drive a locally calibrated snow cover model that was based largely on methods used to develop the *Canadian Daily Snow Depth Database* (Brown et al. 1999) and *Water Balance Tabulations for Canadian Climate Stations* (Johnstone and Louie 1983). The validity of the approach was tested using observed data from the 1980-90 period at two primary climate stations in the area (Muskoka and Wiarton). The performance of the snow cover model versus observed snow depth at the Muskoka station is presented in Figure 1. To complete the climate data set, a snowmaking module was appended to the snow cover model. The estimated technical capacities and decision rules for the snowmaking module were derived from communications with ski industry stakeholders in the study area and are summarized in Table 2. Anticipating technological improvements in snowmaking systems, the study also parameterized a snowmaking module with improved capacities (Table 2).

**Table 2** Snowmaking module technical capacities and decision rules

	Current Snowmaking Technology	Improved Snowmaking Technology
<b>Technical Capacity</b>		
▪ minimum temperature for efficient snowmaking	-5°C	-2°C
▪ snowmaking capacity / day over entire skiable terrain of ski area	10cm	15cm
<b>Snowmaking Decision Rules</b>		
▪ snowmaking window	Nov. 23-March 30	Nov. 23-March 30
▪ snow base depth to maintain	50cm	50cm



**Figure 1** Observed and simulated snow depth at Muskoka climate station 1980-1990. The Muskoka climate station is used for illustrative purposes because it is one of Environment Canada's primary climate stations and it is centrally located within the study area.

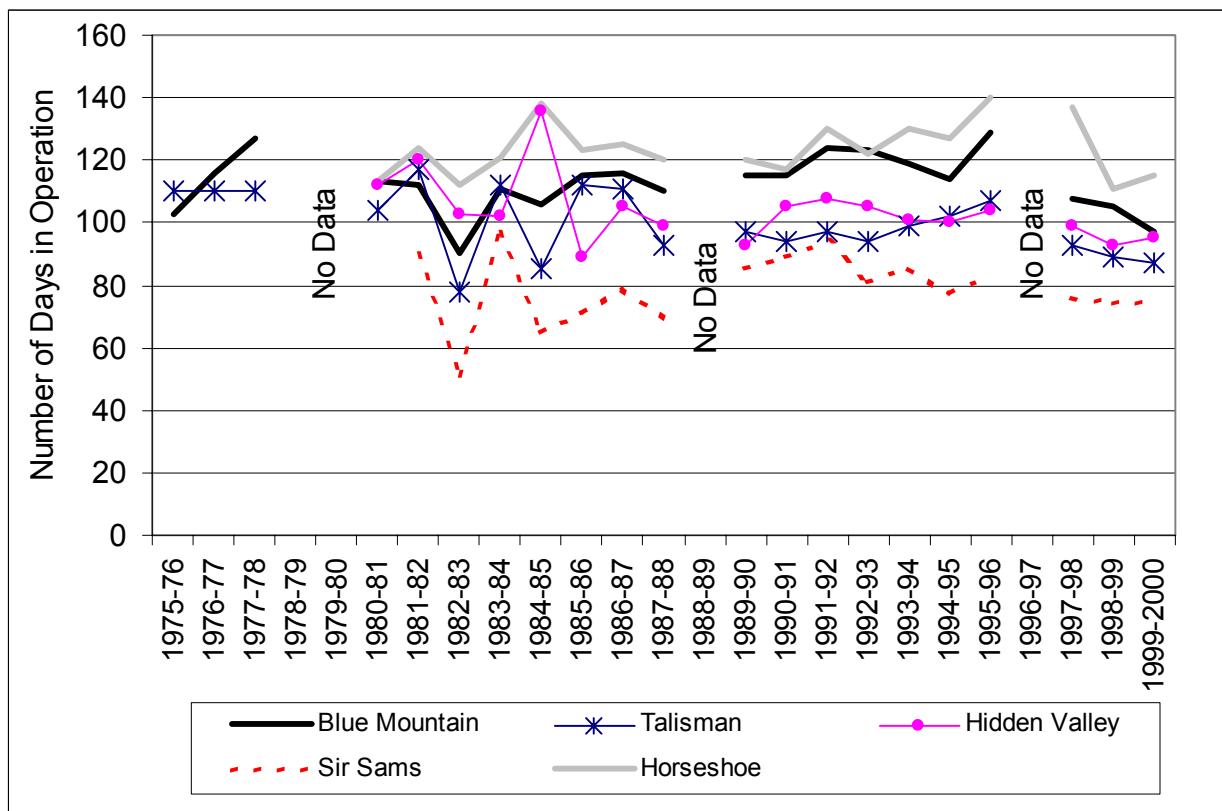
A number of climatological thresholds that define a ‘skiable day’ were identified in a literature review (Crowe et al. 1973, Period and Lamothe 1988). After comparing the thresholds against observed ski conditions and ski area operational activity in the study area, it was determined that these thresholds were unsatisfactory for simulating ski seasons in the study area (Scott et al. 2002). In some cases, snow depth thresholds were unrealistic and dismissed (e.g., 2.5cm in Crowe et al. 1973). The thresholds for minimum and maximum temperature and precipitation were also exceeded frequently in the observed data. This is in part explained by the different decision making of skiers (demand) and ski area management (supply). The former may chose not to ski when it is very cold or during poor snow conditions, but the latter must open to generate business revenue and accommodate those willing to accept sub-optimal conditions. The climate thresholds used to parameterize the ski season simulation model in this analysis were refined through examination of the observed ski operations data and communications with ski industry stakeholders. For the purposes of this study, ski areas were assumed to be closed if any of the following conditions occurred: snow depth < 30cm, maximum temperature  $> 10^{\circ}\text{C}$  for two consecutive days while accompanied by liquid precipitation, or when two-day liquid precipitation  $> 20 \text{ mm}$ . A comparison of the observed and simulated ski seasons at Horseshoe ski area revealed that over the 17-years that observed data were available, the average season length was 124 days and 123 days respectively (minimum seasons were 111 and 100 days and maximum seasons 140 and 152 days). Overall the ski season simulation performed reasonably, missing the observed season length by more than seven days (approximately 5% of an average season) in only 5 of 17 years.

## Results

### Current Climate Sensitivity and Adaptation

Figure 2 displays the observed ski season length at the five ski areas within the study area from 1975 to 2000. Horseshoe consistently had the longest ski season averaging 124 days. Sir Sam’s ski area had the shortest ski season with an average of only 79 days. This is in spite of having several attributes that provide it with a longer potential ski season (located further north, higher elevation, lower average humidity, and north facing ski slopes). The difference in the average

ski season at these two ski areas is related to their respective business models. Horseshoe is located within a one-hour drive of Toronto, and situated along a multi-lane expressway. As a result, Horseshoe resort is able to attract skiers from Toronto who wish to ski for the day and return home in the evening (day trips). Keeping the ski area operational for as long as possible is the business strategy that best allows the Horseshoe resort to capture this demand. In contrast, Sir Sam's ski area is approximately a three-hour drive from Toronto. The greater distance and more variable travelling conditions mean that 'day trips' for skiing are not practical at Sir Sam's ski area. Sir Sam's therefore serves skiers who stay in the area, usually during weekends and holiday periods. During the winter season, Sir Sam's will close in mid-week, even though ski conditions may be perfect, because the number of skiers is insufficient to offset operating costs.



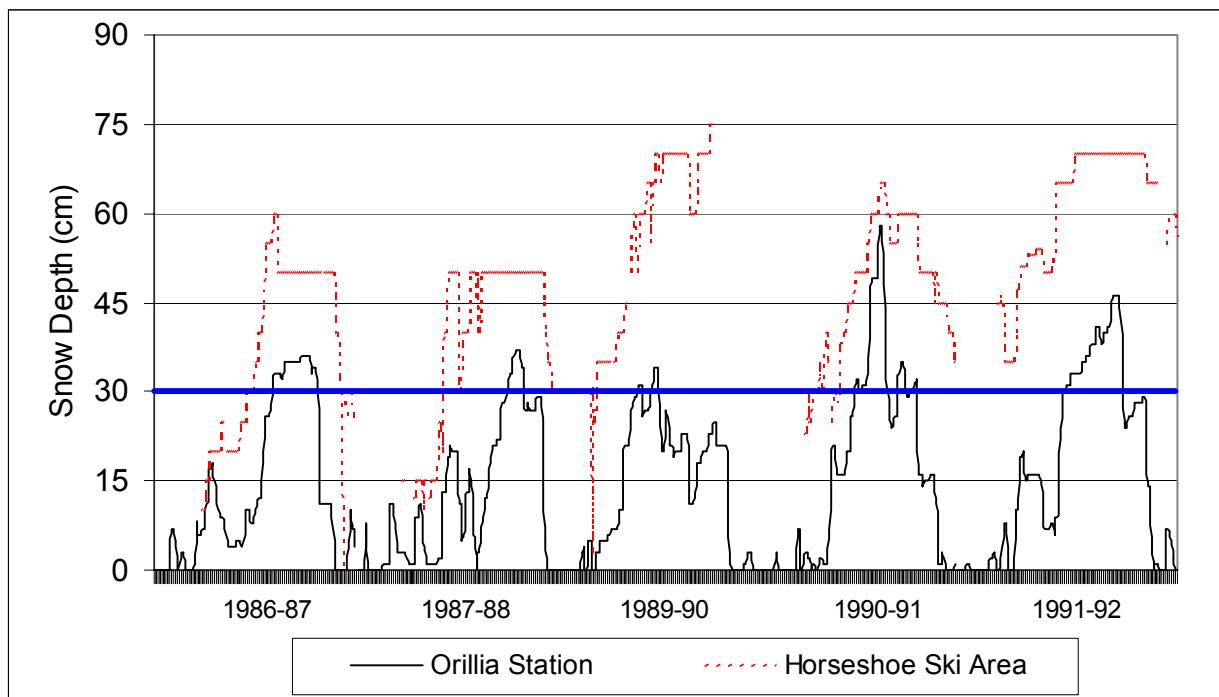
**Figure 2** Inter-resort comparison of observed alpine skiing season length

The average ski season in the region during the 1990s equalled or exceeded that in the 1970s and 80s, even though the winters during the 1990s were on average warmer (the 1990s were the warmest decade in the observational record). Similarly, despite warmer winters, the variability

in the ski seasons at all five ski areas declined in the 1990s. A comparison of the impact of the two warmest winters on record exemplifies this point. In the winter of 1982-83 (second warmest winter on record), there was a notable reduction of the ski season at most of the ski areas. Although the winter of 1997/98 was the warmest in the observed record in this region, none of the ski areas experienced as large a negative impact on the ski season length as during 1982/83. Poor ski conditions and the shortened ski season may still have resulted in a greater economic impact in 1997/98, but annual economic data for the ski industry in the study area are not available.

The explanation for this reduced vulnerability to climate variability may be found in the multi-million dollar investment in snowmaking technology. As of 1977, only half of Ontario's ski areas had some type of snowmaking system in place (Lynch et al. 1981). Most ski areas did not invest substantially in improvements to snowmaking systems until the mid- to late-1980s, in response to the poor ski seasons of 1979/80 and 1982/83. By the mid-1990s, extensive snowmaking systems were in place at all five of the alpine ski areas examined in this study. Both Blue Mountain and Talisman ski areas have sufficient snowmaking capacity to make all of their ski runs operational (from a zero snow condition to a ski-able 30 cm base) with three days of suitable snowmaking temperatures. Four of the five ski areas have 100% snowmaking coverage of skiable areas.

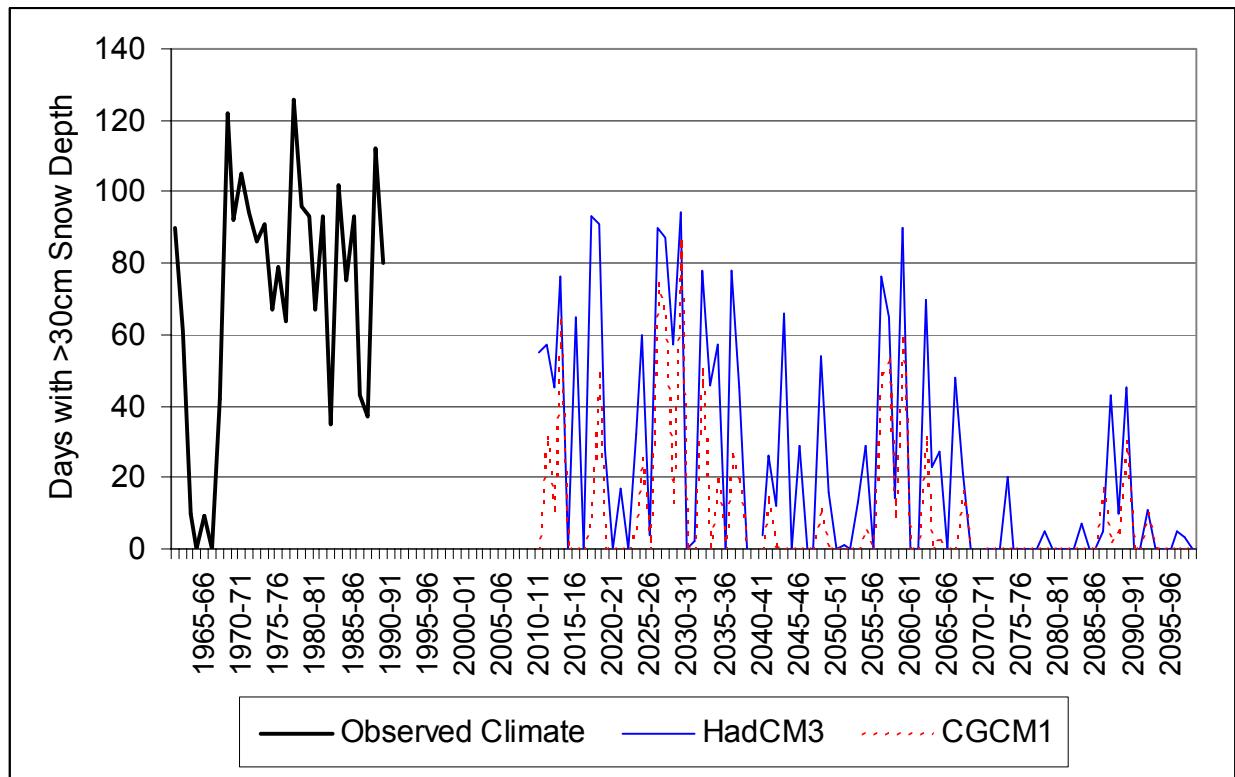
The importance of snowmaking to the ski industry in the study area is revealed clearly in Figure 3, where the recorded natural snow depth at the Orillia climate station is compared with the reported snow depth at the nearby Horseshoe ski area (natural snow fall plus snowmaking). In the years illustrated, the absence of snowmaking would have meant that a skiable 30cm base (solid line in Figure 3) would have been achieved for a very short time. Snowmaking extended the skiing season at the Horseshoe ski area by 33% to 830% during the 1980s and 90s. Results at other ski areas were comparable. The economic viability of the ski areas during these low snowfall winters would have been questionable without snowmaking systems. The estimated CDN\$10 million that the ski industry invested in snowmaking during the late 1980s and early 1990s as an adaptation to climate variability (Scott et al. 2002) more than paid for itself in each of the poor snowfall years identified above.



**Figure 3** Comparative snow depth at Orillia climate station and Horseshoe ski area. Ski areas in the study area cite a 30cm snow base (solid line) as preferred for ski operations.

#### Climate Change Impact Assessment

Analysis of the snow regime in the study area (days with snow cover and days with >30cm snow depth) revealed important changes under each of the climate change scenarios. Figure 4 illustrates the number of days with >30cm snow at Orillia climate station under the CGCM1 and HadCM3 scenarios without snowmaking. More importantly from the ski industry perspective are changes in their capability to make snow. The Muskoka climate station is used for illustrative purposes because this location is central within the study area and it is one of Environment Canada's primary climate stations. Table 3 indicates the number of potential snowmaking days at the Muskoka station from 1961-90 and the simulated potential snowmaking days from 2010 to 2099 under both CGCM1 and HadCM3 scenarios. Using the number of potential snowmaking days from the warmest winter on record in this region (1997/98) as an analogue, such a year would be expected to occur once every decade in the 2010s-30s. The average number of potential snowmaking days in the 2010-39 period is projected to decline



**Figure 4** Simulated number of days with >30cm snow base at Orillia station

between 6% (HadCM3) and 11% (CGCM1). The projected loss of snowmaking days doubles to between 14% (HadCM3) and 23% (CGCM1) for the 2040-69 time frame. By this time, the winter of 1997/98 becomes the average and in the 2070-99 scenarios, a winter similar to 1997/98 would be considered an exceptionally good year for snowmaking.

In the Lakelands region, the primary demand for snowmaking is in the early stages of the ski season and to ensure reasonable skiing conditions during major holiday periods (Christmas and New Year in late December and Spring Break in mid-March). Further analysis was conducted to determine whether the losses in potential snowmaking days coincided with these periods of peak demand for snowmaking. The temporal distribution of potential snowmaking days (by month) under current and projected climate conditions (Table 3) revealed that the early stages of the ski season (late November and December) were not disproportionately affected. Furthermore, when

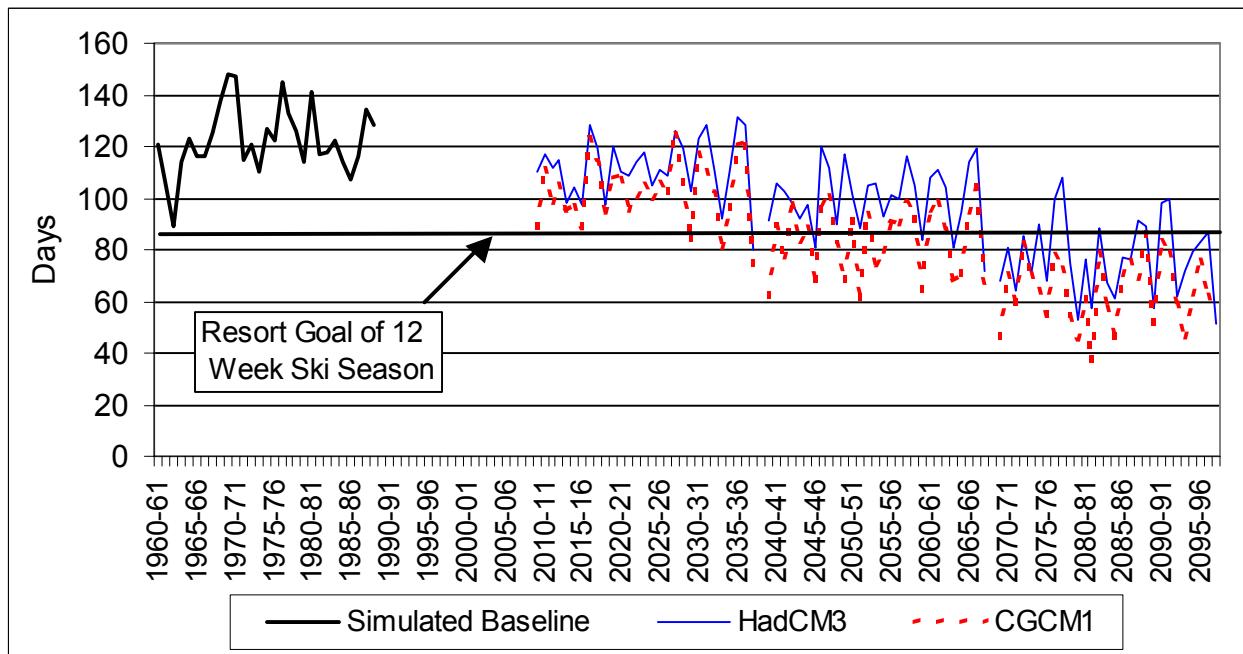
**Table 3** Projected number of potential snowmaking days at Muskoka climate station. Potential snowmaking days are defined as days with minimum temperature of -5°C or colder.

	<b>1961-90</b>	<b>CGCM1 2020s</b>	<b>CGCM1 2050s</b>	<b>CGCM1 2080s</b>		
Nov	10.7	9.4	-12%	7.3	-32%	4.7
Dec	23.5	22.3	-5%	21.6	-8%	19.8
Jan	27.7	25.2	-9%	23.1	-17%	22.2
Feb	27.4	23.0	-16%	19.1	-30%	16.3
March	21.1	18.5	-12%	15.4	-27%	11.6
April	7.8	6.7	-14%	4.5	-42%	1.8
<b>Total</b>	<b>118.2</b>	<b>105.1</b>	<b>-11%</b>	<b>90.9</b>	<b>-23%</b>	<b>76.4</b>
	<b>1961-90</b>	<b>HadCM3 2020s</b>	<b>HadCM3 2050s</b>	<b>HadCM3 2080s</b>		
Nov	10.7	9.2	-14%	6.9	-36%	4.0
Dec	23.5	23.1	-2%	21.4	-9%	16.6
Jan	27.7	27.3	-1%	26.5	-4%	24.2
Feb	27.4	26.0	-5%	25.2	-8%	22.4
March	21.1	19.0	-10%	16.4	-22%	14.2
April	7.8	6.7	-14%	5.7	-27%	3.5
<b>Total</b>	<b>118.2</b>	<b>111.2</b>	<b>-6%</b>	<b>102.1</b>	<b>-14%</b>	<b>84.9</b>

the number of potential snowmaking days in the crucial pre-Christmas period (December 1-20) was assessed, the average number of days in the 2020s and even 2050s (under both CGCM1 and HadCM3 scenarios) exceeded those in the analogue winter of 1997/98.

Unlike previous climate change impact studies of the skiing industry, this analysis was able to examine the impact of climate change scenarios for the early decades of this century (2010-39), which are more relevant to business planning time frames. Again using the Horseshoe ski area as an example, Figure 5 illustrates that average ski seasons continue to shorten as the magnitude of climate change increases. The CGCM1 scenario projected a 15% reduction in the average ski season (wrt the 1961-90 average) in the years 2010-39, while the HadCM3 scenario projected an 8% reduction. The CGCM1 scenario projected a 31% reduction during the years 2040-69 and a 47% reduction for 2070-99. Under the HadCM3 scenario, average ski seasons were projected to shorten by 18% and 36% for these respective time frames.

Figure 5 also displays whether or not a ski season achieved the stated business objective of a 12-week season (as indicated by Horseshoe management). During the observed record from 1980-



**Figure 5** Simulated ski season at Horseshoe ski area

99, this economic benchmark was achieved every year. By the 2050s, the probability of a 12-week ski season with current snowmaking capacities is 55% under the CGCM1 scenario and 89% under the HadCM2 scenario. With the improved snowmaking technology simulation, the probability improved to 86% and 100% respectively.

When the season length projections for the five alpine ski areas in the Lakelands region were compared, the results consistently indicated an overall trend toward a shorter average ski season with some variability in the magnitude of change (Table 4). The more northerly ski areas that are at higher elevation (Sir Sam's and Hidden Valley) were the least sensitive to climate change at all three time frames (2020s, 50s, 80s). Blue Mountain was the most vulnerable ski area, with average season lengths reduced by 18-30% in the 2020s, 30-52% in the 2050s and 54-66% in the 2080s. This is consistent with its location near the shores of Lake Huron, where lower elevation and moderating effect of Lake Huron provide a warmer climate that is less conducive to snowmaking. At all ski areas, improved snowmaking would reduce season losses (Table 4).

Improved snowmaking was most valuable at Blue Mountain, where season losses could be reduced by 10-20% in the 2050s and 2080s.

Maintaining the length of ski seasons under increasing climate change will come at a cost, in the form of increased snowmaking. Assuming no change in current snowmaking capacities, the amount of snowmaking required in the 2020s ranges from approximately 150% to 200% of the baseline period. By the 2050s, snowmaking requirements range from 175% to over 300% of baseline. If improved snowmaking technology were implemented to achieve the ski seasons gains indicated in Table 4, snowmaking requirements would increase further, ranging from 150-280% in the 2020s, 190-410% in the 2050s and 320-510% in the 2080s.

**Table 4** Simulated ski seasons under climate change scenarios using current and improved snowmaking technology. See Table 2 for snowmaking technical capacities.

Ski Area & Snowmaking Technology	Baseline (days) 1961-90	Change in Season Length					
		CGCM1			HadCM3		
		2020s	2050s	2080s	2020s	2050s	2080s
Hidden Valley	126						
Current		-14%	-26%	-39%	-9%	-16%	-30%
Improved		-10%	-20%	-30%	-6%	-11%	-22%
Sir Sam's	125						
Current		-14%	-24%	-38%	-10%	-16%	-30%
Improved		-10%	-18%	-29%	-6%	-12%	-22%
Horseshoe	118						
Current		-15%	-31%	-47%	-8%	-18%	-36%
Improved		-7%	-20%	-34%	-3%	-10%	-25%
Blue Mountain	120						
Current		-30%	-52%	-66%	-18%	-30%	-54%
Improved		-17%	-32%	-49%	-10%	-19%	-39%
Talisman	125						
Current		-22%	-38%	-54%	-16%	-25%	-40%
Improved		-14%	-26%	-38%	-10%	-17%	-31%

## **Conclusion**

The findings in this study are consistent with previous climate change impact assessments of the skiing industry in that the scenarios presented suggest an increasingly challenging business environment for the ski industry under climate change. The study advances the field by incorporating snowmaking as a climate adaptation into the climate change impact assessment. When snowmaking is included in the analysis, the magnitude of the impact of climate change is substantially diminished. In this study, a doubled-atmospheric CO<sub>2</sub> equivalent scenario (~2050s) reduced the average ski season in the study area between 24-52% under the CGCM1 scenario and between 16-30% under the HadCM3 scenario. These scenarios are more optimistic than earlier studies that estimated a 40-100% loss of the ski season in the region under doubled-CO<sub>2</sub> conditions (McBoyle and Wall 1992, Ordower 1995) and clearly demonstrate the importance of climate adaptation. Potential improvements in snowmaking technology could further reduce season losses to between 10-32% under doubled-CO<sub>2</sub> scenarios. This more optimistic scenario must be tempered with the critical uncertainty that the additional costs of snowmaking under warmer conditions may outweigh the economic benefits of an enhanced ski season. Further collaboration between the climate change impact researchers and ski industry stakeholders is required to address this issue. Furthermore, the impact of climate change on skiing demand is another area requiring further research.

The varied impact of climate change among the five ski areas examined in this study illustrates how climate change could alter the competitive relationships between individual ski resorts. The two more northerly ski areas (Sir Sam's and Hidden Valley) have a climatic advantage that could be further exploited in a conducive business environment. This is equally true of competitive relationships between larger ski regions. If the magnitude of climate change impacts in Quebec and the Northeastern United States are such that more Ontario skiers stay within the province, the market share of Lakelands ski areas may increase despite slightly reduced ski seasons. Further analysis of the potential impact of climate change on the major ski areas of North America is required for insight into the potential economic impact of climate change for the ski industry and winter tourism patterns.

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### **Abstract**

Weather, climate and tourism are interconnected in many different ways. All of them are of local as well as of global significance. Weather and climate information is of interest to both tourists and the tourist industry. Information on climate is useful for planning vacations. This information can be obtained via popular media (e.g. tourist guides) or weather services. During the vacation period actual weather information is more important than climate information. In this period climate information does not play an important role. Examples of climate information that is often available are air temperature, relative humidity, precipitation, daily sunshine duration and water temperature on a monthly basis. Additional information that is recommended (especially with high spatial resolution) includes data on UV-radiation, air pollution, noise and bioclimatic conditions. Climate, bioclimate and weather information for tourism in Greece is presented.

Keywords: climate, tourism, recreation, human biometeorology, Physiological Equivalent Temperature, Greece

### **Introduction**

Weather, climate and tourism are interconnected in diverse ways (Lecha and Shackleford 1997, Shackleford and Olsson, 1995). Tourists and tour organizers need to be reliably informed about the role of weather. One usually feels bad having to cancel a weekend trip because of crazy weather. Or what experience could be worse than a vacation with never-ending rain? Travel organizers and tour operators also know - through bad experience - about the important role played by the weather: rainy summers and less snowy winters adversely affects tourism and consequently have a grave effect on the schedules and cash-box of tourism industry.

Tourists and tourism industry need weather and climate information before, during and after the vacation period. In the pre-vacation time weather information can be provided from the media and weather services. Climate information from books and brochures about the climate of the vacation area is usually limited and provide only general information. During the vacation period, weather

information is available from public media services and climate information does not play an important role. After the vacation period weather and climate information is not of substantial interest.

## Methods

Weather and climate have the following characteristics in relation to tourism (Abetz 1996):

- Weather and climate are limiting factors in tourism

The characteristics of weather and climate could scarcely disrupt human activities absolutely but could constitute a very important financial factor. When viewed in the light of tourism, this implies that practically some regions of the world have a minimum tourism potential since their climatic conditions do not allow opportunities for tourism. Tourism administrators do not patronize such kind of areas since this does not yield significant profit. The traveller, however who tours these regions would have to get on with high costs (e. g. transport costs) or physical inconvenience (e. g. body strain). Financial strain can also result from weather variations and changes. Rainy summer or less snowy winters can have grave consequences on tourism.

- Weather and climate are dominating factors of touristic demands

Weather and climate does not only shape the touristic offers but also touristic demand. They influence among other factors the decision about the destination or the kind of activities to be during the holiday season. The climatic factors play a significant role in the three phases of a trip: before, during and after. The meteorological conditions affect also the design/construction of the day's program.

- Weather, climate, health and tourism

Trips in climatically stressed areas can result in health problems (e. g. heat stress, UV-radiation, air pollution and heat stroke). A purposeful climate advisory service can help to prepare and protect travellers and particularly risk groups (elderly people, sick people, children) against the above mentioned climate stress.

Cause and effect relations between the atmospheric environment and human health or human comfort can be analysed by a human biometeorological classification that distinguishes (VDI 1998):

- thermal complex
- air pollution complex
- actinic complex
- odours

- noise
- wind comfort

The classification presented above can be used for the climate and tourism relationships. In this paper only the thermal complex will be discussed.

Examples for climate information that is often available in tourism guides is in reality limited (see Table 1, example of the Greek island Santorini in the Aegean Sea). In most cases monthly values of air temperature, air humidity, precipitation, daily sunshine duration and water temperature are given. This information are not sufficient. More information like the amount of days with storm or days with precipitation are needed. Such kind of data is available from the national weather service networks which include more climatic parameter and more detailed information (see Table. 2, available parameters for the island of Santorini).

This information (Tab. 1 and 2) does not have a spatial component are needed for tourists and tourism industry for detailed information. Elementary meteorological and climatic parameters give a good Information (Fig. 3), but the combined effect is missing.

**Table 1** Climate values for Santorini/Greece taken from a tourism guide book (Adams 1996)

Month	Mean air temperature (°C)	Mean maximum air temperature (°C)	Sunshine duration/day (h)	Precipitation (mm)	Relative humidity (%)	Water temperature (°C)
Jan	11	15	4	74	74	16
Feb	11	16	5	52	73	15
Mar	12	17	5	41	72	15
Apr	15	20	8	21	71	16
May	19	24	10	12	69	19
Jun	22	28	11	2	65	22
Jul	25	29	13	0.1	61	24
Aug	25	29	12	1.5	60	25
Sep	22	27	9	9	68	23
Oct	19	23	7	26	72	21
Nov	16	20	6	52	73	19
Dec	13	16	4	74	74	17

**Tab. 2** Climate parameters for Santorini taken from the Greek climate network on monthly basis (Andreakos 1978)

<u>Parameter</u>	Data	<u>Mean value of days of</u>	Data
Air pressure (hPa)	Yes	Precipitation	Yes
Mean air temperat. (°C)	Yes	Rain	Yes
Mean max. air temperat. (°C)	Yes	Snow	Yes
Mean min. air temperat. (°C)	Yes	Snow rain	No
Absolute max. air temperat. (°C)	Yes	Rainstorm	Yes
Absolute min. air temperat. (°C)	Yes	Hail	Yes
Absolute mean max. air temp. (°C)	Yes	Snow cover	Yes
Absolute mean min. air temp. (°C)	Yes	Fog	No
Mean relative humidity (%)	Yes	Dew	Yes
Mean precipitation (mm)	Yes	Frost	Yes
Maximum precipitation in 24 h (mm)	Yes	Mean min. air temperat. < 0.0 °C	Yes
Mean cloud cover (Octas)	Yes	Mean max. air temperat. < 0.0 °C	No
Sunshine duration (h)	No	Wind speed > 6 Bf	Yes
Cloud cover (0-1.5)/8	Yes	Wind speed > 8 Bf	Yes
Cloud cover (6.5-8)/8	Yes	Wind direction	Yes
		Mean wind speed in Bf	Yes

Many possible combinations of meteorological and climatological parameters for tourism issues are given in Abetz (1996), two examples are given for summer conditions (Davies 1968 and Mieczkowski 1985). One example is the Climate-Index of Davies (Davies 1968) (Eq. 1) where the mean daily maximum air temperature from June to August  $T_{\text{amax}}$ , sunshine duration from June to August S and the sum of precipitation from June to August is included. An example of the summer index of Davies (1968) is given in Fig. 2 for the area of Greece.

$$I = 18 * T_{\text{amax}} + 0.217 * S - 0.276 * N + 320 \quad (1)$$

Another climatic index is given by Mieczkowski (1985) with a combination of seven parameters, three of them alone and two as a bioclimatic combination (Eq. 2).

$$TCI = 8 * Cld + 2 * Cla + 4 * R + 4 * S + 2 * W \quad (2)$$

Where, Cld is daytime comfort index, consisting of the mean maximum air temperature (°C) and the mean minimum relative humidity (%), Cla the daily comfort index, consisting of the mean air temperature (°C) and the mean relative humidity (%), R the precipitation (mm), S the daily sunshine duration (h), W the mean wind speed (m/s). Contrary to other climate indices all the contributing parameters are assessed, each factor can reach 5 points, because of a weighting factor (a value for TCI of 100). Values  $\geq 80$  are excellent, values between 60 and 79 can be regarded as good to

very good. Lower values (40 – 59) are acceptable, while values (< 40) imply bad conditions for tourism (Abetz 1996, Mieczkowski 1985).

The shown climatic indices have some deficits since they do not include the effects of short and long wave radiation fluxes which are generally not included in climatic records. These fluxes can be calculated by the use of synoptic data and theoretical calculations from astronomical data (VDI 1998, Matzarakis et al 2000).

A full application of thermal indices on the energy balance of the human body gives detailed information about the effect of the thermal environment on humans (VDI 1998). One possibility is the application of PMV (Predicted Mean Vote) and PET (Physiologic Equivalent Temperature) (VDI 1998, Höppe 1999, Matzarakis et al 1999). Both thermal indices are well recommended and include all the important meteorological and thermo-physiological parameters (Matzarakis 2001).

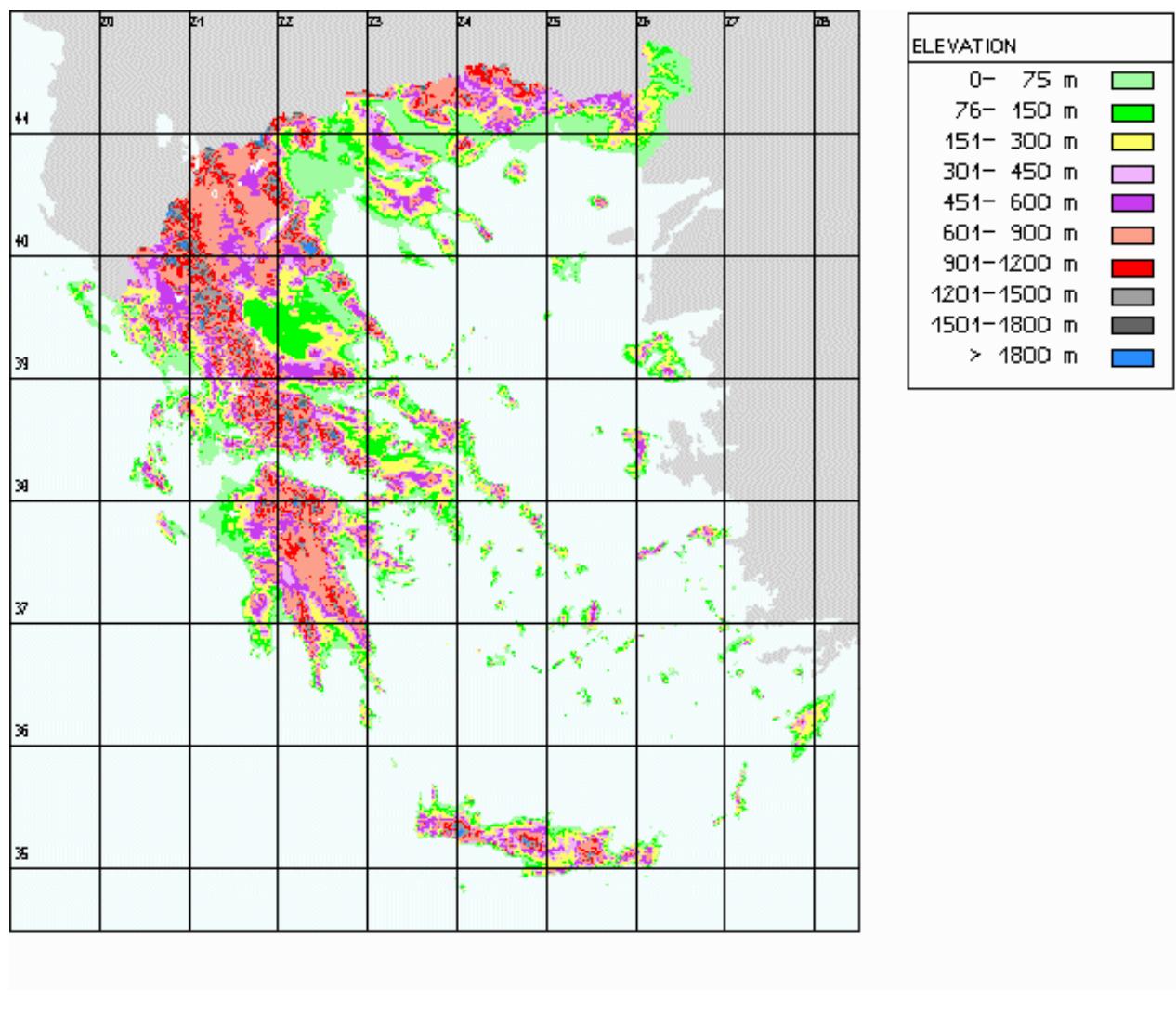
In general the availability of national climatic networks of basic meteorological and climatological data is required. Also data needed for some bioclimatic purposes is available but not in a spatial resolution as is needed for touristic purposes.

The link between the point data as temperature or PET can be done by the construction of maps. For the construction of climatic and bioclimatic maps, a stochastical-statistical model, by the application of linear multiple regression has been used. On the one hand, we used as input data air temperatures or Physiological Equivalent Temperature of the stations was used as dependent variables on the statistical analysis and on the other hand as independent variables the following parameters: latitude, longitude, elevation above the sea level, shortest distance of each grid to the sea (as an indicator for continentality) and a factor of land/sea coverage in percent for parts of the area with a diameter of approximately 40 km were used (Matzarakis 1995, Matzarakis and Mayer 1997).

## Results

Results based on point stations for climate and bioclimate information are given and described in Matzarakis (2001). But this kind of information give information only for a small are. Single point information is limited in spatial scale. Spatial scale information can be generated by the use of the point information. The following results and maps are generated for the meso scale resolution in minutes of degree for the whole area of Greece (Matzarakis 1995).

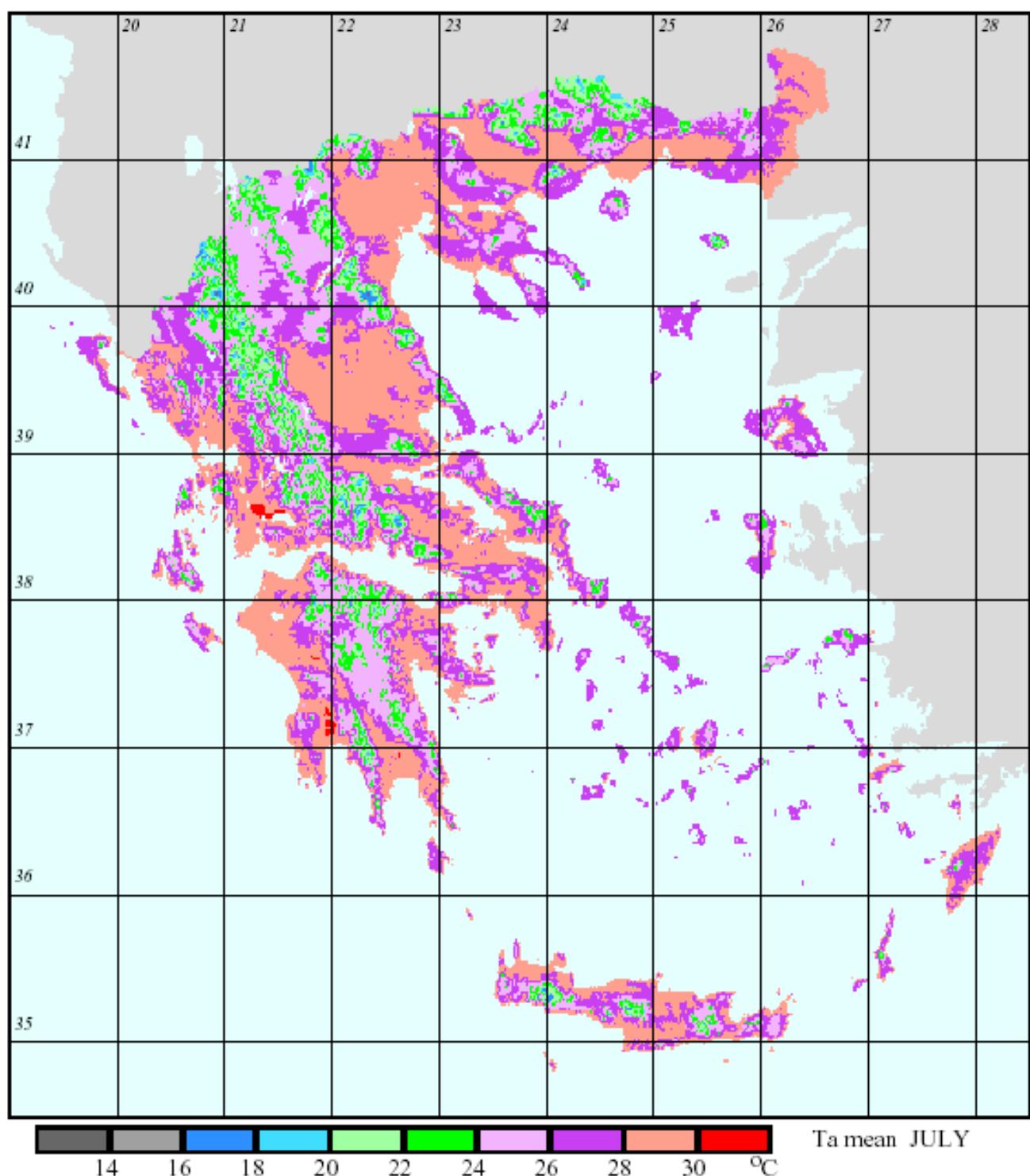
Greece is a country with an extended tourism but also with unused touristic potential especially before and after the main touristic season. The topography of Greece is very complex and highly variable (Fig. 1). This holds many possibilities and not only beach or summer activities during the main touristic season.



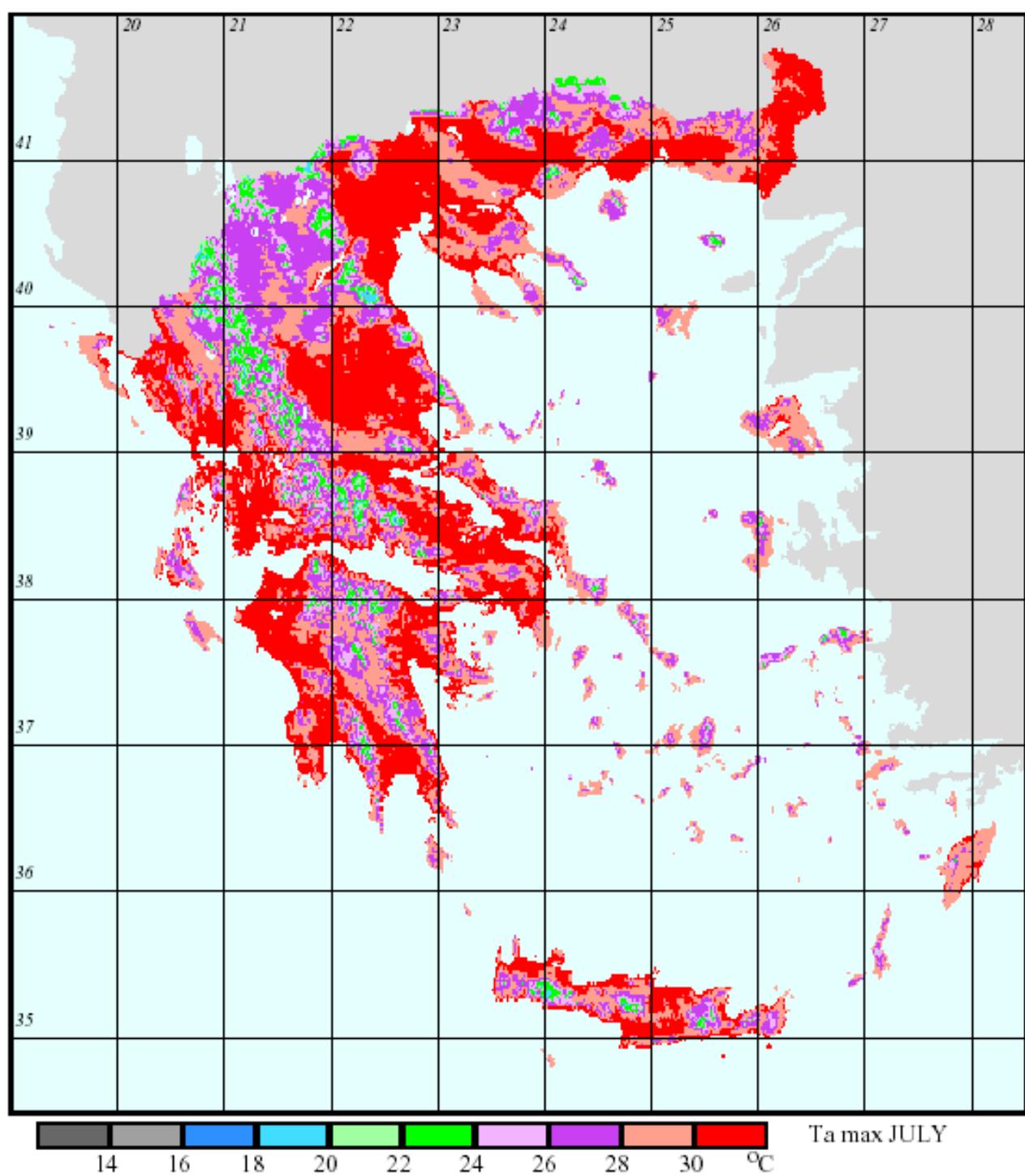
**Fig. 1** Digital terrain model of Greece

The Fig. 2, 3 and 4 show the geographical distribution of the mean air, mean maximum and mean minimum air temperature of July. The distribution shows the differences between the inner mainland of Greece and the coasts and Greek islands. During July the conditions on the Greek islands are quite comfortable and the air temperatures are less than in the inner parts of the Greek mainland. The mean minimum air temperature (Figure 4) is for the biggest part of Greece, especially for elevations lower than 600 m above sea level higher than 18 °C. This is the area where the population of Greece is living and tourists usually spend their vacations.

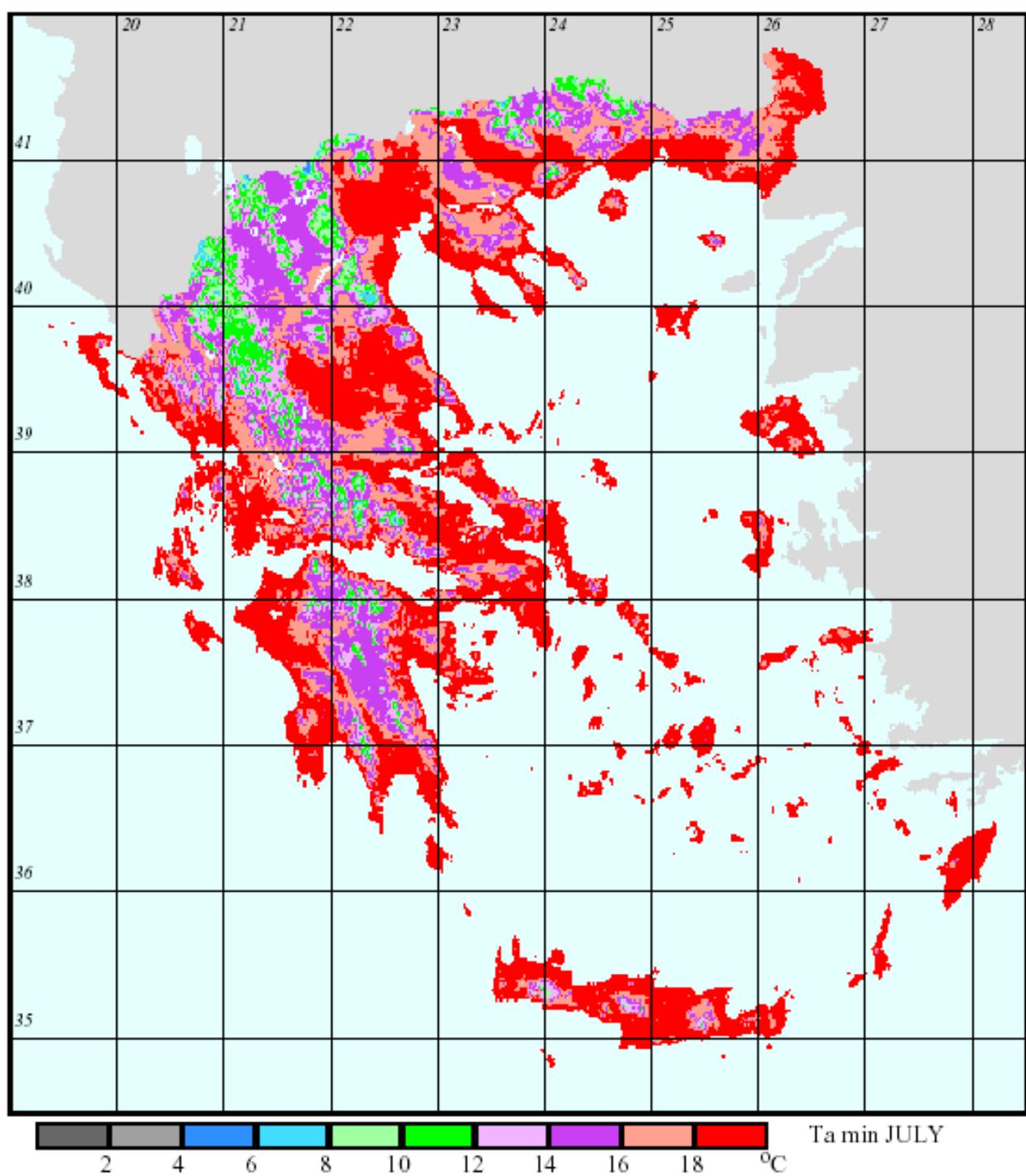
The maps of monthly mean air, monthly mean maximum and monthly mean minimum air temperature for the other months have been developed by the same way and also existing under <http://www.mif.uni-freiburg.de/tourclimgr>.



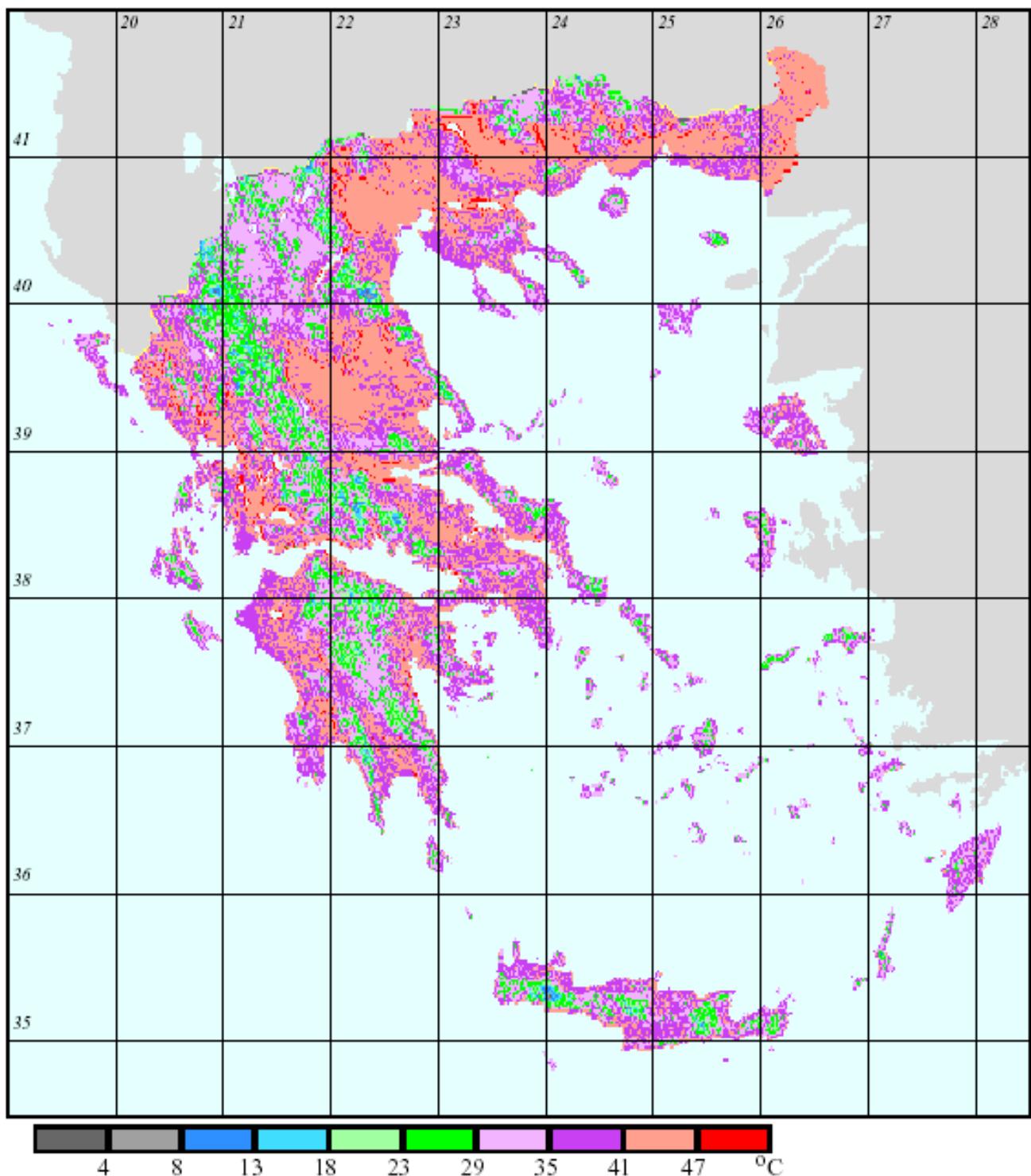
**Fig. 2** Geographical distribution of mean air temperature in July for Greece



**Fig. 3** Geographical distribution of mean maximum air temperature in July for Greece

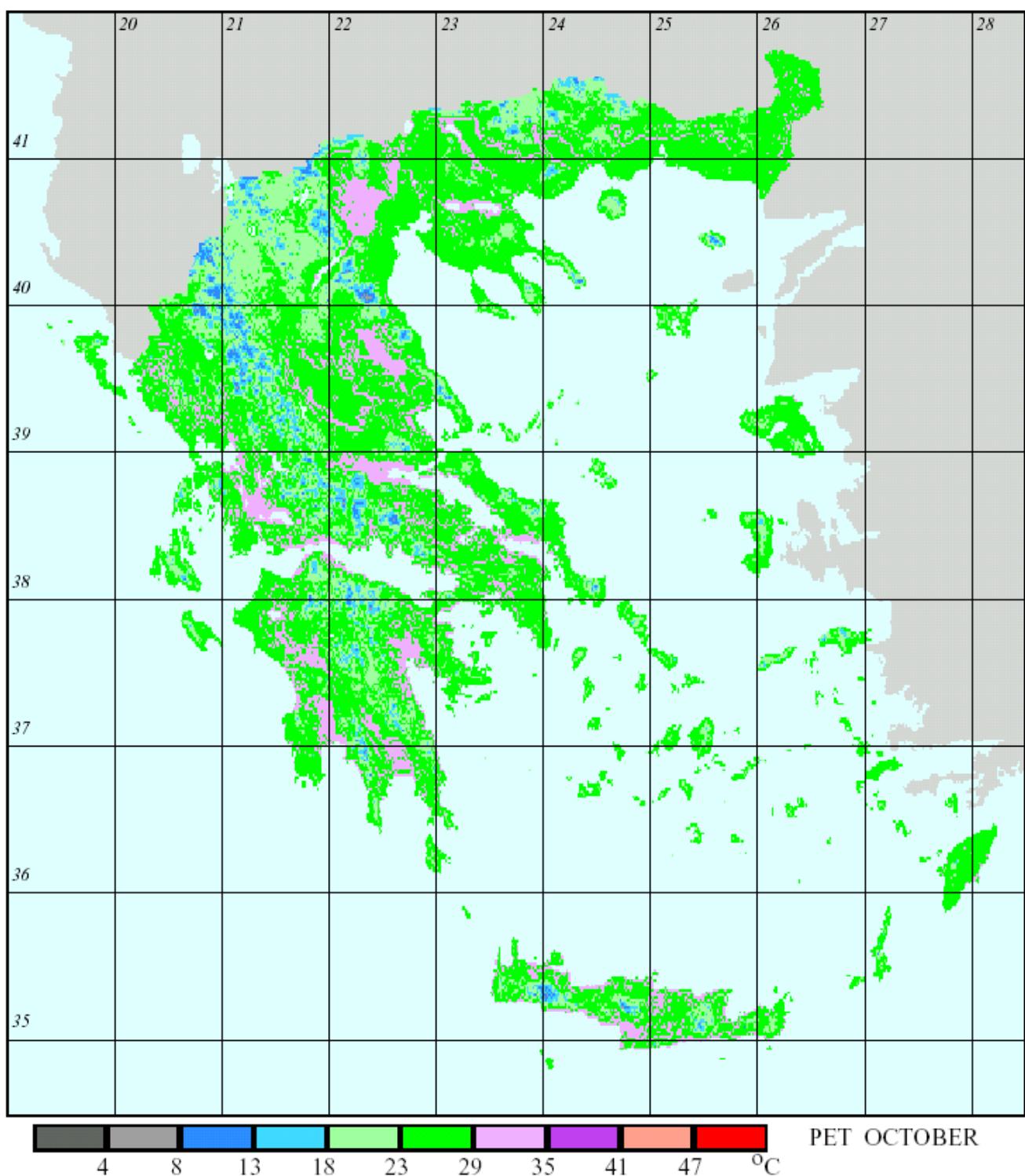


**Fig. 4** Geographical distribution of mean minimum air temperature in July for Greece



**Fig. 5** Geographical distribution of PET in July in Greece

In Figure 5 the geographical distribution of PET of Greece is shown. With this kind of presentation it is possible to quantify areas which are suited for touristic purposes and which are not. As example the inner part of the mainland of Greece is characterised by higher values of PET than the islands of the Aegean Sea does not suffer so much higher values which mean heat stress because of the existence of the Etesian Winds System, which provide better bioclimatic conditions in this area.



**Fig. 6** Geographical distribution of PET in October in Greece

Figure 6 shows the geographical distribution of PET in October. From Figure 6 it can be seen that the values of PET during midday are not lower than 18 °C which means that in the areas for recrea-

tion and tourism during this period of day the conditions are at the level of thermal comfort or slightly warm. This evokes no physiological or slight thermal stress (Matzarakis and Mayer 1997, Matzarakis 2001).

## Conclusions

Meteorological data from the point of view of tourism has to be available not only on a monthly or annual basis but also in form of frequency of exceeded values of thermal indices or parameters which can quantify special bioclimatic conditions to avoid stress conditions in specific areas which are not suited for touristic purposes.

For the characterization of climatic and bioclimatic conditions of areas often visited by tourists, it is not just enough to quantify only climatic variables or climatic indices. Detailed temporal and spatial bioclimatic analysis of the most important meteorological parameters (air temperature, wind speed, air humidity, short and long wave radiation fluxes) and thermo-physiological parameters (activity and clothing) should be included.

Existing meteorological and climatological information for tourism purposes contained in most tourism guides and books are not adequate for tourists and tourism industry. The full climatic data set from the national climate networks of the weather services gives detailed information for some areas. Spatial information with a monthly resolution including the combination of climatic parameter, thermal or climate indices as well as human biometeorological thermal indices (like PMV and PET) can describe the thermal environment of humans and give detailed meteorological and climatological information for diverse tourism purposes (<http://www.mif.uni-freiburg.de/tourclimgr>).

The thermal component is needed to compliment the air pollution component. Additional information about the air pollution conditions in holiday countries is also needed. Other information from the actinic parameters (UV-radiation), noise pollution and odours can also be very helpful for tourists and travellers.

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## **The effect of climate on the use of open spaces in the urban environment: Relation to tourism**

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### **Abstract**

The effects of climate on the use of outdoor spaces in the urban environment is particularly important for the activities that are carried out in the area and consequently for tourism too. Through a series of field surveys, the effect of microclimate on outdoor comfort conditions and the use of open spaces is examined, while it is suggested that there is a strong relationship between these parameters. Responses to the microclimate may be unconscious, but they often result in a different use of open space in different climatic conditions. Field surveys with extensive microclimatic monitoring and interviews with users of open spaces also reveal various issues regarding adaptation, suggesting that a purely physiological approach is inadequate in characterising thermal comfort conditions in outdoor spaces, emphasising the need for investigating different ways to quantify comfort conditions outdoors.

**Keywords:** Outdoor thermal comfort, microclimatic monitoring, field surveys.

### **Introduction**

Understanding and evaluating the effects of climate on the use of outdoor spaces in the urban environment is particularly important for the activities that are carried out in the area and consequently for tourism too. For most European cities, which are rich of cultural heritage and therefore attract a great number of tourists throughout the year, this parameter is of great importance, as tourism presents an important economic factor. Understanding the richness of microclimatic characteristics in outdoor spaces, and the comfort implications for the people using them can assist urban “accommodation”, enhance touristic development and planning of cities, as well as development of wide scale projects, such as EXPO parks.

Improved microclimatic conditions have major implications for the development of cities. By controlling sources of discomfort, sedentary activities, the use of public transport, cycling and walking, are promoted. Successful areas attract large numbers of people, which in turn attract businesses, workers, residents, and the area becomes economically profitable. Finally, successful outdoor spaces can benefit the image of the

city. Such issues are key parameters for tourism and operators organising recreational excursions.

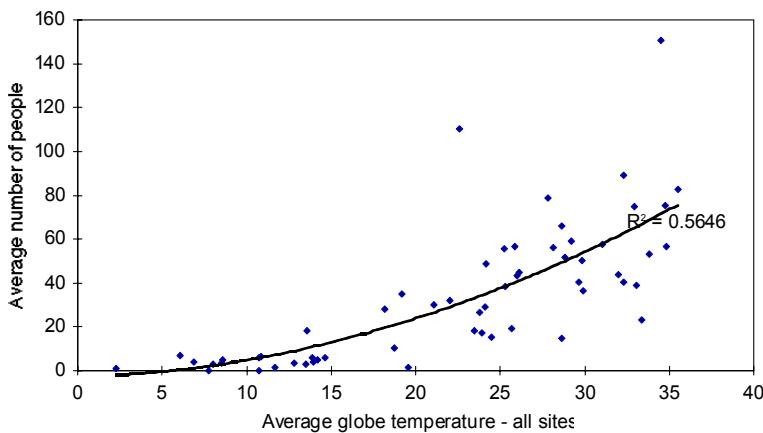
The underlying hypothesis is that thermal and by implication comfort conditions affect people's behaviour and usage of outdoor spaces. Responses to the microclimate may be unconscious, but they often result in a different use of open space in different climatic conditions. Indeed it has been revealed that microclimatic parameters strongly influence thermal sensations, as well as the use of open urban spaces throughout the year (Nikolopoulou *et al.*, 1998; 2001). Therefore, climate should be taken into consideration even at the intermediate scale of the urban block (a scale which has received little attention in research), integral to user satisfaction and therefore to the success of the space. Consideration of such issues can ultimately assist touristic development and the tourism industry.

These issues are extensively examined at the research project RUROS (Rediscovering the Urban Realm and Open Spaces), whereas some of the early findings of the project based on the extensive monitoring of open spaces are presented.

### **Use of outdoor space**

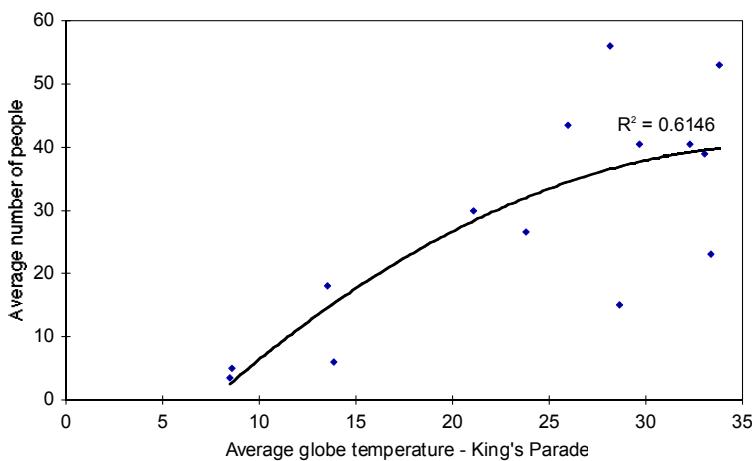
A research project carried out in Cambridge, UK, investigating thermal comfort in the urban context, through 1431 interviews at four different case study areas in the city-centre, at different times of the year, has thrown some light on the complexity of issues involved (Nikolopoulou *et al.*, 2001). Indeed it was revealed, that microclimatic parameters strongly influence thermal sensation and the use of open space throughout the year, even though responses may be unconscious.

Examining the number of people using the different spaces at various intervals – counting the number of people using the spaces at various intervals, during the interview period, eventually calculating a mean value for each day – demonstrated that the warm conditions and presence of sunlight are important factors in the use of the space, as the average number of people sitting in the space increases as globe temperature increases (Fig. 1).



**Fig 1** Average number of people using outdoor spaces as a function of globe temperature ( $^{\circ}\text{C}$ ), in all the different sites.

Furthermore, disaggregating the results for the different sites and examining the situation in the site where there are no means of shading available (King's Parade), it is apparent that the curve, although of increasing slope, tends to stabilise after about 25  $^{\circ}\text{C}$ . This suggests that although the sun is much appreciated during the cooler season, in warm conditions fewer people are using the space (Fig. 2), and because there is a general lack of sitting places available in the city-centre, people sit, but for shorter periods than would do otherwise, e.g. to eat a sandwich, etc.

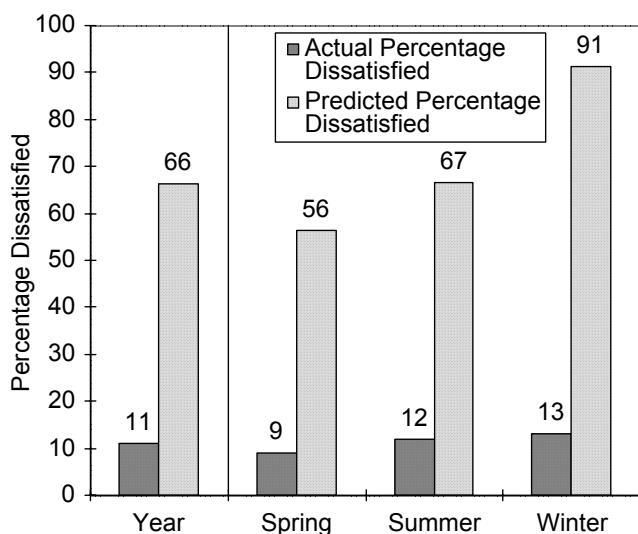


**Fig 2** Average number of people using outdoor spaces as a function of globe temperature ( $^{\circ}\text{C}$ ), in King's Padade, where there are no means of shading.

## Thermal sensation

During the field surveys, the interviewees were reporting their thermal sensation and value judgement, on a 5-point scale, varying from “too cold” to “too hot”.

Comparing such subjective data with the thermal index Predicted Mean Vote (PMV) (ISO 7730, 1994), taking into account the mean objective environmental parameters recorded for the duration of the interview, clothing levels and metabolic rate, for each interviewee, revealed great discrepancy between the two sets of data, regarding thermal comfort conditions outdoors. The Predicted Percentage of Dissatisfied (PPD), based on the theoretical calculation of the Predicted Mean Vote (PMV) for each interviewee (ISO 7730, 1994) (getting a mean value from the individual calculated PPDs), was compared with the corresponding Actual Percentage of Dissatisfied (APD) (Fig. 3). The PPD varies from 56% in spring to 91% in winter, whereas the yearly average is 66%. That implies 944 of the 1431 people sitting outside should be dissatisfied with their thermal environment. In fact, the APD is always around 10%, a figure that is regarded as acceptable, found even in controlled indoor environments. This suggests that adaptation takes place.



**Fig. 3** Comparison between Actual Percentage Dissatisfied and Predicted Percentage Dissatisfied.

## **Adaptation**

The term ‘adaptation’ can be broadly defined as the gradual decrease of the organism’s response to repeated exposure to a stimulus, involving all the actions that make them better suited to survive in such an environment. In the context of thermal comfort this may involve all the processes which people go through to improve the fit between the environment and their requirements. Within such a framework, adaptive opportunity can be separated into three different categories: physical, physiological and psychological (Nikolopoulou *et al.*, 1999).

*Physical adaptation* involves all the changes a person makes, in order to adjust oneself to the environment, or alter the environment to his needs. We can identify two different kinds of physical adaptation, *reactive* and *interactive* (Nikolopoulou *et al.*, 1999). In *reactive* adaptation, the only changes occurring are personal, such as altering one’s clothing levels, posture and position, or even metabolic heat with the consumption of hot or cool drinks, as well as changing position, an effective way of avoiding discomfort, highly relevant to outdoor spaces, where constraints of workspace, etc., do not exist, therefore people are free to move around as they wish. In *interactive* adaptation, however, people make changes to the environment in order to improve their comfort conditions, such as opening a window, turning a thermostat, opening a parasol, etc.

*Physiological adaptation* implies changes in the physiological responses resulting from repeated exposure to a stimulus, leading to a gradual decreased strain from such exposure. In the context of the thermal environment this is called physiological acclimatization, crucial mechanism in extreme environments, but not of central importance in the use of outdoor spaces.

Different people perceive the environment in a different way, and the human response to a physical stimulus is not in direct relationship to its magnitude, but depends on the ‘information’ that people have for a particular situation. *Psychological factors* are therefore influencing the thermal perception of a space and the changes occurring in it, including the following (Nikolopoulou and Steemers, 2000):

- Naturalness of a space, describing an environment free from artificiality, whereby there seems to be increasing evidence that people can tolerate wide changes of the physical environment, provided they are produced naturally.

- Expectations, that is what the environment should be like, rather than what it actually is, greatly influence people's perceptions.
- Experience, directly affects people's expectations.
- Time of exposure, as exposure to discomfort is not viewed negatively if the individual anticipates that it is short-lived.
- Perceived control, as it is widely acknowledged that people who have a high degree of control over a source of discomfort, tolerate wide variations, are less annoyed by it, and the negative emotional responses are greatly reduced.
- Environmental stimulation, probably the main reason for the majority of outdoor activities. Comfortable conditions have been regarded as those where occupants feel neither warm nor cool, and it is increasingly believed that a variable, rather than fixed, environment is preferred whereas a static environment becomes intolerable.

### **Ongoing research: project RUROS**

Based on this evidence, a wide-scale project is being carried out, with the aim of examining and evaluating a wide range of comfort conditions –thermal, visual, audible– across Europe. This study is unique of its kind, both for the issues it investigates as well as the wide range of climatic conditions examined and the surveys carried out.

Project RUROS: Rediscovering the Urban Realm and Open Spaces aims to develop a series of comfort models with subsequent mapping of comfort conditions at the scale of the urban block, which will be useful for urban designers developing new or redeveloping urban areas. The project is funded by the EU 5th Framework Programme, Key Action 4 "City of Tomorrow and Cultural Heritage" from the programme "Energy, Environment and Sustainable Development".

Twelve different organisms participate from nine different countries, involving problem solvers (research institutes and municipalities' technical representatives) working closely together with problem owners (users of open space and city representatives, i.e. municipalities). The common link is the improvement of urban spaces which can assist in revitalising urban spaces as well as improving quality of life.

Two case studies of different nature are examined in each of the cities of Athens (GR), Thessaloniki (GR), Milan (I), Fribourg (CH), Kassel (D), Cambridge (GB) and Sheffield (GB), used as the medium for examining comfort conditions outdoors.

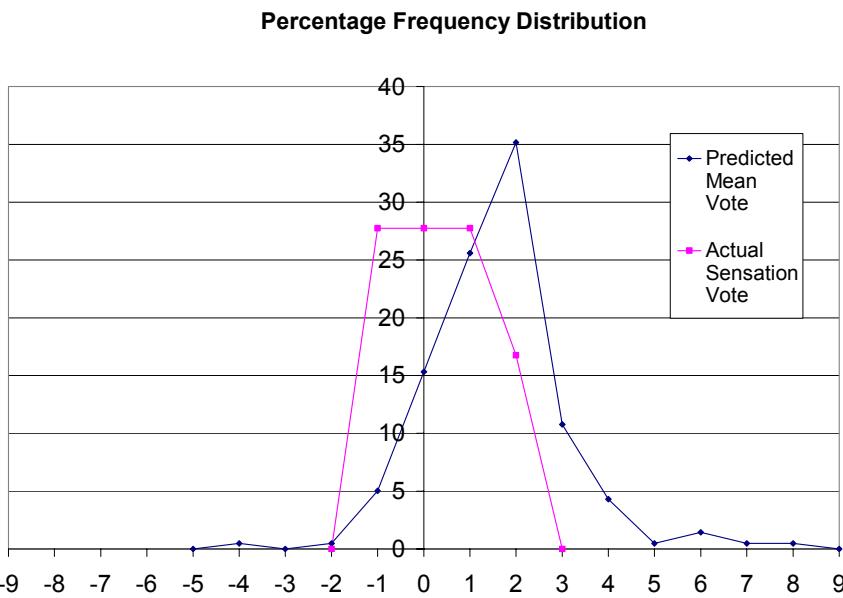
A portable device has been constructed for monitoring objective environmental parameters (air temperature, solar radiation, wind and humidity, horizontal and cylindrical illuminance as well as sound pressure levels). An explicit questionnaire has also been constructed to evaluate people's perception of the space and respective comfort conditions, through direct interviews at the different case study sites.

### **Thermal sensation: summer in Athens**

The first set of data has been collected from the summer surveys in Athens, at the municipality of Alimos. 418 interviews were carried out in two different sites investigated for two weeks in July and August 2001, from 10am to 8pm. The sites differ in character and nature, as one is a neighbourhood square used for relaxation, including playground, open-air theatre, coffee shop and basket-ball field, whereas the other site is at the coastline, used for promenades, swimming, as well as relaxation, and also including playground and coffee-shops.

In the majority, climatic conditions included high air temperatures, intense sunshine, relatively low wind speeds, whereas humidity was low in the square and high in the sea-shore.

People's thermal sensation was reported on a 5-point scale, varying from "very cold" to "very hot". Comparing the data gathered from the interviews, Actual Sensation Vote (ASV), with the thermal index PMV, it is noticed that only 17% of the actual votes falls in the "very hot" region (+2), whereas there is also a 28% in the "cool" region (-1), at circumstances where mean air temperature was 30 °C, and maximum air temperature exceeded 35 °C. However, only 46% of the PMV falls within comfort ( $-1 < PMV < +1$ ), implying that 220 people were dissatisfied with the thermal environment (Fig. 4).



**Fig. 4** Comparison between Actual Sensation Vote and Predicted Mean Vote in Athens during the summer.

## Conclusions

It is clear that microclimatic conditions affect the use of open spaces, whereas a purely physiological approach is inadequate in characterising thermal comfort conditions in outdoor spaces, emphasising the need to investigate different ways to quantify comfort conditions outdoors.

Such concerns are integral to user satisfaction and the success of open spaces and therefore should be taken into consideration at the design of open spaces, ultimately assisting even touristic developments encouraging public use, at different times of the year.

## Acknowledgements

The team of people who collaborated for the construction of the equipment also involved Mr A. Androutsopoulos and Mr D. Karagogos, whereas the Athens surveys were carried out by Ms L. Anastasopoulou and Mr D. Karagogos.

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# **Climate, Forest Fires, and Recreation: Insights from the U.S. Southwest**

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## **Abstract**

Forests rank among the foremost recreational destinations, no more so than in warm semi-arid bioregions. The US Southwest is no exception. Yet, while these areas provide respite from heat and sun, forest fire can pose a serious hazard to recreationists and nearby residents. In the US Southwest this hazard is elevated due to high fuel load buildups resulting from long-term fire suppression policies and to climatic influences. Tree-ring research provides strong evidence that wildfires in the region are linked to synoptic climate processes, notably the El Niño-Southern Oscillation (ENSO). The tree-ring archive for the past 500 years indicates that an unusually wet year, followed by one or two dry years is a particularly influential pattern: high winter precipitation in the first year encourages growth of fine fuels such as brush and grasses, while the following dry years cause the vegetation to become very dry, thus establishing widespread fire hazard conditions. At the same time, dry years are typically characterized by a greater number of sunny days, which may prompt increased visitation. US land managers address the multiple stresses affecting the region's forests through implementation of long-range plans that include both natural and human factors. An important element of these plans is management/reduction of fuel loads, largely focusing on prescribed burning. Shorter-term planning, focusing on the coming wildfire season, is also carried out each year. Knowledge of climate history and processes, and use of climate forecasts, could improve planning, although such information is not yet well integrated into these processes. Further, the plans do not yet deal with the potential implications of diffusion of climate information to the public, even though such information has considerable potential to influence tourism marketing and thus levels/patterns of recreational activity. Today, marketing of tourism in the forests of the US Southwest occurs at all scales from the global to the local, and income from tourism and recreation has become essential to many nearby communities. Increased understanding of climate and its impacts, as well as the implications of enhanced use of climate information by tourists, recreationists, marketers, and business people could enhance planning and decision making with regard to overall land management, fire management, and visitor management. This paper examines important intersections among climate, tourism/recreation and fire regimes in the Southwest, and suggests areas where our regional experience might contribute to similar climate-forest-recreation assessments elsewhere.

Keywords: Forest fire, Climate impacts, Recreation, US Southwest

## **Introduction**

Recreation in the natural areas of the United States is a highly valued activity, one that is important to large proportions of the public. At the same time, many of the areas most valued by recreational users are located in areas where fire is a natural component in ecological processes. In 2000 alone, there were 92,250 fire starts and 7,393,493 acres (2,992,147 hectares) burned.

Management of wildland areas is complicated by a century of fire suppression practices that have rendered large tracts of forest and grassland highly vulnerable to catastrophic wildfire. Almost 40 million acres (16,188,000 hectares) of National Forest Service lands alone are deemed to be at high risk of wildfire. Wildfires are imposing substantial damage on both human and natural systems; at the same time the cost of fighting wildfires, as well as damage costs, are escalating (Husari, 2000). In the National Park system, policies that favor allowing lightning-ignited fires to burn while at the same time refraining from any active intervention to otherwise reduce fuel-load build ups have also resulted in high risk of catastrophic wildfire, as occurred in Yellowstone National Park in 1988 (see, e.g., Bonnicksen 1989).

Dendrochronological records for the U.S. West indicate that large-scale regional wildfires are correlated with sequences of wet and dry winter climatic conditions associated with certain climate patterns. Lag times between climatic conditions and fire occurrence indicate that periods characterized by one or more unusually wet winters, followed by one or more unusually dry winters, provide an entry point for predicting years when probabilities are high for worse than usual fire seasons (Grissino-Mayer and Swetnam 2000; Swetnam and Betancourt 1998, 1999, 2000). Yet adoption of new knowledge and information technologies designed to improve the use of fire-climate information and forecasts, and to improve understanding of links between climate and fire, has not yet occurred to any substantial extent. The following discussion places outdoor recreation in the context of climate and wildfire, and suggests that climate information can be useful not only for fire managers, but also for communities, businesses, and individuals who benefit from recreation and tourism activities but at the same time may be vulnerable to the impacts of fire-climate interactions. The paper concludes with recommendations for improving the resilience and adaptative capacity of

land managers, communities and recreationists located in or near fire-prone recreation areas in the US Southwest.

## **Background**

Numerous publications reflect assessments of potential impacts of climate variability and change at scales ranging from global to local (see, e.g., IPCC 1990, 1998; USGCRP 2001a; USGCRP 2001b). Climate impacts on forest fire, and on tourism and recreation, are among the many issues addressed in these assessments. As noted in the most recent assessment for the United States, “forest growth is likely to increase in many regions, at least over the next several decades . . . [and] some forests are likely to become more susceptible to fire and pests” (USGCRP 2001a, p. 11). Given that forests cover nearly one-third of the U.S. land base, concern about climate impacts on fire regimes is well warranted, for climate influences composition, structure and function of forest ecosystems. Climate also affects the amount and quality of forest resources, as well as social values associated with forests and forested landscapes. Globally, the primary determinants of woody plant distributions are the spatial and temporal distribution of water and temperature (see USGCRP 2001a, p. 494). In assessing wildfire risk, relative humidity and fuel moisture levels are crucial. About 790 million acres (319,713,000 hectares) of federal lands in the United States are used for recreation; 95 percent of these lands are located in the West. In addition, state and local governments manage more than 54 million acres (21,853,800 hectares), of which 45 percent are in the West. (USGCRP 2001a, p. 508).

According to the U.S. National Assessment, outdoor recreation is likely to change as a result of seasonal climate changes, along with related changes in air and water temperatures (USGCRP 2001a, p. 510). However, because recreation is so broad in diverse with regard to its environmental requirements (Cordell et al. 1999), assessing the types, magnitudes, and patterns of change in recreational activity in response to climate change is difficult (USGCRP 2001a). At the same time, the National Assessment Report suggests that “Recreation is likely to expand in mountainous areas where warmer temperatures attract more people to higher elevations” (USGCRP 2001a, p. 510). Recognizing that alterations in disturbances in fire, drought, insect and disease regimes,

the report speculates that managers could attempt to cope with impacts in several ways: “influencing forest ecosystems prior to disturbance [through, e.g., changing forest density], mitigating the forest disturbance itself [e.g., through burning restrictions and prescribed fires to reduce fuel loads], manipulating the forest after the disturbance [e.g., through imposing fire, insect, and disease controls], or facilitating the recovery process [e.g., intervening to manage the system immediately after disturbance or throughout the recovery process through reseeding and other such activities]” (USGCRP 2001a, p. 511).

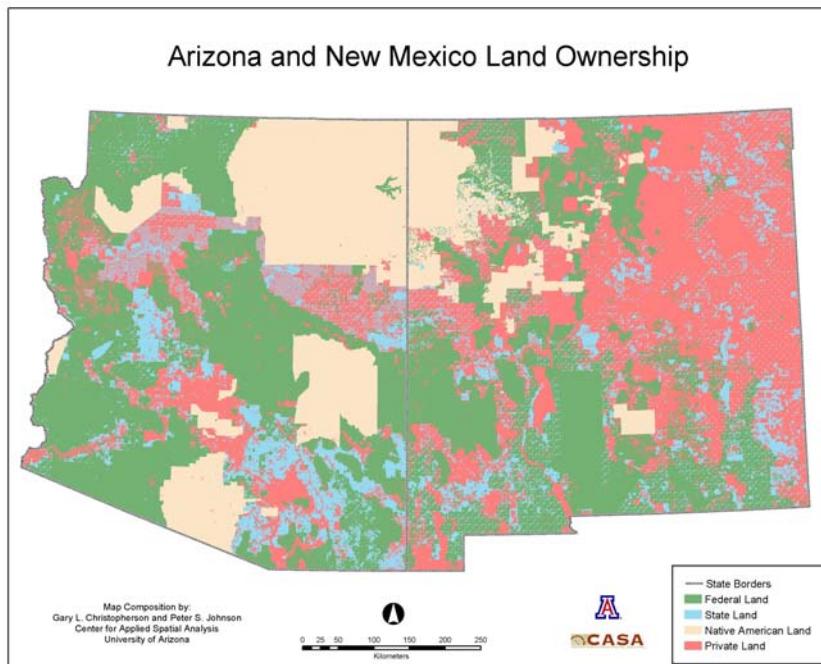
The National Assessment Synthesis Report (USGCRP 2001a) emphasizes that considerable research remains to be done on climate-forest ecosystem interactions, how land use practices and changes in those practices interact with climate variability and change, the interactions among multiple stressors on sensitivity and vulnerability to climate impacts, and human adaptation practices and capacities. As work in the southwestern United States has demonstrated, processes operating over multiple decades, or at the century scale, can affect the degree and nature of fire hazard. Global and synoptic-scale climate processes are correlated with regional patterns of wildfire activity (USGCRP 2001b).

Translating such knowledge and research into policy and decision making processes poses significant challenges. As indicated in a report by the National Research Council (1999) on the opportunities for and barriers to use of climate forecasts, our ability to model ocean-atmosphere interactions, and thereby predict seasonal to interannual climatic variations, has improved, particularly in the past decade. Yet seasonal and longer-term climate forecasts remain under-utilized. In the United States, successful predictions of the 1997-98 El Niño resulted in greater public awareness of climate forecasting. At the same time, much remains unknown about how awareness and use of climate information and forecasts affect decision making and behavior. Given that climate forecasts are inherently uncertain, knowing how to communicate uncertainty effectively is essential to building bridges to users of such information. This, in turn, requires improved understanding of patterns of sensitivity and vulnerability of natural and social systems to climatic stress, in order to determine what information people need, when they need it, and for what purposes (NRC 1999a). It also requires new and better

techniques for assessing the relative impact of climate among the multiple stressors that frame decision making and behavior in any given context (see, e.g., NRC 1999b).

### Outdoor Recreation in The United States

Assessment of outdoor recreation in the United States requires a basic understanding of land tenure patterns across the nation. Most important is the fact that, particularly in the Southwest, much of the land is in federal or state ownership. Arizona is an extreme example of this: only 16 percent of the state's land base is in private hands. In New Mexico, less than half the land is in private ownership (see Figure 1 and Table 1).



**Fig. 1** Much of the land in the US states of Arizona and New Mexico is publicly owned (source: Center for Applied Spatial Analysis, The University of Arizona).

**Table 1** Land ownership patterns in two southwestern states and total for the U.S. (source: Merideth, 2001).

Ownership Category	Percentage of Land		
	Arizona	New Mexico	United States
Federal government	44	36	31
State government	13	11	9
Native Nations	27	10	2
Private	16	43	58

Federal lands include those controlled by the U.S. Forest Service (USFS), U.S Fish and Wildlife Service (USFWS), Bureau of Land Management (BLM), National Park Service (NPS), and Department of Defense (Figure 2). The Forest Service alone manages 63 percent of the officially designated wilderness areas in the United States (USFS 2000). Recreational activities occur on at least some of the lands of all of the lands managed by federal agencies; however, obtaining sufficient data about levels and types of recreational activity is often difficult or impossible. This is particularly the case with regard to USFS and BLM lands, since no broadly implemented and maintained mechanism exists to regularly document and archive visitation statistics. What data exist for these and other areas comes from various surveys, which may only be conducted sporadically, and may involve use of non-compatible techniques. One survey, however, is regularly conducted and provides some insight into outdoor recreation at the national and broadly regional level. This is the National Survey on Recreation and the Environment, which has been conducted by the USFS since 1960.

The results of the survey conducted in 1994-95, which included 17,000 Americans age 16 and older, indicates that almost 95 percent of the population participates in at least one form of outdoor recreation (Cordell et al 1997). Outdoor recreation in the United States encompasses a very large number of activities, ranging from taking a casual walk to hunting fishing, camping and mountain climbing. Indicators of the activities listed in the survey that may be most likely to occur in forests and other natural areas, and changing trends in participation in these activities, are provided in Table 2.

**Table 2** US Population Engaged in Selected Outdoor Activities  
(source: Cordell et al. 1997).

Activity	Number of U.S. Participants	% Change between 1982-1983 and 1994-1995
Hiking	47.8 million	93.5
Camping-developed areas	41.5 million	38.3
Camping-primitive areas	28 million	58.2
Bird watching	54 million	155.2
Back packing	15.2 million	73
Adventure activities (mountain climbing, caving, orienteering, rock climbing)	36.8 million	not available

Of the activities listed in Tables 2, hiking and primitive area camping have increased considerably in recent years. In many parts of the country, particularly the U.S. West, the kinds of outdoor activities listed above have high potential of occurring in areas of fire risk. While the number and proportion of Americans who participate in outdoor recreation provides some basic insights into how widespread such activity is, knowing something about the mean number of days spent in various recreational pursuits provides some clues about the intensity of use of recreational areas. As can be seen in Table 3, people living in the interior West and Pacific Coast, both areas where fire hazard can be especially high, spend more of their time in outdoor recreation than the average American does.

**Table 3** Population Engaged in Selected Outdoor Activities – U.S. and Western U.S. (source: Cordell et al. 1997).

Activity	National		Interior West		Pacific Coast	
	Mean days	Number millions	Mean days	Number millions	Mean days	Number millions
Hiking	16.8	804.7	17.7	87.8	17.7	192.8
Camping-developed	10.7	442.4	9.8	39.3	10.6	92.9
Camping-primitive	9.2	258.6	9.6	34.6	10.3	57.5
Bird watching	87.8	4749.2	92.2	381.7	74.6	548.0
Wildlife viewing	36.9	2307.9	35.9	197.2	30.8	290.5
Back packing	8.6	129.7	8.2	14.5	9.6	36.4
Mountain climbing	4.4	39.8	6.5	9.5	5.2	11.2

Camping is a particularly interesting activity for assessing use of wildlands and for obtaining insights into potential vulnerability to wildfire events. Results of the Outdoor Recreation survey (Cordell et al. 1997) show that camping is somewhat more popular in the West than in other parts of the nation (34 to 38 percent of the population engage in camping as compared with 23-24 percent in the other regions), although the actual number of days people stay out camping is similar across the country, and across types of camping activities. Americans tend to camp, on average, 10 to 11 days a year in developed areas, and 8 to 10 days a year in primitive areas. The likelihood of camping tends to decline with increasing age, although camping with a recreational vehicle is similar for all age groups. This reinforces intuitive ideas that backcountry risk is borne primarily by younger people, while assessing the risks in more developed camping areas must take into account the likely presence of older people and families who may require special assistance in the event of emergencies such as evacuation due to wildfire threat. Fully 25 percent of the people in the interior West enjoy primitive camping, compared with 10 percent in the North and South (Cordell et al 1997). These individuals may be more difficult to identify and evacuate, in the event of wildfire hazard, particularly if they are camping in areas that do not require issuance of permits.

Outdoor adventure activities constitute other activities that may place people at some risk from wildfire. Such activities are enjoyed by about half the people in the West, in contrast to only about a third of the people in the North and South. Of the activities aggregated under this category in the most recent Outdoor Recreation Survey (Cordell et al 1997), off-road driving and horseback riding were most popular, with off-road driving more popular in the North and horseback riding along the Pacific Coast. Hiking is popular across all regions and age groups, with people even over age 50 being well represented. In terms of demographics, it is notable that some 8.3 million hikers and 1.6 million backpackers interviewed were older than age 50, a factor that may be important in situations where rapid evacuation may be required. Hiking is done on average 16-18 days per year in all regions of the United States. More people engage in hiking in the West than in the rest of the United States, and it is likely that much of the hiking occurs during fire season. Rock climbing, mountain climbing, orienteering, and caving, which

may also be linked evacuation risk, are also more popular in the West than elsewhere in the country (Cordell et al. 1997).

### **Fire Risk and Outdoor Recreation**

In the western United States, the activities described above are likely to occur in areas and seasons of high fire risk. Although the record to date shows no significant links between wildfire events and death or injury among recreationists, the data suggest that a substantial proportion of the population may be at risk at any given time during the fire season. This, in turn, suggests a need for carefully focused research into the patterns, seasonality, and locations different types of recreational activity in fire-sensitive areas, demographics of the populations engaging in these activities, and perceptions of risk. The research should also assess the perceptions of land managers and fire managers regarding the level of risk faced by people engaging in recreation on the lands they manage. Camping, in particular, may pose high fire risk, not only for the campers themselves, but with regard to the risk for wildfires originating from improperly managed campfires.

Issues associated with management of wildlife, habitat, and ecosystems are inextricably intertwined with expectations, values, opinions, and activities of the public, as well as of land managers, policy makers, and researchers. Recreation-related economic activities ranging from construction to services and tax revenues, are also important in decision making regarding wildland and fire management. The Outdoor Recreation Survey (Cordell et al. 1997) revealed that the quality of the scenery in recreation areas was “very” or “extremely” important to more than 75 percent of survey respondents. The safety and security of the recreation area generated high levels of response as well, ranging from 73 percent in the West to 84 percent in the South (Cordell et al. 1997). While these responses refer to a wide variety of places, including for example urban swimming pools, picnic areas, etc., it is not unreasonable to assume that safety from natural hazards is also important for a large proportion of visitors.

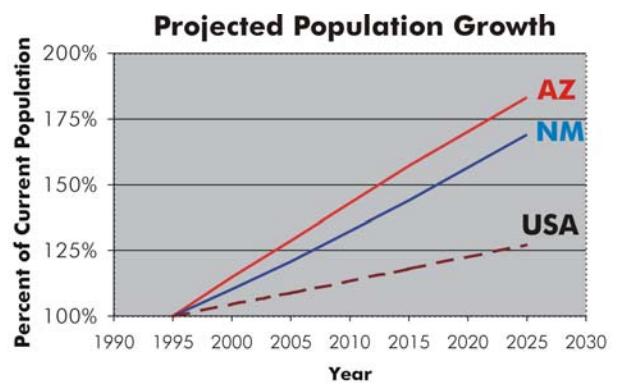
In response to a question about whether management is well balanced between use and protection of recreational areas, more than half of all those surveyed agreed that this was the case. On the other hand, 26.1 percent of those along the Pacific Coast and 21

percent of those in the rest of the West disagreed, suggesting the significant extent to which how best to manage of western lands remains a contested issue. Even more revealing are the responses to the statement, “government should allow more private development on public lands.” Here, 45 percent of respondents in the North disagreed, as did 44 percent in the South. Significantly, fully 53 percent of those in the Pacific Coast region and 55 percent of those in the rest of the West disagreed. These opinions are important, for they contradict actual trends, which show continued expansion into wildlands, as well as expansion of the urban-wildland interface, another factor that must be considered in the context of wildfire risk.

As discussed below, fire is a part of the natural process in the western United States, but at the same time may pose substantial risks to both visitors and residents. These risks exist in a complex context of growing outdoor recreation activity, increasing pressure on natural resources, expansion of human habitation ever farther into wildland areas, significant contests involving traditional resource-dependent activities such as ranching and logging and environmental advocates, fluctuating levels of resources for management of recreational lands and resources, and relative level of economic dependence on recreation and tourism.

## **Wildfire and Recreation in the U.S. West**

The U.S. West is internationally known for its scenic beauty and the wide array of recreational opportunities available. In recent decades, the West has become a magnet for population growth (see Figure 2) and economic development in no small part because of the available recreational amenities. Tourism dollars are a significant source of income in the region and may be crucial to the vitality of some communities, particularly those located in or near major recreation and tourism



**Fig. 2** Arizona and New Mexico are expected to continue growing at a much more rapid rate than the US as a whole (source: US Census and CLIMAS 2000).

destination areas. For example, according to one estimate, tourism accounts for \$12 billion in the economy of Arizona; it generates 115,000 jobs and supports an additional 185,000 indirect jobs (Arizona Department of Commerce, 2001). In rural communities, dependence on recreation and tourism income can be particularly high. Many of these same areas are areas of high wildfire risk, due to a combination of factors: fire-adapted ecosystems, increasing human encroachment on wildland areas, and a century of fire suppression that has resulted in development of exceptionally high fuel loads. Added to these factors, the region is characterized by a high degree of climate variability, both temporally and spatially (Sheppard et al. 1999).

According to forest managers, residents within the southwestern region account for much of the recreational activity in the region. This reinforces research findings indicating that people in the United States now tend to spend shorter amounts of time and to travel shorter distances engage in recreational activities (Cordell et al. 1997). Knowing patterns of wildland visitation, including points of origin as well as destination, activity, and length of stay, can be valuable sources of insight into the extent and nature of fire risk. Such information may also provide insights into the extent and nature of humanly caused wildland fire, as well as the interactions between human behavior, fuel condition, and climatic conditions.

While data analyses for the southwestern states of Arizona and New Mexico are not currently available, data for California provide insights into the value of recreation in the United States, particularly in the U.S. West. These data indicate that the annual average value of recreation in the state is \$1.5 billion. The impacts of wildfire on recreation values are estimated to range from \$5 per average acre burned on BLM lands to \$107 per average acre burned on lands in the state park system. In areas that are scenic, visible or publicly accessible burn, the value is estimated to be much higher (Forest Products Laboratory 2001). Based on US Forest Service data, wildland recreation in California has been estimated in recent years to average 112.1 million recreation visitor days per year (a recreation visitor day (RVD) is defined as 12 hours of participation in any recreation activity). The estimated average market value of this recreation is \$13.26 per RVD (Forest Products Laboratory 2001). Added to this are

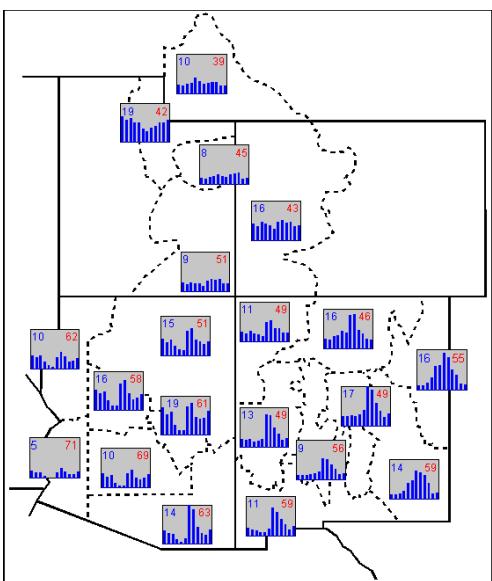
values associated with housing units existing in the urban-wildland interface (discussed later in this paper).

In the U.S. West and South, the widespread fires of summer 2000 produced exceptional losses. Contextualizing the season in terms of local impacts brings home the severity of the season. In remarks to the U.S. Senate Energy and Natural Resources Committee, Subcommittee on Forests and Public Lands Management (September 23, 2000), for example, Idaho Governor Dirk Kempthorne catalogued some of the impacts of fire in his state: 86,000 tons of smoke related pollution were released statewide; tourism fell by 60 percent because of the fires. A total of 1.2 million acres (485,640 hectares) burned in the state, consuming enough timber to build 100,000 single-family homes. In Montana, as a result of the 307,000-acre (124,243-hectare) fire that burned in the Bitterroot Mountains in the summer of 2000, businesses reported a loss of \$270 million; Montana recreation outfitters alone lost \$36 million in canceled trips. A total of 240 structures, including 70 homes, were lost in that fire (Grandstaff 2001).

### Climate in the US Southwest

In order to examine potential linkages among climate, wildfire, and outdoor recreation in

the southwestern United States, it is first necessary to have a basic understanding about the region's climate. At the annual timescale, the climate of the Southwestern United States (see Figure 3) is characterized by a bimodal regime, with precipitation concentrated in winter and summer months (see Sheppard et al. 1999 for a summary of scientific knowledge about climate in the region). The region lies at the interface between the subtropical and mid-latitude climate regimes. It is dominated by the North American monsoon, with related convective storm activity in the summer, and frontal activity in the winter. Precipitation may



**Fig. 3** Precipitation by Month, Colorado River Basin (source: Sheppard et al. 1999).

also occur during the fall due to tropical storm activity. Spring, by contrast, tends to be quite dry. Summer rainfall tends to be highly localized, depending on storm cell location and intensity of convection. Microbursts occurring over a few kilometers are not uncommon. By contrast, winter precipitation tends to be broader in geographical extent and longer lasting in terms of duration, though less intense. While summer precipitation typically is greater in volume, winter precipitation is more important with regard to contributions to streamflow, groundwater discharge, as well as to overall moisture levels that influence levels of fire hazard.

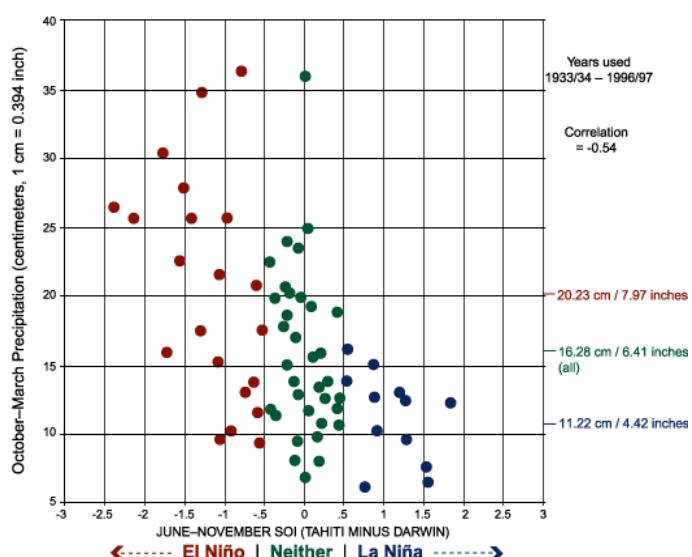
The climate of the Southwest is characterized by a high degree of spatial and temporal variability (Sheppard et al. 1999). This variability is associated with the area's high variation in topographic relief (see Figure 4), its location (with regard to atmospheric circulation) in the interface between the subtropical



**Fig. 4** Topographic Relief, US Southwest

and midlatitude climate regimes, and the influence of synoptic-scale climate processes.

Lowland desert areas tend to receive much less precipitation than do high-elevation areas. Temporal variation in the quantity and quality of snowpack is also important, since both the depth and water equivalence of the snow influence fuel

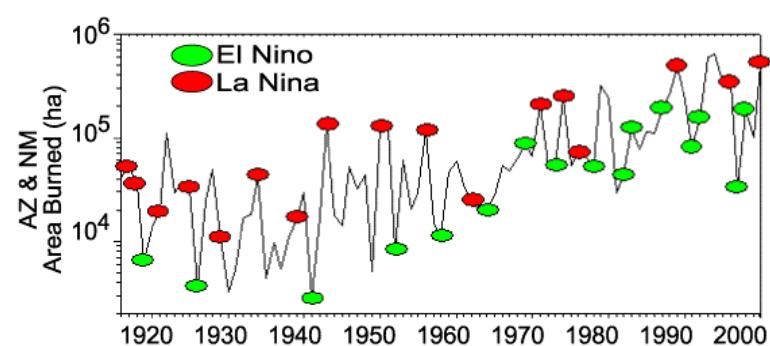


**Fig. 5** ENSO Impact Patterns on Precipitation in the US Southwest (source: T. Pagano, 2001).

moisture levels over the typically dry spring months. Viewed from a regional scale, these months constitute the height of season in the Southwest. Viewed from the perspective of interannual timescales, winter climatic variability in the Southwest is influenced by El Niño-Southern Oscillation (ENSO), with El Niños tending, on average, to produce higher than normal winter precipitation and lower temperatures and La Niñas tending even more strongly to produce drier than normal conditions (see Figure 5).

Dendrochronological research, based on tree-ring archives for the past 500 years, shows that large, regionally extensive fire years correlate to particular patterns of wet/dry climate patterns (Grissino-Mayer and Swetnam 2000, Swetnam and Betancourt 1990, 1998, 1999). As illustrated in Figure 7, ENSO conditions correspond to many significant

fire years. Of particular note, multi-year climate sequences consisting of one or a few abnormally wet years, followed directly by one or more very dry years, correlate with particularly large regional wildfires. Recent patterns bear



**Fig. 6** Relationship Between ENSO and Fire Occurrence: Arizona and New Mexico, 1920 – 2000 (source: T. Swetnam, 2001).

these findings out: the very wet El Niño winter of 1997-1998 was followed by the very dry La Niña winters of 1998-1999 and 1999-2000. A recent analysis found that, at the scale of the entire U.S. West, no significant statistical correlation existed between the relatively weak La Niña conditions during winter 1999-2000 and the 2000 fire season. Rather, the analysts suggested that perhaps anomalously warm tropospheric temperatures may have been implicated. They did note, however, that while the links between the 1999-2000 La Niña did not hold for the entire West, the strongest correlations were found between the two occurred in the Southwest (Brown and Hall 2001).

Whether or not ENSO was a significant influence on the 2001 wildfire season, dry conditions generated by longer-term climatic patterns were certainly implicated in the

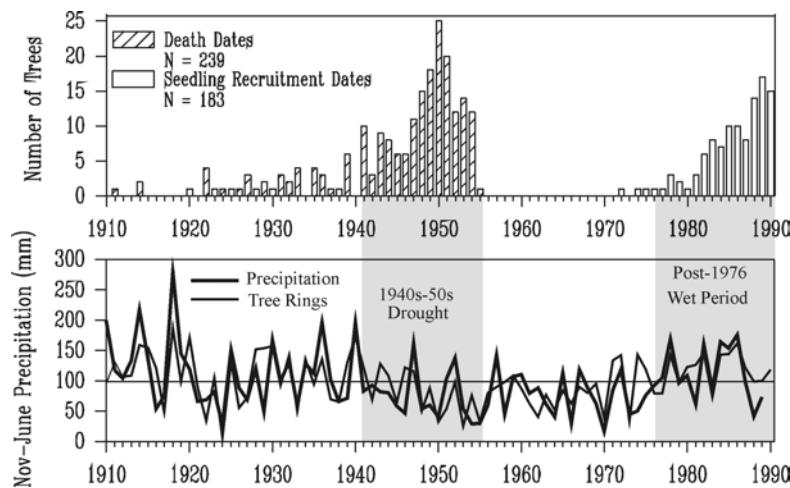
intensity and extent of wildfire activity. Specifically, dry conditions persisted throughout the winter; these conditions were followed by a very dry summer. The combination assured that fuel moisture levels would be exceedingly low, setting preconditions for widespread fire hazard. Many of the largest fires occurred in areas that had already been affected by extended drought conditions.

Recent advances in our ability to use ENSO measurements to forecast winter climate a year or more in advance, are allowing us to improve our capacity to predict relative changes wildfire risk at least a season in advance. Forecasting skill for non-ENSO winters, and for summer-season precipitation, remains extremely low in the Southwest. However, even in non-ENSO years, recent forecasts based on statistical approaches or ensemble analysis of multiple forecasts produced from an array of experimental and operational forecast sources are proving useful in predicting areas of greater and lesser wildfire risk at coarse scales of resolution.

Another climate regime affecting the U.S. Southwest, the Pacific Decadal Oscillation (PDO), appears to enhance the ENSO signal and thus may also influence wildfire regimes. In this case, the positive phase of the PDO may strengthen El Niños (generating a greater potential for wetter than normal El Niño winters) while the negative phase may strengthen dry conditions in La Niña winters (Sheppard et al 1999). These conditions, by influencing vegetation growth and fuel moisture levels, may enhance or reduce chances for large wildfire events, though considerable research and longer-term monitoring is required to affirm linkages between PDO and wildfire in the region.

In general, however, in the Southwest, the PDO tends to strengthen or weaken the ENSO signal, depending on whether the two are in phase or out of phase. There is some evidence that we have experienced a shift in PDO regime in the past few years to the negative signal, which could result in overall decadal or longer drier conditions in the Southwest, thus possibly weakening El Niño (wet) and strengthening La Niña (dry) impacts. The last time the Southwest experienced this phase of the PDO was in the 1950s, when decadal-scale drought conditions plagued the region (Swetnam and Betancourt 1998). As indicated in Figure 7, this was also a time of significant die-off of trees. Tree regeneration did not occur until the 1980s, which coincides with a positive

(stronger El Niño) phase of the PDO. Scientific corroboration of the connection between PDO patterns and tree die-off and regeneration remains to be made, however.



**Fig. 7** Tree Death and Recruitment Relative to Extended Drought and Wet Periods 1910 – 1990 (source: J. Betancourt and T. Swetnam, unpublished).

### Climate and Fire in the Context of Recreation in the U.S. Southwest

Recreation and tourism are very important to the economies and lifestyles of residents of the Southwest, and the many scenic areas provide abundant vacation opportunities for people from the U.S. and from abroad. National Park Service data for 1998, for example, show 12.8 million visits to NPS units in the region, with 11.6 visits occurring in Arizona and 2.1 million in New Mexico (which has fewer national park lands) (Merideth, 2001) (see Table 1).

In the Southwest, most of the wildland recreational activity occurs on public lands. The large extent of public (largely federal) ownership of lands in the region has significant implications for managing tourism in the context of climate and wildfire, for each land management agency has its own rules and policies, even though they all cooperate in fire management through an inter-agency organization, the National Interagency Fire Center (NIFC).

The National Park Service, within the U.S. Department of the Interior (DOI), has a longstanding practice of minimizing interference in natural processes. By contrast, the Bureau of Land Management, also within DOI, actively manages most of its lands for

maximum forage production (the agency also manages some wilderness and protected areas where less-intrusive management is practiced) and for other “multiple use” objectives. The Forest Service, within the U.S. Department of Agriculture (USDA) and the second-largest U.S. land management agency (BLM is the largest in terms of land managed), has found itself increasingly managing its lands for recreational uses, as opposed to earlier emphases on resource extraction activities such as timber production, livestock grazing, and mineral exploration. Like the other agencies, the USFS also has wilderness and other protected areas that it manages with minimal intrusion. Fire suppression, until the past couple of decades, has been the predominant policy with regard to fire management for all non-wilderness areas. While this policy has resulted in the kind of dense forests beloved by many recreational users, it has also created conditions of high fire danger.

All of the agencies distribute leaflets about wildfire hazard and many provide other interpretive information about the benefits and dangers of fire at visitor centers and headquarters. Written policies are also in place requiring posting of information about fire danger and prescribed fire activity. The web sites for the national forest units may provide short-term weather forecasts and average climate information as well. However, there is very little information available to the public that correlates climatic conditions and trends with actual or potential fire danger. For organizations and firms specializing in recreation and tourism at scales from the global to the local, as well as for individuals, such information has potential to beneficially influence planning and decision making within this sector. Likewise, for emergency personnel, climate information may assist in efforts to plan for potential need to take extra steps to protect recreational visitors. This is no small responsibility, as exemplified by a 1996 fire in the Grand Canyon area, when ten hikers had to be airlifted out of the Canyon by helicopter, a dangerous operation even in the best of times. In that same time period and area, 21 firefighters were sent to the hospital, and two neighborhoods in Flagstaff, Arizona were evacuated (CNN 1996).

### **The Urban-Wildland Interface and the Southwest**

The urban-wildland interface constitutes a growing issue throughout much of the country, but especially in U.S. West and Southwest, due to an increasing desire to locate

residential and commercial structures located in or near fire-prone wildland areas . Ewert (1993) has catalogued a variety of definitions for the term: (a) two traditional land uses that occur near or adjacent to each other (Bradley 1984); (b) an area of interaction between different political forces and potentially competing interests (Vaux 1982); (c) a residential/wildland interface that represents areas where problems are related to the urban environment (Lee 1984); (d) a natural resource ‘ecotone’ where a transition occurs between two communities comprising urban and natural environments and containing characteristics of both; the zone has unique attributes as well (Hansen 1962). Ewert stresses that important differences exist between interface areas and more remote locations, based on functionality. The urban-wildland interface, he maintains, provides an array functions, including outdoor recreation, watershed services (water quality and quantity), improvement in air quality, commodity production, reduced stormwater runoff peak flows, close-by wildlife habitat, and space for urban and industrial development. These areas also provide restorative environments (see Kaplan and Caplan 1989).

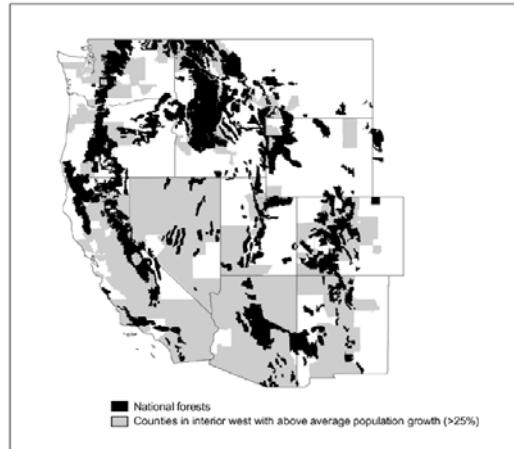
The interface has also been broadly defined as “the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels” (National Wildland/Urban Interface Fire Program, no date, <http://www.firewise.org/>). Forested areas have especially high value for residential development, both for year-round and recreational use (see Figure 8 for an illustration of growth patterns near national forests in the U.S. western states). Property values may be significantly enhanced in a forested setting, yet closely spaced trees, picturesque roofs with wood shingles, perimeter areas filled with pine needles, a large woodpile close to the house, and other elements actually increase fire hazard considerably. A program initiated through a collaboration of the U.S. Forest Service, National Association of Foresters, U.S. Bureau of Land Management and Bureau of Indian Affairs, National Park Service, US Fish and Wildlife Service and National Fire Protection Association seeks to educate residents in interface areas about how to protect their properties and lives from devastating wildfire, and how to work together to minimize the risk (see <http://www.firewise.org/> communities). The program was established in the wake of devastating wildland fires and loss of more than 1400 homes in California and Florida in 1985.

However, this program has not yet incorporated climate considerations into its risk evaluation and mitigation process.

Data assembled for California provide some basic insights into the magnitude of potential risk fire risk at the urban-wildland interface. According to 1995 data from the California Department of Forestry and Fire Protection, 35 percent of the state is considered to be in the urban-wildland interface zone; 25 percent of the state's population is estimated to live in this zone. Another report notes that there are an estimated 1 million housing units in wildlands or in the interface zone in California. The estimated replacement

values of these homes is \$107 billion for the structures alone. Fire records for the time period 1985 – 1994 indicate that some 703 homes are lost each year to wildfire in the state. The average loss per home burned (including value of contents and other tangibles and intangibles) amounts to some \$232,000. The average total annual monetary loss associated with loss of homes to wildfire in the state is \$163 million. According to the Insurance Services Office, Property Claims Services, between 1970 and 1993, there were \$3.5 billion in inflation-adjusted losses occurring from catastrophic wildfires.

Data for Arizona indicate that 129,680 homes are at risk from wildfire. The number of household members at risk has been estimated at 341,058, and the projected value of loss from these homes burning at \$10,387,368 (Polley and Thal 2001). The nature of the interface varies widely in the Southwest. Flagstaff, for example, a scenic and rapidly growing city in northern Arizona, is situated on a large, high-elevation plateau in the midst of mixed conifer landscape. The city has 40,000 acres (16,188 hectares) in the urban wildland interface. By contrast, Tucson, Arizona, located at the base of three mountain ranges in the Sonoran desert in the southern part of the state, has approximately 34,000 acres (13,760 hectares) of wildlands are in the urban interface zone



**Fig. 8** County-Level Population Growth >25% and Location of National Forests (source: US Government Accounting Office, 1999).

(<http://www.fs.fed.us/r3/coronado/fire>). Here, the steep gradient from the desert floor to the highest peaks, approximately 2,500 feet above sea level to some 10,000 feet (4345 m to 3048 m) provides an environment in which fires may burn through vegetation ranging from cactus forests through chaparral, oak, pine and spruce-fir forests. This transition among vegetation types occurs within 27 miles (43.45 km), which is equivalent to the kinds of changes one normally sees when traveling from Mexico to Canada. The at-risk interface areas are located in the foothills adjoining the Santa Catalina, Rincon, and Santa Rita Mountains that lie, respectively, on the northern, eastern, and southern sides of the city. The fact that the wildlands are within full view of the city, where those watching the fire may voice strong demands for aggressive interventions that may, for example, put fire fighters at high risk adds to the challenges managers face in managing fires in this zone. Further, heavy use of the wildlands at the interface pose challenges for fire management. The Santa Catalina Mountains alone feature more than 1,100 miles of trails, a small lake, a ski resort, campgrounds, and picnic areas. A small permanent community, Summerhaven, is located on top of Mount Lemmon in the Catalinas. This community, which has a permanent population of about 100 and a seasonal population of about 300, is at especially high risk of destruction from wildfire and poses large problems for protection of residents in that it has only one paved escape route.

All of the mountain areas in the Tucson area, as well as in other urban-wildland interface areas of the state, receive heavy recreational use. Serious issues exist with regard to lack of sufficient evacuation routes in most of these areas. Further, while signs advise visitors of fire hazard, based on assessment of current weather conditions and related fuel moisture, there is no good information available about longer-term fire hazard based on assessment of climate impacts on fuels.

Fire managers on Coronado National Forest, in southeastern Arizona, regularly carry out prescribed burns, generally at a scale of 2,000 to 6,000 acres (809 to 2,428 hectares) per year, to decrease the risk of damaging wildfires. Even so, they anticipate an increase the number of management-ignited and non-suppressed, naturally occurring burns in the future. At the same time, with urban growth continuing in the interface zone, the imperative to reduce fire hazard continues to intensify. Whether thinning and prescribed burning can sufficiently reduce the risk of catastrophic losses from wildfire in

urban interface areas of the Southwest is an open, and intensely debated, question. Local fire ecology experts express serious doubts that wildfire events can be prevented, even with these measures, due to the exceptionally large amounts of fuels that need to be cleared out and a related lack of sufficient institutional and resource capacity to reduce hazard levels in any relatively short time frame. Equally challenging is convincing the public that open, park-like vistas are more desirable and valuable than the dense forests that most people are accustomed to enjoying.

The kinds of risks described above are increasing across the Southwest, including areas that have up until now been relatively remote from “urban” encroachment. For example, the Chiricahua Mountains, in southeastern Arizona, have traditionally been surrounded by rural uses, particularly ranching. But now, with aging of the ranching population and increased conversion of open spaces to alternative uses (especially primary and secondary residences), the nature of fire risk is changing, and interface-related fire risks are certain to escalate.

Even remote protected areas may present considerable risk. At Chiricahua National Monument, located about 3 hours’ drive southeast of Tucson, visitation averages around 85,000 people a year. Heaviest visitation occurs in the spring, the season when wildfire danger is highest due to the typically dry conditions that prevail April, May and June. Dry conditions over one or more preceding winters can produce increased fire risk during these months. The use of the canyon bottoms (which are full of hazardous fuels) for hiking, and the location of visitor facilities and residences of staff members in a box canyon that has only one outlet, pose potential challenges for staff who may have to evacuate themselves and visitors rapidly. The Monument’s wildfire management plan (NPS 1992) stipulates that areas can be closed if staff believe fire danger warrants such action, but does not explicitly link climate with assessment of fire danger. With increased conversion of surrounding ranchlands into seasonal and permanent residences, and with what is likely to be a related rise in recreational activities in the Monument and surrounding Chiricahua National Forest, recreation-related wildfire risk is sure to increase.

The story of the Cerro Grande Fire in Los Alamos, New Mexico illustrates many of the issues raised in this paper. This fire was set as a prescribed burn in May 2000 in a high-elevation forested area of Bandelier National Monument but escaped, eventually burning 43,000 acres (17,402 hectares). Costs and losses associated with the fire are estimated to exceed US\$1 billion. The fire destroyed more than 200 homes and other

structures. Some 18,000 people were evacuated from the communities of Los Alamos and White Rock. Residents came back to a severely altered landscape: many of their favorite hiking areas had been transformed from inviting forests and trails to moonscapes of charred remains. Subsequent reseeding and relatively wet winter conditions restored a green carpet to much of the area, but recreation options

**Fig. 9** Popular Recreational Trail After Cerro Grande Fire, Los Alamos New Mexico, May 2000 (source: D. Honeyman).

have been altered radically (see Figure 9). Some areas remain off-limits entirely; others will not return to their forested state for fifty years or more (Ramos and Pearcy 2000, Foxx 2001).

The original prescribed burn was one of a series of fires that had been detailed earlier in the Monument's fire management plan. The decision to light the fire was based on an assessment that fuel moisture conditions in that particular area were conducive to setting a controllable fire (see NPS 2000). However, the assessment did not take into account essential information about the fuel conditions in nearby lower elevations, nor did it take into account climate information which indicated that (a) strong winds were typical at that time of year and (b) based on more than 500 years of fire history data, a wet year, followed by one or more dry years, were highly correlated with major wildfires (NPS 2000; see also, e.g., Swetnam, Allen and Betancourt 1999). This was very much the case, for a very wet 1997-98 El Niño was followed by dry winters in 1998-99 and 1999-2000.



Scientists speaking at a workshop, held in February 2000 to alert fire managers about exceptionally strong potential for widespread wildfire in the US Southeast, Southwest, Intermountain West, and Pacific Coast regions, had stressed that prescribed burns should not be set during the 2000 fire season, based on the pattern of climatic events and existing fuel load conditions. Although individuals who might have influenced the process that ultimately resulted in the Cerro Grande fire participated in the workshop, analysis of the post-fire assessment (NPS 2000) reveals that embedded knowledge and practices of decision makers prevailed over openness to incorporating alternative information. The workshop, one of a series subsequently organized by the Institute for the University of Arizona's Institute for the Study of Planet Earth (ISPE) and Laboratory for Tree-Ring Research (LTRR), specifically aimed to establish communications between fire managers and climatologists in order to "raise a red flag" that the probabilities were very high that it would be a bad fire year for much of the West, Southwest, and Southeast. The fire year turned out to be worse than anyone anticipated.

### **Introducing Climate Information into Strategic Wildfire Planning**

Information is significantly lacking about how many visitors are in wildland areas of the Southwest at any given time. Even in areas where visitors must pay an entry fee or obtain a back country permit, long-term records of visitation patterns by month or by season may not be available in any usable form. This makes it very difficult to track climate influences on visitation patterns in terms of numbers of visitors, where they came from, where they are going, length of stay, and proposed activities. It also confounds efforts to incorporate recreational patterns and visitor data into climate-related fire risk assessments.

Nevertheless, climate impacts can be assessed in other ways, notably with regard to influence not only on fire regimes, but also on policy making and institutional change. Integrated assessment projects, such as the Climate Assessment for the Southwest (CLIMAS) project, funded by the Office of Global Programs of the U.S. National Oceanic and Atmospheric Administration (NOAA-OGP), afford a multidisciplinary approach to incorporating such issues into assessments of climate sensitivity, vulnerability, and adaptation capacity. Further, through providing Web-based information

and holding events such as fire-climate workshops (see, e.g., Garfin and Morehouse 2001), researchers associated with the University of Arizona (Tucson, Arizona) and the Desert Research Institute (Reno, Nevada) seek to build skills among fire managers, land managers, and other decision makers in interpreting and using climate information and climate forecasts (<http://www.ispe.arizona.edu/CLIMAS> and <http://www.dri.edu/CEFA>).

Three fire-climate workshops have been held to date, one in winter 2000, and two in the late winter of 2001. Each was supported by funds from the University of Arizona's Institute for the Study of Planet Earth, NOAA-OGP, and the U.S. Forest Service's Riverside Fire Laboratory; the two workshops held in late winter 2001 were also supported by funding from the Joint Fire Science Program of the National Interagency Fire Center. At the workshops, climatologists and fire researchers are encouraged to identify information needs, as well as the possibilities and caveats associated with using such information. Many of these discussions focus on the use and utility of climate forecasts as well as of historical and paleoclimate information and fuel load assessments. Spatial scales of the climate information provided range from global to local and temporal scales range from one month to seasonal, annual, and interannual. Among the primary goals of the workshops is providing information useful for improving strategic planning for prescribed burns and anticipating resource needs to fight wildfire before and during the fire season in each region. Tourism and recreation concerns need to be explicitly addressed in venues such as these, as well as in projects aimed at development of new decision support tools to be used for anticipating and planning for fire risk. As discussed below, this task has multiple facets and requires multiple research and information/knowledge transfer strategies.

### **Conclusions and Recommendations**

In the aftermath of the Summer 2000 wildfires, the U.S. Congress appropriated \$1.8 billion for wildfire management. An initiative is underway to assure that some of this funding goes toward fire-climate research and improving the use of climate information in fire planning. One goal of such research should be identification of vulnerabilities and existing adaptation strategies associated with recreation and tourism in and near wildlands. Another should be development of a better understanding of the institutional

factors that either facilitate or constrain adoption of new knowledge and information by both resource managers and the recreation/tourism industries. Further, improvements are needed with regard to understanding in the public values, perceptions, and beliefs that influence decisions about recreation—including location, duration, and types of activity as well as any trends influencing values, perceptions, and beliefs. We also need to continue working on identifying the kinds of climate information needed to prepare for and respond to changes in wildfire hazard, as well as how best to disseminate the information effectively to the wide range of potential users of such information.

Climate forecasts have potential to furnish valuable input to fire planning processes, including planning for prescribed burns as well as for anticipating resource needs associated with seasonal wildfire projections. However, the potential benefits of climate information for fire management have not yet been fully assessed, largely because such forecasts have not yet been fully integrated into strategic planning processes and policies. Optimism exists that climate information will soon begin to play a role in planning and decision making processes. For example, the Joint Fire Science Program, an interagency initiative that (among other things) coordinates fire research and funds research projects, included climate climate-fire research and introduction of climate information into decision processes in recent calls for research proposals.

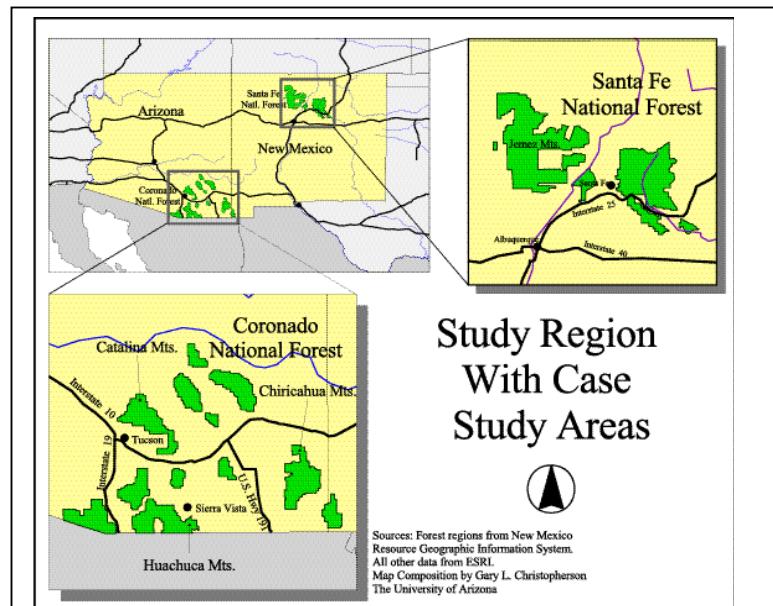
In the Southwest, such concerns, as well as other issues related to developing better scientific knowledge and better ways to visualize and communicate complex scientific information, are being addressed through a number of avenues, including development of experimental web-based information products aimed at both experts and non-experts, and development of proposals for funding of research projects designed to develop new scientific knowledge and improve our understanding of the structural and institutional factors facilitating or impeding the adoption and use of climate information and forecasts.

Such projects hold promise for improving communications among scientists, decision makers, and the public, including the many people who engage in recreation on fire-prone lands. University of Arizona researchers associated with WALTER (Wildland Alternatives project), for example, are currently working on a project funded by the U.S. Environmental Protection Agency, to build an integrated, GIS-based model for use in

strategic planning for fire management. The model, FCS-1, focuses on four specific mountain ranges, the Jemez Mountains in New Mexico and the Chiricahua, Huachuca, and Santa Catalina-Rincon Mountains in Arizona (see Figure 10). The model combines climate, fuels (see Figure 11), fire history, and social factors in a manner that will allow users to build scenarios through modifying parameters, and thus produce a map showing the spread of a hypothetical fire based on the scenario constructed. The intent is to construct a prototype that can be refined through further research and development and that can be modified for use in other geographical areas. While fully using the model will require considerable expertise to run, a simplified version is expected to be made available to non-experts, including community members in each of the study areas.

As noted above, the CLIMAS Project sponsors an annual fire-climate workshop for addressing common

research issues as well as presenting forecast information for the coming fire season. The project also proposes to add mesoscale analysis of climate-fire relationships in the Southwest within the next two years. The goal of this initiative is to develop information needed to improve regional fire-climate prediction and modeling capacity. In addition, research is currently underway to develop new techniques for building knowledge about the many institutional factors that may influence the integration of climate information and forecasts into decision making processes.



**Fig. 10** The FCS-1 case study sites include three mountain ranges in southeastern Arizona, and one in northern New Mexico (source: Center for Applied Spatial Analysis, University of Arizona).

The impacts of climate variability and change on tourism and recreation remain seriously understudied; this is an area that clearly needs to be addressed. The need is very apparent with regard to the U.S. Southwest, where recreational activities and residential development are generating intensive impacts on wildlands and wildland interface areas. In this context, not only are climatic patterns of importance for protecting individuals, communities, and property, but human activities are crucial to the development of fire regimes in the context of climatic variability and change. Attaining the kinds of information needed to address these questions requires long-term research and monitoring. This in turn requires a much more focused effort on tracking recreational use patterns, as well as assessment of changes in cultural values, institutions, and policies.

Substantial links exist between recreation, forest fire, and climate in the southwestern United States. Yet knowledge of how the three factors interact to produce varying levels of risk not only in terms of fire hazard to recreational users, but also in

terms of economic impacts and community resilience and adaptation capacity. Further, fire itself, as well as the impacts of prevention and mitigation strategies (including the use of climate information), may have significant but as yet poorly understood impacts on social and cultural structures and values. Much research remains to be done to better understand these issues. Carrying out such research requires much better data than are currently available, particularly

**Fig. 11** Heavy Fuel Load Conditions in the Santa Catalina Mountains (source: B. Morehouse).

at the level of individual public lands units. Such data needs to be collected regularly and in a methodologically consistent fashion, with the goal of building long-term time series. Both collection and archiving of these data need to be standardized in order to allow comparisons at local, regional, national, and international scales. The international component is important for developing comparative studies across the globe and is essential in regions, such as the U.S. Southwest, that are located along international



borders. Finally, communication of the data must be carried out in a fashion that emphasizes transparency; that is, the procedures used to collect the data, the means of archiving, any caveats related to the use of the data, and other such information must be readily available and understandable not only to scholarly researchers but also to those in the public and private sectors who seek to use the data.

Addressing the above requirements would facilitate not only research within particular localities, regions, or nations, but also comparisons across different geographical areas, climate regimes, and ecosystem types around the world. From the perspective of fire-climate-recreation/tourism research, investigations focusing on links among these elements in arid and semiarid lands is especially needed, particularly those which explore how to expand the range of information available for making decisions about where, when, and how long in advance to plan for utilization of fire-prone lands and resources. Such research should aim to integrate perspectives from a variety of natural-science and social-science disciplines as well as those of government agencies, communities and individuals whose missions, activities and livelihoods may be seriously affected by wildfire events. In addition, regular interactions among all of these entities should be supported. Such interactions would be very useful for sharing knowledge and experiences, identifying commonalities and differences among regions and social systems, and ultimately working toward development of common techniques and theories for assessing the implications of climate and wildfire for the very important areas of tourism and recreation.

### **Acknowledgements**

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# **Climatological basis for planning in mountain recreation**

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## **Abstract**

The following paper contains the analyses of main climate elements with the special emphasis on snow regime, especially on snow depth, as well as minimum temperature and relative humidity relations. Annual course of relevant climatological parameters has been performed by means of 10-day period means. The example of the presentation of bioclimate conditions, which can be also applied for the mountainous resort planning, can be found in the paper by Zaninovic, 2001.

The analyses have been made for the northern part of the mountain Velebit in Croatian part of the Dinaric Alps (Zavizan, 1961-1990). This area has been mainly intended for tourism and recreation. This mountainous ridge presents the boundary between the maritime climate at the Adriatic coast and mountain continental climate over the inland. Its summit area experience abundant amounts of snow with long lasting snow cover especially on the eastern slopes exposed to the continental influence.

**Key words:** annual course, extreme value analysis, snowmaking, mountain recreation, Croatia

## **Introduction**

Planning of recreation activities and design of objects in mountainous regions requires meteorological analyses that pay special attention to the extreme climate conditions. In such cases the land use decisions do not primarily depend on thermal comfort values. In the case of ski resort planning the decisions are based in the first place on snow conditions which are supposed to be the natural resource for the development of winter snow recreation over the region. Depending on the frequency of simultaneous appearance of adequate minimum temperatures and relative humidity snowmaking could be introduced in order to make the ski season longer and in such a way a winter resort economically operational.

## Data and methods

Mountain Velebit is located along the eastern Adriatic coast 150 km in length with the highest summits of about 1700 m a.s.l. The specific mountain climate of Velebit under the strong maritime influence has been performed for the purpose of planning in mountain recreation by the annual course of 10-day period means and frequencies (number of days) of different climatological parameters. It is supposed that ten-day period is much more convenient for holiday planning than most frequently used monthly interval. The estimation of snow has been deduced by means of Jenkinson GEV distribution (general extreme value distribution). The appearance and duration of snow cover with different snow depths, as well as the frequency of simultaneous appearance of determined minimum temperatures and relative humidity have been analysed in more detail.

The data basis for these analyses have been meteorological measurements during the period 1961-1990 at the main meteorological station Zavizan located on the northern part of Velebit Mountain at 1594 m a.s.l.

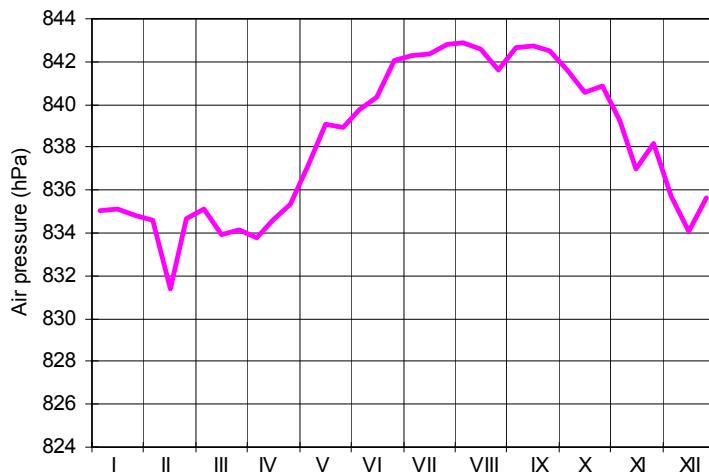


**Fig. 1** Position of meteorological station Zavizan at the top of Velebit Mountain, Dinaric Alps

## Results

### Air pressure

Time variations of air pressure presented by the ten-day period means (Fig. 2) show the dependence on general circulation of atmosphere, altitude, as well as continental or maritime influence of ground. During winter and early spring the air pressure changes are under the dominant influence of general circulation characterised by extended and well developed, frequently stationary anticyclones and cyclones with great pressure gradient at the boundary of the system. During the warm part of the year, especially during summer, general circulation is weaker, and the other influences, as dependence with altitude, are more expressed. The mean air pressure changes very little. At the summit area of mountain Velebit, which corresponds to the height of 850 hPa level, mean air pressure increases constantly from April to July, and reaches its maximum in August. This course is typical for the mountainous areas of Croatian continental inland.



**Fig. 2** Annual course of 10-day period means of air pressure. Zavizan, 1961-1990.

### Air temperature

Mean monthly air temperature values are on average between  $-4.2^{\circ}\text{C}$  in January and February and  $12.1^{\circ}\text{C}$  in July (Fig. 9). Mean daily temperatures less than  $0^{\circ}\text{C}$  appear from the middle of the second decade of November till the beginning of the third decade in March as well as about the middle of April. The warmest days are from the middle of July till the mid of August, when daily means are on average

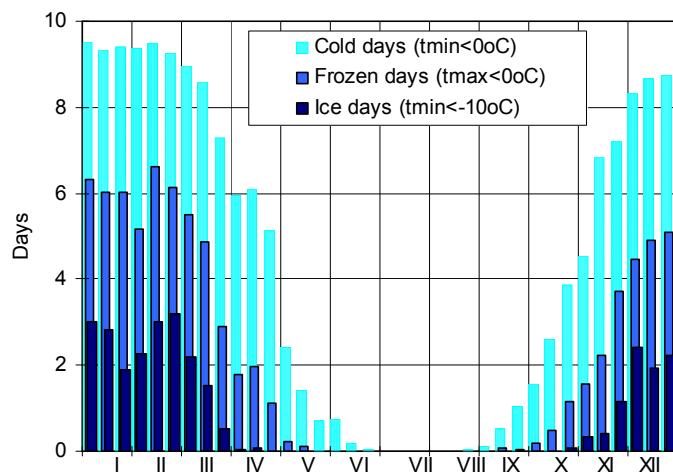
between 12°C and 14°C. Mean daily temperatures are more stable during summer (standard deviation is 3.3-3.4°C) than during winter (standard deviation is 4.8-5.1°C).

Annual maximum temperatures mainly do not exceed 25°C. Absolute maximum measured during the observed period was 27.6°C (Tab. 1).

Absolute minimum temperatures less than 0°C can be expected in all months except in July. They appear every year in the period from October to April. The probability for their non-appearance is very small in May (7%), and in September 37%.

**Table 1** Absolute maximum and minimum temperatures. Zavizan, 1961-1990.

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Max (°C)	11.2	13.7	16.5	16.6	20.6	22.6	27.6	25.7	27.2	20.3	16.4	14.4	27.6
Min (°C)	-24.5	-21.7	-22.6	-10.8	-9.8	-3.1	0.2	-0.4	-3.8	-10.1	-16.8	-23.2	-24.5



**Fig. 3** Annual course of 10-day period mean number of days with different extreme temperatures. Zavizan, 1961-1990.

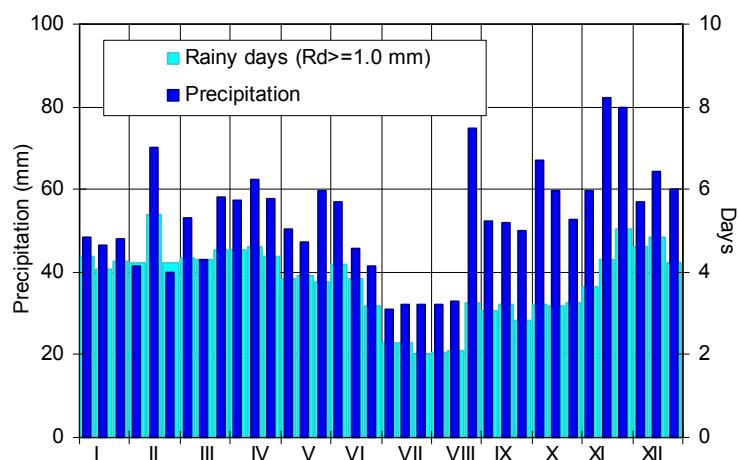
At the top area of mountain Velebit the hot days ( $t_{\max} \geq 30^{\circ}\text{C}$ ) do not appear, the day with the warm night ( $t_{\min} \geq 20^{\circ}\text{C}$ ) appeared only once during the observed 30 years and this happened in the third decade of July. Warm days ( $t_{\max} \geq 25^{\circ}\text{C}$ ) are also rare (6 in 30 years). Days with low temperatures are much more frequent. There are 29 days with  $t_{\min} \leq -10^{\circ}\text{C}$  during the year, 23 of them in winter. 79 days with  $t_{\max} < 0^{\circ}\text{C}$  appear during the period from the second decade of September till the second decade of May, the most frequently in winter (15-19 days per month, more rare in spring (0.3-13.6

days per month) and in autumn (0.1-7.5 days per month). Cold days ( $t_{\min} < 0^{\circ}\text{C}$ ) can be expected in all months except in July, although they are extraordinary rare in June and August. They appear in more than 25 days per month in the period from December to March (Fig. 3).

#### *Precipitation*

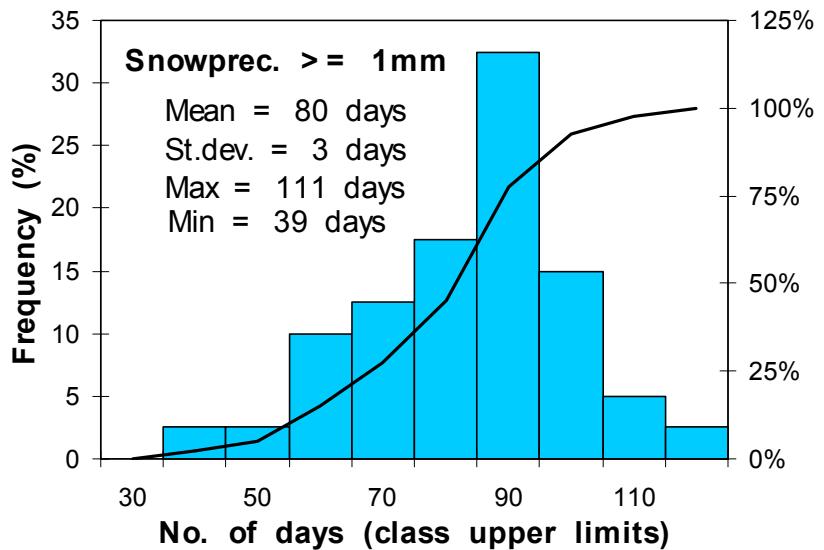
Annual course of precipitation show maritime characteristics with primary maximum in November (222 mm) and secondary one in May (178 mm), and minimum in July (95.5 mm) (Fig. 3).

The area at the top of northern Velebit experiences more than 10 rainy days monthly from October to June (about 14 days in December), and minimum in July (about 7 days). The mean number of rainy days for the 10-day periods is presented in Fig. 4.



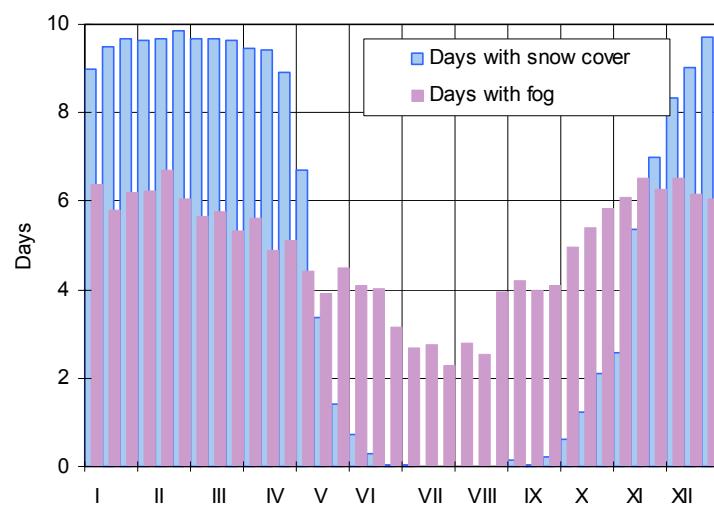
**Fig. 4** Annual course of 10-day period precipitation totals and mean number of rainy days. Zavizan, 1961-1990.

On the average the snow falls for the first time in the first half of October, and for the last time at the end of May. This means that the mean snow season lasts over more than seven months. Mean annual number of days when snow falls and snow precipitation amounts  $\geq 1\text{mm}$  is 80 days at Zavizan. During the year it falls in nearly equal number of days in each month from December to April (11.4-13.0 days) and in other months is rather rare (Tab. 2). Snow falls in 30-120 days annually with the greatest probability for the duration of 80 to 90 days.



**Fig. 5** Frequency of the mean number of days with snow precipitation  $\geq 1$  mm.  
Zavizan, 1953/54-1992/93.

Snow cover  $\geq 1\text{cm}$  can be expected from mid October to the second half of June. The occurrence of higher snow cover can be expected during shorter periods: snow cover  $\geq 10\text{ cm}$  from November the 10<sup>th</sup> till May the 13<sup>th</sup>, snow cover  $\geq 30\text{ cm}$  from November the 28<sup>th</sup> till May the 3<sup>rd</sup>, and snow cover  $\geq 50\text{ cm}$  from December the 22<sup>nd</sup> till April the 25<sup>th</sup>. During these periods snow cover of respective depths occurs in 83%, 84% namely 90% of days. The first and the last date of occurrence of snow cover with different depths are very variable from year to year.

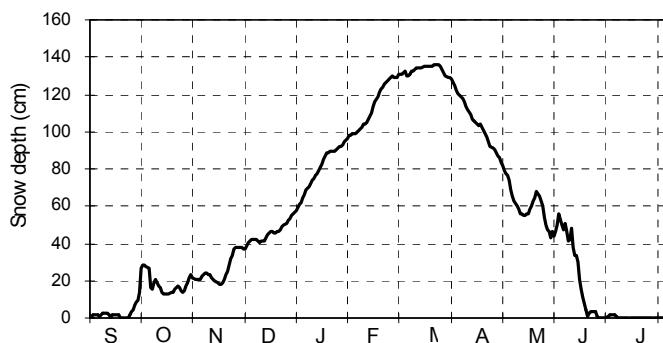


**Fig. 6** Annual course of 10-day period mean number of days with snow cover and days with fog. Zavizan, 1961-1990.

A snow cover  $\geq 30$  cm can be expected on average on 36% days/year and on 31% days/year it is not lower than 50 cm. These data are interesting as they provide information about the period when skiing is possible without greater problems.

In a “normal” snow season snow cover is present in all days in each month during the period January to March, in December in 22-31 days and in April in 26-30 days. At the end of autumn (November) snow will be on ground in 9-18 days and at the end of spring (May) the duration of snow cover is between 5 days and two weeks. Outside this interval snow cover is rather seldom phenomenon.

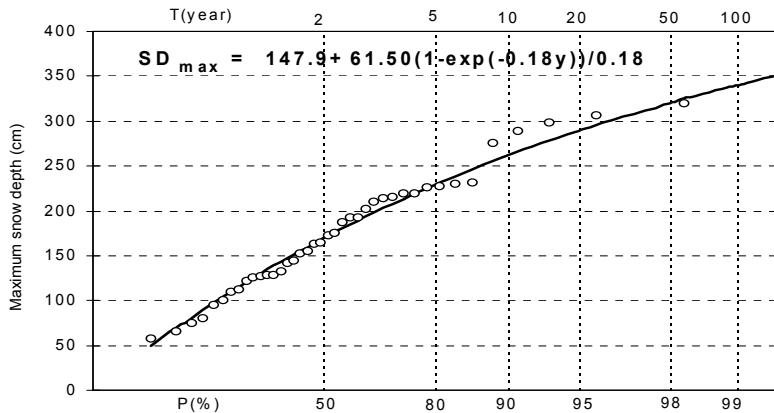
Annual course of mean daily snow depth, obtained as the 5-day period averages, presents an important information for different users (Fig. 7). Snow cover of about 20 cm during October and the first half of November rises up to about 60 cm till the end of December. At the end of January it achieves about 100 cm, in February 130 cm, and during March mean daily snow depth varies about this value. In April snow melts rather rapidly and at the end of month it amounts about 80 cm. In May and during the first half of June snow depth is very variable showing certain peaks.



**Fig. 7** Annual course of 5-day period mean snow depth. Zavizan, 1961-1990.

Annual maximum snow depth appears most frequently in March and in February. During the period 1953/54 to 1992/93 the greatest snow depth in particular winter was from 58 cm in winter 1988/89 to 320 cm in winter 1983/84 (Fig 7).

The estimation of annual maximum snow depth according to the Jenkinson GEV distribution (Jenkinson, 1969) enable the determination of expected maxima for particular return periods. For example, for the 50-year return period maximum snow depth of 320 cm can be expected to be exceeded by only a 2% probability on the top area of the mountain Velebit (Fig. 8).



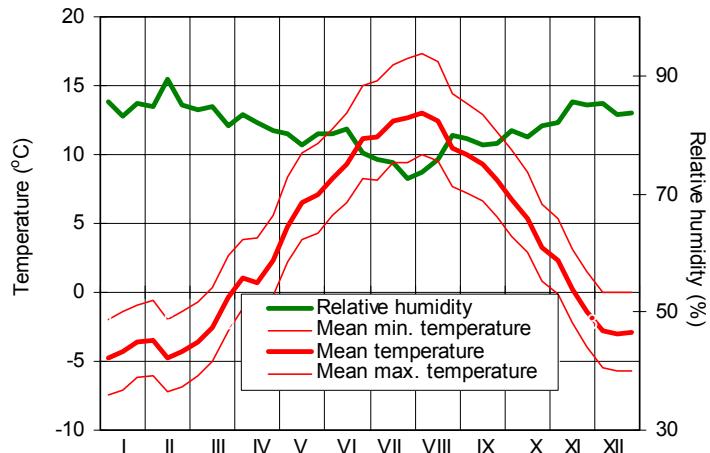
**Fig. 8** Estimates of maximum snow depth according to the Jenkinson GEV distribution for Zavizan. Period: 1953/54 - 1992/93.

**Table 2** Annual course of various snow parameters. Zavizan, 1953/54 - 1992/1993.

	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Snow season
No. of days with snow cover $\geq 10\text{cm}$													
Mean	0.0	0.1	2.0	9.5	22.1	27.9	27.0	29.8	26.1	9.2	0.5	0.0	154.0
No. of days with snow cover $\geq 30\text{cm}$													
Mean	0.0	0.0	0.9	4.5	15.8	24.7	26.0	29.2	23.7	6.7	0.3	0.0	131.7
No. of days with snow cover $\geq 50\text{cm}$													
Mean	0.0	0.0	0.3	2.5	10.6	21.0	24.4	27.5	20.5	4.6	0.2	0.0	111.6
No. of days with snow precipitation $\geq 0.1\text{mm}$													
Mean	0.0	0.6	3.4	8.2	12.5	12.5	13.0	13.0	11.4	4.0	1.0	0.2	79.6
Maximum depth of snow cover (cm)													
Max.	0	18	87	142	167	230	287	320	298	272	106	3	320

### Relative humidity

Mean monthly values of relative humidity have small annual amplitude. Minimum in July is 75% and maximum in February 84% (Fig. 9).



**Fig. 9** Annual course of 10-day period mean air temperature, mean maximum temperature, mean minimum temperature and relative humidity.  
Zavizan, 1961-1990.

#### *Relation between air temperature and relative humidity*

In order to make the skiing season longer it is recommended to introduce snowmaking. This process demands the determined minimum temperature and relative humidity conditions. According to the technological requirements the frequency of simultaneous appearance of temperatures less or equal  $-2^{\circ}\text{C}$  and relative humidity less or equal 80% measured at 7 a.m. has been analysed for the period winter 1961/1962 to winter 1997/1998.

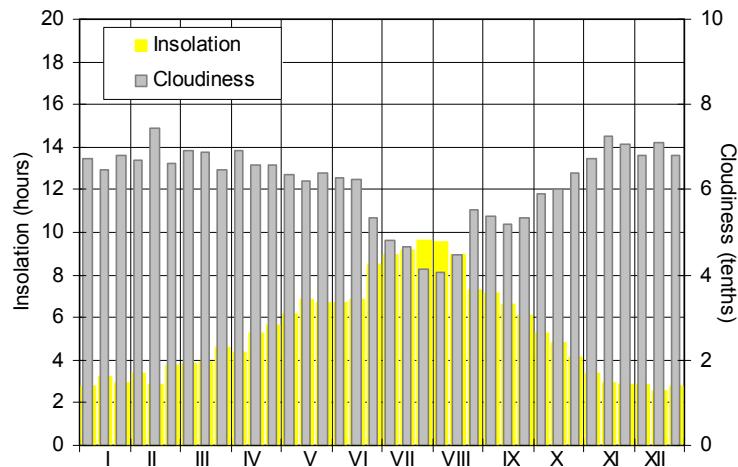
On average 20 days with such conditions can be expected during winter, rather rare in each month from about 2 days in November and April to about 5 days in January (Tab. 3).

**Table 3** Days with temperatures less or equal  $-2^{\circ}\text{C}$  and relative humidity less or equal 80% at 7 a.m. Zavizan, 1961/1962 –1997/1998.

Month	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	winter
Average	0.0	0.0	0.0	0.5	1.5	3.2	5.4	4.3	3.5	1.6	0.1	0.0	20.2
St. dev.	0.0	0.0	0.2	0.7	1.4	2.1	3.0	2.6	2.5	1.5	0.4	0.0	5.5
Min.	0	0	0	0	0	0	0	0	0	0	0	0	10
Max.	0	0	1	3	5	7	14	9	10	8	2	0	34

### *Sunshine duration*

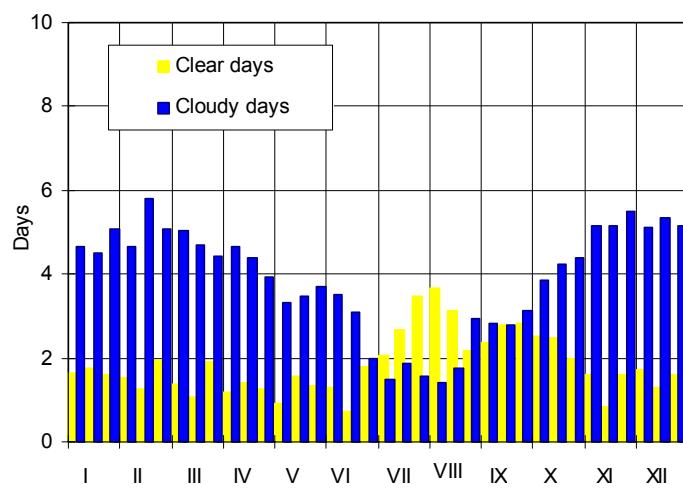
The area of Zavizan has on average 1969 hours of sunshine during the year, with maximum mean daily insolation of 9.3 hours in July and minimum of 2.7 hours in December (Fig. 10).



**Fig. 10** Annual course of 10-day period mean daily sunshine duration and cloudiness. Zavizan, 1961-1990.

### *Cloudiness*

On the top area of northern Velebit Mountain 39% of the days during the year are cloudy, mostly during the cold part of the year. It is the most clear from July to October with 7-9 clear days monthly (Fig 11).



**Fig. 11** Annual course of 10-day period mean number of clear and cloudy days. Zavizan, 1961-1990.

## **Discussion**

The presented climate analyses performed in the first place for selection of ski resort, can be later on also used for the biometeorological prospect in the frame of tourist promotion, which pays special attention to the thermal comfort conditions of the location or region.

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## **Climate and tourism – an Australian perspective**

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### **Abstract**

Visitors who come to Australia from cooler countries can experience problems. They are neither adapted to nor prepared for our warmer climates and they often have little information about thermal conditions in Australia. In order to meet tourists' needs for information, a climatology based on thermal comfort considerations has been developed. Because heat stress is the major thermal problem in Australia, we divide the country into three main regions on the basis of January 3 pm temperature and vapour pressure. These zones are subdivided on the basis of summer severity (in the tropical north) or of winter conditions (in the southern and central regions). Climate-based conflict between tour operators and the Commonwealth government can occur. An example of this was when tour operators objected to a walking track in the Uluru - Kata Tjutu National Park (Ayers Rock and the Olgas) being closed by the National Parks and Wildlife Service (NPWS) on hot days, for safety reasons. There was a legal challenge to the track closures by a consortium of tourism operators in 1999. On-site field measurements of heat stress were written into a report for the NPWS, along with an assessment of the risk to tourists from heat stress. The litigation was settled out of court and the policy of track closures based on forecast maximum temperatures remains in place. These case studies from Australia emphasise the point that climate is a resource for the tourism industry, and like any resource, it requires prudent management.

**Keywords:** thermal comfort • thermal stress • tourism

## **Introduction**

In 1998 more than 600 million people travelled internationally, a figure that is expected to soar to 1.6 billion by 2020. Tourists suffer from a special vulnerability, often unfamiliar with their destination's language, traffic patterns, customs and, of course, its climate (Mieczkowski, 1995). People who come to Australia from cooler countries are no exception. They are neither adapted to nor prepared for our warmer climates, they often have little information about thermal conditions in Australia and they tend to arrive in summer (our most thermally stressful season) in order to escape the Northern Hemisphere winter. Recommendations have been made that improved specific travel information relating to climate and human health should be provided for tourists (WMO, 1995). A climatology for tourists has been developed by the Australian Bureau of Meteorology to provide some much-needed information for our visitors and the tourism industry.

### **A climatology for tourists**

#### ***Variables to form basis of classification***

Most climate classification systems are based on plant growth factors, usually rainfall and temperature (Stern et al, 2000). What climatic variables are important to tourists? Mieczkowski used a combination of monthly means or totals of air temperature, relative humidity, precipitation, sunshine duration and wind speed in his tourism climate index. The chart presented here is based solely on thermal comfort considerations (disaggregated into temperature and water vapour), which could be a drawback. The classification scheme is not based on an index as such, but rather the overlaying of two fields of spatial climatic data. On the other hand, the chart is equally applicable to building design, urban design and health/quality of life considerations as well as to tourism.

The classification takes no account of rainy days. The major Australian attractions (Uluru, the Great Barrier Reef, Kakadu national park) are in the hot zones: rainy days are more of a problem in cooler climates. Mieczkowski's tourism climate index assumes that rainy days are always unfavorable for tourists. Like much work done in

temperate countries, Mieczkowski's work could benefit from consideration of conditions in hotter climates. In the tropics, rain can actually provide *more comfortable conditions* for outdoor activity because of its cooling effect and because rain implies cloud, which means less intense radiation from the sun.

The inclusion of solar radiation was considered, because tourists can suffer serious ill effects from our intense sunshine, but it made the scheme too complex. However, information about radiation is implied in the classification: the arid zones have the greatest solar radiation. The variability of the climate – its day-to-day fluctuations – was another relevant variable which had to be omitted. It is true that information about average conditions is not the whole story: tourists do need to know something about the variability of the climate and the chance of extreme events such as tropical cyclones.

### ***Seasonal conditions used***

As Mieczkowski notes, annual climatic averages are of no use to tourists; they are interested in climatic conditions during specific times of the year. In summer, most of Australia is too hot. In the northern tropics and the central arid zone (where our major tourist attractions are found) winter is the most comfortable time of year. Since summer heat stress is our major problem, it was decided to base the climatology largely on summer conditions; on comfortable limits of maximum temperature and 3 pm vapour pressure in January, the southern hemisphere midsummer.

### ***Thermal comfort definition used***

Various definitions of thermal comfort were considered. Mieczkowski considered that sunshine was undesirable once the temperature reached 33°C, implying that temperatures above 33°C are too great for comfort. An earlier ASHRAE Standard set the upper limit of summer comfort indoors at 26.1°C and vapour pressure of 1.9 kPa. The current ASHRAE Standard 55-92 (ASHRAE, 1992, 1995) sets the upper summer indoor comfort limit at an Effective Temperature (Gagge et al, 1986) value of 26 °C and wet bulb temperature of 20°C.

We have adopted a less stringent definition of thermal comfort. Visitors come to Australia for our scenery and climate rather than the art, architecture and history: they will be outdoors much of the time. It has been shown (Nikolopoulou, 2001) that people have lower expectations of comfort when outdoors, so the upper comfort limit can be set higher than for indoor conditions. Accordingly, we set the upper comfort limit at a mean January max temperature of 30 °C and mean 3 pm January vapour pressure of 2.1 kPa.

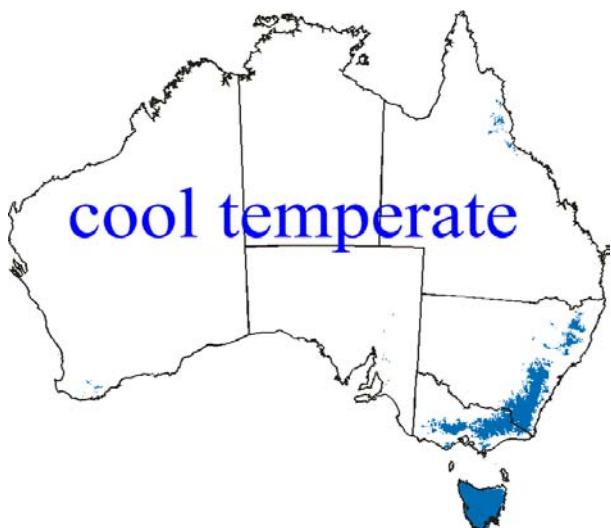
How do these conditions rate on a thermal comfort scale? If clothing is set at 0.3 clo (shorts and singlet) and activity level at 115 W/sq m (walking at 0.89 m/sec), then air and radiant temperatures of 30 deg C combined with a vapour pressure of 2.1 kPa lead to an Effective Temperature of 29.96 °C. This is well above the current ASHRAE standard for indoor comfort mentioned above. The value of the Predicted Mean Vote thermal index (Fanger 1970) for these conditions is 1.83, indicating that 69% of people would be dissatisfied. Outdoors in daytime, the mean radiant temperature would obviously be greater than air temperature, so the level of discomfort here is an under-estimate. It should be remembered that Fanger's index was derived from samples of college age subjects sitting inside climate chambers.

## Results

The temperate zone is defined as the region where summer temperature and vapour pressure are both below the upper comfort limits described above. The hot dry zone is defined as the area where summer maximum temperature is above the upper limit for comfort, but summer water vapour pressure is below its upper comfort limit. In the warm/hot humid zone, water vapour pressure is above the comfort limit. Each of these zones is subdivided on the basis of summer severity (in the tropical north) or of cool annual or winter conditions (in the southern and central regions).



**Fig. 1** Mild temperate zone



**Fig. 2** Cool temperate zone

Parts of the temperate zone can be cold, especially in the mountains in the southeast of the mainland and in Tasmania. This zone is subdivided into mild temperate (Fig. 1) and cool temperate zones (Fig. 2) by home heating needs (annual heating degree days<sup>1</sup> greater than 2000). This is the thresh-hold where edge insulation of concrete slabs becomes cost-effective.

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<sup>1</sup> The HDD figure (base 18 deg C) for each day is the difference between 18 and the day's mean temperature. For example, if the mean temperature for the day is 11 deg C, that day contributes 7 HDDs to the annual total. For days over 18 deg C, the HDD figure is zero.



**Fig. 3** Hot dry zone with cold winter

In the hot dry zone, winter nights can be very cold. Accordingly, the zone is subdivided by winter temperature (July mean temperature less than 14°C) into a zone with cold winter (Fig. 3) and a zone with mild winter (Figure 4).



**Fig. 4** Hot dry zone with mild winter

The warm/hot humid zone, where uncomfortable summer conditions are the dominant consideration, is subdivided by summer maximum temperature into a warm humid

zone and a hot humid zone (mean January maximum temperature greater than 30°C). Note that the hot humid zone fails *both* the summer water vapour and temperature criteria!



**Fig. 5** Warm humid zone



**Fig. 6** Hot humid zone

## **Discussion**

### ***Caveat and drawbacks of the chart***

As Pontius Pilate nearly said: “what is comfort?” It depends on individual perceptions and on what climate you are used to, in other words, on acclimatisation (de Dear and Brager, 1998). This climatology takes no account of acclimatisation, as tourists are not acclimated, unless they come from a region with a climate similar to that of their destination.

Another issue worth noting is that climate classifications are simplified views of complex reality: unfortunately Australia does not divide neatly into 6 separate and homogeneous zones. The very act of drawing a boundary on a chart is rather misleading: there is no sharp demarcation of climate, but just a gradual change as one climate merges into another. Within each zone, there are variations, too, depending on elevation, distance from the coast and land use effects.

### ***Need for standardised information provision practices***

Bushwalker alerts (warnings of dangerous weather conditions for walkers) are issued by the Australian Bureau of Meteorology’s Tasmanian Regional Office, but not by other state forecasting offices. If walkers from Tasmania are visiting another part of Australia and don’t hear a walker alert, then they may incorrectly assume that conditions are safe, with adverse consequences. This illustrates the need for consistent information provision practices within a country.

Internationally standardised information for tourists is also desirable. Is this an impossible dream? Mieczkowski’s tourism climate index requires only information which all national meteorological services can provide: with minor modifications, it could be applied internationally.

### ***Ethical dilemmas for government services***

Understandably, tourism organizations are keen to promote their country and seldom mention problems which the unfortunate traveller may encounter. The problem is not confined to the private sector. Many national economies depend on income generated by tourism. Not surprisingly, government officials seldom, if ever, warn in-bound tourists of health, safety, or other issues (Richter and Richter, 1999).

Australia is no exception to this pressure; we don't want to discourage tourists. However, some of Australia's most famous tourist attractions are located in quite hostile climate zones: we need to strike a balance between promoting tourism and warning tourists of the dangers they face.

The Australian Bureau of Meteorology has experienced pressure to encourage tourism. For example, a number of local councils in the cooler parts of the country have asked us to take temperature readings in urban areas rather than at the nearby airports where our observations are often made. They have noticed that the temperature in town is usually warmer than at the exposed airport site we use. It would appear that if reported temperatures were a degree or two warmer, then tourists would flock to the particular city/town!

### ***Possible conflict with tour operators – a case study***

Climate-based conflict between tour operators and the Commonwealth government can occur. An example of this was when tour operators objected to a walking track in the Uluru - Kata Tjuta National Park (Ayers Rock and the Olgas) being closed by the National Parks and Wildlife Service (NPWS) for heat-safety reasons. There was a legal challenge to the track closures by a consortium of tourism operators in 1999.

The Uluru-Kata Tjuta National Park stands as one of Australia's most significant tourist attractions, particularly with international visitors. A busy local airport and several resort facilities within the park enable hundreds of thousands of visitors per year (ca 400,000 in 1996/7) to enjoy some of the most spectacular and dramatic desert scenery on the planet.

While the landscape and ecology that attracts so many tourists owe their unique character largely to Central Australia's arid climate, the climatic context of these attractions poses significant risks to the health of visitors. Many tourists arrive unacclimatised from a Northern hemisphere winter. They are greeted by very high summer temperatures, some of the most intense solar radiation on record, and heavy infrared radiation fluxes from the denuded lithospheric environment that is completely unshaded by vegetation. Some visitors are elderly and physically unfit to perform the relatively strenuous exercise that these attractions demand. Even young and fit visitors to the park can expose themselves to considerable risks through their alcohol intake the night before, and their unsuitable clothing and inadequate fluid intake on the day.

In the context of these risk factors it is perhaps not surprising that the NPWS, who manage the park on behalf of the indigenous landowners (the local Aboriginal tribes), typically attend a few dozen incidents of heat-related illness each summer (e.g. over 20 separate rescue operations were logged in the summer of 1996/7). Apart from the undesirable implications for the actual victims, these cases are the cause of extreme anxiety for the traditional owners of the park whose ancient culture places on them a responsibility of care far exceeding levels normally found in Western cultures.

These heat-related illness cases within the park raise legal concerns as well. The NPWS owes a common law duty of care for all visitors to the park, although this duty has yet to be tested in court.

Thermal injuries can range from mild heat exhaustion to serious heat stress, heat-stroke and, in some cases, death. These incidents clearly indicate a need for some rational risk management and safety strategies. In response, in 1988 the NPWS implemented a policy of park closures at 11:00 hrs on days when the Australian Bureau of Meteorology forecasts maximum temperature at the nearby Yulara aerodrome to exceed 36°C. This threshold emerged from a review of NPWS's log of heat-related incidents. The closure policy was applied specifically to a walking track known locally as "The Valley of the Winds" within the Olgas (Kata Tjuta). Commercial sensitivity of the tourism sector to such a policy prompted the peak

industry body in Australia, the Tourism Council, to launch complex litigation against the NPWS. The matter was heard by the Australian Administrative Appeals Tribunal. The ultimate resolution of that dispute relied heavily on scientific expert evidence relating to heat stress assessments on the Valley of the Winds (VOW) walking track during >36°C days, as described below.

### ***Assessment of thermal stress - general***

There is no heat stress index developed to date which provides the true answer to the evaluation of heat stress in all situations. When all factors that influence man's response to heat are considered, there will always be a certain degree of inaccuracy when predicting individual situations (ISO, 1989). Nevertheless the Wet Bulb Globe Temperature (*WBGT*) index stands out as the most widely used and well-documented index of heat stress, especially within occupational health and hygiene circles. Industrial standards used in the management of hot workplaces are based on the concepts of permissible heat exposures and Threshold Limit Values (TLV) of *WBGT*, (ACGH, 1992; ISO, 1989). The standards have been derived from extensive laboratory and field experience with heat, and therefore represent a rational basis for assessing heat stress on the VOW walking track. The ACGIH heat exposure TLVs listed below are based on the assumption that nearly all individuals wearing light summer clothing (0.6 clo units), with adequate water and salt intake should be able to function effectively under the given thermal conditions without exceeding a deep body temperature of 38°C.

**Table 1** Permissible heat exposure threshold limit values (source: ACGH, 1992)

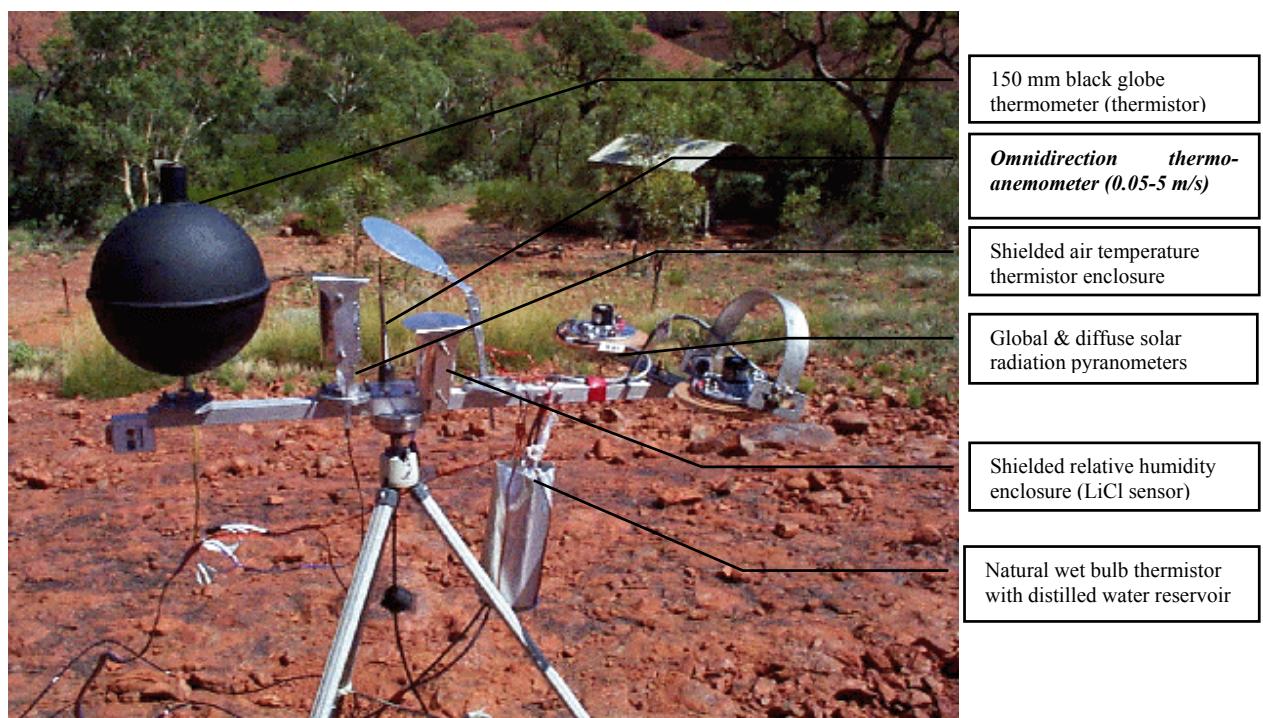
<i>Work/rest regimen</i>	<i>Light Work Load</i>	<i>Moderate Work Load</i>	<i>Heavy Work Load</i>
Continuous work	30.0 °C	26.7 °C	25.0 °C
75% Work, 25% rest each hour	30.6 °C	28.0 °C	25.9 °C
50% Work, 50% rest each hour	31.4 °C	29.4 °C	27.9 °C
25% Work, 75% rest each hour	32.3 °C	31.1 °C	30.0 °C

### ***Thermal stress assessment on the VOW walking track***

Tourists walking the VOW track were estimated to have a metabolic rate falling within the "moderate" work-load category, mainly on the basis of gradients

throughout the terrain. If sustained continuously from start-to-finish of the walking track (2~3 hours) the appropriate TLV in Table 1 would therefore be 26.7°C *WBGT*. However, there are climbs along the VOW track where the TLV for "heavy" work-loads (25°C *WBGT*) would be more appropriate.

Direct measurements of all the relevant thermal environmental parameters were made on the VOW walking track during a day that was forecast by the Australian Bureau of Meteorology to reach maximum air temperatures in excess of 40°C at the nearby Yulara aerodrome. The NPWS policy of VOW walking track closure was in place on the day in question. A tripod with various sensors for *WBGT* and other basic microclimatic measurements was installed in a representative site and left in place for the entire day. Figure 7 illustrates the equipment used in the field tests.



**Fig. 7** The tripod with sensors measuring all relevant heat balance variables as well as *WBGT* parameters.

The tripod supported all sensors at a height of 1m above ground level, corresponding to waist height of a walking subject. Sensors were connected to a Campbell Scientific 21X datalogger that scanned its input channels once every 10 seconds, then archived an average of 60 measurements every 10 minutes. All sensors were exposed

according to the guidelines listed in ISO Standard (ISO, 1989). Note that the black globe and natural wet-bulb sensors were exposed to direct solar radiation in accordance to accepted international standards (ISO, 1989) while the air temperature sensor was not. Readings from these three sensors were combined using the outdoor version of the index equation,  $WBGT_{outdoor}$ , as listed in ISO 7243 (1989):

$$WBGT_{outdoor} = 0.7 t_{nw} + 0.2 t_g + 0.1 t_a \quad (\text{eq. 1})$$

where  $t_{nw}$  is natural wet bulb temperature ( $^{\circ}\text{C}$ )

$t_g$  is equilibrium black globe temperature ( $^{\circ}\text{C}$ ), and

$t_a$  is air temperature ( $^{\circ}\text{C}$ )

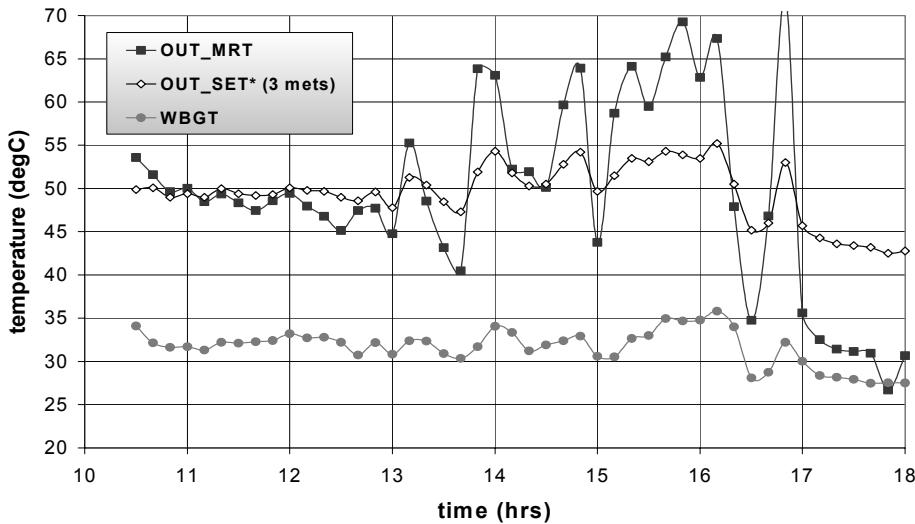
The inclusion of air temperature in this form of the equation is intended to reduce  $WBGT$  values below those that would result from the more familiar indoor version of the WBGT equation being applied in situations where the black globe thermometer is directly exposed to solar radiation:

$$WBGT_{indoor} = 0.7 t_{nw} + 0.3 t_g \quad (\text{eq. 2})$$

Time series of various thermal stress index calculations are plotted in Figure 8 below, starting at 0930 hrs and finishing at 1800 hrs. Plotted along with  $WBGT$  are values of the OUTdoor Mean Radiant Temperature  $OUT\_MRT$  and the OUTdoor Standard Effective Temperature,  $OUT\_SET^*$  (Pickup and de Dear, 2000).  $OUT\_SET^*$  is the outdoor adaptation of the classic indoor climate index by Gagge *et al.* and can be defined as the temperature of a hypothetical isothermal, reference environment where air temperature ( $t_a$ ) is equal to mean radiant temperature, ( $t_{mrt}$ ), relative humidity ( $rh$ ) of 50 %, wind speed ( $v$ ) of  $0.15 \text{ ms}^{-1}$ , such that a person in the reference environment, wearing 0.6 clo and standing quietly with a metabolic rate of 1.2 mets, has the same mean skin temperature ( $t_{sk}$ ) and skin wettedness ( $w$ ) as the person in the actual complex environment (Gagge *et al.*, 1971; Gagge *et al.*, 1986; Pickup and de Dear, 2000).

Outdoor mean radiant temperature  $OUT\_MRT$  is the temperature of a hypothetical isothermal, reference environment ( $t_a = t_{mrt}$ ,  $rh = 50\%$ ,  $v = 0.15 \text{ ms}^{-1}$ ) such that a person in the reference environment has the same net radiation exchange as the person in the actual, complex radiative field. In effect, short and long-wave radiative

exchanges between the subject and the real environment are measured, and then equated to the longwave exchanges in the isothermal reference environment with a temperature of *OUT\_MRT*.



**Fig. 8** Observed levels of Mean Radiant Temperature (*OUT\_MRT*), Standard Effective Temperature (*OUT\_SET\**) and Wet Bulb Globe Temperature (*WBGT*) on the Valley of the Winds walking track during a day with a maximum air temperature of 44°C.

Mean radiant temperature (*OUT\_MRT*) records in Figure 8 show the significant effects of intense solar radiation and long-wave (infrared) radiation loads from the bare rock surfaces of the walking track. The latter recorded maximum surface temperatures in excess of 70°C and these are responsible for some of the extreme values of *OUT\_MRT* in Figure 8. The *OUT\_SET\** values in Figure 8 were calculated with an assumed metabolic rate of three met units (176 W/m<sup>2</sup>), corresponding to a steady walk of about 3 to 4 km/h with some gentle climbing. In Figure 8 it can be seen that, from the start of measurements mid-morning until the sun disappeared behind the western canyon wall at about 17:00hrs, the *OUT\_SET\** index registered temperatures at about 50°C or above, except for a very brief late afternoon storm. The *WBGT* values derived from the technique described earlier in this paper exceeded the TLV for moderate workloads (26.7°C in Table 1) throughout the entire period of observation. It seems highly likely that this TLV of 26.7°C would still be exceeded by *WBGT* measurements on a milder day with maximum air temperature of only 36°C (the NPWS threshold for park closure). Even if the tourists were required to take the walk much more easily, resting for 30 minutes in every hour, the

corresponding TLV of 29.4°C would still have been exceeded from 9:00 through 17:00 hrs on the day plotted in Figure 8. These findings lent strong support to the NPWS policy of walking track closure on days with a high likelihood of heat stress (forecast  $T_{max} > 36$ ). The litigation was settled out of court and the policy of track closures based on forecast maximum temperatures remains in place.

### ***OUT-SET – an index of outdoor thermal stress***

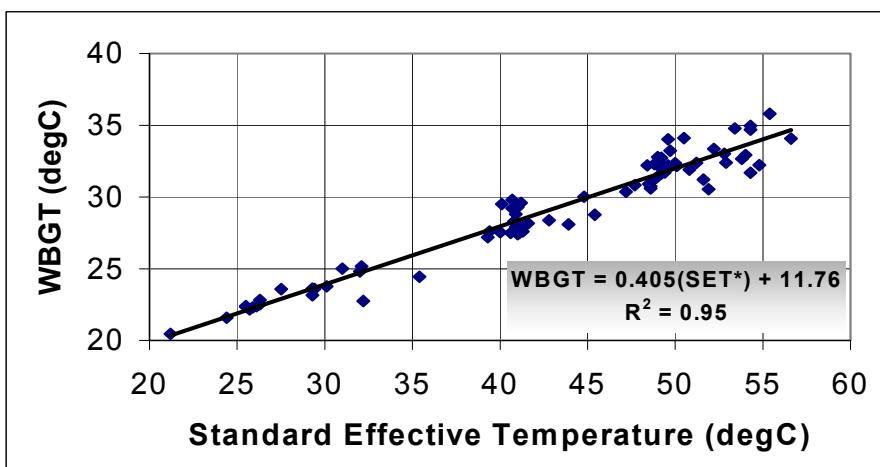
Plenty of **outdoor** thermal indices exist but to date, the most sophisticated and thoroughly researched indices come from indoor applications, largely as a result of the air conditioning industry's sponsorship of thermal comfort research programs. The International Society of Biometeorology has recently become aware of the need to bring outdoor indices up to or beyond the standards set by the air conditioning industry for indoor applications, and has formed a Working Group to develop a Universal Index of Thermal Climate (UTCI). The Working Group's deliberations to date have focused on enumeration of the end-users and applications envisaged for the UTCI, and also the minimum requirements of the UTCI. The previous section of this paper described a very common end-use for the UTCI - namely provision of thermal comfort forecasts or heat stress warnings to the public and other weather-sensitive and weather-information sensitive end-users. For example, the Australian National Rugby League is being pressed by commercial/media interests to begin their season at the height of summer, and in so doing, are at risk of exposing players to significant risks of heat-related illness.

Until the UTCI Working Group has finished its job, outdoor thermal comfort researchers are required to choose from numerous options that are available in the public domain (or a few that are commercially available). A recent example of the former is *OUT-SET\**, as mentioned in the previous section. This index is not particularly new index in that it is based on Gagge *et al.*'s 2-node model & the Standard Effective Temperature (indoors). Inputs include  $t_a$ ,  $t_{mrt}$ ,  $v$ ,  $rh$ ,  $clo$  and  $met$ . Other researchers have adapted indoor thermal comfort indices to outdoor contexts - for example, Jendritzky's (1981) modification of Fanger's (1970) Predicted Mean Vote (PMV) which is widely acknowledged in thermal comfort research circles as

being satisfactory in near-neutral thermal environments but grossly inaccurate in conditions beyond moderately warm or cool.

### ***Conversion of OUT\_SET\* into WBGT***

Indices such as *PMV* or *SET\** (and their outdoor versions) can provide information on the impacts of changes in any one of the six basic input parameters on overall thermal discomfort, but much more field experience with two- or three-parameter indices such as *WBGT* has been built up over the last several decades. For example, the occupational health and safety guidelines for heat exposure are specified in terms of threshold limiting values for *WBGT*, not *OUT\_SET\**, simply because the former has been in widespread use for so much longer. This indicates a need for new and more sophisticated outdoor thermal climate indices, such as *OUT\_SET\**, or indeed, the anticipated *UTCI* to have transfer functions for mapping back to the vast body of knowledge we have built up over the years with older indices such as *WBGT*.



**Fig. 9** Linear relationship between WBGT and OUT\_SET\* indices measured side-by-side in moderate through to extreme thermal conditions.

To achieve this for *OUT\_SET\** with respect to *WBGT*, a simple linear regression equation was fitted between simultaneous measurements of both indices across a sample of over 70 thermal environments of varying levels of heat stress. This enables an *OUT\_SET\** measurement to be translated back to its equivalent *WBGT* index value which can then be compared to the relevant threshold limit values of the type listed in Table 1 above.

## **Conclusions**

An Australian climatic classification scheme directed at the needs of tourists was developed, based on thermal comfort considerations. A case study was presented, showing how the outdoor version of the Standard Effective Temperature, *OUT\_SET\**, can be used in the management of tourism and recreation in the potentially dangerous climate of Australia's interior. Both studies illustrate ways in which climatic resources can and should be managed for the benefit of the weather sensitive tourism industry.

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# BIOMETEOROLOGICAL POTENTIAL OF CROATIAN ADRIATIC COAST

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## Abstract

The article deals with the analysis of biometeorological conditions in the period 1979-1998 at 8 meteorological stations along the Croatian Adriatic coast: Rovinj (Istra Peninsula), Crikvenica (Kvarner Bay), Šibenik (middle Adriatic coast) and Dubrovnik (southern Adriatic coast) at the coast, as well as at the islands Rab, Vela Sestrica, Hvar and Palagruža. The most comfortable periods at the Adriatic coast are April and May as well as September and October. During the hottest summer months July and August it is warm in the morning and evening and hot in the afternoon. Due to the cooling effect of the sea and the wind, the excess heat episodes are rare and they happen mostly only in the afternoon. From the late autumn until the early sprig, the biometeorological conditions are ideal for the sport activities.

Key words: thermal sensation, TWH index

## Introduction

The information about biometeorological conditions, as the complex influence of several meteorological parameters on thermal sensation of man, has the great importance in tourism. In combination with some other meteorological parameters, such as air and sea temperature, sunshine duration, amounts and number of days with precipitation and wind roses can be presented graphically like posters to tourists. It enables everyone to choose the most convenient period for holidays, depending on personal conditions and needs. For example, elder and deceased people, who difficulty bear summer heat, could choose the period of pleasant biometeorological conditions, which prevail at the Adriatic coast during spring and autumn, to take vacation with slow walks. For sportsmen, who prefer an active vacation, pleasant or even cool conditions would be more convenient than summer heat, when the organism has to spend energy for defence from heat.

## Data and method

In the first part of the article the climatological and bioclimatological prospect, based at the analysis of 10-day periods of meteorological parameters, important for the tourism and recreation is presented.

In the second part the biometeorological conditions in the period 1979-1998 at eight meteorological stations along the Croatian Adriatic coast are analysed. These are Rovinj at Istra Peninsula, Crikvenica situated in Kvarner Bay, Šibenik at middle and Dubrovnik at southern Adriatic coast, as

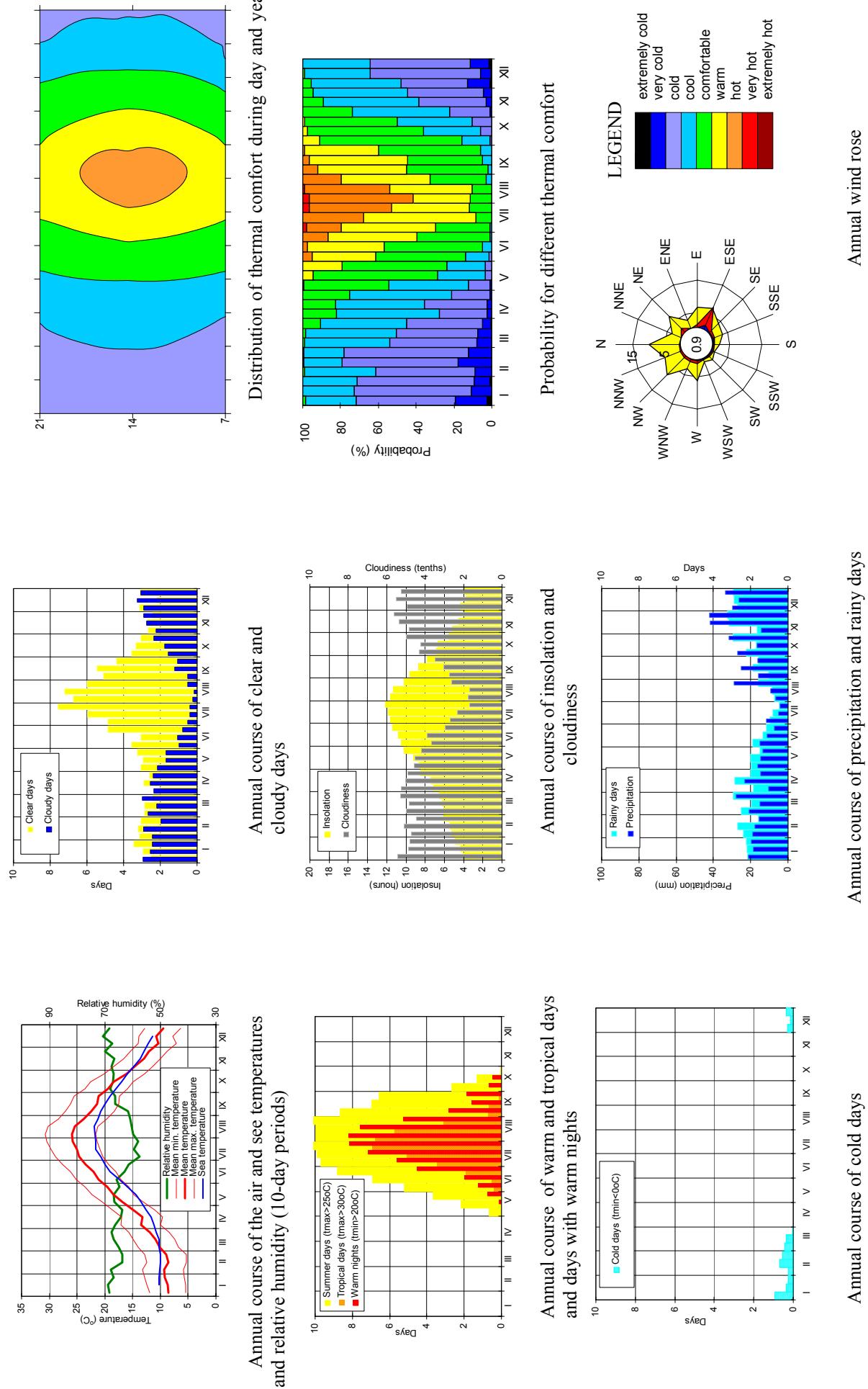
well as at the islands Rab, Vela Sestrica (National park Kornati islands), Hvar and Palagruža. The biometeorological conditions are analysed by means of the ten-day mean values of thermal sensation at 7am, 2pm and 9pm, and by means of the probability of occurrence of different thermal sensation. The thermal sensation is defined by means of TWH index (temperature-wind speed-humidity), (Zaninović, 1992; Zaninović, 1994).

### **The prospect of climate and bioclimate**

The climatological and biometeorological prospect contains the analysis of thermal, aesthetic and physical parameters important for the tourists. The analysis is performed for 10-day periods, as a better information for the tourists, which usually spend a week or two on holidays rather than a month. So the tourists can be informed about the weather they can expect during their holidays.

The bioclimatic prospect of Hvar is presented at the Figure 1. The thermal parameters are presented at the three pictures on the left. The first one presents mean, mean minimum and mean maximum temperatures. The annual courses of the number of days with different temperature characteristics are below: warm ( $t_{\max} \geq 25^{\circ}\text{C}$ ) and tropical days ( $t_{\max} \geq 30^{\circ}\text{C}$ ) and days with warm nights ( $t_{\min} \geq 20^{\circ}\text{C}$ ), and cold ( $t_{\min} < 0^{\circ}\text{C}$ ), ice days ( $(t_{\max} < 0^{\circ}\text{C})$  and days with  $t_{\min} \leq -10^{\circ}\text{C}$  (those two don't appear in Hvar). In the middle column the aesthetic and physical characteristics of climate are presented. From the aesthetic parameters clear and cloudy days (the picture at the top) and insolation and cloudiness (middle picture) are analysed. The annual courses of physical parameters: precipitation and number of days with precipitation are at the bottom. The analysis of biometeorological conditions is presented by means of thermal comfort distribution during the year as well as the probability of occurrence of different thermal sensations. Finally, there is the annual wind rose for all terms together. Sometimes, for example especially for the sailors, the roses for seasons and different terms of observations can be presented separately.

**Fig. 1** HVAR – CLIMATE AND BIOCLIMATE, 1961-1990.



## Bioclimatic conditions along the Adriatic coast

The bioclimatic conditions along the Adriatic coast are analysed by means of the thermal comfort distributions during the year and the probabilities of occurrence of different thermal sensations at eight meteorological stations: Rovinj (Istra Peninsula), Crikvenica (Kvarner Bay), Šibenik (middle Adriatic coast) and Dubrovnik (southern Adriatic coast) at the coast, as well as at the islands Rab, Vela Sestrica (Kornati islands), Hvar and Palagruža (fig. 2).



**Fig. 2** The position of analysed stations.

The Croatian Adriatic coast has different biometeorological conditions although is relatively small area. Generally, the period of the prevailing *cold* thermal sensation lasts from the December until March, but mornings and evenings are *cold* earlier (in November), while in spring at the most stations *cool* afternoons begin to occur already at the beginning of March (Figure 3). However, at some locations (Šibenik and Palagruža) the prevailing *cold* sensation occurs already in November, mainly due to strong winds rather than low temperatures. On the other hand, the *cold* period at some station is rather shorter. In December in Crikvenica, Vela Sestrica at Kornati islands and in Hvar only mornings and evenings are *cold*, while the

afternoons are partly *cold* only in January and February. April in spring and October and somewhere November in autumn are *cool*. At Palagruža, the island isolated in the middle of the Adriatic sea, the period of *cold* sensation lasts until the end of April, while May is *cool*. The most pleasant period with prevailing sensation of *comfortable* occurs in May and June as well as in September and in the first part of October. During summer *warm* is prevailing, while *hot* occurs only during the hottest part of the day, mainly from the middle of July until the middle of August. Only at the island Palagruža the sensation *very warm* occurs on average only in the first 10-day period in August. On the other hand, the sensation of *very hot* on the average occurs only at Vela Sestrica at the end of July and at the beginning of August.

The analysis of the probability of occurrence of different thermal sensation gives more detail information about bioclimate. On the Figure 4 the probabilities of occurrence of days with different thermal sensations according to the mean daily values are presented. Although they don't appear in the average values, the sensations of *extremely* and *very cold* appear during the winter. The most frequently they appear in Šibenik and Palagruža, usually connected with strong winds. For example, in Šibenik in January and February even up to 20% of *extremely cold* sensation mainly as the effect of well-known bora wind appears. On the other hand, during the winter months, when it is *cold* on average, one can expect even 20 to 40% of *cool* days according to the mean daily values of thermal sensation. During the summer, the mean daily sensation *very hot* appears relatively rarely, even at Vela Sestrica where in July and August mean afternoon values of thermal comfort are in the class *very hot*.

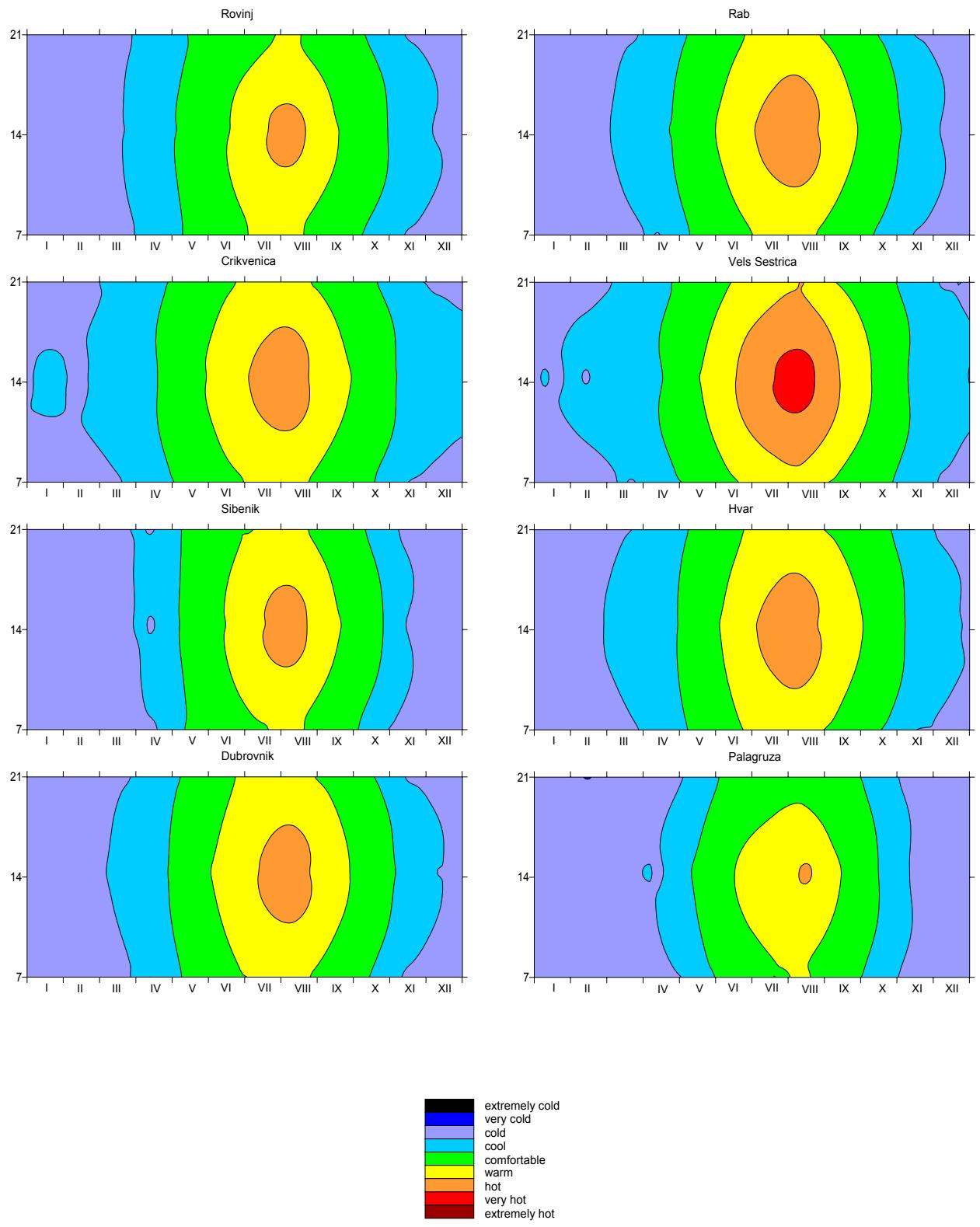
Choosing the period in which the tourist wants to spend the holidays, he can get quite precise information about the thermal sensation that he can expect in that period.

## Conclusions

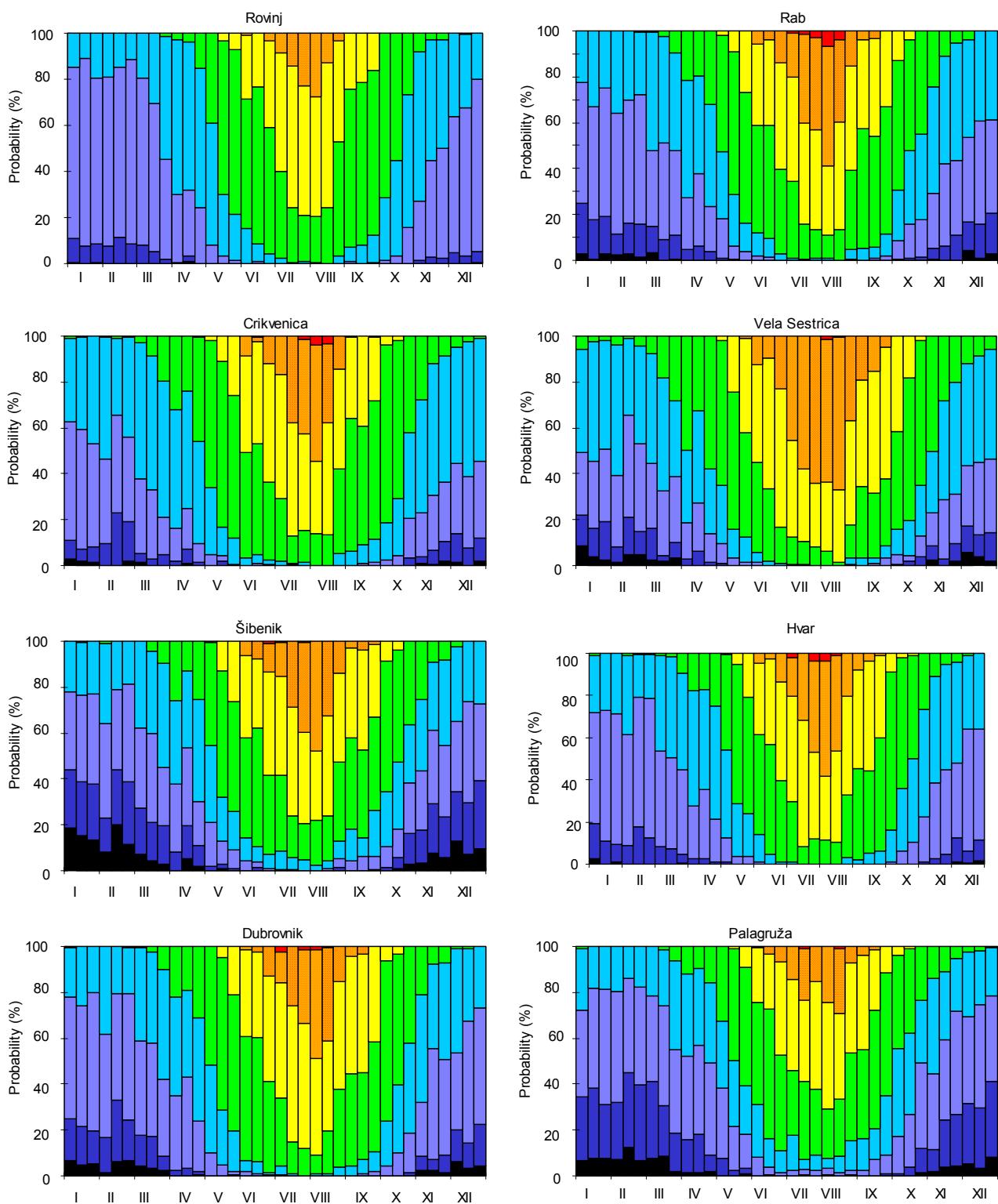
The analysis of climate and bioclimate, especially if is presented at clear and simple way that everyone can understand it, gives a basis for promotion of natural possibilities of tourist destinations. The tourist managers can use the meteorological knowledge in propaganda and offer wide spectra of possibilities for spending holidays, from the summer tourism with sun and sea bathing, but also for health, recreation or sport purposes, depending on climate and bioclimate conditions during the pother parts of the year. Also, physicians should warn their patients what periods are inconvenient for them and suggest the best period for improving their health.

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**Fig. 3** The thermal sensation according to TWH-index during day and year along the Croatian Adriatic coast, period 1979-1998.



**Fig. 4** The probability of occurrence of different thermal sensations according to TWH index along the Croatian Adriatic coast, period: 1979-1998.

## **DISCUSSIONS AND OUTCOMES – by the participants of Workshop**

All agreed that the tourism climate index (TCI) or equivalent is a useful concept. Its value lies in the fact that it is simple, descriptive, uses standard data, includes a range of variables etc, but is arbitrarily constructed and has never been verified. A new TCI is needed, one that is better designed, and then tested and verified.

TCI or equivalent does not deal with assessment of catastrophic events. What is needed is something that does. Risk takers (resort developers) vs. risk accepters (insurance companies).

What risks are tourism companies taking? How do we assess this? A lot depends on the scale of development.

The significance and importance of qualitative (vs. quantitative) information in tourism climate research was discussed, as for example, in forecasting tourism demand.

What about tropical locations? Tourism in a tropical and equatorial environments – eg SE Asia, Indonesia, Darwin...?

Tropical coastal areas have a large amount of tourism development, but most research in temperate regions.

Long haul to the tropics is fastest growing sector for travel Europe.

We need to explore the distinction between impacts of climate on tourists vs. impact on the tourism industry (i.e. tourism development).

What do planners need? We (the scientists) need to translate the technical work of researchers (climatologists) into simple language and explain this in uncomplicated terms for use by planners, tourist operators etc. Methods used should be transparent but simply expressed **and** explained.

Planners need to know how much climate will improve or deteriorate in the future. Good TCI index would show this.

Make the classic jump from theory to practice. Eg: global warming will result in the need for an increase in the number of air-conditioned hotel rooms. What are the costs of doing this vs. doing nothing? This is an example of a simple, straightforward translation of the significance of climate change.

What about sea level? Need to convey “scientifically correct” information to planners. For example, regionally detailed and highly accurate measurements show that sea level is not rising in the tropical Pacific. Do planners believe otherwise?

There is a need to provide potential tourists with probabilistic information on climate to be expected at various destinations. Leads to improved information and improved choice. Costs: to tourists (eg heat stroke) vs. costs to tourism operators. Already tourists and tourist operators can take out insurance on likelihood of “bad” conditions occurring. This raises the point: How do insurance companies define “bad weather”? We need to look into this.

Climate derivatives (eg HDD) are currently being traded on stock exchanges (like commodity futures). Are there analogues in tourism climate work? Is the TCI for example a climate derivative?

The day's proceedings showed up a surprising diversity of expertise among those attending the Workshop – especially a diversity of approaches that are likely to be mutually beneficial.

Interlinkages both of concepts and applications were commented on – e.g. thermal indices used in architecture and design considerations and in recreational park planning and management.

Importance of non-thermal facets (aesthetic) of climate - Christine Brandenburg (land-use/park planner) drew attention to importance of clear skies (sunny conditions) in assessments of recreation climates.

Importance of only using thermal indices that have been checked and verified using field data - Marialena Nikolopoulou (architect) drew attention to the fact that PMV (i.e. predicted thermal satisfaction) had little or no relationship with actual satisfaction.

Planners require climate data that is quality-checked, easy to use [i.e. well sorted]. Point raised by Christine Brandenburg, a land-use/park planner.

Role of climate in considerations of destination choice - especially in relation to increasing use of the Internet.

UV risk as related to ozone-layer thinning is not well understood, in Argentina.

Heatwave prediction – up to six-day forecast accuracy is good. Application of this?

Andreas Matzarakis stated that climate information available for tourists to Greece is inadequate.

Catastrophic events in coastal tropical areas – data/info on this for tourism.

What may be useful to develop is a tourism climate equivalent to *The Lonely Planet* guide.

Need to keep in mind that human behavioural response considerations are important in many applications.

The Workshop group acknowledged the importance of human body-atmosphere heat balance schemes and resulting indices to tourism climate research. These indices integrate the thermally relevant atmospheric, environmental and physiological variables. But they are often applied inappropriately. There is a need to settle on a base-standard for heat balance models used in tourism-recreation research. Suggested guidelines are summarised below:

Standard/typical/mean state for general application of heat balance models.

Body and environment

Metabolic rate:  $80 \text{ W m}^{-2}$

Assume individual is acclimatised.

Body area (DuBois)  $1.8 \text{ m}^{-2}$

Posture: standing (approx equiv)

Clothing albedo: 0.30

Warm-season clothing insulation (amount) = 0.5 clo

Cool-season clothing insulation (amount) = 1.0 clo

Albedo of surroundings: 0.25

Sky condition:  $n/N = 1$  (i.e. cloudless)

Mean radiant temp (longwave only) = air temperature ( $T_{mrt,l} = T_a$ )

Application to climate conditions (i.e. with standard data)

Daily “maximum” thermal condition:

Daily maximum air temp

Solar noon

Sky condition:  $n/N = 1$  (i.e. cloudless)

Wind speed:  $0.5 \text{ m s}^{-1}$

Longwave mean radiant temp (longwave) = air temperature ( $T_{mrt,l} = T_a$ )

Daily “minimum” thermal condition:

Daily minimum air temp

Solar radiation = zero

Wind speed:  $0.5 \text{ m s}^{-1}$

Longwave mean radiant temp (longwave) = air temperature ( $T_{mrt,l} = T_a$ )

Note: Need to generate mean values from above real-time calculations.

Standard (input) climate data:

Daily “maximum” thermal condition:

Maximum daily air temperature

Vapour pressure near middle of day

Daily “minimum” thermal condition:

Minimum daily air temperature

Vapour pressure at night or near sunrise

It is important to recognise that research methods in tourism climate have to be both transparent and consistent.

As far as possible we should adopt standard methods and indices.

Develop specialist tourism climate forecast indices, say for golf, skiing...

Overall, multipurpose regional (and city scale) scale index that guidebooks, govt advisory services etc could use.

Use same methods approach for both cold and warm tourist climate applications/conditions.

## **Future Research Topics**

Climate therapy: Health climatology - climatic elements related to health therapy. Demand could be large – especially respiratory diseases.

Include UV-related themes.

Bioclimate information for tourists and recreationists. Say, advisory services provided by local Meteorological Services for: a) day-trippers and vacationers planning weeks ahead.

Need for and usefulness of bioclimate advisory services for tourists – especially trampers and other outdoor pursuits.

Investigate precisely the type of bioclimate information that should be available to tourism decision-makers – what are their needs?

Commission consider the international standards for definitions for key terms: outdoor recreation, recreationist, tourism, tourist. See World Tourism Organisation Webpage.

The need for developing conceptual framework(s) for tourism climate research. Start by doing an inventory of research to date, and then categorise these. Conduct a review of and search for common approaches, methods...paying close attention to covers all disciplines that deal with tourism.

What about the globalisation of tourism?

Land use planners, architects, urban planners could have data that are useful to tourism climate assessment.

Publications on tourism climate information for travel industry for promotional purposes and marketing.

Tourist planners (including tourist industry) and tourists are two very distinct groups. The former are most interested in capturing/attracting the largest possible numbers of vacationers.

There are those interested in various aspects of tourism climate: climate as an asset, climate impacts and methods of climate assessment, so interactions need to be considered.

Future of the CCTR? All agreed that it should continue. In the meantime, list Workshop delegates on Website along with the area of specialism alongside name link to other websites.

Review usefulness of new label: “Impacts of climate on tourism.”

Consider posting (this) Consider posting summary report on a) ISB Webpage; b) IJB c) Notice CLIMLIST d) other relevant journals or webpages, both disciplines and tourism industry.  
Summary report on a) ISB Webpage; b) IJB c) Notice CLIMLIST d) other relevant journals or webpages, both disciplines and tourism industry.

## **PRIORITIES IN TOURISM CLIMATE RESEARCH**

- Significant (implications) of climate change in heavily used tropical areas.
- Communication with the public on tourism-climate issues.
- Communication with the travel industry on tourism-climate issues.
- Is the info the public need on tourism-climate the same as what climate scientists think they need?
- What information do tourists need for their decision-making processes (eg prospect of extreme events - hurricanes)?
- Standard approach to thermal climate assessment - how do we handle spatial vs. temporal variability of climate and how we adapt to contrasts?
- How we handle, in context of tourism climate, physical and mechanical climate facets eg fogs, high wind, rain, sea-surface temp...?
- How we handle, in context of tourism climate, aesthetic climate facets eg sunshine, cloud...?
- Establish international tourism bioclimate information-base - eg TCI equivalent for world for main tourist activities.
- Verification of thermal index schemes using physiological field-testing and associated statistical testing.
- Tourists' health vulnerability indicators in relation to climate of destination (eg heat stress, vector-borne diseases...)
- Expand qualitative approach to include more tourism categories and extend to broader effects - eg moods, emotional responses (to understand the whole climate [personal] experience).
- Better understanding of what climate-related information that tourists want.
- Assessment of trends in tourists' choice of destination and projecting into the future.
- Recreational activities that exploit extreme climate conditions – what about information for this group? How do we present data and guidelines for this group? – noting that thermal comfort is not important here.
- Identify one bioclimate index simple and reliable for use globally in tourism climate research.
- Appropriate standard index needs to be convincingly “sold” to the public, and assess suitability and appropriateness in eyes of public.
- Decide among ourselves on appropriate methods and approaches - eg which indices can be used where and how and validating these beforehand.
- Identify and characterise the various interest groups we are trying to reach. Elements and methods to be used. Tourism industry; local communities; decision-makers and policy makers; scientist; and tourists.
- During holidays, weather forecasts have big influence decisions of recreations. Research is required in this area.
- Forecasts should be based on data from the region to which the forecast applied, as opposed to data from other nearby regions.
- Include biometeorological information and guidelines in standard weather forecasts – eg Canada uses wind chill and Humidex.
- Point was raised that national meteorological services should have a biometeorology branch. This would do much to assist future research in tourism climatology.
- New “TCI” is needed that is rationally based, verified and tested with real data.
- Our research need to deal separately with the meso and micro scale; results of our research need to be translated and presented in easily understood; consider in our research all of the facets of climate: thermal, physical and aesthetic.

- Need for a comparative study that investigates national-cultural differences in tourism climate preferences etc for a number of countries worldwide.
- Use website to provide tourism climate guide for travellers.