Bas Amelung - Krzysztof Blazejczyk - Andreas Matzarakis

Climate Change and Tourism
Assessment and Coping Strategies

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Introduction

Tourism is one of the world's largest, fastest growing and most climate-dependent economic sectors, yet in 2003 the interactions between this industry and climate change had been subject to only sparse and scattered scientific investigation. There was a lack of scientific networks and frameworks to guide future research and make it more efficient. To start filling these gaps, a scientific workshop was held in Warsaw in November 2003 with the following aims:

1. to strengthen the network of scientists and stakeholders working in the field of climate change and tourism; and
2. to develop an agenda for further research, e.g. on impacts, vulnerabilities, adaptation options, emissions, and mitigation potentials.

This book is a collection of the best papers from among the more than thirty-five contributions presented to the Warsaw workshop. The selected papers reflect the complex and interdisciplinary nature of the issue, and cover a broad range of topics, including:

- tourism's contribution to climate change;
- climate change impacts on tourist health and comfort at global, regional and local levels;
- climate change impacts on non-climate tourism resources; and
- regional integrated assessments of tourism.

As the papers were finalised within months after the workshop, the material represents the scientific state of affairs of 2004. Nevertheless, we feel this book makes a valuable contribution to the existing literature on climate change and tourism. It contains insights and perspectives, and identifies problems that continue to be highly relevant for the "climate change and tourism" research community to this very day.

Bas Amelung, Krzysztof Blazejczyk and Andreas Matzarakis
THE TOURISM INDUSTRY AND ITS ADAPTABILITY AND VULNERABILITY TO CLIMATE CHANGE

Geoffrey Wall

Faculty of Environmental Studies, University of Waterloo, Waterloo, Ontario N2L 5X4, Canada

E-mail address: gwall@fesmail.uwaterloo.ca

Abstract: In the consideration of climate change and tourism, it is suggested that more emphasis be placed on risk assessment. The vulnerability of tourism to climate change is discussed briefly and the difficulty of generalising across a multitude of locations and activities is stressed. Limitation and adaptation are discussed and the need for both is acknowledged. Case studies of skiing and marinas and recreational boating from the Great Lakes region of North America are presented and a variety of research needs and opportunities is suggested.

KEYWORDS: Adaptation, Great Lakes, limitation, recreation, research needs, risk, tourism, vulnerability, uncertainty

1. INTRODUCTION

In a scientific context, it is often useful to define terms at the outset so that misunderstandings can be avoided and, ideally, the adoption of common definitions can enhance the likelihood of the generation of cumulative knowledge. However, for present purposes, no attempt will be made to define tourism or recreation or to distinguish one from the other – the leisure industries accept the money of both groups who may often be found in identical locations doing similar things. It will also be left to others to address the attributes of climate change in all its complexities: how much, how fast, what climatic parameters, what locations? However, the answers to these questions are of great significance to tourism and underpin issues of vulnerability and adaptation that are the subject of this presentation. Suffice to say that the author is persuaded by the accumulating evidence that climate change is occurring for anthropogenic and other reasons – hence the need to consider the possible implications. Even if the prognostications about climate change prove to be incorrect, and I am persuaded that this is unlikely, then atmospheric processes will still vary in ways that are
difficult to predict over both short and long time scales, with consequences for tourism-related businesses and their patrons. Thus, one does not necessarily have to accept the findings and rhetoric of the most extreme prophets of climatic doom to promote the value of a more sophisticated understanding of relationships between tourism and recreation, and weather and climate, than is available at present. Thus, this contribution does not examine climate change per se. Rather, it is based upon the assumptions that climate and weather, which are inherently variable on a multitude of time scales, may change at an unprecedented rate in future decades, and that such events have implications for tourism.

Of course, there are many uncertainties. This is a term used by cautious scientists who correctly acknowledge the complexities of the climate system and the need for further research to enhance understanding. However, the term is an unfortunate one for it permits sceptics, both academics and public officials, to dismiss the growing evidence that the climate is changing with the admonition to let them know when there is more certainty about what may be happening now and what may occur in the future. But certainty will only exist after the fact (and even then the processes may still be incompletely understood). For this reason, it is preferable to use the term “risk”. Risks are extremely difficult to calculate but risk is a more palatable and actionable term than uncertainty. As a society, we maintain the armed forces, hoping that they will never have to fight, and we insure our homes but hope that we will never have to phone the insurance company at short notice. What risks do tourism businesses face from climate change and variability and what can be done to reduce these risks? Are there also opportunities associated with the changing circumstances? – It is a rare event, even a catastrophic one, which does not allow some people to benefit!

The uncertainties that usually surface in climate change deliberations and are given most prominence in discussions are usually those that are associated with physical systems. The climate modellers have been particularly successful in using these uncertainties to garner increased research funds. However, it is contended that the uncertainties of human systems are much greater than those of physical systems. Much more needs to be known about human responses to the vicissitudes of weather and climate. Furthermore, climate change is one among many phenomena that are part of an increasingly turbulent environment. There are many forms of global change – population growth and distribution, urbanisation, technological changes and political upheavals to name a few. In the past few years, the global system, including the tourism system, has been disrupted by wars, terrorism, the Asian economic crisis and contagious diseases among other factors. It is impossible
to study everything at once and just as we abstract tourism from broader human systems to facilitate analyses, it is necessary to remember that climate change is only one form of global change and may not be the most important for all places and activities, and at all temporal and spatial scales. Thus, both tourism and climate change should be considered in a broad context (although this is difficult to do) and the most challenging situations may be in places where the various forces of global change, both human and physical, are imposed upon each other (such as in coastal cities and remote mountain communities that are being opened to tourism).

2. THE VULNERABILITY OF TOURISM TO CLIMATE CHANGE

Vulnerability refers to the extent to which a system may be (adversely) affected, disrupted or displaced by an external force. In this case, we are concerned with components of the tourism system and the challenges associated with climate change.

The magnitude of the implications of climate change for tourism and recreation will depend upon both the distribution and importance of tourism phenomena and the characteristics of climate change. Other things being equal, locations whose economies are highly dependent on tourism appear to be at the greatest risk.

Tourism is both widely distributed and highly concentrated. Some claim that tourism is now the largest industry in the world and there are few areas that are untouched by tourism. In this sense it is a global industry. At the same time, tourism is not evenly distributed and is highly localized in specific places, especially cities, coasts and mountains. Cities are often major tourism attractions but they usually have a diversified economy. It is often the less-populated areas which have a high dependence on tourism and many coastal and mountain locations specialise in catering to tourists. Both because of their relatively simple economic structure and the seasonality of their businesses, and because such areas are likely to experience many of the physical consequences of climate change, they may be more vulnerable. Much tourism and recreation is concentrated in high energy environments, such as mountains and coasts, and it is these areas which appear to be particularly vulnerable to climate change through modifications in the hydrological cycle, particularly changes in water levels, stream flow and the magnitude and timing of snowfall.

Elsewhere and writing in an international context, the author (Wall, 1992; 1993) has suggested that domestic travel patterns are likely to be more stable than international travel because the former often take place in relatively short periods of free time and time limitations place constraints on the
destination choices of travellers. Conversely, long-haul destinations are more at risk than those depending largely on a local market. Furthermore, destinations which rely primarily upon their natural resource base to attract visitors, such as mountains and coasts, are likely to be more at risk than those which depend upon cultural or historical attractions. In the developed world, even destinations which have an international reputation (such as Niagara Falls), rely heavily upon the regional market for a large proportion of their visitors and it appears that remote locations, distant from large urban markets, are likely to be most at risk.

One of the major attributes of most tourist destinations is seasonality. Not only is there a regular round of activities associated with the seasons, there is also variation in activity in areas lacking a marked seasonal climate. This is because seasonality in areas of demand results in seasonal variations in visitation to areas of supply. Thus, for example, the desire for many Canadians to escape the Canadian winter to warmer climates creates a seasonal demand in temperate and tropical areas which do not have the same degree of annual variation in temperature. Smith (1990) has pointed out that vacation travel decisions are influenced by conditions at home as well as at potential holiday destinations and has demonstrated that, with economic factors removed, a good statistical fit exists between annual data on vacationers travelling by air from Britain to Portugal and rainfall in the previous summer in Britain. He suggests that in a warmer world, many winter vacations currently taken in Florida or Mexico by residents of the colder parts of the USA and Canada may become less compelling under the relatively large increment of winter warming projected for these latitudes.

The length of the season is also of crucial importance for private sector operators of tourist facilities. Capital is invested all year round but, for many activities and destinations, the operating period is limited and profits must be made in a short period of time. Furthermore, use is further peaked in a limited number of holidays and weekends, and a few inclement weekends may tip the balance between profit and loss. Anything which influences the length of operating seasons, be they climatic factors or otherwise (such as the length and timing of school holidays), is likely to have an impact upon the viability of tourist businesses. It should also be remembered that the climatic and weather parameters which influence tourism, both singularly and in combination, vary from activity to activity. It may be very important, for example, to know whether precipitation falls as rain, snow, sleet, freezing rain or ice pellets. Also, some activities are much more sensitive to meteorological conditions than others. Although there is some information on the minimum climatic conditions
necessary for particular activities to take place (Crowe, McKay and Baker, 1978) and suggestions have been made concerning the responses of participants in different activities to changes in the weather (Paul, 1972), more work in these areas is needed.

In addition to the relatively direct impacts of climate upon tourism which have been considered, climate also impinges upon recreation in a less direct fashion. Thus, for example, an abundance of snow may make the skiing conditions very good but the journey to the slopes impossible. Conversely, recent observations in Alberta indicated that, although snowfall was reduced, many skiers were attracted to the hills by the mild, sunny weather. On a longer time scale, climatic change will influence the distribution of vegetation types, wildlife and fish species on which some forms of tourism depend. Much tourism takes place on or near the shoreline and the presence of water enhances many forms of tourism even if water contact is not required. Fluctuations in climate at meso and macro scales have implications for water levels and discharge, and influence amenity and property values. Hare (1985) pointed out that, at the low-water point of the mid-sixties in the Great Lakes, the water retreated hundreds of meters from some of the beaches and shores of Lake Huron. Furthermore, the volume of water has implications for water quality and, in some locations, such as parts of the Mediterranean and the Great Lakes where beaches are closed periodically because of pollution, this is already marginal for body-contact recreations.

The above discussion has indicated the far-reaching consequences of weather and climate for tourism. However, it is extremely difficult to generalize concerning the possible implications of climate change for tourism. It is difficult to think of almost any area of land or water which, with or without human modification or management, does not have potential to provide some recreation opportunities. At the same time, the range of tourism activities is extremely large and they have varied environmental requirements. The implications of climate change for coasts, including coastal resorts and wetlands, inland lakes, natural areas, and winter and summer activities have been reviewed elsewhere and will not be repeated here. Rather, the discussion will now turn to a consideration of what can be done to address the challenges.

3. LIMITATION AND ADAPTATION

Strategies to respond to global climate change are often considered under the headings of limitation and adaptation (Task Force on Climate Adaptation, 1993). Limitation refers to attempts to curtail the production of greenhouse gases and thereby to reduce the magnitude and speed of climate
change. Adaptation accepts that climate change is likely to occur and attempts to identify steps which may be taken to restrict its adverse consequences and to take advantage of opportunities. Limitation and adaptation should not be regarded as alternative strategies for they are interrelated and can occur at the same time.

In the early discussions of global climate change, there was a reluctance to consider adaptation. As it was becoming increasingly recognised that climate change would have multiple consequences for human systems, the remedy was seen to be the reduction of greenhouse gases. This was the narrow perspective of the proponents of limitation of the production of such gases and hence limitation of climate change. Adaptation was seen as weakening the case for limitation, the mere acknowledgement that systems could adapt was seen as undermining the limitation cause.

Increasingly, adaptation has become more widely recognised as a necessary strategy, in part because many believe that climate is already changing and it will be necessary to adapt to these changes even if limitations are placed upon the production of greenhouse gases. Thus, limitation and adaptation are now more frequently seen as being complementary rather than competitive strategies. It follows, however, that tourism could be vulnerable to and will have to adjust to both climate change and to the limitation strategies that are imposed to reduce the production of greenhouses gases.

3.1 Limitation

Most forms of recreation involve travel between participants' homes and recreation sites. Since people eat and sleep and most like to be comfortable whether they are at home or away, the consumption of energy in travel between origins and destinations is seen as the most important contribution of tourism to the rising concentrations of greenhouse gases. It is true that the temporary movement of people from temperate to tropical latitudes has local implications for energy and water consumption but on-site recreational activities are usually viewed as being minor net contributors to the global production of greenhouse gases. However, the increased demands for energy and water and the generation of wastes may have far-reaching local consequences, particularly as tourists tend to make much larger demands than local residents for these scarce resources.

While trips are, by definition, discretionary activities for participants in most forms of tourism, they are certainly not discretionary for the businesses and communities which cater to tourists and
depend upon their expenditures. It follows that policies designed to curb travel may have considerable implications for destination areas. In the 1970s, when gasoline was in short supply in North America, the economies of tourist destination areas were adversely affected (Knapper, Gertler and Wall, 1981). However, it was found that many urbanites elected to save their gasoline for recreation, there being more alternatives for modifying the journey to work than the journey to play to dispersed locations that were poorly served by public transportation. More recently, restrictions on mobility in the British countryside as a response to foot and mouth disease have demonstrated clearly that the economies of many rural areas depend as much on the production of leisure experiences as on agricultural products.

In summary, tourism and recreation are not usually viewed as major net generators of greenhouse gases, except perhaps in the travel phase, but policy initiatives taken to curb travel, perhaps through the pricing or rationing of gasoline, may have substantial implications for destination areas. Limitation strategies will not be addressed further in this document; rather the emphasis will now be placed on adaptation.

3.2 Adaptation

Adaptation involves adjustments to social and economic activities to enhance their viability and to reduce their vulnerability (Task Force on Climate Adaptation, 1993). Adaptation is a practical means of accommodating current climatic variability and extreme events as well as adjusting to longer-term climate change to climate. In fact, both natural and human systems are already adapted to an unknown extent to much of the variability in current climates. With respect to human systems, drawing upon natural hazard research, it is likely that adjustments to operating systems are most likely to occur in situations of intermediate risk. Where risks are small or uncommon, no adjustments are usually required. Where risks are high, investment is less likely to be forthcoming. It is in the intermediate situation where investments to reduce risk are likely to be most necessary and most productive. It follows that it is changes in the magnitude and frequency of extreme events through which the implications of climate change will most likely be imposed.

Three main groups can be considered with respect to the potential to adapt to climate change. These are the participants themselves, the businesses which cater to them, and the institutions that provide the context in which they operate. Each will be considered in turn.
3.2.1 Participants
A great deal of money is invested in recreational equipment. However, much of this equipment is mobile. By definition, tourism and recreational participation results from choices and, although choices are not unconstrained, a great deal of flexibility is involved. Tourists have considerable choice concerning whether or not to participate, where to go, what activities to participate in and when to travel. In fact, since the product of tourism is an experience, participants may be able to substitute activities and locations without a great deal of loss in the quality of their recreation. It is true that those wishing to observe particular species of plants and animals may find them less accessible or replaced by others, and fishermen may be required to change their quarry in particular locations, but in so far as there are still wild spaces and provision of tourism and recreational opportunities, most potential participants are likely to be able to satisfy their leisure needs.

3.2.2 Businesses
The flexibility of participants may be a problem for those catering to tourists’ demands. Much recreational provision, be it a ski hill, a campground, a marina or a national park, is fixed in location with sunk capital that cannot readily be liquidated and re-invested. If the quality of the recreational resources and associated experiences is degraded or if the length of operating seasons is curtailed below economic viability, then there may be considerable economic dislocations for recreational businesses and the communities on which they depend. However, there are likely to be both winners and losers as participants exercise their choices in modified ways.

3.2.3 Institutions
One factor that will influence adaptation of tourism settings to climate change is the flexibility of the institutions whose decisions impinge on tourism. The timing of public holidays, school vacations, and of hunting and fishing seasons, the dates of opening and closing of parks and other tourism attractions may all need to be modified in new climatic circumstances. For example, the increased length of summer may permit longer camping seasons in temperate latitudes provided conditions are not adversely affected by declining water levels or the reduced availability of water. However, if parks remain open longer, it is not known if more visits will be made or if they will be more widely spaced throughout the season. Also, enhanced economic benefits could come at the expense of increased environmental deterioration as the parks host more visitors for longer periods of time.
Thus, it is suggested that all but the most specialized tourists may be able to adapt quite well to climate change but their very flexibility may exacerbate the challenges faced by many tourism operators who are immobile and rely on short operating seasons to generate economic returns.

4. CASE STUDIES

In order to provide some specific examples of climate-related risks and adjustments, two examples from the Great Lakes Region of North America will be described briefly.

4.1 Great Lakes Skiing

Some of the earliest research to examine the impact of climate change on tourism was on the skiing industry in the Great Lakes region (Scott, Wall and McBoyle, in press). McBoyle and Wall (1986), using the climate change scenarios available at the time, found that the ski season to the north of Lake Superior would be reduced by 30 to 40%. Skiing conditions would also be curtailed in south-central Ontario, resulting in the contraction or possible elimination of the ski season (40% to 100% reduction). Skiing in the Lower Laurentian Mountains of Quebec was projected to experience a 40 to 89% reduction in season length (McBoyle and Wall, 1992). Lamothe and Periard Consultants (1988) similarly projected that the number of skiable days would decline by 50% to 70% in southern Quebec. Comparable results were also projected for ski areas in the Great Lakes region of the United States. For example, Lipski and McBoyle (1991) estimated that Michigan’s ski season would be reduced by 30 to 100%.

An important limitation of these early studies on climate change and skiing in North America (and indeed the international literature) has been the omission of snowmaking as a climate adaptation strategy. In order to reduce their vulnerability to current climate variability, ski areas in eastern Canada and the Midwest, Northeast and Southeast regions of the U.S. have made multi-million dollar investments in snowmaking technology and many now have complete snowmaking coverage of skiable terrain. Scott et al. (2002) were the first to examine snowmaking as an adaptation strategy. Using a range of climate change scenarios based on the Intergovernmental Panel on Climate Change’s (IPCC) Special Report on Emission Scenarios (SRES), Scott et al. (2003) found that with current snowmaking capabilities, doubled-atmospheric CO₂ equivalent scenarios (~2050s) projected a 7% to 32% reduction in average ski season in the central Ontario study area. With improved snowmaking capabilities, modelled season losses were further moderated to between 1%
and 21%. The findings clearly demonstrate the importance of snowmaking as an adaptation strategy, as the vulnerability of the ski industry was reduced relative to previous studies that projected a 40% to 100% loss of the ski season in the same study area under doubled-CO₂ conditions (McBoyle and Wall, 1992). Similar reassessments of widely-cited earlier climate change studies on the Quebec ski industry and other areas of North America are required.

Importantly, snowmaking requirements to minimize ski season losses in the study area were projected to increase 191% to 380% by the 2080s (Scott et al., 2003). However, it should be recognised that while snowmaking is an effective adaptation strategy, it is not without associated challenges, for both capital and operating costs are substantial and there are large water requirements. The additional snowmaking requirements and greater energy required to make snow in warmer average temperatures would be an important cost increase that could affect the profitability of some ski areas. Thus, it may not be the inability to provide snow on ski hills, but the cost of making additional snow and the negative perceptions related to no snow conditions in ski market areas that could cause adverse economic impacts within the Ontario ski tourism industry.

Large corporate ski entities in the region like Intrawest and American Skiing Company may be less vulnerable to the impacts of climate change than single ski operations because they generally have more diversified business operations (real estate, warm-weather tourism resorts and four-season activities), are better capitalized (so that they can make substantial investments in snowmaking systems) and, perhaps most importantly, are regionally diversified (which reduces their business risk to poor snow conditions in one location). Other possible adaptations include the extension of operations in mountainous areas to higher latitudes where snowfall may continue to be reliable, as has occurred in the European Alps, but this strategy has ecological consequences, particularly where operations are conducted above the tree-line.

4.2 Marinas and Recreational Boating

Almost all forms of recreation are enhanced by the presence of water. Some, such as bathing and fishing, cannot be undertaken in the absence of water of appropriate quantity and quality. Other activities, such as hiking and camping often are attracted to shorelines and may be enhanced by the presence of water even if no direct contact with water is involved. It follows that anything which impinges upon the quantity or quality of water is likely to affect outdoor recreation. Furthermore, if
water is in short supply, recreation will come increasingly into competition with other uses of this scarce resource.

The Great Lakes constitute a dramatic example of the implications of fluctuating water levels and, hence, climate variability, for recreational activities. The Great Lakes have long been a Mecca for recreational boating and fishing, and their shores are the location of recreational facilities such as private cottages and public parks. The lakes are also used for water supply, navigation and power generation, and the levels of the lakes fluctuate in response to climatic variations. Fluctuating water levels are required for the maintenance of ecological processes but some users, such as power generation and navigation, would prefer greater stability and relatively high levels, whereas others, such as cottagers, would prefer relatively stable lower levels. Marinas and recreational boating are harmed by extremes of both high and low water, particularly the latter which is the most likely situation under global climate change.

High water episodes were experienced in 1951-1952, 1973-1974 and 1985-1986 with low water periods in 1934 and 1964. Thus, there is a long history in the Great Lakes of adjusting to climate variability in periods of both flood and drought (Great Lakes Commission, 1990; Scott, 1993; Parker et al., 1993). Surveys undertaken in 1992 of marina operators and recreational boaters on the Canadian side of the Great Lakes indicated that almost all had incurred costs at some time or other associated with fluctuating water levels (Bergmann-Baker, Brotton and Wall, 1995). Since they had been operating their marinas (approximately one-third had been a marina operator for less than five years although most marinas were considerably older), in times of low water, 67 percent of respondents had experienced problems of access to docks or berths, 64 percent with inadequate channel depths, 62 percent had ramp access difficulties, 45 percent were forced to use fewer slips, 21 percent experienced short boating seasons and 13 percent had dry rot in wooden structures. In response to these problems, 55 percent had dredged, 45 percent had adjusted their docks, 44 percent restricted the sizes of boats, 44 percent had to relocate boats, 27 percent closed slips, 19 percent constructed floating docks, and 7 replaced rotted structures. Unfortunately, it is not possible to put a precise dollar value on these adjustments but clearly it has been substantial. In addition, other adjustments were made in periods of high water. In fact, there are examples of marina operators experiencing low-water problems at times when they were still paying off loans acquired to build breakwaters to protect themselves from high water.
Boaters also accrue a variety of costs but they are more mobile than marina operators and, thus, can adjust more easily. However, they may be affected in other ways. For example, global warming may increase fish productivity if water quality is not adversely affected but some significant species may decline and alien species may find it easier to colonize the lakes.

5. Research Needs

Tourism and recreation is an area which is data rich but information poor. There is a wealth of studies of tourism and recreation but most are site-specific and few have addressed relationships with weather and climate. The output of the General Circulation Models is not suited to site or even regional studies and usually does not include variables in a form which are pertinent to recreation. Climate varies over short distances, and with height and aspect in mountainous regions, and at a scale which is important for recreation but beyond the resolution of existing models. In consequence, it is difficult to combine the available recreation and climatic information. Greater spatial resolution, a greater variety of climate and climate-related variables, and a reduction in the uncertainty associated with climate scenarios generated from General Circulation Models are required if improved estimations of the likely implications of climate change for tourism and recreation are to be made. However, the improvement of such information is insufficient, by itself, to further such understanding. In fact, complementary research strategies are required, such as investigation of the adaptation of participants and recreation businesses to existing climatic variability.

The wealth of existing data on current weather and climate is generally not well-used by tourism and recreation operators at present. Much might be learned through the use of existing climate data to assess current lengths of operating seasons, their temporal and spatial variability, and the associated economic viability of recreation businesses. Such studies would have considerable practical applications. However, such investigations are not often undertaken, particularly by small operators. In fact, there is an as yet unrealized potential for practical work using existing weather and climate information which could aid the decision making of tourism and recreation enterprises. One outcome of such analyses might be the more widespread acceptance of the utility of including climate change as one factor among others in assessments of the viability of recreation investments. However, even if climate change could be reliably forecast now, it is doubtful if the industry has, at
present, sufficient understanding of its sensitivity to atmospheric variability to plan rationally for future conditions.

In order to make rational, objective, decisions concerning responses to the vagaries of climate, it is essential that the decision maker (in this case the tourist or the proprietor of a tourist enterprise) has an explicit understanding of weather-activity relationships. The identification and measurement of the economic impact of weather variation is a key exercise in the establishment of this interaction. The economic assessment of weather hazards, or "weather costing", is not only possible and practical, but it enables comparisons to be made between sites and greater efficiencies to be achieved (Taylor, 1970). However, "weather costing" has yet to achieve its full potential among recreation enterprises.

Climate is only one factor among many which influence tourism and recreation. There is a need to assess the relative importance of climate as compared to other variables for both different activities and different locations.

Since tourism involves, by definition, activities undertaken by choice, it is important to understand how alternative opportunities are evaluated by potential participants. Choices are not unconstrained and, if future choices are restricted by a modified climate, participants may be able to substitute one activity for another or one location for another. The assessment of the extent to which particular recreations and locations may be substitutes may thus be a fruitful area of research.

Assessment of the implications of climate change for natural area designation and management is an important research area which is now receiving attention but merits further examination (Wall, 1989; Staple and Wall, 1996; Scott and Suffling, 2002). These areas are important tourism resources.

Other topics which are worthy of investigation include: assessment of the means by which recreational provision can be diversified to reduce vulnerability; evaluation of the role of extreme events in influencing recreational provision, and the influence of land use zoning, insurance and other social adjustments in influencing recreational provision in high-energy locations such as shorelines and mountains.

6. SUMMARY AND CONCLUSIONS

This paper has been concerned with the implications of atmospheric processes, particularly climate change, for tourism. It has been suggested that the frequent mention of uncertainties be replaced by
a greater concern with risk. The vulnerability of tourism to climate change has been discussed briefly and the difficulty of generalising across a multitude of locations and activities has been stressed. A distinction has been made between limitation and adaptation, the need for both has been acknowledged and it has been recognized that both have implications for tourism. Case studies of skiing and marinas and recreational boating from the Great Lakes region have been presented as examples of impacts and adaptation in response to climate variability. A variety of research needs and opportunities has been suggested. However, in the absence of comparative studies, it has not been possible to indicate whether tourism is more vulnerable than other economic sectors or has more or less potential to adapt. Similarly, given the present state of knowledge, it has been possible to outline vulnerabilities with respect to tourism activities and locations in only the most general way. The potential to address these vulnerabilities has been illustrated but the appropriate mix of limitation and adaptation strategies required to address tourism vulnerabilities, as for other sectors, has yet to be ascertained.

Given the existing state of knowledge, it may be premature to make recommendations for policy but some pertinent observations can be made. Coastal areas appear to require careful attention given their susceptibility to changing water levels and their significance for tourism and recreation. Operators of ski areas in climatically marginal areas may need to upgrade their snow-making equipment and diversify their activities, strategies which could pay dividends even in the absence of climate change. Summer activities in middle and high latitudes may benefit from extended seasons provided that coastal processes are not disrupted and water is not in short supply.

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CLIMATE CHANGE, TOURISM AND AIR TRANSPORT - GLOBAL SUSTAINABLE TOURISM REQUIRES SUSTAINABLE AIR TRANSPORT

P. M. Peeters¹ and J. Dings²

1. NHTV-CSTT, PO Box 3917, 4800 DX Breda, The Netherlands
2. CE, Delft, The Netherlands

E-mail addresses: peeters.p@nhtv.nl (P. M. Peeters) and jos.dings@transportenvironment.org (J. Dings)

ABSTRACT

Though most tourism trips use surface based transport modes, air transport is responsible for up to 60% of the impact of tourism on climate change. However, the share of air transport within tourism grows fast posing a risk for tourism in case policy measures are taken to prevent dangerous climate change. Technology will not be able to solve the emissions problem, therefore policies should also be directed at checking air transport volume growth. Economic measures like emission trading are most efficient if set at a sufficiently strong level. The social impacts of such policies will be limited if the policies are consistent over a longer time span. A technological revolution towards emission free aviation will take many decades to develop, but may in the (very) long term provide new opportunities for air transport growth.

KEYWORDS: climate change, air transport, tourism, policy instruments, technology.

INTRODUCTION: AIR TRANSPORT AS RISK TO TOURISM

Most attention for sustainable development in the tourism sector goes to tourism destinations (see for example APAT, 2002, Cohen, 1978, Theuns, 2001, Tour Operators Initiative, 2002, UNEP, 2002). From several recent papers and articles it becomes clear that transport between the place of residence and the tourism destination dominates the environmental effects of tourism (Becken et al., 2003, Ceron and Dubois, 2003, Gössling, 2002, Peeters, 2003). In this paper the dominance of air transport in the overall effects of tourism on climate change will be demonstrated.

The energy efficiency per tourist day decreases due to the increase of distances travelled per vacation and the decrease of the length of stay. Making the sector more dependent on cheap oil supply and more vulnerable to threads as international terrorism, war and infectious diseases like
SARS. Most economical sectors are working on opportunities to radically reduce the emission of greenhouse gases. One exemption so far is air transport. Its growth will exceed about three times the energy efficiency the sector can gain in the coming decades. Zero climate effects air transport is technologically feasible, but requires action now, will take 30 to 40 years to develop and an investment of 100 billion or more. This means volume reduction will have to play an important role to reach the targets preventing dangerous climate change (Graßl et al., 2003). These targets, like those set by the environmental sustainable transport (EST) project of the OECD (Wiederkehr and Caïd, 2000) ask for a reduction in 2030 of greenhouse gas emissions of 80% with respect to the 1990 levels. The more the tourism sector depends on burning oil, the more measures against greenhouse gas emissions pose a risk to the profitability of the sector. Specifically long haul destinations could become inaccessible due to these measures.

In this paper ‘tourism’ is defined as the leisure related part of tourism. The international definition often used in tourism statistics is broader, defining every visitor staying between one night and one year outside their usual environment as a tourist visitor (UN, 2000), thus including most business travellers as well. However in transport statistics normally leisure and tourism related transport (L&T transport) is distinguished from business related trips, as is the case in this paper.

**Volume of leisure transport**

In 2000 the total volume of world passenger transport was 26,000 billion passenger kilometres (pkm) for all transport modes together (Schaper and Victor, 2000). Of this figure about one third may be attributed to L&T transport (Gössling, 2002). For air transport the L&T share is higher. On the flights between Europe and the United States the L&T share is about 80% (Humphreys, 2003). The world-wide average share of L&T air transport is by our estimate 50-65%. In 2000 this resulted in an air transport share of 20-26% of total world-wide L&T transport. The car is used for 51-55% of pkm, leaving 23-25% for other modes (rail, bus and ferry).

Post 11th of September 2001 projections of air transport in 2020 suggest a volume of between 8,300 billion pkm (Airbus, 2002, Boeing, 2003) and 9,500 billion pkm (Pulles et al., 2002). Though older projections are higher (Lee et al., 2001, Penner et al., 1999) we have used the figure of 9,000 billion pkm air transport in 2020 as the best estimate.
The Vision 2020 project (WTO, 1998) predicts an increase of the share of long-haul tourism from 18% in 1995 to 24% in 2020. Both short haul and long haul markets are likely to shift towards longer average travel distances. The L&T share of total air transport is estimated to increase to 55-75% in 2020. This results in a share of air transport pkm for L&T transport between 22% and 28% in 2020, which is the annual equivalent of 4950 to 6750 billion pkm. Unfortunately no analyses for growth of air transport due to tourism growth are available. All global prognoses are solely based on statistical extrapolations. The impact of low cost companies on the general publics attitude to travel have even not been included.

**Climate change effects**

Human induced greenhouse effects of motorised transport are caused by emissions from burning fossil fuel. The emissions of carbon dioxide (CO$_2$) are directly proportional to the kind and amount of fuel used. The effects of carbon dioxide on climate change are well understood (Houghton et al., 2001, Penner et al., 1999). In air transport also other gases like nitrogen oxides (NO$_x$) and water vapour have effects on the climate. Aircraft emit most water vapour at cruising levels of 10,000 to 14,0000 meters, where these gases play a role in the forming of contrails and cirrus clouds, with strong but poorly understood effects on climate (Houghton et al., 2001, Penner et al., 1999, Williams, 2002).

The total effect on climate change is usually expressed in carbon dioxide equivalents (CO$_2$-e), using the ‘equivalence factor’, the effect of all emissions divided by the effect of CO$_2$ only. For surface transport (road, rail and shipping) this factor is about 1.05 (Gugele et al., 2003). Due to the contrail and cirrus forming the equivalence factor for air transport is 2.7 (Penner et al., 1999, RCEP, 2003: 15, 16).

A world average for fuel consumption and emission factors for the three modes of transport (air, cars and other) are difficult to provide. Eurostat (Eurostat, 2000) gives wide ranges for the European context. For car transport an average of 100 gram CO$_2$ per pkm has been assumed. For aircraft a world average passenger aircraft emission factor for 2000 has been established to be 138 gram/pkm, by combining data from several sources (Boeing, 2003, IATA, 2002, Pulles et al., 2002). For the other modes of transport the average of the Eurostat range given has been chosen. See Table 1 for the result.
Table 1: Emission factors for leisure and tourism related transport modes

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>CO2 (average value) gram/pkm</th>
<th>Equivalency factor</th>
<th>CO2-e (average value) Gram/pkm</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>100</td>
<td>1.05</td>
<td>105</td>
<td>Eurostat, 2000</td>
</tr>
<tr>
<td>Air</td>
<td>138</td>
<td>2.7</td>
<td>373</td>
<td>Boeing, 2003, IATA, 2002, Pulles et al., 2002</td>
</tr>
<tr>
<td>Other</td>
<td>45</td>
<td>1.05</td>
<td>47</td>
<td>Eurostat, 2000</td>
</tr>
</tbody>
</table>

Table 2: Total emissions of CO2-e for leisure and tourism related transport (values between brackets for the maximum air transport case)

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>2000 CO2-e (Gton)</th>
<th>Share (%)</th>
<th>2020 CO2-e (Gton)</th>
<th>Share (%)</th>
<th>Growth rate%/annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>0.491 (0.889)</td>
<td>40 (33)</td>
<td>1.131 (1.938)</td>
<td>41 (52)</td>
<td>4.3 (4.1)</td>
</tr>
<tr>
<td>Aircraft</td>
<td>0.634</td>
<td>52 (60)</td>
<td>1.421</td>
<td>52 (60)</td>
<td>4.1 (4.0)</td>
</tr>
<tr>
<td>Other</td>
<td>0.096</td>
<td>8 (7)</td>
<td>0.184</td>
<td>7 (5)</td>
<td>3.3</td>
</tr>
<tr>
<td>Total</td>
<td>1.221 (1.475)</td>
<td>(7)</td>
<td>2.737 (3.253)</td>
<td></td>
<td>4.1 (4.1)</td>
</tr>
</tbody>
</table>

These emission factors will change in the coming two decades. From data given by World Business Council for Sustainable Development, 2001, an efficiency increase of 0.7% per annum has been derived. The world-wide increase in energy efficiency for railways and busses has been assumed to be about 1% per annum. Based on information given by Lee et al., 2001, Penner et al., 1999 and Pulles et al., 2002 an average fleet fuel efficiency increase of 1.3% per annum has been assumed.
From these assumptions the world-wide CO$_2$-e emissions have been calculated for L&T transport (see Table 2).

Air transport appears to be the major contributor to climate change at 52-60% of total L&T transport, both in 2000 and 2020. The 2020 amount of total L&T transport is 45-55% of the OECD sustainable transport target for 2030. When L&T transport emissions continue to grow at the rate of 4.1% per annum up to 2030, this share will be 70-80% of the OECD target in 2030. Over half of this is caused by L&T air transport.

Not only tourism transport, but also tourism accommodation and activities contribute to climate change. Gössling estimates the world-wide CO$_2$-e emissions for accommodation at 0.081 Gton and for activities at 0.055 Gton (Gössling, 2002). This means L&T transport takes 90% of all leisure and tourism related greenhouse gas emissions. The climate impact share of aviation dominates the total impact and therefore sustainable tourism can only be effectively achieved if sustainable air transport is available.

**Techniques to mitigate climate effects**

**Evolutionary Technology**

The fuel efficiency increase is predicted to be 1.3%, gained by all technological means currently available or under development: increased engine efficiency, better aerodynamics and lower aircraft construction weights. Further increases in engine efficiency are hampered by environmental trade-offs between fuel consumption and emissions of NO$_x$ and noise (Lee, 2003). Lower fuel consumption asks for higher engine turbine entry temperatures increasing NO$_x$ emission. Lower noise asks for higher bypass-ratios (larger fans), adding weight and resulting in a net decrease of fuel efficiency. Also it has been shown efficient aircraft engines to be more likely to form contrails (Lee, 2003).

Airframe and aero-engine manufacturers normally make a trade-off between fuel cost and total direct operational costs (DOC). The kerosene price dictates the amount of fuel saving technology the designer will incorporate into his aircraft design. So, long-term forecasts for high kerosene prices will result in more fuel efficient designs. For example, increasing wing aspect ratio (wing slenderness) will give a strong reduction of aerodynamic drag, but it will increase airframe cost. A higher kerosene price will result into a higher aspect ratio for the minimum DOC design point.
Lower weight and higher lift to drag ratios increase airframe efficiency. A further reduction of construction weight may be reached by using advanced (composite) materials and more optimised designs. However, more stringent safety regulations and the very high cost for introducing new materials in primary construction, reduce opportunities of further weight reductions. As a rule of thumb a 3% empty weight reduction is required for a reduction of 1% of fuel consumption (Peeters, 2000).

Increases in aerodynamic efficiency are still possible with technologies as winglets – bent up wing tips - and ‘riblets’ - plastic foils with a special ribbed surface, reducing friction drag. These may reduce fuel consumption by up to 5% for long haul aircraft. All together some 5-10% extra efficiency improvements over the next two decades may be reached with evolutionary technology.

**Revolutionary Technologies**

To reach sustainable development aviation has to increase its environmental efficiency with over 5% per year to reduce the total impacts, unattainable with evolutionary technology. Several revolutionary options seem available.

Bio-fuels - kerosene made from plant material - may reduce CO$_2$ emissions for the whole life-cycle to zero, if the plant material is produced with zero emissions agricultural methods. However the water vapour and NO$_x$ emissions will not change and thus two-thirds of the effect on climate will remain.
Figure 1: Operational optimum flight schedules for a long range large aircraft at a typical flight (6000 km and 75% seat occupancy; source: Peeters, 2002)
Another alternative fuel is hydrogen. An extensive study on hydrogen aircraft showed the technical viability and the economic and environmental effects of this option (Brewer, 1991). A recent project is the European Cryoplane (Faass, 2001). One of the problems of hydrogen often mentioned is safety. However, Faass shows safety of a hydrogen fuelled aircraft may be much better as for conventional kerosene based aircraft.

The Cryoplane is based on the Airbus A310 passenger aircraft with an upward extension of the fuselage to accommodate the high volume of the low-density liquefied hydrogen. From the study it appeared the empty weight of the aircraft increases with 20-25%; the maximum take off weight reduced by 15% (for the long-range version). The specific energy consumption increases with 8-15%.

The emission of CO₂, SO₂, CO, soot and unburned hydrocarbons are zero with hydrogen fuel. However water vapour emissions will increase with a factor 2.6 per MJ energy. The emission of NOₓ may be reduced with 50% to 90% depending on the technology used. Faass calculated the global warming potential (GWP) parameter at several cruising altitudes and found a reduction between 35% at 12,000 m and 85% at 9,000 m cruising altitude. Though these are impressive reductions, it is still far from a zero-emissions aircraft and with the high growth rate for air transport the total effect will still be growing.

To reach a zero-emission aircraft design, combining electric engines, unducted fans, fuel cells and hydrogen may be a viable solution (Peeters, 2000, Snyder, 1998). The disadvantages of fuel cells for aircraft are their weight and volume. This will partly be offset by the lower weight of hydrogen and by a low weight for the electric engines, using super cooling with the available liquid hydrogen. Also the total system propulsive efficiency is about double that of the hydrogen turbofan combination. Optimised for the properties of this propulsion system, the aircraft will reduce its specific energy consumption with 50% to 65% compared to the current kerosene based state-of-the-art aircraft. Even compared to a highly efficient future design using advanced technology engines, aerodynamics and structures the energy consumption reduction may be between 20% and 50% for long haul respectively short haul aircraft.

The cruising speed of the aircraft has been reduced to mach 0.65 giving a block time increase of 10% for a short haul typical flight and 23% for a long haul one. The climate change effect will be virtually zero as the water may be released as a liquid.
### Operational Efficiency

Following options are available to reduce climate change impact of air transport:

- reducing power-on delays at take-off and before landing; reducing flight holding time
- optimisation of routes
- optimisation of flight path and speed/altitude schedules
- network optimisation and fleet composition

The first two options may increase the fuel efficiency with 10% (RCEP, 2003), but do not only require technical, but also organisational and political action. The scattered European Airspace is an obstacle for increasing route efficiency, as is the already over-crowded airspace combined with strong growth.

Airline flight operations controllers will try to optimise the flight paths for low costs, making a trade-off between fuel cost and flight time related operational costs (crew, depreciation, maintenance). *Figure 1.* shows a DOC optimum for a long range large aircraft. For this flight the optimum is a cruise altitude of 11,500 m and a cruise speed of mach 0.855. The figure also shows the fuel optimum to be at mach 0.83 and the NO\textsubscript{x} optimum at 11,000 m altitude and mach 0.78.

*Table 3* gives the effects of diverting from the DOC optimum to the fuel or NO\textsubscript{x} optima. Generally spoken the fuel optimum reduces also NO\textsubscript{x} emissions, and leads to a small to very small increase of DOC. The NO\textsubscript{x}-optimum increases DOC with 3% and reduces fuel consumption, but less as for the fuel optimum.

<table>
<thead>
<tr>
<th>Type</th>
<th>Fuel optimum DOC</th>
<th>Fuel optimum NO\textsubscript{x}</th>
<th>NO\textsubscript{x} optimum DOC</th>
<th>NO\textsubscript{x} optimum Fuel</th>
<th>NO\textsubscript{x} optimum NO\textsubscript{x}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short range medium size</td>
<td>+1,4, -2,9, -6,5</td>
<td>+2,6, -2,4, -7,3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium range medium size</td>
<td>+1,1, -1,5, -5,3</td>
<td>+3,6, -0,5, -11,0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long range medium size</td>
<td>+0,3, -3,3, -10,0</td>
<td>+3,2, -1,8, -12,4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long range large size</td>
<td>+0,5, -1,2, -4,0</td>
<td>+3,8, -0,4, -11,5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Another way to reduce climate change effects is by reducing cruising altitude and thus avoiding contrails or cirrus clouds to be formed (Williams, 2002). The total elimination of contrails may reduce the air transport radiative forcing with 50%. But there are unfavourable effects as well. The aircraft will be forced to fly at lower than optimum flight levels, causing an increase of about 4% of CO$_2$ emissions. Though on a yearly base this may be small compared to the reduction of 50% by removal of the contrails, it is important to consider that the effects of CO$_2$ emissions are accumulating year after year. While the effect of contrails is zero at the moment they are dissolved from the skies. Another problem with reduction of the cruising altitude is the exponential increase of the workload of air traffic controllers and the reduction of the capacity of airspace. This may reduce the current growth of air transport especially in the crowded air space over Europe and the United States.

The effects of climate change of air transport also depend on the sort of network. The extremes are a fully-connected network (all relations point-to-point) and the hub-and-spoke network. The fully-connected network gives the shortest distances flown, but also smaller passenger flows and therefore the employment of smaller, less fuel efficient aircraft at lower occupancy rates. The hub-and-spoke network increases distance flown and number of flight cycles per connection (many passengers have to transfer flights at the hub airport), increasing fuel consumption. On the other hand larger more fuel efficient aircraft are used at higher occupancy rates. From a Dutch preliminary study on network effects it appeared the hub-and-spoke network generates up to 20% more emissions for a given origin-destination passenger travel pattern (Peeters et al., 1999). If the total transport volume is calculated as a function of network economic efficiency a higher volume for hub-and-spoke networks is most likely, further increasing total environmental effects of this option.

**Policy instruments**

**Introduction**

The possible measures to reduce the climatic impact of aviation will not be implemented automatically. The market will primarily take measures that save money. Airlines have for example implemented ranges on cost effective measures to reduce fuel burn and hence costs. Other, more expensive or institutionally more complex, measures, will not be implemented without a change in policies. Therefore, this section is entirely devoted to possible policy instruments to reduce aviation's climatic impact. Note: the description focuses on the supply side of the aviation industry.
One could also imagine taking measures at the demand side, for example by promoting short-distance tourism.

As the instruments aim at mitigating the climatic impact of aviation, they need not necessarily lead to a volume reduction, although such a reduction might be a consequence. This section is mainly based on (Wit et al., 2002) and aims to explore legally feasible instruments and their interrelation with technological, operational and volume impacts.

**Technical Standards**

The first option, technical standards, may at first sight seem a straightforward and logical option, but it has some serious drawbacks. In the past, technical standards were developed at ICAO level to reduce noise and NO\textsubscript{x} emission from newly produced aircraft. In particular for noise, these standards have proven effective; the noise ‘footprint’ area of a today’s aircraft is dozens of times smaller than aircraft from the 1960s. But the setting of standards for CO\textsubscript{2} emissions i.e. fuel consumption is much more complex. Noise and NO\textsubscript{x} emissions are related to landing and take-off, which is relatively easily standardised, whereas fuel consumption is related to the entire flight, which is very variable depending on the flight profile. This complicates the development of an adequate fuel efficiency indicator for aircraft. Currently one of the CAEPs (CAEP: Civil Aviation and Environmental Protection, one of ICAO’s committees) technical working groups is considering this issue but a solution is not yet in sight. Another drawback is that technical standards only work for new aircraft, so that the existing fleet is not affected. A third drawback is that once the standard is reached, there are no incentives left for further improvements. And fourth: given the history of noise and NO\textsubscript{x} standards, it seems hard to imagine that a technical standard for fuel consumption comes in place that is more stringent than today’s aircraft performance.

**Improvement of Air Traffic Control**

Improvements in ATC procedures could reduce congestion and hence avoid useless fuel burn. This could bring benefits in the order of magnitude of 5%. But it is in the field of *contrail avoidance* where ATC improvements offer most climatic potential. As described previously, the formation of contrails contributes about one-third to the climatic impact of aviation. Fortunately, contrail formation can be quite accurately predicted as it depends on temperature and humidity of the exhaust gases and on temperature and humidity of the ambient air. It follows that ATC could
enormously contribute to reducing the climatic impact by making aircraft fly through air masses with low contrail risks. In case of military aircraft, this is already done for visibility reasons, so strictly technically speaking this improvement should be feasible. But it is also easy to understand that such an extra boundary condition to flight movements greatly complicates ATC flight path allocation procedures and may cause problems of safety (see also section ‘Operational Efficiency’).

**Market Based Options and Economic Incentives**

The third and probably most discussed option is generally named ‘market based options’ or ‘economic incentives’ to reduce climatic impacts. Options discussed here are ticket charges (e.g. VAT), taxes of fuel, emission charges and emission trading schemes.

Ticket charging could be justified from a fiscal point of view, but is not a very efficient tool to reduce emissions. International aviation is not subject to VAT, contrary to normal international economic activities in general and passenger car, rail and coach transport in particular. This exemption could be considered an indirect subsidy to aviation, which makes (privately bought) airline tickets cheaper than they would be without this exemption. The UK has a so-called Air Passenger Duty (APD) in place, which is a fixed charge on passengers leaving the UK and is often considered a repair of the VAT exemption. However, from an environmental economics point of view, such ticket charges that are not differentiated on the basis of aircraft emission profiles, give no incentives to airlines to use cleaner and more environmentally efficient aircraft. Therefore they are not particularly efficient tools in mitigating environmental impacts.

Fuel taxation is often mentioned in the debate around aviation and climate change as a logical policy option, but is in practice hardly feasible. The option is logical as a) other transport modes do pay fuel taxes and therefore face a competitive disadvantage and b) the fuel tax is directly related to CO₂ emissions and therefore is a more environmentally efficient policy tool than the ticket charge. However, the fuel tax instrument has two serious drawbacks. The first is that it provides incentives to buy fuel outside the charged area and take it inside (tankering) which leads to both economic distortions and to extra emissions from the excess fuel carried. This might certainly be the case when the fuel tax rises to substantial levels. The second drawback is that numerous bilateral Air Service Agreements (ASAs) prohibit taxation of aircraft fuel used for flights between the countries,
which implies that all ASAs should be revised, which is at best a slow and at worst an impossible process.

Emission charging has been in discussion from the time it became clear that the fuel tax is problematic from an economic and legal point of view. The principle of emissions charging is territorial, which means that all emissions released in a certain airspace – e.g. EUROCONTROL airspace - are charged. This avoids the problem of economic distortions that a fuel tax has: identical aircraft flying the same routes are charged the same amount. Emissions charging can be designed in a revenue-raising way – as a kind of emissions tax – and a revenue neutral way. In the latter case, an environmental efficiency baseline for air transport operations needs to be set, for example grams of CO₂ emissions per revenue tonne kilometre (RTK: addition of passenger and freight kilometres in one metric) carried. Airlines that perform better than this baseline receive a rebate, where others pay a fee. Both revenue-raising and revenue-neutral incentives score better than fuel and ticket charges on criteria such as environmental efficiency and legal feasibility.

Emissions trading is gaining interest following the Kyoto Protocol and the European emissions trading directive for large stationary sources issued October 2003. The aviation sector has expressed its interest in a so-called ‘open’ trading regime, which means that it should be possible to trade emissions with other sectors, for example under the provisions of the Kyoto Protocol. A problem here is that currently CO₂ emissions from international aviation fall outside the scope of the Kyoto Protocol. Hence a specific solution for aviation should be developed under the framework of the United Nations Framework Convention on Climate Change (UNFCCC). The legal and practical feasibility of this, and of the role of ICAO, is rather uncertain and is currently subject to study.

All economic incentives discussed potentially lead to revenues. Even emissions trading could lead to substantial revenues if permits are auctioned rather than ‘grandfathered’. To put it even stronger: economic efficiency, internalisation of external costs, demands revenue-raising charges instead of revenue-neutral ones, and for auctioning tradable permits instead of grandfathering them. Although economic theory favours revenues to be generated from internalising externalities, it is exactly the issue of revenues that give rise to two difficult questions: 1) who receives them and b) what should be done with them? The first one is primarily a political problem that will not be discussed here further.

The report previously mentioned (Wit et al., 2002) extensively deals with the second question. The conclusion is that, from an economic efficiency point of view, revenues from environmental charges
could best be used for either decreasing distorting tax such as those on labour or to reduce budget deficits. Theoretically, they could also be used to finance government expenditure that increases welfare. However, there are no general rules for such expenditures, so the first two options are the safest bet.

Another frequently mentioned option is to form a fund from which environmental investments can be paid, either inside or outside the aviation sector. Although this sounds like an appropriate destination for revenues from an environmental charge, there are theoretical and practical drawbacks.

The main theoretical drawback is that earmarking revenues from charges or taxes for specific purposes is generally not optimal from a socio-economic point of view. The reason is that the level of revenues from an optimal charge (i.e. a charge related to external costs) does not necessarily have to correspond with the optimal size of an investment fund. In other words: there are so many ways to spend public money that it would be very coincidental if spending it on a fund with a very specific purpose turned out to be the best way.

The main practical drawback relates to distributional and political issues. Suppose a European charge were in place, to what degree should revenues from this charge finally accrue to, say, American firms? It is easy to imagine the problems associated with both restricting the use to Europe and opening it up to other continents. It remains unclear how a development to the creation of zero emission aviation will have to be financed. Ideally the charges are high enough to induce this development, but this will clearly ask for very high rates, which may be politically impossible.

**International politics**

In developing these options, the two most active high-level players are currently the European Union (EU) and the UN’s International Civil Aviation Organisation (ICAO). As climate change is a global problem, all parties agree that global solutions are preferable. But it is not certain whether ICAO has the authority to effectively implement an emission trading regime. Besides, ICAO attaches numerous provisos to other economic incentives. And finally, the difficulties of achieving consensus make the global process very slow. Therefore the EU is currently considering whether or not to introduce an environmental incentive scheme on top of the EUROCONTROL charges, or its own emissions trading regime for intra-EU flights. The future will learn what options will be applied, and at what geographic level.
Socio-economic effects

De Villiers, deputy Secretary-General of the WTO said in his opening speech at the World Tourism Organisation seminar on tourism and air transport in May 2000 (WTO, 2000: page 9): “good and efficient air links are vital for the development of tourism”. At some twenty major tourism destinations 70% of international tourists arrive by air transport, according to De Villiers.

However, as has been shown in section 0 of this paper, air transport is responsible for only 20-28% of all L&T passenger kilometres travelled. In terms of number of trips this share is even much lower, due to the relatively large average travel distance with aircraft. As world-wide statistics on total numbers of international and domestic holidays, length of stay, distance travelled and mode of transport are not available it is difficult to find a number for this. In the Netherlands the share of air transport for all trips for long vacations (more than three consecutive nights) is 19%. For total international tourism this share is between 18% and 23% (based on IATA, 2002).

At macro economic levels, global measures reducing the amount of passenger air transport may not have much negative effects. Most important variables for the sector are the total number of leisure days available, the accommodation used, the total amount of money spent on activities and on transport. The number of kilometres travelled is only loosely related to the total travel cost, so the number of pkm is not a main driving economic force for the sector as a whole. Of course some subsectors or individual enterprises may suffer from such measures, but others will gain from it.

Another often mentioned objection to reducing air transport for tourism is the negative impact on developing countries and poverty reduction. WTO and UNEP want to use tourism to eliminate poverty (see the ST-EP programme, WTO, 2002). As billions of tourists are required world-wide to make any difference on poverty, and most of these tourist will originate from the developed world, requiring intercontinental air travel, such a development may boost air transport ten to fifty times beyond its current volume. This is not sustainable, and economically and practically impossible.

Of course tourism may have beneficial effects on the economic position of developing countries and may reduce poverty, but it should be based on short haul markets within the region for mass-tourism and exclusive long-haul tourism generating large local revenues with small numbers of tourists, like some forms of eco-tourism. An important parameter to relate poverty and sustainable tourism would be the amount of the tourism revenues going directly to the poor divided by the total greenhouse gases emitted through the tourism product (for transport, accommodation and activities).
Socio-economic impacts may be limited provided that the socio-economic constraints of charges and technological requirements are predictable in the long term, so that airlines and tourism industry can anticipate in their investments in cleaner technology, better operation and slower growth of traffic volume.

**Conclusions, discussion and research recommendations**

**Conclusions**

The primary global environmental problem with tourism is the climatic impact of air transport: its growing share is now about half of total climatic impact of tourism. The total GHG emissions of leisure and tourism related air transport is in the same order of magnitude as the target level defined by OECD in the EST programme (20% of the 1990 level). This projection includes trend development of technology. Advanced technology may reduce specific emissions with an extra 10-20%. Technology may also be developed to create zero climate-impact aviation, but this will take decades to happen and may cost in the order of one hundred billion of Euro to develop. The fuel cell aircraft will be slower and more expensive to operate. This kind of improvements depend on political support, as they are not likely to develop on their own.

If air transport seeks to become sustainable, current growth of impact has to be reversed to a reduction using operational efficiency increases and especially volume growth control. This requires multilateral and global action, like emissions trading at European or global level, or emission incentives and ATC improvement both at EU level. Emission incentives may also be used to directly or indirectly raise funds to develop zero GHG emissions aviation technology.

The socio-economic impacts may be limited provided the socio-economic constraints and technological requirements are predictable in the long term, enabling airlines and tourism industry to anticipate on it with investments in cleaner technology, more efficient operations and reduced growth of transport volume.

**Discussion**

Tourism becomes more dependent on energy, primarily due to the increased use of cheap air transport. The advantages of this are short term growth and competitiveness for some of the players within the tourism industry. However this may result in risks for the industry as a whole: in the long term the world will inevitably run out of cheap oil - which does not mean run out of oil - both due to
physically exhausting oil fields and the likely political action on increasing visibility and socio-economic impacts of the deteriorating environment.

Effective measures will directly or indirectly increase cost for oil, ending the cheap air transport era. How disastrous such developments will turn out to be for the tourism industry is primarily determined by dependency of tourism on air transport. A tourism sector based on short haul travel, coupling regional origins and destinations will not suffer too much. Long haul tourism is more vulnerable to international political developments, terrorism and war, as is short haul tourism. Aiming at increased shares of intercontinental tourism means aiming at growing economic risks for the sector and adds to the strong economic cycles of the sector and the destination area’s. The disadvantages of these risks and cycles are more detrimental for the vulnerable economies of developing countries as for developed countries.

Aviation seems to be about the last sector to leave the fossil fuel era. Being the last one will come at a cost. Other sectors investing now already in low emission technology may demand from other sectors to do the same and to stop spoiling the total effect of emission reductions. Of course it is wise to start reductions within sectors where the cost per ton reduction is low. But also for these sectors an artificial high cost for oil or emissions will be necessary to give an incentive for the transitions required for sustainable development. These incentives will of course also effect aviation. At this point it is possible to give an answer to the question: is aviation on a sustainable track for development? To reach sustainable development The OECD has developed four criteria (OECD, 2001):

I. Regeneration: renewable resources are used without exceeding their long-term rates of natural regeneration.

II. Substitutability: the use of non-renewable resources shall be limited to levels, which can be offset by substitution by renewable resources or other forms of capital.

III. Assimilation: releases and emissions to the environment shall not exceed its assimilative capacity; persistent and/or bio-accumulative substances shall not be emitted.

IV. Avoiding irreversibility: irreversible adverse effects of human activities on ecosystems and on bio-geo-chemical and hydrological cycles shall be avoided.

Aviation does not meet any of these sustainable development requirements (Upham, 2003). The regeneration criterion is not met as aviation depends largely on oil consumption. The assimilation criterion is not met with the growing impact on climate change. Therefore the fourth criterion is also
not met as climate change is irreversible, at least for generations to come, and the resulting loss of species is irreversible. The most important distinction between aviation and other transport sectors is the substitution criterion: the industry puts no effort into development of the revolutionary technology required for a transition to non-fossil fuels, therefore its volume has to be reduced to 20% of its current volume. Of course this is also not an aim of the industry.

Two solutions may exist. Firstly the aviation industry may trade their lack of sustainability with extra efforts within other economic sectors. Secondly the industry takes the challenge for a new technological revolution. Otherwise the demand of air transport should substantially be reduced. For the tourism sector options for this are increasing the length of stay for vacations and reducing the average distance travelled by tourists. For medium distance vacation a shift towards more sustainable transport modes is also an effective option.

Research recommendations

The effects of tourism on climate change are not systematically known. The ESF-LESC workshop in Milan 2003 (Viner and Amelung, 2003) sets the following research priorities: development and evaluation of public education campaigns; determining greenhouse gas emissions attributable to tourism; and GHG mitigation strategies for the tourism sector. On almost all research levels knowledge is required:

A. Theoretically on the interrelation of sustainability, tourism/tourists/enterprises and mobility.
B. Basic economic, social and environmental data.
C. Models and tools based on A. and B. for tourism and transport behaviour on global, national and regional levels to support policies for developing sustainable tourism and transport.

For air transport many theories exist both on the technological, economic and social sciences. Also data on air transport are readily available, both on transport volumes and economics. Models are available for projecting growth of transport volumes and social and environmental effects. However these are all on an aggregated level with respect to travel motives. Therefore almost no tourism specific data, theory or models are available on the relationship between air transport and climate change.

To solve the gap in data it is proposed to extend the standards for tourism data collection (TSA, Tourism Satellite Account) of the WTO/OECD (UN, 2000) with environmental data. Environmental data are transport energy consumption, emissions of CO₂ and NOₓ and other gases. Also data should
be included giving information on distance travelled, travel time, travel cost and variables indicating other costs made by the traveller, like (un-)reliability, comfort levels and number of transfers. Based on these data and existing transport theory, models may be developed for the world tourism industry, relating tourism attraction to tourist travel flows and distribution between origins and destinations. From these models the social, economic and environmental effects of policy measures and global developments caused by climate change for the near and far away future may be derived. Another important issue for research is the relationship between air transport, tourism sector prosperity, impact on climate change and phenomena like ‘holiday happiness’ and the ‘value of distance’ within the social and psychological destination choice processes. The importance of accelerated increase of travel distances is often supposed, but seldom demonstrated by the sector and may play a role within the political system of transition to a tourism sector with less or no climate effects.

REFERENCES


THE VULNERABILITY TO CLIMATE CHANGE OF THE MEDITERRANEAN AS A TOURIST DESTINATION

B. Amelung¹ and D. Viner²

¹. International Centre for Integrated Assessment and Sustainable Development (ICIS), Maastricht University, Maastricht, Netherlands
². Natural England, Norwich, UK

E-mail addresses: b.amelung@icis.unimaas.nl (B. Amelung), david.viner@naturalengland.org.uk (D. Viner)

ABSTRACT Tourism is highly dependent on climate. Climate factors, such as temperature, wind, and sunshine, account for a large share of the success of major tourism regions, such as the Mediterranean. Climate has been traditionally regarded as a fixed property of these destinations, with only climate variability being of interest. The overwhelming consensus of the scientific community is that the global climate is changing. This paper explores the possible consequences of climate change for tourist comfort in the Mediterranean by applying Mieczkowski’s (1985) Tourism Climatic Index (TCI) to the outcomes of a range of SRES climate scenarios. The analysis suggests that major shifts are to be expected in the attractiveness the Mediterranean. It will see its comfort distribution change from a ‘summer peak’ to a ‘bimodal distribution’, as they become less attractive in summer and more attractive in spring and autumn. The Tourism Climatic Index proves to be a valuable tool for assessing the impact of climate change on tourism. It shows that tourism in the Mediterranean is vulnerable to the impacts of climate change, and that there is a need for stakeholders in tourism, to explore the vulnerability of their own businesses and policies to climate change.

KEYWORDS: Tourism climatic index, tourism, climate change, Mediterranean, vulnerability

INTRODUCTION

The Mediterranean region is one of the most heavily visited tourist destination areas in the world. No official figures for the region are available from the World Tourism Organisation (WTO);
however according to Mather et al. (in press) an estimated 100 million tourists currently visit the Mediterranean region on an annual basis, spending close to 100 billion US dollars. UNEP (1999) even estimates the annual number of visitors to the coastal regions of the Mediterranean at 150 million. Climate factors, such as temperature and sunshine, determine a large share of these international tourism flows. Statistical analyses by Maddison (2001), Lise and Tol (2002), and Hamilton (2003), and a simulation study by Hamilton, Maddison and Tol (2003) show the relevance of climatic factors as determinants of tourist demand. According to Maddison (2001) the maximum daily temperature should ideally be close to 30°C, while Lise and Tol (2002) estimate the optimal (24-hour) mean daily temperature to be around 21°C. The Mediterranean tourist sector has traditionally been characterised by strong differences in visitor numbers between the winter and the summer season. For example, in Spain in the early 1990s, total tourist expenditures were around 50% higher in the peak month of August than in an average month, and around 30% lower in February (González and Moral, 1995).

There is overwhelming evidence that the global climate is changing as a result of greenhouse gas emissions. Atmospheric concentrations of CO2 and other greenhouse gases are on the increase (CO2 concentrations have in the past 500,000 years not risen above 300 parts per million volume (ppmv); however, the current concentration is 380 ppmv), causing increased radiative forcing and higher temperatures around the globe (IPCC, 2001b). It is estimated that the global mean temperature will increase by approximately 1.4 to 5.8°C during the 21st Century (IPCC, 2001b). Changes in the mean climate will also be accompanied by changes in the frequency and distribution of extreme events. Climate change may well alter the relative climatic conditions in Europe. Agnew and Viner (2001) explored the impacts of climate change on a range of different destinations; this was the first attempt to examine the multi-sectoral and global changes in tourism flows as a result of climate change. Viner and Amelung (2003) report on the wider issues that surround the interactions of climate change with tourism and the environment. Several studies that specifically examined the Mediterranean region (Perry, 2000a; 2000b; 2001; Rotmans et al., 1994) suggest that in the summer season climatic conditions will deteriorate in this region and improve in western and northern Europe. In contrast, conditions in autumn and spring (the shoulder seasons) are expected to improve in the Mediterranean region.

This chapter explores the effects of climate change on the climatic resources for tourism in the Mediterranean, using the Tourism Climatic Index (TCI) devised by Mieczkowski (1985). The TCI
includes ratings for thermal comfort, sunshine, precipitation and wind. To capture some of the uncertainties around climate change, a few different emissions scenarios are taken into account, which were developed by the Intergovernmental Panel on Climate Change (IPCC). The IPCC undertook an exploration of the possible global changes in socio-economic conditions and population (IPCC, 2000). This resulted in a range of future plausible scenarios, known as SRES scenarios, from which greenhouse gas emissions and atmospheric concentrations of these gases could be estimated. These emissions have in turn been used to explore the response of the global climate system.

The structure of the paper is as follows. In section two, the concept of the ‘tourism climatic index’ (TCI) is discussed, addressing key issues such as the selection of component factors, and weighting. Section three gives a brief overview of the methodology and the data that were used, followed by the presentation of the results in section four. In section five, a discussion of the results is combined with the main conclusions and policy recommendations.

METHODS
The tourism climatic index as a concept has evolved from more general knowledge about the influence of climatic conditions on the physical well being of humans. In the 1960s and 1970s systematic research in this field yielded many insights, ranging from preferred temperatures, and the role of relative humidity to the appreciation of wind. It should be noted that the appreciation of climatic conditions is dependent on a host of non-climatic factors, such as clothing and the level of activity (Matzarakis, 2001a).

Mieczkowski (1985) was among the first to apply the general findings about human comfort and climatic preferences to the specific activities related to recreation and tourism. He devised a tourism climatic index consisting of five variables: daytime thermal comfort index, daily thermal comfort index, precipitation, hours of sunshine and wind speed. The thermal comfort indices are based on effective temperature, which is a measure of temperature that takes the effect of relative humidity into account. Values for all variables are mean monthly values. These are transformed into ratings, following a scheme that is based on either empirical findings of physiological research or qualitative assessments of tourist preferences, for example in relation to precipitation and sunshine. Table 1 represents this transformation scheme.
The product of effective temperature expresses the combined effect of dry bulb temperature and relative humidity on human thermal comfort. Effective temperature is equal to dry bulb temperature if relative humidity equals 50%. For temperatures higher than 10°C, humidity levels exceeding 50% correspond with higher effective temperatures; lower humidity levels correspond with lower effective temperatures. This heat-reinforcing feature of humidity increases with temperature.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Effective temperature (°C)</th>
<th>Mean monthly precipitation (Mm/month)</th>
<th>Mean monthly sunshine (Hours/day)</th>
<th>Wind speed (Km/h)</th>
<th>Wind chill cooling (Watts/m²/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
<td>Trade wind</td>
</tr>
<tr>
<td>5.0</td>
<td>20 – 27</td>
<td>0.0 – 14.9</td>
<td>&gt; 10</td>
<td>&lt; 2.88</td>
<td>12.24 – 19.79</td>
</tr>
<tr>
<td>4.5</td>
<td>19 – 20 &amp; 27 – 28</td>
<td>15.0 – 29.9</td>
<td>9 – 10</td>
<td>2.88 – 5.75</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>18 – 19 &amp; 28 – 29</td>
<td>30.0 – 44.9</td>
<td>8 – 9</td>
<td>5.76 – 9.03</td>
<td>9.04 – 12.23 &amp; 19.80 – 24.29</td>
</tr>
<tr>
<td>3.5</td>
<td>17 – 18</td>
<td>45.0 – 59.9</td>
<td>7 – 8</td>
<td>9.04 – 12.23</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>15 – 17</td>
<td>60.0 – 74.9</td>
<td>6 – 7</td>
<td>12.24 – 19.79</td>
<td>5.76 – 9.03 &amp; 24.30 – 28.79</td>
</tr>
<tr>
<td>2.5</td>
<td>10 – 15</td>
<td>75.0 – 89.9</td>
<td>5 – 6</td>
<td>19.80 – 24.29</td>
<td>2.88 – 5.75</td>
</tr>
<tr>
<td>2.0</td>
<td>5 – 10</td>
<td>90.0 – 104.9</td>
<td>4 – 5</td>
<td>24.30 – 28.79</td>
<td>&lt; 2.88 &amp; 28.80 – 38.52</td>
</tr>
<tr>
<td>1.5</td>
<td>0 – 5</td>
<td>105.0 – 119.9</td>
<td>3 – 4</td>
<td>24.30 – 28.79</td>
<td>2.88 – 5.75</td>
</tr>
<tr>
<td>1.0</td>
<td>-5 – 0</td>
<td>120.0 – 134.9</td>
<td>2 – 3</td>
<td>28.80 – 38.52</td>
<td>5.76 – 9.03</td>
</tr>
<tr>
<td>0.5</td>
<td>135.0 – 149.9</td>
<td>1 – 2</td>
<td></td>
<td>9.04 – 12.23</td>
<td>1000 – 1125</td>
</tr>
<tr>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1125 – 1250</td>
</tr>
<tr>
<td>0.0</td>
<td>-10 – -5</td>
<td>&gt; 150.0</td>
<td>&lt; 1</td>
<td>&gt; 38.52</td>
<td>&gt; 38.52</td>
</tr>
<tr>
<td>-1.0</td>
<td>-15 – -10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2.0</td>
<td>-20 – -15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3.0</td>
<td>-25 – -20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relationships between the variables of precipitation and sunshine and their respective ratings are straightforward. For every 15 mm of precipitation half a point is subtracted, and for every hour of sun, half a point is added, up to a maximum of 5 points. Regarding wind, Mieczkowski (1985) considers four different regimes. The normal system applies to those months in which the mean daily maximum temperature is between 15° and 24°C. For higher temperatures, the optimum value is set at a moderate wind speed, to reflect the pleasant effect of evaporative cooling. Any wind is considered to be uncomfortable if mean daily maximum temperatures exceed 33°C (hot climate system). In climate systems in which mean daily maximum temperatures are below 15°C, the wind chill regime applies, which is a function of wind speed and air temperature. According to the recent biometeorological literature, short and long wave radiation is essential for deriving modern thermal
indices (Matzarakis, 2001a; 2001b; Skinner and De Dear, 2001). Information of these environmental parameters is, however, not generally available in standard observed climate datasets.

All ratings have a maximum value of 5. The mapping of scores to index values depends on the kind and level of tourist activity. Beach holidays require other climatic conditions than a ski holiday. The index that is developed in this chapter reflects the climatic conditions required for light outdoors activities, such as touring. Mieczkowski acknowledged that the weights used in his equation are ultimately subjective, although they do have a basis in scientific knowledge. In the Mieczkowski paper, the highest weight is given to the daytime comfort index to reflect the fact that tourists are generally most active during the day. The amount of sunshine and the amount of precipitation are given the second-highest weights, followed by daily thermal comfort and wind speed. After summing the weighted individual components, the result is multiplied by two, so that the maximum score is 100. The final formula developed by Mieczkowski (1985) is as follows:

\[
TCI = 2 \cdot (4 \cdot ThC_{DT} + ThC_{DL} + 2 \cdot Sun + 2 \cdot Prec + Wind)
\]

While the Mieczkowski index, and other indices such as the one developed by Hatch (1988), were not originally devised to explore the impacts of climate change on tourist comfort, they can be used for that purpose: see Rotmans et al. (1994) for a grid-based application to Europe using the Hatch index, and Scott and McBoyle (2001) for a case-based application to various cities in North America using the Mieczkowski index.

Table 2: TCI distributions. Adapted from Scott and McBoyle (2001)

<table>
<thead>
<tr>
<th></th>
<th>All months</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal</td>
<td>≥ 80</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poor</td>
<td>≤ 40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Summer Peak</td>
<td>-</td>
<td>-</td>
<td>1st highest TCI</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Winter Peak</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1st highest TCI</td>
</tr>
<tr>
<td>Bimodal</td>
<td>-</td>
<td>1st or 2nd highest TCI</td>
<td>-</td>
<td>1st or 2nd highest TCI</td>
<td>-</td>
</tr>
<tr>
<td>Dry season Peak</td>
<td>-</td>
<td>1st highest TCI (or Autumn)</td>
<td>-</td>
<td>1st highest TCI (or Spring)</td>
<td>-</td>
</tr>
<tr>
<td>Spring Peak</td>
<td>-</td>
<td>1st highest TCI</td>
<td>-</td>
<td>3rd or 4th highest TCI</td>
<td>-</td>
</tr>
<tr>
<td>Autumn Peak</td>
<td>-</td>
<td>3rd or 4th highest TCI</td>
<td>-</td>
<td>1st highest TCI</td>
<td>-</td>
</tr>
</tbody>
</table>
In this chapter the Mieczkowski index is used to explore the changes in tourist comfort brought about by climate change in the Mediterranean region. A major aim is to identify possible spatial shifts in climatic attractiveness in Europe during different seasons. Furthermore, the implications for seasonal shifts in climatic attractiveness are considered, following the example of Scott and McBoyle (2001). They use a classification of six annual TCI distributions: optimal, poor, summer peak, winter peak, bimodal, and dry season peak.

A distribution qualifies as 'optimal' if all monthly ratings are 80 or higher; it qualifies as 'poor' if all monthly ratings are 40 or lower. If these conditions do not apply, there are four other options. The summer and winter peak distributions apply if the highest TCI ratings occur in summer or winter respectively. If the scores in spring and autumn are higher than in both summer and winter, the bimodal distribution applies. The 'dry season peak' is somewhat ambiguous, because the dry season can fall in both the spring and the autumn season. Therefore, in this chapter, the 'dry season peak' distribution is split up into spring peak and autumn peak. In a spring peak (autumn peak) distribution, the highest TCI scores occur in the spring (autumn) season, with autumn (spring) not coming in second place; otherwise the bimodal distribution would apply.

The characteristics for each of these distributions are given in Table 2. Note that the relationship between months and seasons is directly related to the hemisphere that is considered. For example: in the northern hemisphere, the spring season is taken to encompass the months of March, April and May, while in the southern hemisphere, it is taken to encompass the months of September, October and November.

Two data sets underlie the results presented here: the CRU CL 1.0 dataset, containing 0.5 x 0.5 degree 1961-1990 Mean Monthly Climatology data, assembled by the Climatic Research Unit, University of East Anglia, Norwich, UK (New et al., 1999); and results from an integration of the HadCM3 forced global climate model with the four standard IPCC emissions scenarios (Johns et al., 2003). This chapter aims at exploring the implications of various emissions scenarios, rather than the model uncertainties in the different Global Circulation Models (GCMs). For the analyses in this chapter, the most widely used GCM is therefore used, which is HadCM3. The use of the standard SRES scenarios does and will allow comparison with other studies.

The CRU CL 1.0 global grid-based dataset was constructed from a dataset of station 1961-90 climatological normals, numbering between 19800 for precipitation and 3615 for wind speed (New et al., 1999). The station data were interpolated to obtain a 0.5° lat x 0.5° long grid-based dataset,
covering the entire landmass of the earth except for Antarctica. Values for all the component variables of the Mieczkowski index could be extracted from the CRU dataset, either in unmodified form or after some simple manipulations. An example of such manipulations is the conversion of the available data on vapour pressure into the required data on relative humidity.

For the construction of the dataset of future climatic states, results from an integration performed with HadCM3 were used. The spatial resolution of these gridded data is 2.5º latitude x 3.75º longitude, which is coarser than the resolution of the CRU 1.0 dataset. The HadCM3 dataset consists of monthly normals for four time slices: 1961-1990, 2010-2039, 2040-2069, and 2070-2099. These time slices were available for a number of scenarios, of which the four standard SRES scenarios: (A1F, A2a, B1a, B2a) were used in this analysis. For more details regarding the SRES scenarios and their implications for the climate system, the reader is referred to IPCC (2000).

The absolute results of climate model runs are considered less reliable than the changes they indicate over time. A standard procedure therefore is to calculate the differences between a simulated future state and the simulated baseline state and to combine those with the observed baseline state to obtain a projected state. This standard practice is followed here. For temperature, absolute change is used, while for the other variables (precipitation, relative humidity, sunshine hours and wind), relative change is preferred to avoid negative values. The drawback of this procedure is that relative changes can be very large if the initial value is close to zero. Therefore, increases are limited to a maximum of 100% in this chapter.

The calculation of projections is straightforward. Values for mean and maximum temperature are computed by adding the simulated changes to the observed historical values. Values for the other variables are computed by adding the percentage change. The differences in spatial resolution between the two datasets imply that the changes, which are based on the coarse HadCM3 dataset, must be added to the baseline, which is based on the finer CRU dataset. The value that is added to a particular baseline cell depends on the location of this cell. If this cell can be uniquely mapped to one HadCM3 land cell, the value of this cell is used. If the cell is right on the border between two HadCM3 cells, the average value of these two cells is used, if either or both of these cells are land cells. In all other cases, an average is used of the land cells at a distance of less than one HadCM3 cell. Only land cells are used, since many climatological phenomena are very different over land and over sea; it would be misleading to use the sea dynamics from the HadCM3 model for projections related to land cells in the CRU grid.
The projected values for the component variables are subsequently converted into the five sub-indices, following the rules that were listed in Table 1, with one adjustment: the effective temperature concept is replaced by the more recent apparent temperature concept, following Scott and McBoyle (2001). Please note that the procedure for combining the CRU data with the HadCM3 projections results in some coastal areas and islands to disappear from the map (e.g. southern Italy). This is a technical artefact that is totally unrelated to any expected changes in the real world, such as sea level rise.

RESULTS
To get an overview of the historical situation, the TCI was calculated for the baseline period of 1961-1990 (later on referred to as the 1970s). These calculations have been made for the whole world, but in this chapter, attention is focused on the Mediterranean region, complemented by Western Europe, which generates the largest flow of tourists to the Mediterranean. Figure 1 represents the summer scores (June, July, and August) on the Mieczkowski TCI.

Figure 1: TCI scores in summer, 1961-1990
The northern Mediterranean region achieves excellent scores on the tourism climatic index, while scores in the northern parts of Europe are considerably lower, yet still good. In North Africa there is a marked distinction between the coastal zone and the rest of the area, with scores decreasing rapidly with increasing distance from the Mediterranean Sea.
In wintertime (December, January, and February), scores are consistently low in the whole of Europe. Only in parts of Spain and Italy, TCI scores are acceptable. Conditions are much better in the southeastern section of the Mediterranean region comprised by Libya and Egypt. In most of the Mediterranean region, TCI scores are somewhat higher in autumn (September, October, and
November) than in spring (March, April, and May). In the former season, the much better scores on daily comfort, and the somewhat better scores on daytime comfort and wind more than offset the poorer scores on precipitation and sunshine.

According to the classification of TCI distributions, adapted from Scott and McBoyle (2001), the dominant seasonal regime in the Mediterranean region and the whole of Europe is the summer peak regime: the mean score in the summer months of June, July and August, is higher than in any other season (see Figure 2).

![Figure 2: TCI distributions, 1961-1990](image)

In North Africa, the bimodal regime is most common, which is characterised by a situation in which scores in both spring and autumn are higher than those in summer. The dominant factors in this TCI distribution are the daily and daytime thermal comfort indices, which are rather low in the hot North African summer and much higher in the pleasant spring and autumn seasons. In contrast with this general result, large parts of Morocco and northern Algerian have a summer peak distribution, caused by the cooling effect of altitude in the Atlas mountain range. Farther away from the coast, there is a narrow strip of land with a spring peak regime, marking the transition towards a winter peak regime that is dominant in most of the African continent.

The exploration of future climatic conditions starts with an analysis of shifts in seasonal regimes. Seasonality is a key issue in tourism and it is of major importance for the profitability of tourism in the Mediterranean region. Explorations with all four scenarios indicate shifts in the same direction, although the rate of change differs. For illustrational purposes, only the most extreme SRES
scenario (A1F) is discussed in this chapter. This scenario resembles, nevertheless, the development pathway that society is currently following.

The general trend that can be observed is that all climatic zones shift northwards. The bimodal distribution slowly takes control of most of the northern Mediterranean region, while the winter peak distribution becomes dominant in most of North Africa. In Europe, changes are relatively small between the baseline situation and the 2020s. By then, the TCI distribution is expected to change only changes in parts of the Spanish interior and along the Spanish east coast. By the 2050s, changes become much more dramatic. The bimodal regime dominates large sections of the coastal zones in the Mediterranean region. In the 2080s, almost all of Portugal, Spain, Italy, Greece, Turkey, and the Balkan are in the bimodal zone. In contrast, in North Africa, the influence of the bimodal regime becomes more and more restricted, until in the 2080s it only dominates the northern parts of Morocco and Tunisia (see Figure 3).

![Figure 3: TCI distributions, 2070-2099, A1F scenario](image)

Looking at the four seasons individually, climatic conditions change dramatically in summer and spring. The Mediterranean changes from being a region with very good or excellent summer conditions up to the 2020s into being a region with marginal or acceptable summer conditions in the 2050s and 2080s. Northern Europe, in contrast, changes into a region that is characterised by excellent summer conditions. Changes for the United Kingdom in particular are remarkable. Also note the changes in the Alps. While this region currently scores low on tourist comfort in summer, it will be one of the best places for light tourist activities by the 2080s (see Figure 4).
With respect to TCI conditions in spring, the northern Mediterranean region will improve considerably. While in the 1970s the region achieved marginal or acceptable scores of around 60, future conditions may become very good or even excellent. The southern-most countries, i.e. Spain, Greece, and Turkey, will benefit most from these changes. Spring conditions will remain excellent in large stretches of the coastal zone of North Africa, although this strip will become narrower and narrower. The reason for this is that daytime comfort will deteriorate markedly in the whole of North Africa except for the Atlas mountain range. In the coastal zones, this is partly compensated by higher scores on daily comfort and wind. In the mountainous zones of Morocco and Algeria, TCI scores will improve significantly, as a result of higher scores on all five components.

Figure 4: TCI scores in summer, 2070-2099, A1F scenario

DISCUSSION

In this chapter the impact of climate change on tourist comfort is explored for the Mediterranean region. This impact is potentially very large, albeit not just in a negative sense. According to the explorations based on the SRES A1F scenario, the projections indicate that particularly in spring, tourist comfort will improve in most of the Mediterranean region, in particular in Spain, Greece and Turkey. Improvements are also projected for the autumn season. The analysis suggests that in the summer season tourist comfort in the Mediterranean will deteriorate enormously, whereas in the source countries of the North of Europe conditions will improve. The implication of this would be a significant reduction of the flow of tourists and revenues from northern to southern Europe in summer. Since the summer season is by far the most important season for tourism in Europe, it is doubtful whether improvements in the spring and autumn seasons can fully compensate for the deterioration in summer conditions, unless institutional changes were to take place simultaneously.
It is important to note that in this chapter, the results from only one of the SRES scenarios are taken into account. However, this A1F pathway is the one that society has followed since 1990. The other scenarios yield less dramatic results than the A1F scenario, but the direction of the changes is identical. Changes in all four scenarios considered indicate that the Mediterranean will change from a summer peak zone to a bimodal zone. Until the 2020s in the A1F scenario, these shifts only occur in the interior of Spain and along the Spanish east coast. By the 2050s almost the entire region will have a bimodal distribution.

The described changes are not necessarily detrimental for tourism in the Mediterranean per se. From an economic efficiency perspective, it is even preferable to have a long tourist season with evenly spread demand rather than only a few weeks of very high demand. With improved conditions in the shoulder seasons, the tourist season is lengthened and the occupancy rate can be improved. Under the assumption that the summer season will remain the main holiday period in Europe, however, it is doubtful that the deteriorating climatic conditions will decimate tourist demand altogether.

The climatic conditions of the Mediterranean are a very important pull factor for tourists. However, they are by no means the only attraction in the region. Attractive landscapes, cultural heritage, traditional lifestyles and beaches are among the other factors that have made the Mediterranean basin one of the most popular tourist destinations in the world. The results should thus be put in this perspective. Moreover, tastes and fashion are by no means stable over extended periods of time. The modern holiday activity of sunbathing, for example, was not part of popular culture until quite recently. Many things may change over the next decades that increase or decrease the relevance of the tourism climatic index.

The significance of climate change in the broader picture of influences on tourist development is a further direction for additional study. Tourist developments are shaped by an amalgam of factors, including political stability, economic growth, technological advances, and demography. In the day-to-day practice of the tourist industry, climate factors are overwhelmed by all kinds of other influences that require immediate action: SARS, fads and fashion, terrorism, etc. Climatic effects on tourist comfort will perhaps not be so evident, but the compound effect of years of creeping change can have quite dramatic results, which are irreversible in a human lifetime.

In this chapter, the focus has been on monthly and annual means of climatic variables. Perhaps even more important than means are extreme events, such as heat waves, torrential storms, and gales. As
the frequency of these extreme events is expected to increase due to climate change (IPCC, 2001a), their effects may provide the first signs that climate change is having an effect on tourist comfort.

ACKNOWLEDGEMENTS
This chapter resulted from Bas Amelung's visit to the Climatic Research Unit, 3 to 26 August 2003. The research was supported by the Center for Integrated Study of the Human Dimensions of Global Change, through a cooperative agreement between the National Science Foundation (SBR-9521914) and Carnegie Mellon University. The HadCM3 data has been supplied by the Climate Impacts LINK Project (DEFRA Contract EPG 1/1/154) on behalf of the Hadley Centre and the U.K. Meteorological Office.

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UNEP (1999) Tourism and sustainable development: Recommendations and proposals for action formulated by the Mediterranean commission on sustainable development and adopted by the eleventh ordinary meeting of the contracting parties to the Barcelona convention (Malta, 1999).
Viner, D. and Amelung, B. (2003). Climate change, the environment and tourism: The interactions. Proceedings of the ESF-LESC workshop Climate change, the Environment and Tourism: The Interactions, Milan 4-6th June.
CLIMATE AND THE DESTINATION CHOICE OF GERMAN TOURISTS

J.M. Hamilton

1. Centre for Marine and Climate Research, Hamburg University, Hamburg, Germany

E-mail address: jacqueline.hamilton@zmaw.de

ABSTRACT The attractiveness of a tourist destination is partly dependent on its environmental and climatic resource base. Climate change can be expected to have an effect on this attractiveness and will subsequently alter patterns of demand. An application of the pooled travel cost model using survey data on the destination choices of German tourists is presented in this study. Data on the climate, beach length and indicators of cultural, natural resource and economic attractiveness of the destination countries are used in the regression analysis. Optimal climate values were calculated and a climate index was used to examine the change in climatic attractiveness under an arbitrary scenario of climate change. It was found that, for European countries during the summer months, there would be an increase in attractiveness. However, the northern European countries become relatively more attractive closing the gap on the currently popular southern European countries.

KEYWORDS: climate change, destination choice, tourists, Germany

INTRODUCTION
An increase in the globally averaged surface temperature of between 1.4 and 5.8°C by 2100 is predicted by the IPCC (2001). Based on such predictions, climate change impact studies have been produced for many different economic sectors, such as agriculture (Jones and Thornton, 2003) and energy (Cartalis et al., 2001). However, the impact on the world’s largest industry, tourism, has been examined by only a few studies. Studies on the measurement of destination attractiveness (Hu and Ritchie, 1993; Shoemaker, 1984) have shown that climate is one of the most important destination attributes. Typically, when estimating tourism demand the attributes of destinations are not included. However, these attributes, according to Morley (1991), will determine the utility of a visit to a certain destination with a certain set of characteristics. This study looks beyond the different spatial attributes of destinations by introducing temporal ones; different months have different climatic conditions. Moreover, climate change implies that these attributes will change over the long term and therefore utility and the resulting patterns of demand will change.
With the above in mind, the purpose of this research is to examine, by way of a case study, the demand of German tourists in terms of destination characteristics. Only two studies have examined quantitatively the sensitivity of tourism demand to climate and climate change. Maddison (2001) examined climate as a determinant of the destination choices of British tourists and estimated a demand function that included climate variables and beach length for each country. The estimated function was then used to examine changes in the number of tourists as well as changes in welfare using projected changes in temperature and precipitation under a “business as usual” greenhouse gas emissions scenario. Lise and Tol (2002) adapted Maddison's model and applied it to data on the destination choices of Dutch tourists. The pooled travel cost method, which was used in both of these studies will be applied here to survey data on German tourists. In this study, however, the set of destination attributes used in the regression analysis is extended and the temporal aspect is examined at the monthly scale as opposed to the quarterly scale.

This paper is structured as follows. In the next section, the pooled travel cost method is discussed. The data used in this study and the results of the regression analysis are presented in the third section. The implications of these results are discussed in the fourth section. The fifth section concludes.

METHODS

The studies by Maddison and Lise and Tol use a technique called the pooled travel cost method, a microeconomically founded method that includes characteristics of destinations, which Morley (1992) and Papatheodorou (2001) argue to be necessary. This technique is a variant of the family of travel cost models, which have been widely used for estimating the demand for recreation sites. Two different types of these models exist: those that focus on single sites and those that examine multiple sites. In the former case, the purpose is to calculate the total economic value of the site and in the latter case, the object is to obtain a measure of the change in value when site characteristics change. It is this second set of models that is useful for examining the impact of climate change.

The basic premise of both types of model, however, lies in the fact that in order to use services provided by a certain site you have to travel there. This will involve a cost in terms of travel expenditure and the opportunity cost of time. Assuming that recreation is a normal good then sites with a higher travel cost will be visited less than those with the same characteristics but a lower travel cost. In the case of single sites, individuals who incur a lower travel cost for a certain site will
visit that site more frequently than those individuals with a higher travel cost will. Using data on the number of visits and the cost of these visits, a demand function can be estimated. The total value of the site can be measured by the area under the demand curve. In the case of multiple sites, the characteristics of sites are included in the demand function.

As travel is necessary for the consumption of the environmental amenities at a particular site, it is said to be a complement to them. That is, changes in the price of travel will affect the number of trips and through this, the quantity consumed of the amenities. Further, travel cost exhibits the quality of weak complementarity for the environmental amenities. Weak complementarity exists when there is a price where demand for the market good will be zero and changes in the public good, the environmental quality, will have no effect on welfare. In terms of travel to a site, this means that if the price of travel to a particular place is so high that no one wants to go there then changes in the qualities of that site do not bring any benefits to consumers. This enables the use of the demand curve for the market good to estimate the value of the non-market good, which in this case is the environmental quality of a site. When certain characteristics of a site improve, the demand curve for the market good, in this case travel cost, will shift outwards and to the right and so more of the favoured amenities are available at the same travel cost. To value this change, the difference in the area under the demand curves but above the market price for the original level of amenities and for the improved level is calculated.

Freemann (1993) describes the methods used to estimate the demand for multiple sites, with the qualification that these models have limitations through their simplification. One technique involves pooling the number of visits to recreation sites and estimating a single demand equation. The set of explanatory variables will include quality variables, which must be sufficiently varied across the sites, in order to use regression techniques to estimate the demand function. The coefficients on the parameters are the same across all sites. Freeman states that such models can be used to examine changes in the characteristics at one site, but argues that as they do not contain substitute site qualities or prices in the specification, it is not possible to examine the case where quality changes occur at more than one site.

Maddison (2001) adapted the recreation demand model described by Freemann (1993) and applied it to a case study of British tourists' outbound destination choices. For each country and quarter, the individual visits were pooled together. The resulting dataset consisted of data on the economic, geographic and climatic characteristics of each site as well as the travel cost to the site. Moreover,
he assumed that tourists have perfect information about the climate of countries. He estimated the demand function of British tourists as a group and this is then used to analyse the impact of changes in climate. The application of this method to survey data on the destination choice of German tourists is presented in the following section.

German tourists make up the second largest market in terms of expenditure (after the USA) and account for 10% of world spending on tourism (WTO, 2001). Their market importance means that an examination of the possible impacts of climate change on the patterns of demand is of particular interest. A further application of the PTCM model provides an opportunity to extend the model to include climate and other variables that have never been used in tourism demand estimation. Whereas previous PTCM studies have used quarterly data and focussed on outbound tourism, this study uses monthly data and the origin country Germany is included as a destination option. This section describes the application of the pooled travel cost model to the case of the destination choices of German tourists.

Table 1: Countries included in the analysis

<table>
<thead>
<tr>
<th>Albania</th>
<th>Finland</th>
<th>Lebanon</th>
<th>Slovenia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>France</td>
<td>Libya</td>
<td>South Korea</td>
</tr>
<tr>
<td>Austria</td>
<td>Germany</td>
<td>Malta</td>
<td>Spain</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Greece</td>
<td>Morocco</td>
<td>Sweden</td>
</tr>
<tr>
<td>Canada</td>
<td>Hungary</td>
<td>Netherlands</td>
<td>Switzerland</td>
</tr>
<tr>
<td>China</td>
<td>Iceland</td>
<td>Norway</td>
<td>Syria</td>
</tr>
<tr>
<td>Croatia</td>
<td>Ireland</td>
<td>Poland</td>
<td>Tunisia</td>
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<tr>
<td>Cyprus</td>
<td>Israel</td>
<td>Portugal</td>
<td>Turkey</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Italy</td>
<td>Romania</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Denmark</td>
<td>Japan</td>
<td>Slovakia</td>
<td>USA</td>
</tr>
<tr>
<td>Egypt</td>
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</tbody>
</table>

The dependent variable data were taken from a representative survey of 7780 German citizens who were asked about their holidays of more than 5 days that they took in 1997 (Forschungsgemeinschaft Urlaub und Reisen e.V., 1998). The respondents provided information on the region, country or group of countries where they took their holiday. They also specified in which month it took place. From the individual responses, visitation rates for each country (or group of countries) and month combination were calculated. The countries included in the analysis are presented in tables 1 and 2. Information was also provided on total holiday expenditure but not on travel cost. The estimation of travel cost was impeded by variety of travel modes that were used to get to destinations and only data on the state of residence, not place of residence, was available. For
this reason, distance between the destination and state capital city was taken as a proxy for travel cost.

Country specific variables were included in the analysis. There are many groups of countries in the data set and so for each of the variables a group value was calculated using market shares for 1995 (WTO, 2002). Table 2 contains the country groups. GDP per capita, population and population density are taken from the World Resources Institute (2000). Richer countries are more likely to have the basic facilities necessary for tourism, such as quality transport infrastructure and banking services. Richer countries will also have a developed network for domestic tourism and recreation and so the necessary tourist specific infrastructure will be in place. Such countries are more likely to be favoured as international tourist destinations. For population density, it is unclear what effect on tourism demand they have. Densely populated countries may be attractive as they will contain many towns and cities but on the other hand, if this implies a lack of natural areas, they may then be unattractive for tourism. The stability index compiled by Kaufmann (1999) is a proxy for the perception of citizens of the likelihood that their government will be overthrown by non-constitutional means. This has been included in the specification of the model to capture the influence of tourists' concerns about safety on the demand for a destination. Of course, the internal perception may be different from that of the tourists.

Table 2: Country groupings included in the analysis

<table>
<thead>
<tr>
<th>Country Grouping</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium and Luxembourg</td>
<td>Estonia, Latvia, Lithuania, Russian Federation and Ukraine</td>
</tr>
<tr>
<td>Bosnia-Herzegovina, Macedonia and Yugoslavia</td>
<td>Costa Rica, El Salvador, Guatemala, Mexico, Nicaragua and Panama</td>
</tr>
<tr>
<td>Bolivia, Colombia, Ecuador, Guyana, Peru and Venezuela</td>
<td>Brazil and Paraguay</td>
</tr>
<tr>
<td>Argentina, Chile and Uruguay</td>
<td>Antigua, Bahamas, Barbados, Bermuda, Cuba, Dominican Republic, Guadeloupe, Jamaica, Martinique, Puerto Rico, St. Lucia and Trinidad and Tobago</td>
</tr>
<tr>
<td>Benin, Burkina Faso, Cameroon, Gabon, Ghana, Kenya, Madagascar, Mauritius, Nigeria, Senegal, the Seychelles, Togo, Uganda, Zambia and Zimbabwe</td>
<td>Botswana, Lesotho, Namibia, South Africa, Swaziland and Tanzania, Bahrain, Jordan, Oman and Saudi Arabia</td>
</tr>
<tr>
<td>Brazil and Paraguay, Argentina, Chile and Uruguay</td>
<td>Benin, Burkina Faso, Cameroon, Gabon, Ghana, Kenya, Madagascar, Mauritius, Nigeria, Senegal, the Seychelles, Togo, Uganda, Zambia and Zimbabwe</td>
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</tr>
</tbody>
</table>
At a national scale, it is difficult to find comparable data on resource characteristics that are relevant to tourism. One of the key tourist markets is the "sun, sand and sea" holiday. For this particular type of holiday, the availability of beaches is important. To capture the effect of this on demand, the length of beach for each country, taken from Delft Hydraulics (1990), was included in the country dataset. Existing studies used population density and population as proxies for the existence of untouched natural areas and the number of cultural attractions respectively. Both population and population density are included in this analysis, as they may have an independent effect, however other variables are used as a proxy for natural and cultural attractions. In this study, the total area of all protected areas in a country is taken as a proxy for the availability of undeveloped land. The attractiveness of the landscape and the scope for outdoor recreation will depend on this. The total areas protected in each country were obtained from World Conservation Monitoring Centre (WCMC, 2002) for 1996. Only those protected areas of more than 1000 ha in any of the six International Union for Conservation of Nature and Natural Resources (IUCN) categories are included in the WCMC data set. The categories cover nature reserves, wilderness areas, management areas, national parks and monuments, and protected landscapes. Of course, larger countries are more likely to have larger protected areas, as will richer countries that will be able to afford to protect more of their territory. The number of sites on the World Heritage List (UNESCO, 2001) was used as a proxy for the historical and cultural attractiveness of a country. Sites on the world heritage list are those that are considered cultural or natural properties of outstanding natural value. Examples of such sites are Angkor in Cambodia and the Red Square in Moscow.

Climate data were taken from a data set on the recent climate in countries (Mitchell, 2002). For each country, monthly averages for the period 1961-1991 are available for the following: daily temperature (mean, minimum and maximum), precipitation, number of wet days, cloud cover, vapour pressure, and the number of ground frost days. Some of the climate variables show a strong correlation with each other. Vapour pressure and temperature, ground frost days and temperature and wet days and cloud cover are highly correlated (0.87, -0.9 and 0.87 respectively.) On the one hand, this is because of the natural relationship between them and on the other hand because data on vapour pressure and the number of ground frost days was estimated using temperature. For this reason two possible specifications of only three climate variables each were analysed. Both contain mean monthly temperature and average monthly precipitation, as in the studies carried out for the UK and the Netherlands.
The first specification contains the number of wet days per month. A wet day is defined as any day with rainfall greater than 0.1mm and the use of this variable in conjunction with precipitation provides more information on the spread of rainfall over the month. As an alternative to the inclusion of wet day frequency, the average cloud cover as a percentage was used in the second specification. The effects of sunlight on the psychological balance have been documented by Parker (2001) and the variable cloud cover has been included to capture the effect of sunlight at the destination country.

There are certain disadvantages to using country aggregated climate data, particularly for large countries. Tourist destinations within a country may have a particular climate that is quite different from that of the national average and areas with extreme conditions, such as deserts or mountain ranges, which may be of little interest for tourists, will have an effect on the country average. Country data was preferred to capital city climate data, which is also inaccurate. As far as the author knows, a data set containing the climate of only tourist destinations in each country does not exist.

As Germany was included as a destination, a dummy, “HOME” was used to control for Germany being chosen more frequently. It is usual that domestic tourism makes up a large part of total tourism, as familiarity of culture and language or visits to friends and relatives will make the origin country a popular destination. Besides climate, other factors may influence temporal choice, such as public holidays or school holidays. To control for this, monthly dummies are included in the analysis. The variables and their definitions are shown in Table 3.

The log of the number of visits was used, as this was found, using the maximum likelihood procedure as described by Maddala (1977), to fit the data better than the linear form. It also conveniently prevents the model predicting negative numbers of visits. The majority of recreation studies use this functional form, as did the aforementioned tourism and climate studies. As the error components from same country observations are likely to be correlated, panel corrected least squares regression analysis was used instead of ordinary least squares. It is expected that the following variables have a positive relationship with the dependent variable: Stability, GDP per capita, temperature, beach length and the “HOME” dummy variable. Whereas the coefficients of distance, precipitation and cloud cover are expected to be negatively signed. For the other variables, it is unclear what sign to expect.
Table 3: Definition of the variables used in the analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>VISITS</td>
<td>Number of visits from Germany in 1997</td>
</tr>
<tr>
<td>GDPPC</td>
<td>GDP per capita, market prices (1995 US$)</td>
</tr>
<tr>
<td>POP</td>
<td>Population (thousands)</td>
</tr>
<tr>
<td>PDEN</td>
<td>Population density (number per square km)</td>
</tr>
<tr>
<td>STAB</td>
<td>Stability index value (range -2.5 to 2.5)</td>
</tr>
<tr>
<td>BLEN</td>
<td>Beach length (km)</td>
</tr>
<tr>
<td>PROTECT</td>
<td>Area of protected areas (ha)</td>
</tr>
<tr>
<td>HER</td>
<td>Number of heritage sites</td>
</tr>
<tr>
<td>DIST</td>
<td>The distance between the origin and destination capital (km)</td>
</tr>
<tr>
<td>TEMP</td>
<td>Average monthly mean temperature (°C)</td>
</tr>
<tr>
<td>PRE</td>
<td>Average monthly precipitation (mm)</td>
</tr>
<tr>
<td>WETD</td>
<td>Average number of wet days per month</td>
</tr>
<tr>
<td>CLOUD</td>
<td>Average monthly cloud cover in percent</td>
</tr>
<tr>
<td>HOME</td>
<td>Will take the value unity when Germany is the destination, otherwise 0</td>
</tr>
<tr>
<td>M1</td>
<td>Will take the value unity for January, otherwise 0</td>
</tr>
<tr>
<td>M2</td>
<td>Will take the value unity for February, otherwise 0</td>
</tr>
<tr>
<td>M3</td>
<td>Will take the value unity for March, otherwise 0</td>
</tr>
<tr>
<td>M4</td>
<td>Will take the value unity for April, otherwise 0</td>
</tr>
<tr>
<td>M5</td>
<td>Will take the value unity for May, otherwise 0</td>
</tr>
<tr>
<td>M6</td>
<td>Will take the value unity for June, otherwise 0</td>
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<tr>
<td>M7</td>
<td>Will take the value unity for July, otherwise 0</td>
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<tr>
<td>M8</td>
<td>Will take the value unity for August, otherwise 0</td>
</tr>
<tr>
<td>M9</td>
<td>Will take the value unity for September, otherwise 0</td>
</tr>
<tr>
<td>M10</td>
<td>Will take the value unity for October, otherwise 0</td>
</tr>
<tr>
<td>M11</td>
<td>Will take the value unity for November, otherwise 0</td>
</tr>
<tr>
<td>Sources: see text</td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS**

The results of the regression analysis are presented in Table 4. For specification 1, the regression explains 57.5% of the variation in the log of the number of visits. The number of heritage sites, length of beach and the level of GDP per capita are all highly significant and signed as expected. The stability variable “STAB” has a positive relationship to the dependent variable but it is not significant. The coefficient for “PROTECT” is negatively signed but is significant only at the 10% level. Although protected areas may be an attraction for tourists many of these protected areas may not in fact be accessible for tourists or tourist development has been restricted because the land has been protected. The coefficient on “DIST” is as expected, highly significant and negatively signed. The popularity of domestic tourism is reflected in the positive and highly significant coefficient for the variable “HOME”. The coefficients on population and population density are not significant. From the monthly dummies, the months February and November are found to be negative and significant. This result is plausible considering that these two months lie either side of the Christmas and New Year holiday period, when many people take holidays and also a large portion of the household budget will be used during the festive period. The typical holiday months of July and
August are not significant. A possible reason for this, at least for the main destination market of Europe, is that differences in demand are due to climatic differences.

Table 4: Results of the regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Specification 1</th>
<th>Specification 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>t-ratio</td>
</tr>
<tr>
<td>M2</td>
<td>-4.091E-01</td>
<td>-2.45</td>
</tr>
<tr>
<td>M11</td>
<td>-6.020E-01</td>
<td>-4.44</td>
</tr>
<tr>
<td>HOME</td>
<td>1.980E+00</td>
<td>6.02</td>
</tr>
<tr>
<td>GDPPC</td>
<td>3.120E-05</td>
<td>2.48</td>
</tr>
<tr>
<td>POP</td>
<td>-4.480E-07</td>
<td>-1.25</td>
</tr>
<tr>
<td>PD</td>
<td>-2.590E-04</td>
<td>-0.75</td>
</tr>
<tr>
<td>STAB</td>
<td>2.480E-01</td>
<td>0.84</td>
</tr>
<tr>
<td>BLEN</td>
<td>5.538E-04</td>
<td>2.73</td>
</tr>
<tr>
<td>PROTECT</td>
<td>-8.600E-09</td>
<td>-1.58</td>
</tr>
<tr>
<td>HER</td>
<td>5.130E-02</td>
<td>2.64</td>
</tr>
<tr>
<td>TEMP</td>
<td>4.817E-02</td>
<td>3.04</td>
</tr>
<tr>
<td>TEMPSQ</td>
<td>1.363E-04</td>
<td>0.23</td>
</tr>
<tr>
<td>WET</td>
<td>3.502E-01</td>
<td>3.85</td>
</tr>
<tr>
<td>WETSQ</td>
<td>-1.540E-02</td>
<td>-5.2</td>
</tr>
<tr>
<td>PRE</td>
<td>-2.061E-02</td>
<td>-2.25</td>
</tr>
<tr>
<td>PRESQ</td>
<td>7.610E-05</td>
<td>2.77</td>
</tr>
<tr>
<td>CLOUD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOUDSQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-3.989E-01</td>
<td>-0.8</td>
</tr>
</tbody>
</table>

Temperature is highly significant. However, the square of temperature is not significant. Therefore, the optimal temperature cannot be calculated. Here we have a positive relationship between demand and temperature: as temperature increases so will demand. Purely from the human physiological point of view, this is rather unlikely, as at high temperatures, particularly in combination with high levels of humidity, a state of discomfort will occur. The variable temperature has a maximum value of 31°C in the dataset used here. This is perhaps not high enough to be able to detect the optimal. For precipitation, a minimum is found at 135mm per month, which is much higher than the observed values for any month in Germany or in Northern Europe. Before this point, any increase in precipitation will have a negative effect on demand. There is an optimal number of wet days at 11.4 days per month. The Northern European countries have more wet days per month all year round and such a value is typical of a Mediterranean winter.
For the second specification containing the variable cloud cover, the greatest changes are seen in the climate variables. Temperature and precipitation are no longer significant. Moreover, cloud cover and its squared term are not significant. Therefore, the optima cannot be calculated. For the majority of the other variables there are no changes in sign and significance. Compared to the first specification, the $R^2$ is slightly lower at 0.547.

**DISCUSSION**

According to the Third Assessment Report of the IPCC, it is projected that global surface temperature and the sea level are expected to increase during this century. Based upon the results of a set of different climate models and greenhouse gas emissions scenarios, an increase in the global mean temperature of between 0.8°C and 2.6°C is projected for the period 1990 to 2050 (IPCC, 2001). Globally the average annual precipitation is also expected to increase, however at the regional scale there may also be considerable decreases in the level of precipitation. It is possible to examine the impact of these changes on the attractiveness of a destination using the results of this case study. This has been done through the construction of a climate index. The index is calculated by multiplying the climate data for each country by the coefficients for each of the climate variables resulting from the regression analysis and then the calculated values for each of the variables are added together. Using the resulting values, the contribution of climate to demand can be calculated and the countries then ranked according to their climatic attractiveness. Then using an arbitrary scenario, for the European summer months, of a 2°C temperature increase, a 15% decrease in precipitation and a 10% decrease in the number of wet days per month, new climate index values were calculated. Figure 1 shows the index values for August for certain European countries for the observed data and for the arbitrary scenario for specification 1. For specification 1, the climate scenario leads to an increase in the index value for every country; the increase is particularly so for the northern European countries. Figure 2 shows the index values of the countries as a fraction of Spain’s value. Under a scenario of climate change, the northern European countries come much closer to Spain’s attractiveness and make considerable gains on the other southern European countries. In particular, domestic tourism becomes even more attractive relative to the biggest outbound market - Spain. The popular neighbouring countries, the Netherlands, Poland, Denmark and the Czech Republic, would experience an increase in popularity.
This study has further investigated the relationship between climate and demand for particular destinations. There are, however, some limitations of this study with regard to the method. The usefulness of the pooled travel cost method is limited because of the omission of substitution effects. As the substitute site qualities and prices are not included in the demand function in the model presented here, the effect of these on the demand for a destination are not known. If for example the model predicts an increase in the number of visits to a certain destination, after a change in one or more characteristics, it is not possible to say which destinations are now avoided because they have become relatively less attractive. Moreover, the failure to account for substitution effects in the model poses a further problem when changes occur at all sites. This would be the case with climate change, which will occur globally. The decision to go on holiday or not is not included in this model, therefore increases in the total number of tourists cannot be predicted.

The implications of climate change were examined only for the summer months in Europe using an arbitrary scenario. This is of limited use, as the relative attractiveness of the climate of the different months and of other continents is also of interest. Modelled scenario changes are available for all countries of the world (Mitchell et al., 2003). Although the use of the arbitrary scenario is useful to illustrate the effect of climate change on a range of countries for a particular month, the work of this paper could be refined by using the detailed country climate change data. This task will be left for a subsequent paper.

![Figure 1: Climate attractiveness index for the month of August for selected European countries](image)

Figure 1: Climate attractiveness index for the month of August for selected European countries
A limited amount of research has been undertaken on the relationship between tourism demand and the natural resource, climate. The pooled travel cost method, employed here, exploits the necessity of travel to a destination and the associated costs of this travel to analyse the effect destination characteristics, such as climate, have on demand. Expanding on the work of existing studies, that looked at the UK and the Netherlands, a tourism demand function, which included economic, climatic and other country characteristics as explanatory variables, was estimated using survey data on the destination choices of German tourists. Moreover, this study examined destination choice at the monthly level, examined domestic and outbound tourism. In addition, the set of country characteristics was extended: proxy variables to measure safety and cultural attractiveness were included. Two specifications with different climate variables were examined.

An index of climate attractiveness for each country and month was calculated and used to examine the changes in attractiveness under an arbitrary climate change scenario. The northern European countries increase in attractiveness with climate change; the southern European countries becoming relatively less attractive. Using a more detailed climate change scenario, for each country and month, as opposed to an arbitrary one for a particular month and a restricted set of countries, would be an improvement on the current study.
Climate change will not just have an impact on destination attractiveness because it becomes warmer or wetter but also through other effects such as sea-level rise or flooding. Destination characteristics that have a positive relationship with demand, for example beach length and heritage sites may experience adverse impacts through these secondary effects. In order to sustain demand, adaptation measures will have to be implemented.

Although the travel cost methodology provides us with an insight into the relationship between tourism demand and destination characteristics, it inadequately describes the substitution process. Analysing the relative changes in attractiveness and therefore changes in the flows of tourists would allow a more detailed assessment of the impact of climate change on tourism destinations. For this reason, further research is needed to find suitable ways to model this process.

REFERENCES


MULTIANNUAL AND SEASONAL WEATHER FLUCTUATIONS AND TOURISM IN POLAND

Krzysztof Blazejczyk¹,²
¹ Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warsaw,
E-mail: k.blaz@twarda.pan.pl
² Faculty of Geography and Regional Studies, University of Warsaw, Poland,
E-mail: kblazejczyk@uw.edu.pl

ABSTRACT The paper presents relationships between weather conditions and tourism activity in temperate climatic zones on an example of Poland. The day-to-day changes of weather, its seasonal fluctuations and multiannual variability are studied. The new bio-thermal weather classification is applied. It bases on human heat balance and principal meteorological characteristics. The results indicate that tourism activity depends on actual weather. However, it is also influenced by economic and political conditions.

KEYWORDS: bio-thermal weather classification, tourism, recreation, climate seasonality, Poland, human heat balance, MENEX_2005

INTRODUCTION
Tourism and recreation are important to national economies and personal income of its citizens. There is also increase in the number of people interested in tourism/recreation services for personal rest and relaxation as well as for health reasons. When choosing the location and period of recreation we should consider not only social conditions and prices but also climate and weather features. The last two features are key for outdoor recreation abilities and affect our satisfaction/dissatisfaction as well as human’s health (Blazejczyk, 2000, Matzarakis and Mayer 1991, 1997). Several international research teams (e.g. International Society of Biometeorology, European Institute of Climate-Tourism Research), carry out the projects assessing interactions between climate, recreation and tourism.

Favourable climate and weather conditions are essential advantages for recreational and tourism activity. However, in temperate climatic zone they are characterised by seasonality. For example coastal and lakeland regions in Poland are most attractive during June-August. More then 80% of
tourists visit Polish coastal region during three summer months. In the mountains we observe two
tourism seasons: June-September and January-March. The summer season attracts more than 40% of
visitors and 26-28% of visitors in winter (Fig. 1).

![Figure 1: Annual visitors flows in two regions in Poland: A – Polish coast of Baltic Sea, B – Sudety Mts.](image)

Various concepts and methodologies are in use when considering bioclimatic criteria for tourism
and recreation. Most climate evaluation methods apply simple climate characteristics, e.g. maximal
and minimal temperature, its amplitude and temporal changes, cloudiness, solar and UV radiation,
precipitation totals and days etc. (Kozlowska-Szczesna et al., 1997, Mieczkowski, 1985). Some
authors propose to use simple biometeorological indices, e.g. Wind Chill Index, Equivalent and
Effective Temperature etc. (Lee, 1980, Maarouf and Bitzos, 2001).

The methods based on the human heat balance brought the new dimension in the research of man-
atmosphere relationships. Various models adapted for indoor conditions are in use (see Parsons
1993). However, for outdoors studies only a few models assess physiological components of man-
environment heat exchange in a realistic manner: Blazejczyk (1994), Brown and Gillespie (1986),
Budyko and Cicenko (1960), de Freitas (1985, 1990), Höppe (1984), Jendritzky (1990), Nielsen et
al. (1988).

Another approach in climate-tourism research considers the complex of meteorological elements
(i.e. the actual weather) influenced human organism (Blazejczyk, 2001, de Freitas, 2001). Several
proposals of weather classification were developed in former USSR (Čubukov, Nevraev, 1960,
Danilova, 1988), in Germany (Ungeheuer, 1955) and in Poland (Blazejczyk, 1979, Wojtach, 2003).
More recently, there is the proposal of Blazejczyk (2002, 2004b) that is based on man-environment
heat exchange that creates the so called bio-thermal conditions.

The aim of the present paper is to analyse how multiannual and seasonal fluctuations of weather can
influence tourist flows and ability of outdoor recreation. The research is based on meteorological
data for two stations: Kolobrzeg in the Polish coast of the Baltic Sea and Szczawno in the Sudety Mountains which represent two different regions of temperate climate zone. Meteorological data were compared with statistical information dealing with tourist flows in particular years and seasons.

**METHODS AND DATA SOURCES**

**Principles of bio-thermal weather classification**

The research dealing with climate-tourism relationships should consider three categories of information (de Freitas, 2003):

- aesthetic factors (cloudiness, visibility, sunshine duration, day length),
- physical state of the atmosphere (precipitation, snow cover, wind, solar radiation, UV radiation, air pollution),
- bio-thermal conditions (human heat balance considerations).

According to this concept, the actual weather is one of the basic demand indicators of recreational and tourism potentials of any time, season and/or region. The weather classification used in this study includes most of the components considered by de Freitas. The classification bases on the man-environment heat exchange model MENEX_2005 (Blazejczyk, 2006). The equations used for calculations of the human heat balance components and bio-thermal indices are shown in Annex 1. Classification consists of three levels: weather type, subtype and class. Every individual weather situation is described by seven digits: the first digit provides information on weather type, second, third and fourth digits illustrate weather subtype and the last three digits – weather class.

**Weather types**

Recreation and tourism should provide the people rest, joy and amusement. Several researches report that heat state in humans plays very important role in human health and well being (Blazejczyk, 2000, Kuchcik, 2001, Matzarakis and Mayer, 1991). Thus during outdoor recreation and tourism heat balance of an organism must be considered as a main indicator of enjoyment. Subjective temperature (STI) is an indicator that gives information about actual bio-thermal conditions (Blazejczyk, 2003a). As bio-thermal conditions we should understand the thermal conditions considered from the point of view of the human organism. They are influenced both, by meteorological stimuli and by physiological response of an organism. STI point to temperature that
is observed just around the cold and hot receptors in the human’s skin. The thermal signals from the receptors are recognised by central nervous system as various thermal sensations. Thus, the principal information dealing with weather type is thermal sensations experienced by a person walking outdoors with the speed of 4 km/hour. Thermal sensations are evaluated based on STI values as follows:

<table>
<thead>
<tr>
<th>Weather type index</th>
<th>STI (°C)</th>
<th>Description of weather:</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>&lt; -38.0</td>
<td>- very cold</td>
</tr>
<tr>
<td>-2</td>
<td>-38.0 to -0.5</td>
<td>- cold</td>
</tr>
<tr>
<td>-1</td>
<td>-0.4 to 22.5</td>
<td>- cool</td>
</tr>
<tr>
<td>0</td>
<td>22.6 to 32.0</td>
<td>- comfortable</td>
</tr>
<tr>
<td>1</td>
<td>32.1 to 46.0</td>
<td>- warm</td>
</tr>
<tr>
<td>2</td>
<td>46.1 to 55.0</td>
<td>- hot</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 55.0</td>
<td>- very hot</td>
</tr>
</tbody>
</table>

**Weather subtypes**

Solar radiation is important meteorological factor that influences humans outdoor (Blazejczyk, 1998, 2004a, Blazejczyk et al., 1993, Brown and Gillespie, 1986, Nielsen et al., 1988). The second digit in the classification system defines intensity of solar radiation stimuli. In this purpose the value of solar radiation absorbed by nude man ($R' = R/Irc$, see Annex 1) was applied. The following limits of $R'$ values are used:

<table>
<thead>
<tr>
<th>Second digit:</th>
<th>$R'$ (W m$^{-2}$)</th>
<th>Radiation stimuli:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 75.0</td>
<td>- weak</td>
</tr>
<tr>
<td>2</td>
<td>75.1 to 150.0</td>
<td>- moderate</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 150.0</td>
<td>- strong</td>
</tr>
</tbody>
</table>

The third characteristic of weather is the kind of physiological strain ($PhS$), which depends on predominant way of heat elimination from the body. The $PhS$ index is used to define physiological strain as follows:

<table>
<thead>
<tr>
<th>THIRD DIGIT:</th>
<th>$PHS$ VALUE</th>
<th>PHYSIOLOGICAL STRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>&lt; 0.75</td>
<td>- HOT STRAIN</td>
</tr>
<tr>
<td>T</td>
<td>0.75 TO 1.50</td>
<td>- THERMONEUTRAL</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 1.50</td>
<td>- COLD STRAIN</td>
</tr>
</tbody>
</table>

Cold physiological strain is manifested by: decrease in skin temperature, reduction of peripheral blood flow, increase in blood pressure, increase in thermal insulation of skin tissue, shivering (Blanc, 1975, Clark and Edholm, 1985).
Hot physiological strain leads to: increase in peripheral blood flow, a decrease in blood pressure, increase in heart rate, sweating, dehydration, temporal changes in skin temperature (Blazejczyk, 1998, Blazejczyk et al., 2000, Clark and Edholm, 1985, Kenney, 1985, Malchaire, 1991).

Fourth weather feature is sultriness intensity. It is evaluated with the use of heat stress index (HSI) of Belding and Hatch (1955). The following HSI limits are applied:

<table>
<thead>
<tr>
<th>Fourth digit</th>
<th>HSI (%)</th>
<th>Sultriness intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt; 30.0</td>
<td>- non sultry</td>
</tr>
<tr>
<td>1</td>
<td>30.0 to 70.0</td>
<td>- moderate</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 70.0</td>
<td>- great</td>
</tr>
</tbody>
</table>

**Weather classes**

Availability of tourism and recreation outdoors is influenced not only by bio-thermal conditions but also by general features of weather including: daily amplitude of air temperature, daily precipitation and snow cover.

Daily amplitude of air temperature is the difference between daily maximum (\(t_{max}\)) and daily minimum (\(t_{min}\)) temperatures (\(dt=t_{max}-t_{min}\)). It 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 are assessed:

<table>
<thead>
<tr>
<th>Fifth digit</th>
<th>(dt) (°C)</th>
<th>Daily thermal contrasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(\leq 8)</td>
<td>- neutral</td>
</tr>
<tr>
<td>1</td>
<td>&gt; 8</td>
<td>- stimulated.</td>
</tr>
</tbody>
</table>

Recreation is also strongly limited by precipitation. The duration of rain- or snowfalls during the daytime hours is critical. However, this information is not commonly inserted into meteorological databases. Hence, daily totals of precipitation (\(RR\)) are applied in classification as follows:

<table>
<thead>
<tr>
<th>Sixth digit (RR) (mm)</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>1</td>
<td>(\geq 1)</td>
</tr>
</tbody>
</table>

Snow cover (\(SC\)) is very important for winter ski tourism. It can be effectively practised when \(SC\) depth is \(\geq 10\) cm. Thus the snow conditions are assessed as follows:

<table>
<thead>
<tr>
<th>Seventh digit</th>
<th>(SC) depth (cm)</th>
<th>Snow conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt;10</td>
<td>- no snow</td>
</tr>
<tr>
<td>1</td>
<td>(\geq 10)</td>
<td>- snowy day.</td>
</tr>
</tbody>
</table>
Digital description is applied in bio-thermal weather classification. Every digit contains information dealing with the considered weather characteristics (Table 1).

Table 1: Characteristics of weather components as well as their indicators used in bio-thermal classification of weather

<table>
<thead>
<tr>
<th>Weather type</th>
<th>Weather characteristic</th>
<th>Weather subtype</th>
<th>Physiological strain</th>
<th>Sultriness intensity</th>
<th>Daily thermal contrasts</th>
<th>Precipitation</th>
<th>Snow cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal sensations</strong></td>
<td>Radiation stimuli</td>
<td>1 (weak)</td>
<td>C (cold)</td>
<td>0 (non sultry)</td>
<td>0 (no rain)</td>
<td>0 (no snow)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 (moderate)</td>
<td>T (thermo-neutral)</td>
<td>1 (mode-rate)</td>
<td>1 (rainy day)</td>
<td>1 (snowy day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 (strong)</td>
<td>H (hot)</td>
<td>2 (great)</td>
<td>1 (significant)</td>
<td>1 (snowy day)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For example the record 1_2H0_110 means warm weather with moderate radiation stimuli, with hot physiological strain and no sultriness. There are stimulated daily thermal contrasts and precipitation, but no snow cover.

**Evaluation of weather for recreation and tourism**

The next step in our considerations is evaluation of weather for various forms of recreation and tourism. The most common forms are: sun baths (staying in the sunny place – SB), air baths (staying in the shaded place- AB), mild recreational activity (e.g. walking, light plays, shopping – MR), intensive recreation and summer tourism (e.g. football, biking, climbing, jogging etc. – AR), ski tourism (ST).

The usefulness of each individual weather situation for different forms of recreation and tourism was analysed and every class of weather was evaluated using the following weather evaluation indices (WEI): 0 – unfavourable, 1 – favourable with limitations, 3 – favourable without limitations.

Table 2 contains several examples of WEI values for the most frequent weather conditions in temperate climatic zone. When analysing multiannual weather series mean values of weather evaluation index (WEIavg) for consecutive pentads of the year were calculated. The values of WEIavg can be validated as follows:
WEIavg General validation of weather for various forms of recreation and tourism:
< 0.50 - non useful,
0.50 – 1.20 - moderately useful,
1.21 – 2.00 - useful,
> 2.00 - very useful.

Table 2: Weather evaluation indices (WEI) of individual weather situations (some examples) for various forms of recreation and tourism: sun baths (SB), air baths (AB), mild recreation (MR), active recreation and summer tourism (AR), ski tourism (ST)

<table>
<thead>
<tr>
<th>Weather type</th>
<th>Weather subtype</th>
<th>Weather class</th>
<th>WEI for:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R’ PhS HSI dt RR SC</td>
<td>SB AB MR AR ST</td>
<td></td>
</tr>
<tr>
<td>-2</td>
<td>1 C 0 0 0 0</td>
<td>0 0 1 3 0</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>1 C 0 0 0 0</td>
<td>0 0 1 3 0</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>1 C 0 0 0 1</td>
<td>0 0 1 3 3</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>1 C 0 0 1 0</td>
<td>0 0 1 1 0</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>2 C 0 0 1 0</td>
<td>0 0 1 1 0</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>2 C 0 1 0 0</td>
<td>0 1 3 3 0</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>2 C 0 1 1 0</td>
<td>0 1 1 1 0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2 T 0 0 0 0</td>
<td>3 3 3 3 0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2 T 0 0 1 0</td>
<td>1 1 1 1 0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2 T 0 1 0 0</td>
<td>3 3 3 3 0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 H 0 1 0 0</td>
<td>3 3 3 1 0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 H 1 1 0 0</td>
<td>1 1 1 1 0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 T 1 1 0 0</td>
<td>1 1 1 0 0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3 H 0 1 0 0</td>
<td>3 3 1 1 0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3 H 1 1 0 0</td>
<td>1 1 0 0 0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 H 1 1 0 1</td>
<td>1 1 0 0 0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 H 2 0 0 0</td>
<td>0 0 0 0 0</td>
<td></td>
</tr>
</tbody>
</table>

Data sources
The fluctuations of weather conditions were assessed based on daily meteorological data for the selected stations represented two tourist regions in Poland (Fig. 2). The central part of the Polish coast of the Baltic Sea is represented by Kolobrzeg meteorological station. The data for the period of 1961-2001 were taken. For the general information of air temperature changes the data of 1951-2001 were analysed. Sudety Mts. were taken as an example of the region of mountain tourism. The meteorological data from Szczawno for the period of 1956-2000 were used in the studies. The data
applied in the paper represent the longest, possible to use periods of observations to study long-term, multiannual changes in meteorological and bioclimatic conditions.

Weather characteristics were defined for every day of the studied periods. Bio-thermal indices were calculated for the midday hours (12:00 UTC). The BioKlima©2.5 software package was used in this purpose. Statistical analyses were made using STATGRAPHICS Plus 2.0 software package. Information dealing with tourist flows was taken from statistical yearbooks of the chosen regions. In general, the yearbooks exist for the period of 1968-2001. However, the two administrative changes in Poland in 1975 and again in 1996 resulted in data gaps. There were analysed data of total number of tourist objects (hotels, camps, resorts) and total number of hotel services. To make the data comparable the index of tourists per bed was calculated for every year with the available data.

RESULTS

Changes in tourists' flow

Studying tourist flows it is important to consider their multiannual variability. Due to administrative changes the number of hotel services can be compared for the period of 1975-1995. We can notice gradual decrease in visitor flows in both studied regions. Very dramatic changes were observed twice: in 1982 and in 1989-1990. The first fluctuation was caused by political reasons (so called “war state” declared in December 1981 by the Polish government). The second jump occurred as a consequence of the economical transformations started in Poland in 1989 (Fig. 3). In addition we
can also find that the amount of hotel services in the seashore region is considerably higher then in mountainous one.

![Figure 3: Annual number of hotel services (HS) in the studied regions](image)

In order to quantify tourist flows independent of administrative divisions the normalised index of the annual number of tourists per 1 bed in the hotels ($TPB$) was calculated. The index illustrates even small changes in the tourist flows, which can be caused by actual weather conditions. In the both regions the number of tourists per bed is similar each other (Fig. 4). Gradual decrease in $TPB$ index is also evident during the period of 1976-1994 whereas slight increase is seen in the last years (1999-2001).

![Figure 4: Annual number of $TPB$ index (tourists per bed) in the studied regions](image)

**Changes in general climatic conditions**

In the previous 50 years thermal features of climate were quite similar in the regions under investigation. Mean daily air temperature for July was 16.5°C in the mountains and 16.9°C at the seashore regions. Multiannual fluctuations in air temperature in July ($t07$) were very similar varying from about 14°C to about 20°C. Slight positive trends in $t07$ at both stations is observed. The coldest
were the summers 1977-1980 and 1960-1962, while the warmest were the years 1994-1995, 1999 and 2001 (Fig. 5).

Considerably great differences were observed in the precipitation totals ($RR$): 106.5 mm in the mountains and 84.1 mm at the seashore. There are not significant trends in summer precipitation totals. The driest summers occurred almost at the same years (1963, 1969, and 1983) in both regions with $RR$ of 17-26 mm. The years 1990-1992 and 1994 were also relatively dry. Significant differences in $RR$ values between studied stations were observed starting from 1997. In the mountains monthly precipitation totals were 2-10 times higher than at the seashore (Fig. 5).

![Figure 5: Changes in mean monthly air temperature ($t$) and monthly precipitation totals ($RR$) in July in the studied regions](image)

**Changes in weather conditions**

**Seashore location**

At the seashore region only one, summer culmination of tourist flow is observed (Fig. 1). Therefore, to illustrate multiannual variability of weather conditions the data for July were used. The results indicate that during the studied period (1961-2001) monthly values of principal bio-thermal indices have changed.
Monthly minimal and mean values of subjective temperature increased slightly (2.9°C and 1.8°C per 10 years, respectively). On the other hand slight decrease in the maximal \( STI \) was noted (-0.8°C per 10 years). In effect at the end of studied period monthly \( STI \) amplitudes were significantly lower then in its beginning (45°C and 30°C, respectively). Considering fluctuations in physiological strain we can see that maximal and average monthly \( PhS \) values did not change. However, very low minimal \( PhS \) values point to “strong hot strain” events that occurred during the periods of 1967-1971 and 1983-1995 (Fig. 6).

![Figure 6: Changes in maximal (max), minimal (min) and average (avg) monthly values of subjective temperature (\( STI \)) as well as their trend lines, July 1961-2001, seashore station (Kolobrzeg)](image)

Only three indices of weather characteristics have changed significantly during the last 40 years: thermal sensations, radiation stimuli and precipitation. The first two indices have increased gradually (0.16 and 0.09 per 10 years, respectively), while the third decreased considerably.
Amelung B., Blażejczyk K., Matzarakis A., 2007: Climate Change and Tourism – Assessment and Coping Strategies

(-0.03 per 10 years). Figure 7 shows an increase in thermal sensations (from “comfortable” to “warm”) and in intensity of radiation stimuli is observed. The precipitation index points that in 60. almost during 50% of days the rain was noted (index values of 0.4-0.5). However, in 90. the index was only 0.1-0.3, i.e. 10-30% of rainy days have occurred.

\[ y = 0.0097x + 1.7714 \]
\[ y = -0.003x + 0.4065 \]
\[ y = 0.0169x + 0.4844 \]

![Figure 7: Changes in mean monthly values of the indices of weather characteristics and their trend lines, July 1961-2001, seashore station (Kolobrzeg)](image)

**Mountain region**

Tourist flows in the mountain region are concentrated twice a year, in the summer and in January-March periods (Fig. 1). Variability in bio-thermal weather characteristics during the summer is presented on Figure 8. There are not significant changes in subjective temperature (STI) and physiological strain (PhS). During the entire study period (1956-2000) mean STI values ranged from about 35°C to 45°C, indicating of “warm weather”. Only twice, in 1983 and 1994 STI was considerably higher (>50°C). Extreme STI values pointed that thermal sensations in man varied from “cool” to “very hot”. Mean PhS values point to “thermoneutral” conditions in respect to adaptation processes in humans. However, PhS ranged from 0.06 (“great hot strain”) to 3.15 (“moderate cold strain”).

Considering several weather characteristics and correspondent weather indices we also note that not significant change occurred in the summer season. In general mean values of thermal sensations index fluctuated around 1 (“warm weather”), radiation index - between 1.5 and 2.0 (“moderate” or “strong radiation stimuli”), strain index - from 0.5 to 1.0 (“thermoneutral” or “cold strain”). The
ranges of sultriness and precipitation indices point to predominance of “non-sultry” and “no rain” weather conditions (Fig. 9).

Figure 8: Minimal (min), maximal (max) and mean (avg) monthly values of bio-thermal indices of subjective temperature (STI) and physiological strain (PhS) as well as their trend lines, July 1956–1997, mountains

Figure 9: Mean monthly values weather indices, July 1956-2000, mountains
Significant changes of bio-thermal conditions are observed in the winter season. Subjective temperature increased gradually, particularly its maximal and mean monthly values (3.4°C and 2.1°C per 10 years, respectively). The most important $STI$ growth was noted in 1987-1988 when $STI_{\text{max}}$ and $STI_{\text{avg}}$ increased from 20°C to 40°C and from 5°C to 20°C, respectively. Significant temporal trends are also found for $PhS$, mainly its maximal monthly values. They decreased gradually from about 5 in the beginning of the period to about 4 in the last years of XX century (-0.26 per 10 years) pointing to slight softening of cold strain (Fig. 10).

Changes were also observed in weather indices. The greatest increase occurred in thermal sensations, particularly in the last decade of the studied period (0.13 per 10 years). The warming of weather corresponds with the lack of snow cover with 10-cm depth. The absence of snow cover that observed in the years 1964-1965, 1973-1975 and 1982-1984 is also correlated with relatively slight warming of weather” (Fig. 11).
Influence of weather conditions on tourists’ flow

Figure 4 shows several periods with dramatic changes in tourist flows. Two of them were caused by political and economical situations: in 1982 and in 1989-1990. However, we can observe also fluctuations, which could be affected by weather conditions. Such fluctuations include the periods 1971-1973 at the seashore and 1976-1978 in the mountains.

Seashore location

At the seashore tourist flow in 1972 was considerably higher then in 1971 and 1973. Comparing weather characteristics for July we can see in 1972 a relatively long period of stable, high values of subjective temperature. Similar stable STI periods were also observed in June and August. In 1971 and 1973 the great day-to-day fluctuations of STI were common. Regarding physiological strain, very low PhS values in 1971, indicate strong “hot strain”. However, in 1972 and 1973 PhS values pointed to “thermoneutral” conditions (Fig. 12).

Comparing the frequency of particular classes of weather characteristics we can evaluate which feature of weather play the most important role in regulation of tourist flows. Thermal sensations are very important at the seashore region. In 1972 tourists could benefit of frequent “hot” conditions which are pleasant for beach recreation. “Strong” radiation stimuli and predomination of “neutral” daily thermal contrasts in the summer 1972 were also favourable for sunbathe (Table 3).
Figure 12: Daily changes of subjective temperature (STI) and physiological strain (PhS) indices in July of consecutive years, seashore

Table 3: Frequency (in days) of particular classes of weather characteristics, July, seashore

<table>
<thead>
<tr>
<th>Year</th>
<th>Tourists per bed</th>
<th>Thermal sensations: Radiation stimuli:</th>
<th>Physiological strain:</th>
<th>Sultriness intensity:</th>
<th>Daily thermal contrast:</th>
<th>Precipitation:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cool</td>
<td>cool</td>
<td>comfortable</td>
<td>warm</td>
<td>hot</td>
</tr>
<tr>
<td>1971</td>
<td>84</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>1972</td>
<td>99</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>1973</td>
<td>74</td>
<td>0</td>
<td>8</td>
<td>14</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Mountain region

Multiannual fluctuations of tourist flows in mountains were influenced by both, winter and summer weather. In the years with the highest number of tourists the subjective temperature in summer were relatively low and stable within the range of “warm” and “hot” sensations. In the winters of 1976-1978 the STI values were similar each other. January weather was differentiated when comparing
physiological strain. In 1977 PhS values were very stable within the range of “moderate cold”. In 1976 and 1978 great day-to-day fluctuations were noted and very often they reached level of strong “cold strain” (Fig. 13).

![Graph showing daily changes of subjective temperature and physiological strain](image)

**Figure 13:** Daily changes of subjective temperature in January (STI-01) and in July (STI-07) as well as of physiological strain (PhS) in January and July of consecutive years, mountains

Comparing other weather characteristics we can see that low number of tourists in 1978 might also be caused by the small amount of snowy days in the winter (Table 4).

**DISCUSSION**

The problem of multiannual changes of climate characteristics – mainly air temperature and precipitation – is studied very frequent. In Poland long climatic records are well documented for Cracow, Warsaw, Wroclaw and Gdansk (Lorenc, 2000, Paczos, 1993, Trepinska, 1997). In each series authors reported fluctuations in air temperature. They have found relatively warm and cold periods. Fluctuations of bioclimatic conditions were studied based on Cracow series. The series contains records of all essential meteorological elements that allow for the calculation of various bioclimatic indices (Blazejczyk and Twardosz, 2002, Blazejczyk et al., 2003, Piotrowicz, 2003). The authors have found periodical variability in subjective temperature and other indices. During the last 10-15 years of XX century a significant increase in heat loads of the human organism was observed.
The present studies confirm significant changes of weather bio-characteristics in the winter. However, in the summer months the changes did not occur or they are insignificant.

Great seasonal variability of weather is one of the limitation for tourism and recreation. In temperate climatic zone tourism industry can adapt to seasonal fluctuations of weather by promotion the various forms of recreation and tourism. The studies carried out in Warsaw Agglomeration (Blazejczyk, 2002) show that in consecutive pentads of the year various forms of activity should be preferred. In the summer sun and/or air baths are recommended. Spring and autumn weather is favourable mostly for active recreation and tourism. In the winter time intensive recreation and tourism can be applied (Fig. 14). Depending on the season and actual weather the customer should have the possibility to find places and equipment for the most favourable recreation and tourism activity.

Table 4: Frequency (in days) of particular classes of weather characteristics, January and July, mountains

<table>
<thead>
<tr>
<th>Year and Month</th>
<th>Tourists per bed</th>
<th>Weather characteristics:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cold</td>
<td>cool</td>
</tr>
<tr>
<td>1976 Jan</td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>1976 Jun</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1977 Jan</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>1977 Jun</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1978 Jan</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>1978 Jun</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 14: Mean values of weather evaluation index ($WEI_{avg}$) for various forms of activity: SB - sun baths, AB - air baths, MR - mild forms of active recreation, AR - intensive tourism, Warsaw, 1994-2001

CONCLUSIONS

A strong influence of actual weather conditions on tourist flows is observed in Poland. The relationships for seasonal and multiannual fluctuations of weather were found. Unfavourable weather condition reduced tourist flows up to 15-20% of.

Significant seasonality of visitors was found. At the seashore more than 80% of tourists come in the summer months. In the mountain regions two peaks of tourism activity occurs: summer (40% of visitors) and winter (25% of visitors).

Both, seasonal and multiannual fluctuations of weather result in adaptation within the tourism industry. The most popular are: reduction of staff during out of season periods and increase of prices in the periods of favourable weather (to recompense losses in income caused by unpleasant conditions). Additional adaptations are called for. It seems that tourism organisers and proprietors of hotels and recreation centres should be more active to propose clients facilities to use various forms of activity, not only passive but also active.

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Paczos, S. (1993) Charakterystyka termiczna ziem polskich w ciągu ostatnich 200 lat (Thermal characteristic of Poland in the last 200 years). Zeszyty IGiPZ PAN, 18, 49-82.


Annex 1. Equations used for the calculations of the human heat balance and bio-thermal indices (due to BioKlima©2.5)

\[ M + Q + E + Res = S \]

\[ Q = L + R \]

\[ L = (Lg + La - Ls) Irc \]

\[ Lg = 0.5 \times [0.97 - 5.667 \times 10^{-9} (273 + Tg)^4] \]

\[ La = 0.5 \times [0.97 - 5.667 \times 10^{-9} (273 + T)^4] (0.82 - 0.25 \times 10^{-0.094 \cdot v'}) \]

\[ Ls = 0.95 \times 5.667 \times 10^{-8} (273 + Tsk)^4 \]

\[ Tsk = (26.4 + 0.0214 \cdot Mrt + 0.2095 \cdot t - 0.0185 \cdot RH - 0.009 \cdot v') + 0.6 \cdot (Icl - 1) + 0.00128 \cdot M \]

\[ Irc = hc' / (hc + hc' + 21.55 \times 10^{-8} \cdot T^{3.75}) \]

\[ hc = (0.013 \cdot ap - 0.04 \cdot t - 0.503) \cdot (v + v')^{0.4} \]

\[ hc' = (0.013 \cdot ap - 0.04 \cdot t - 0.503) \cdot 0.53 / \{Icl \cdot [1 - 0.27 \cdot (v + v')^{0.4}] \} \]

\[ Icl = 1.691 - 0.0436 \cdot t \]  
(at \( t < -30^\circ C \) Icl = 3.0 clo, and at \( t > 25^\circ C \) Icl = 0.6 clo)

\[ Mrt = [(R/Irc + Lg + La) / (0.95 \times 5.667 \times 10^{-8})]^{0.25} - 273 \]

\[ R = (1.64 \times 0.254 - h)^3 \times (1 - 0.01 \cdot ac) Irc \]  
(at \( h < 4^\circ \))

\[ R = (103.6 \cdot Lnh - 140.6) \times (1 - 0.01 \cdot ac) Irc \]  
(at \( h > 4^\circ \) and \( N < 20% \))

\[ R = 1.4 \cdot e^{(15.38 - 16.07 \cdot h)} \times (1 - 0.01 \cdot ac) Irc \]  
(at \( h > 4^\circ \), \( N > 50% \))

\[ R = 0.951 \cdot h^{1.039} \times (1 - 0.01 \cdot ac) Irc \]  
(at \( h > 4^\circ \), \( N > 80% \))

\[ E = he \cdot (v - vpsk) \cdot w \cdot Ie - [0.42 \cdot (M - 58) - 5.04] \]

\[ vpsk = e^{(0.058 \cdot Tsk + 2.003)} \]

\[ w = 1.031 / (37.5 - Tsk) - 0.065 \]  
(at \( Tsk > 36.5^\circ C \) \( w = 1.0 \), at \( Tsk < 22^\circ C \) \( w = 0.001 \))

\[ he = t \cdot (0.00006 \cdot t - 0.00002 \cdot ap + 0.011) + 0.02 \cdot ap - 0.773 \]  
\[ Ie = hc' / (hc' + hc) \]

\[ C = hc \cdot (t - Tsk) Irc \]

\[ Res = 0.0014 \cdot M \cdot (t - 35) + 0.0173 \cdot M \cdot (0.1 \cdot v - 5.624) \]

\[ STI = Mrt - \{[(S)^{0.75} / (5.39 \cdot 10^{-8})] + 273^{0.25} - 273 \} \]  
(at \( S < 0 \) W·m\(^{-2}\))

\[ STI = Mrt + \{[(S)^{0.75} / (5.39 \cdot 10^{-8})] + 273^{0.25} - 273 \} \]  
(at \( S \geq 0 \) W·m\(^{-2}\))

\[ PhS / E \]

\[ ac \ – \ albedo \ of \ clothing \ (\%), \]

\[ C \ – \ heat \ exchange \ by \ convection \ (before \ acclimation, \ W·m\(^{-2}\)) \]

\[ E \ – \ evaporative \ heat \ loss \ (before \ acclimation, \ W·m\(^{-2}\)) \]

\[ h \ – \ Sun \ altitude \ (^\circ) \]

\[ hc \ – \ coeff. \ of \ turbulent \ heat \ transfer \ (K·W^{-1}·m^{-2}) \]

\[ hc' \ – \ coeff. \ of \ turbulent \ heat \ transfer \ through \ clothing \ (K·W^{-1}·m^{-2}) \]

\[ he \ – \ coeff. \ of \ evaporative \ heat \ transfer \ (hPa·W^{-1}·m^{-2}) \]

\[ Icl \ – \ clothing \ insulation \ (clo) \]

\[ Ie \ – \ coeff. \ reducing \ wet \ heat \ transfer \ through \ clothing \ (dimensionless) \]

\[ Irc \ – \ coeff. \ reducing \ dry \ heat \ transfer \ through \ clothing \ (dimensionless) \]

\[ L \ – \ net \ long-wave \ radiation \ in \ man \ (before \ acclimation, \ W·m\(^{-2}\)) \]

\[ La \ – \ thermal \ radiation \ of \ the \ atmosphere \ (W·m\(^{-2}\)) \]

\[ Lg \ – \ thermal \ radiation \ of \ the \ ground \ (W·m\(^{-2}\)) \]

\[ Ls \ – \ thermal \ radiation \ of \ the \ human \ body \ (before \ acclimation, \ W·m\(^{-2}\)) \]

\[ M \ – \ metabolism \ (135 \ W·m^{-2}) \]

\[ Mrt \ – \ mean \ radiant \ temperature \ (^\circ C) \]

\[ N \ – \ cloudiness \ (\%) \]

\[ PhS \ – \ Physiological \ Strain \ (dimensionless) \]

\[ Q \ – \ radiation \ balance \ in \ man \ (before \ acclimation, \ W·m\(^{-2}\)) \]

\[ R \ – \ absorbed \ solar \ radiation \ in \ man \ (W·m^{-2}) \]

\[ Res \ – \ respiratory \ heat \ loss \ (W·m^{-2}) \]

\[ RH \ – \ relative \ humidity \ of \ air \ (\%) \]

\[ S \ – \ net \ heat \ storage \ (before \ acclimation, \ W·m^{-2}) \]

\[ STI \ – \ Subjective \ Temperature \ (^\circ C) \]

\[ t \ – \ air \ temperature \ (^\circ C) \]

\[ T \ – \ air \ temperature \ (K) \]

\[ Tg \ – \ ground \ temperature \ (^\circ C) \]

\[ Tsk \ – \ skin \ temperature \ (^\circ C) \]

\[ v \ – \ wind \ speed \ (m·s^{-1}) \]

\[ v' \ – \ body \ motion \ (1.1 \ m·s^{-1}) \]

\[ vp \ – \ vapour \ pressure \ (hPa) \]

\[ vpsk \ – \ vapour \ pressure \ at \ the \ skin \ surface \ (hPa) \]

\[ w \ – \ skin \ wettedness \ (dimensionless) \]
CLIMATE CHANGE IN PORTUGAL: 
POTENTIAL IMPACTS ON TOURIST HEALTH

E. Casimiro\textsuperscript{1,2} and J. Calheiros\textsuperscript{3}

1. Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa, Lisbon, Portugal
2. INFOTOX Consultores de Riscos Ambientais e Tecnológicos, Lisbon, Portugal
3. Faculdade de Ciências da Saúde, Universidade da Beira Interior, Covilha, Portugal

Email: emvmcasimiro@sapo.pt

\textbf{ABSTRACT} 
Tourism is an important economic industry sector in Portugal contributing significantly to the national GDP and employment. Regional climatic changes may have adverse impacts on tourist health and consequently in the tourism industry. In this paper, potential changes on tourist thermal comfort and vector-borne disease transmission risks were assessed based on potential climate change scenarios for Faro and Lisbon.

\textbf{KEYWORDS}: Tourist health, climate change, Portugal, thermal comfort, malaria, Leishmaniasis.

\textbf{INTRODUCTION}

Tourism is an important economic industry sector in Portugal, employing over 5\% of the working population, and spending by foreign tourists contributes to about 4.5\% of the national GDP (INE 2000). In 2001 non-residents made up about 60\% of the tourism market, with visitors from UK, France, Spain, and Germany contributing to more than 60\% of foreign tourism receipts. The main tourism destination regions are the southern coastal region of the Algarve accounting for 41\% of the Portuguese tourism market, followed by the central coastal metropolitan area of Lisbon and Tagus Valley region (LVT), and thirdly by the islands of Madeira (INE, 2002).

Amongst other factors, the success of the tourism industry in Portugal can be attributed to the country’s:

- long sunny warm days and mild winters;
- long coastline and good quality beaches;
- rich culture and gastronomy;
- low cost of living relative to other EU countries;
relative close proximity to tourism generating EU countries;
status as a “safe” destination since it is a stable democracy;
status as a very low health risk destination, with EU regulation standards for drinking water quality, food hygiene, and air quality, as well as free of exotic diseases like malaria.

Favourable climatic and health risk conditions are thus important pull factors for tourists in Portugal. Climatic changes may result in significant impacts on both of these pull factors and thus potentially affect the country’s tourism industry.

Climate change is anticipated to affect human health through a variety of pathways. Some are direct pathways such as extreme thermal exposure and floods. Others involve intermediate and multiple pathways such as those affecting the transmission dynamics of vector-borne and water-borne diseases. These impacts are obviously not limited to the local population; all individuals (locals and visitors) in a region are vulnerable to the potential climate change impacts of that region. Visitors are even more vulnerable to health problems abroad due to the following reasons: they are not acclimatised to the country they are visiting (physiologically, or behaviourally); they don’t always speak the language so may not be able to follow warnings or advice, or know where to seek treatment; they are very dependent on hotels and restaurants; and they may be exposed to new pathogens for which they have not developed immunity. Potential negative impacts of climate change on tourist health in Portugal may weaken the country’s attractiveness as a tourist destination.

Results from a comprehensive investigation on the potential impacts of climate change in Portugal identified several health outcomes that might increase, these include: heat-related deaths associated with more frequent and intense heatwave periods; exacerbation of asthma and other respiratory diseases associated with the potential increase in ambient air levels of tropospheric ozone and aeroallergens such as pollen; increased water and food-borne disease transmission risk as warmer temperatures may favour pathogen survival and biotoxin production, while increased precipitation variability may favour human exposure to these agents; increases in temperature and precipitation variability may also increase the potential risks of rodent and vector-borne diseases that are currently endemic such as leptospirosis, leishmaniasis, Lyme disease and possibly Mediterranean spotted fever, as well as an increase in the risk of re-introduction of diseases such as malaria, West Nile virus fever, and schistosomiasis (Casimiro & Calheiros, 2002).

In the current paper, potential changes on tourist thermal comfort and vector-borne disease transmission risks were assessed based on climate change scenarios for Portugal. The aim of the
study is to point out the potential direction of change and identify mechanisms to avoid/reduce these health impacts. This research forms part of an integrated project entitled: Climate Change in Portugal: Scenarios, Impacts and Adaptation Measures (SIAM Project). The primary objective of SIAM is to assess the vulnerability of Portugal to climate change scenarios.

METHODS

Impacts were assessed for the two most popular tourist districts in Portugal; namely Faro in the Algarve and Lisbon in the LVT region. Together these two regions contribute to about 65% of the tourism market in Portugal. Seasonal tourism variation indicated by the number of nights slept per month per region is summarised in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algarve</td>
<td>3.5</td>
<td>5.2</td>
<td>6.4</td>
<td>8.3</td>
<td>9.2</td>
<td>11.4</td>
<td>13.9</td>
<td>14.9</td>
<td>11.7</td>
<td>8.4</td>
<td>4.0</td>
<td>2.8</td>
</tr>
<tr>
<td>LVT</td>
<td>5.5</td>
<td>5.9</td>
<td>8.6</td>
<td>9.9</td>
<td>9.7</td>
<td>9.0</td>
<td>9.3</td>
<td>11.4</td>
<td>9.8</td>
<td>9.2</td>
<td>6.4</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Modelled climate data used in the assessment was from the regional model, HadRM3, provided by the Climate Impacts LINK Project of the Hadley Centre for Climate Prediction and Research (UK). Daily climate data was used throughout the assessments.

The HadRM3 climate data from model runs based on greenhouse gas emission projections from the A2 and B2 Intergovernmental Panel on Climate Change - Special Report on Emission Scenarios (IPCC SRES) were used. These scenarios focus on changes in economic, technological, demographic trends and energy use as major drivers for emissions and hence global climate change. They are explained in more detail in Nakicenovic (2000). In the A2 scenario storyline, economic prosperity is the principal goal, but with strong population growth and slow technological developments. While in a B2 world, technological advances are much slower and the general goal is on local advances to solutions to social, economic and ecological problems. Invariably under these scenarios global CO₂ emissions will be highest in the A2 scenario. Estimates of global CO₂ levels and mean annual temperatures for Faro and Lisbon are shown in Table 2.
Table 2: Global CO₂ levels and mean annual temperatures

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Period</th>
<th>Global CO₂ Concentration (ppm)</th>
<th>Average of Mean Annual Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Faro</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lisbon</td>
</tr>
<tr>
<td>Control</td>
<td>1990</td>
<td>354</td>
<td>16.9</td>
</tr>
<tr>
<td>A2</td>
<td>End of 21st century</td>
<td>857</td>
<td>21.1</td>
</tr>
<tr>
<td>B2</td>
<td>End of 21st century</td>
<td>615</td>
<td>19.8</td>
</tr>
</tbody>
</table>

The A2 scenario run for the period of 1961-90 was adopted as the baseline (control) period from which climate and consequent impact changes were evaluated. Data from model runs of the A2 and B2 scenarios for the period of 2070-2100 were used as future climate data.

Observed daily mean temperatures for Faro (airport) for 1965-90 and Lisbon (Tapada) during 1960-90 were obtained from the Portuguese National Institute of Meteorology and used in the malaria and leishmaniasis assessments.

Table 3: PET threshold values for different grades of thermal sensitivity and physiological stress on humans (Matzarakis & Mayer 1996)

<table>
<thead>
<tr>
<th>PET (°C)</th>
<th>Thermal Sensitivity</th>
<th>Grade of Physiologic Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 4</td>
<td>Very cold</td>
<td>Extreme cold stress</td>
</tr>
<tr>
<td>4 – 8</td>
<td>Cold</td>
<td>Strong cold stress</td>
</tr>
<tr>
<td>8 – 13</td>
<td>Cool</td>
<td>Moderate cold stress</td>
</tr>
<tr>
<td>13 – 18</td>
<td>Slightly cool</td>
<td>Slight cold stress</td>
</tr>
<tr>
<td>18 – 23</td>
<td>Comfortable</td>
<td>No thermal stress</td>
</tr>
<tr>
<td>23 – 29</td>
<td>Slightly warm</td>
<td>Slight heat stress</td>
</tr>
<tr>
<td>29 – 35</td>
<td>Warm</td>
<td>Moderate heat stress</td>
</tr>
<tr>
<td>35 – 41</td>
<td>Hot</td>
<td>Strong heat stress</td>
</tr>
<tr>
<td>&gt; 41</td>
<td>Very hot</td>
<td>Extreme heat stress</td>
</tr>
</tbody>
</table>

Thermal comfort affects human health and well-being, and consequently the attractiveness of a tourism location. In the present study the Physiologic Equivalent Temperature (PET) index described by Höppe (Höppe 1999) was used to assess thermal stress on tourists. The RayMan model (Matzarakis 2001) was used to calculate daily PET values for Faro and Lisbon at midday throughout the years for three climate scenarios. Insufficient observed daily climate records hindered the calculation of PET values for these two locations. Consequently the control climate scenario runs for Faro and Lisbon, were assumed to be indicative of current (baseline) climate conditions. An internal heat
production of 80W and a clothing heat transfer resistance of 0.9clo were assumed for all PET calculations. Physiological stress levels used here correspond to the PET threshold values summarized in Table 3.

The relationship between climate and vector-borne diseases is well documented. In this study the favourable temperature ranges described by Casimiro and Calheiros (2002) for malaria and leishmaniasis transmission were used to assess the potential impact of climate change on disease transmission risk of these two vector-borne diseases. Malaria transmission risk was assessed based on the adult mosquito (anopheline) survival temperature range (10 - 40°C) and the parasite (Plasmodium) development suitable temperature range (14.5 – 35°C for P. vivax and 16 – 35°C for P. falciparum). Leishmaniasis transmission favourable temperature range used was 15 – 28°C.

Although currently there are no locally transmitted cases of malaria in Portugal, Faro and Lisbon have the highest imported malaria cases in Portugal with Lisbon having an annual average of 35 imported malaria cases in past five years (DGS 2001). Most imported malaria cases are due to the African tropical strains of the malaria causing pathogen, P. falciparum and less frequently due to P. vivax (Proença et al.1988). Currently, the mosquito Anopheles atroparvus offers the most public health concerns of transmitting malaria in Faro as well as in Lisbon. This mosquito has a widespread and abundant distribution and was the principle species involved in the malaria transmission in Portugal prior to the disease eradication in the late 1950’s. Recent ongoing field studies indicate that the mosquito population in Portugal are currently not infected with plasmodia and consequently can not transmit the disease to humans (de Almeida 2003). Nevertheless, in view of the fact that malaria causing pathogens are present in both study regions (in individuals with imported malaria) there is a small possibility that part of the local mosquito population may become infected with the pathogen. Therefore, the current risk of malaria transmission in both regions is very low.

Visceral leishmaniasis (VL), also known as kala-azar, is currently an endemic infectious disease in Faro and Lisbon. Most common symptoms include high fever, chills, fatigue, abdominal pain and diarrhoea. Anaemia and enlargement of the spleen and liver are typical clinical manifestations. If untreated VL has high fatality rates. Children and the immuno-compromised are most vulnerable to VL. The disease causing protozoa is transmitted from animal reservoirs to humans by the bite of female Phlebotomus (sandflies). Ph. perniciosus is the sandfly that offers the most public health concerns in both study regions (Pires 2000). Dogs are the principal reservoir hosts of Leishmania infantum, the protozoa involved in VL transmission in the study regions (Campino 2000).
RESULTS

PET values calculated from the control climate scenario run for Faro and Lisbon indicate that both regions have four months per year with over 50% of days within the thermal favourable ranges of “comfortable and slight heat stress” (Figure 1). Faro’s thermal favourable months are May, June, September, and October, while Lisbon’s are from June to September. In addition, it also indicates that in Faro the months of July and August have most days with moderate to strong heat stress, and that in both locations, days with extreme heat stress account for less than 5% of the days in the hottest months (July and August). Although, episodes of extreme heat stress days are rare, the significant impact this might have on the population can be severe.

Results shown in Figure 1 also indicate that Faro has fewer months with cold stress than Lisbon, with the former having six months (Nov-Apr) that have more than 50% of days with slight to moderate cold stress, while Lisbon has eight months (Oct-May). The same figure also shows both locations having five months (Nov-March) with some days with strong to extreme cold stress. January is the month with the highest (about 45% for both regions) number of days with strong to extreme cold stress.

Compared to the baseline scenario (Figure 1), both future climate change scenarios used in this study indicate significant changes in the thermal comfort levels in Faro and Lisbon (Figures 2 and 3).

The number of months with more than 50% of days within the favourable thermal ranges mentioned above may decrease in Faro from the four months in the control scenario to three (April, May, October) in both future climate scenarios, whereas an increase is possible in Lisbon. Climate change may also double the number of months in Faro having most days with moderate to strong heat stress. In both locations, thermal stress seems to be more pronounced for the A2 scenario. This is to be expected as the A2 scenario has higher CO₂ emissions and consequently higher ambient temperature, which is a key input variable used to calculate PET. In addition, this scenario also has other climatic characteristic that increase PET values such as relative humidity and windspeed.

One of the most dramatic changes indicated in Figures 1-3 is the significant increase in the number of months with several days with extreme heat stress in both locations. Apart from the obvious thermal discomfort this may also result in increased heat related illnesses such as heat stroke and exhaustion, and increased mortality.
Climate change is also anticipated to reduce the number of months with any degree of cold stress in both locations. For example, January which often has days with strong to extreme cold stress might see the greatest reduction in cold stress. It is anticipated that any reduction in cold stress is likely to improve the health of tourists and local residents.

Figure 1: PET derived thermal stress levels for Faro and Lisbon using control climate data

Figure 2: PET derived thermal stress levels for Faro using HadRM3 A2 and B2 scenario climate data
The potential impact of climate change on the favourable temperature ranges for malaria and leishmaniasis transmission are presented here. Results presented in Table 4 indicate that the current climate (and control scenario climate) is already conducive to adult anopheline survival having over 80% of the days per year suitable for survival in both locations. If this favourable range is assumed, climate change may increase the number of days suitable for survival in Faro and Lisbon. An increased mosquito density in the regions is thus a possibility.

Since currently all of the days in May through to October already favour adult survival in both locations, this potential increase in mosquito density is anticipated to be most noticeable from November to April. As adult anophelines are both a nuisance (noisy at night, bite discomfort etc.) and of concern to public and tourist health, higher mosquito densities in Faro and Lisbon may aggravate the current situation.

Table 4: Favourable periods for malaria and leishmaniasis transmission in Faro and Lisbon

<table>
<thead>
<tr>
<th>% days per year within favourable temperature range</th>
<th>Faro</th>
<th></th>
<th>Lisbon</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>90</td>
<td>82</td>
<td>96</td>
<td>92</td>
</tr>
<tr>
<td>Control</td>
<td>60</td>
<td>55</td>
<td>71</td>
<td>68</td>
</tr>
<tr>
<td>A2</td>
<td>48</td>
<td>49</td>
<td>63</td>
<td>59</td>
</tr>
<tr>
<td>B2</td>
<td>46</td>
<td>46</td>
<td>49</td>
<td>48</td>
</tr>
<tr>
<td>P. vivax development</td>
<td>52</td>
<td>52</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>P. falciparum development</td>
<td>48</td>
<td>47</td>
<td>61</td>
<td>58</td>
</tr>
<tr>
<td>Leishmaniasis transmission</td>
<td>49</td>
<td>48</td>
<td>59</td>
<td>56</td>
</tr>
</tbody>
</table>
Table 4 also indicates that in both locations the climate is favourable for *P. vivax* development in more than 50% of the days per year. Climate change may increase this favourable developmental period by at least 10%. However, as indicated by Figure 4 this increase is not uniform throughout the year. In Faro, favourable days for *P. vivax* development are anticipated to increase significantly from October to May, remain practically unchanged in September, and decrease slightly during June-August. Results for Lisbon indicate a similar seasonal change on the number of days favourable for *P. vivax* development.

Climate change may have a similar impact on *P. falciparum* developmental favourable periods in Faro and Lisbon. An annual increase in the number of favourable developmental days is anticipated (Table 4), with the increase probably being more noticeable from October to May (Figure 4). A slight decrease is anticipated for July and August, while minimal changes are indicated in June and September. Results for Faro also indicate a similar change pattern.

The results presented here indicate that climatic changes in Faro and Lisbon may become more favourable for anopheline survival and plasmodium development and thus potentially more favourable for malaria transmission.

Potential changes in leishmaniasis transmission risk in Faro and Lisbon were also assessed. Results based on observed mean daily temperature indicate that in Faro about 46% of the days per year are within the favourable range mentioned above and in Lisbon about 49% of the days are in the same range (Table 4). Similar findings were also obtained using the control run daily mean temperature,
in which 46% of days in Faro and 48% of days in Lisbon were within this range. The results also indicate that in Faro a slight increase in the number of days per year that fall within in this temperature range is possible, with the A2 climate change scenario having 49% days favourable, and the B2 scenario 48%.

Figure 5 shows the monthly distribution of favourable periods for leishmaniasis transmission. It is interesting to note that this seasonal pattern is in agreement with the observed field activity pattern of the sandflies that are captured in these two locations. September is not only the month with highest sandfly densities, but also when most *Leishmania* infected vectors were captured (Pires 2000). The figure also indicates that significant seasonal changes are anticipated for Faro. Significant decreases in days suitable for transmission are observed from June to September. Since these months are currently those with the highest sandfly activity, one may speculate that this decrease may reduce the risk of contracting leishmaniasis in Faro during the peak tourism season. However, the significant increase in the number of days favourable for development indicated from October to May might result in an increase in disease risk transmission in these cooler months. Climate change in Lisbon may also increase the number of days per year within the leishmaniasis transmission favourable range, with 59% of days favourable in the A2 scenario and 56% in the B2 scenario (Table 4). Figure 5 shows that although a slight decrease in June though to September may result due to climate change, the months most favourable for transmission remain from May to October. The seasonal results for Lisbon also indicate that the number of days favourable for
transmission may increase from October to April. The results presented here suggest that the overall risk of contracting leishmaniasis in Lisbon may increase due to climate change.

**DISCUSSION**

Portugal’s temperate climate is an important factor contributing towards the success of its tourism industry. Sunny warm summer days make it attractive for sun lovers while mild winters are an attraction to those wanting to escape the harsh winters from their home counties in northern Europe. The fact that Portugal is considered a destination that offers a low health risk to the tourist is believed to enhance the country’s attractiveness as a tourist destination.

Studies have indicated that climate change may discourage tourism to Mediterranean countries by substantially reducing thermal comfort and possibly air quality in parts of Greece, Italy, and Turkey; by potentially increasing the risk of infectious disease like malaria and food poisoning in Spain; and increased risks of natural disasters like forest fires, floods, and drought in various Mediterranean locations (Viner and Agnew 1999, Perry 2001). Regularly repeated publicity on these adverse impacts could act as a deterrent to tourism. In this paper, potential changes on tourist thermal comfort and vector-borne disease transmission risks were assessed based on potential climate change scenarios for Faro and Lisbon.

It is important to note that in this paper, the results from only one climate change model (HadRM3) are taken into account. Since climate data from other regional climate models all point towards the same direction of change, it is anticipated that potential impacts on tourism health based on climate data from these models will indicate impacts along the same direction as those described here.

Both future climate change scenarios used in this study indicate potential significant changes in the thermal comfort levels in Faro and Lisbon. On the one hand, thermal comfort may reduce in the summer, but on the other, increase in spring, autumn and winter months.

Such seasonal changes in thermal comfort may result in new opportunities for the tourism industry as improved thermal comfort in spring and autumn months may become favourable enough to lengthen the (“summer”) tourism season to the shoulder seasons. In addition, the significant reduction in cold stress in the winter months is likely to make Portugal a more attractive destination for winter tourism.

Results also indicate deterioration in thermal comfort levels in summer, with a substantial increase in days with extreme heat stress in both regions. The significant health impact this may have on
tourist health and discomfort may make Portugal a less attractive destination for summer tourism. However, since climatic conditions are not the only tourism attraction to these regions, further research on the validation of the relationship between PET values and tourism demand in Faro and Lisbon is needed in order to assess this impact fully.

Nevertheless, these negative thermal comfort impacts may be minimized by applying appropriate adaptation measures that reduce heat stress such as: increased use of air-cooling devices in tourist related accommodation and attractions; establishment of a tourist friendly heat-watch early warning system; implementation of education programmes that make tourists (and people employed in the industry) aware of heat stress and what they should do to avoid heat stress such as staying in the shade and replacing fluid loss during extreme heat; and encouraging urban planners and architects to introduce design features that reduce heat load.

Potential impacts of climate change on the transmission risks of the two vector-borne diseases: malaria and leishmaniasis, assessed in this paper are discussed below.

In both locations the results indicate that climate change may become more favourable for mosquito survival and parasite development and thus potentially more favourable for malaria transmission. If a population of Plasmodium infected mosquitoes were to be introduced into the regions, then the malaria transmission risk may increase from the current very low level to potentially a medium-low risk level. Higher risk levels are not anticipated in either location as infected individuals would be treated for the disease, and thus reducing the parasitic prevalence rates. Moreover, the mosquito potentially involved in malaria transmission in Portugal prefers to feed on animals and not humans.

Since climate change may favour mosquito survival, research into how this might alter the transmission risk of other mosquito-borne diseases of concern in Portugal such as West Nile virus fever is called for. Furthermore, as higher mosquito survival rates (and higher ambient temperatures) may lead to more mosquito bites per hour at each location, the level of discomfort in tourists may increase accordingly.

Leishmaniasis is endemic in both regions studied. It is speculated that climate change may reduce the disease transmission risk in Faro during the summer tourism season, but increase the risk from October to May. In Lisbon, the risk of contracting leishmaniasis may also increase due to climate change.

Adaptation measures outlined in the National Assessment (Casimiro & Calheiros, 2002) such as parasite and vector monitoring and associated surveillance programmes are urgently needed to
reduce tourist vulnerability to vector borne diseases studied here. These programmes should also take into account the key role that accompanying pets have in leishmaniasis transmission dynamics. The use of window screens, insect repellents and protective clothing in these locations is also advisable.

It is important to note that the vector-borne diseases studied here used temperature as the only factor of change in the assessment of disease transmission risks. Although temperature is a key factor for pathogen and vector survival, interpretations made here should be made with caution as other factors such as breeding sites suitability, humidity, hosts, and predators also influence disease dynamics and may also change with climate change. Furthermore, disease transmission risk is also very dependent on the quality of public health infrastructure, the individual susceptibility to the pathogen, medical technology advances, and human behaviour. Additional research to determine which and to what extent environmental factors affect vector-borne disease transmission dynamics in Portugal is needed in order to conduct more in-depth assessments.

In this paper, “future” climate data from model runs indicative of the climate at the end of the 21st century (for two scenarios) were used. This is a very long period in time, and likely to be one with very dramatic climate changes relative to the baseline climate. Since tourism development strategies are normally considered for shorter time periods, perhaps it would be more important to perform similar assessments based on climate changes for smaller time frames. Results of such assessments would not only be able to be validated with observed climate and climate-related health impacts that may occur during the same time period, but also probably more widely accepted and used by decision makers.

ACKNOWLEDGMENTS

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CHANGES IN SNOW PARAMETERS IN CROATIAN HIGHLAND

M. Gajić-Čapka¹ and S. Horak²

¹. Meteorological and Hydrological Service of Croatia, HR-10000 Zagreb, Croatia
². Institute for Tourism, HR-10000 Zagreb, Croatia

E-mail address: capka@cirus.dhz.hr (M. Gajić-Čapka), sinisa.horak@iztzg.hr (S. Horak)

ABSTRACT

Croatian tourism is the most developed along the Croatian Adriatic coast and on the islands. Croatia’s highland area belonging to the Dinaric Alps, or isolated mountains in northern lowland are suitable for tourists’ stay, both during summer season, and during other periods of the year, especially during winter season. Snow conditions along the part of Croatian highland, including depth of snow cover as well as its duration enable the development of winter tourism oriented mainly on snow related activities such as cross-country skiing or snow mobiling rather than on alpine skiing only.

The climatological base for tourism estimates are snow regime characteristics with special emphasis on time analysis (fluctuations and trends) in different meteorological parameters related to snow (air temperature, total precipitation and air pressure) as well as snow parameters (snow cover frequency, duration and magnitude) themselves. The results presented in this paper refer to the northern part of Velebit Mountain (western Dinaric Alps), which is one of the potential ski resorts.

The climatological base includes analyses of annual course and probability of snow parameters for the referent period 1961/62-1990/91.

At the same time concerns with climate variability and change urge special emphasis on time analysis (fluctuations and trends) that has been deduced for snow parameters (intensity and frequency) and different meteorological parameters related to snow (air temperature, total precipitation and air pressure) during the second half of the 20th century.

KEYWORDS: Snow parameters, Annual course, Probability, Fluctuations, Trend, Zavižan, Croatia

INTRODUCTION

The main resources for tourism development in many countries, as well as in Croatia, are landscape characteristics and climate that attract tourists to particular destination (Weber et al., 2002). It is
therefore obvious that significant changes of one of those two factors could significantly impact tourism destination attractiveness. Many tourism destinations, especially those with tourism as the main economic activity, are concerned with climate changes today, whose implications are last few decades visible almost all around the world. According to projections, those changes will continue and their final consequences on human life are not fully known yet. It is in particular relevant to those destinations that could experience significant climate changes, especially during winter season, such as land area of north hemisphere (Buerki, Elsasser and Abegg, 2003). Therefore the information and knowledge on climate changes should be, and in some cases already is, incorporated into strategic, especially long-term development plans of certain areas.

Croatian tourism is the most developed along the Croatian Adriatic coast and on the islands. The coastal area has experienced significantly positive impact of tourism industry on the local economy. At the same time, lot of other resources suitable for tourism development in Croatia are still not recognized nor valorized according to their possibilities. That is the case with Croatia’s highland area that, although not higher than 1900 m (only 85 square kilometers of Croatian land is above 1500 m) is suitable for tourists’ stay, both during summer season when high temperatures in other parts of Croatia are not pleasant for many people, and during other periods of the year, especially during winter season. Snow conditions along the part of Croatian highland, including thickness of snow cover as well as its duration, are sufficient and they enable the development of winter tourism, oriented mainly on snow related activities such as cross-country skiing or snow mobiling rather than on downhill skiing only. Some experts estimate that the length of winter tourism season in Croatian mountains is much shorter today than it could possibly be due to the shortage of infrastructure and facilities. According to those estimates, total capacity of fifteen mountain resorts is around 38000 visitors daily (the accommodation facilities’ capacity of those resorts is about 2500 beds today) and the length of winter and summer season is estimated on 100 and 200 days, respectively.

Further, it is estimate that only about 10 per cent of all ski trips purchased in Croatia are realized within country. Among all domestic ski trips the majority are one-day trips enabled by relatively good accessibility of those ski resorts as well as by the fact that those resorts are close to urban areas. However, those ski resorts are relatively small, both considering their capacity and equipment, especially in comparison to alpine ski resorts. The literature shows that such destinations – small resorts at lower altitudes are in particular sensitive on negative changes in winter conditions (Breiling and Charamza, 1994; Breiling and Charamza 1999; Breiling, Charamanza and Skage,
The increase of average daily temperature and, at the same time, the decrease in precipitation in winter mountain destinations could decrease the economic effects from tourism and, at the same time, increase the adaptation costs and necessary investments in winter tourism supply. The development plan of winter and mountain tourism in Croatia, that is currently working on, should take into account estimates and forecasts on climate changes on Croatian mountains and their possible impact on winter tourism development.

The climatological base for tourism estimates are snow regime characteristics with special emphasis on time analysis (fluctuations and trends) in different meteorological parameters related to snow (air temperature, total precipitation and air pressure) as well as snow parameters (snow cover frequency, duration and magnitude) themselves. The results presented in this paper refer to the northern part of Velebit Mountain (western Dinaric Alps), which is one of the potential ski resorts considered in the mentioned development plan. The Velebit Mountain is spreading 150 km along the eastern Adriatic coast of Croatia (Figure 1). Its altitude ranges from the sea level on the costal side up to about 1800 m and it descends towards hinterland to the highland plateau of Lika at the altitude of about 600 m. This mountain is the main weather and climate modifier along the coastline and the continental hinterland. The climate differences that appear over the broader region are already pronounced over the variously located slopes of Velebit itself. The main weather types bringing precipitation mainly in the form of snow during winter months are cyclones in the Adriatic with the prevailing winds from SW quadrant over Velebit.

Figure 1: Location of meteorological station Zavižan at the top of the Velebit Mountain, Dinaric Alps
DATA AND METHODS
Meteorological measurements started in the mountainous areas of Croatia mainly in the middle of the 20th century. The highest mountain meteorological station Zavižan (1594 m a.s.l.) located on Northern Velebit Mountain close to the Adriatic coast started with the measurements in 1953. The snow conditions are presented by means of the average annual course of mean daily snow depth, the beginning and the end of snow cover of different depth in particular winter during the observed period, the correlation between some snow parameters (snow cover ≥ 1 cm, snow cover ≥ 30 cm, snowfall and snow depth) and temperature, precipitation and air pressure for the winter period (December, January and February), as well as the analysis of the time fluctuations and trend in snow parameters and winter temperature during the second half of the last century.

The time series of the annual number of days with snowfall and snow cover, and mean daily snow depth have been smoothed by the 11-year binomial filter to eliminate the short-term fluctuations and to emphasize long-term variations. Simultaneous temperature changes are presented by means of winter temperature fluctuations. The original data series have been tested for linear trend by non-parametric Mann-Kendall rank-test. This test for randomness against trend compute correlation statistic using the ranks of the data and not the data values themselves. Rank correlation method is robust so that it is not necessary that the data are normally distributed (Mitchell et al., 1966; Sneyers, 1990).

RESULTS
The annual course of the mean daily snow depth, obtained as 5-day period averages, presents the first information for winter sports and tourism showing on average duration of days with various snow cover depth (Figure 2). A snow cover of about 20 cm during October and the first half of November rises up to about 60 cm by the end of December. At the end of January it reaches about 100 cm, in February 130 cm, while during March mean daily snow depth varies about this last value. In April, snow melts rather rapidly and at the end of the month it amounts to about 80 cm. In May, and during the first half of June, snow depth is a very variable showing occasional peak. On average a sufficient snow cover of at least 30 cm lies on ground between November 22 and June 11. Such a long stay of this snow cover to the end of snow season is rather uncertain. It is a result of the calculated average appearance of daily snow cover. In spring months snow can fall resulting with high snow cover, but also there are springs with no or rather thin snow depth. Due to this instability
the end of spring or especially June would not be favourable for ski tourism. The curve of minimum daily depth is hardly to be seen, because it is 0 cm for each day, namely in each month it can happen that there is no snow on the ground (Figure 2).

The problem of high inter-annual variability is present especially at the beginning and at the end of snow season having as a consequence shorter winters with good snow conditions than seems at the first sight. The appearance of snow cover of different depth during the period from December to April is rather stable, while in November as well as in May and June it varies considerably from year to year (Figure 3). The last date of occurrence of snow depth ≥10 cm, ≥30 cm and ≥50 cm is more stable than the date of their beginning. Figure 3 also indicates that since the end of 80’s the duration of snow cover is shorter (earlier disappearance of higher snow cover) and there is a high variability in snow abundance.

![Figure 2: Annual course of the 5-day period means of daily snow depth (cm) at Zavižan](image)

duration as well as abundance appeared also in the Swiss Alps (Beniston, Rebetez, Giorgi and Marinnuci, 1994; Marty, 2006) and in the Slovenian Alps (Cegnar, 1996). Available meteorological results of trend analyses for the period ending at the beginning of 1990’s show that the western Dinaric Alps experienced similar extreme snow conditions as the Alps and the Tatra Mountains (Gajić-Čapka, Čapka., 1996; Lapin, Fasko, 1996).

Figure 3: The first and the last date of occurrence of snow depth $\geq 10$ cm (rombs), $\geq 30$ cm (lines) and $\geq 50$ cm (bars) at Zavižan, period 1953/54-2001/02

Trends of observed winter (D, J, F) snow parameters experience practically no trend in the period 1953-2002. Number of days with snowfall (determined by means of the number of days with snow precipitation $\geq 1.0$ mm) and mean daily snow depth have statistically insignificant decrease (-1.2 days/10years respectively –0.2 cm/10years) and number of days with snow cover $\geq 30$ cm has statistically insignificant increase of 0.2 days/10years (Figure 4).

Snow is negatively correlated with temperature, significantly at $\alpha=0.05$ level. This means that warmer winters are associated with less snowfall, lower snow depth and a shorter duration of snow cover. The same relations have been obtained on the Swiss Plateau at lower altitude sites up to 1000 – 1500 m a.s.l. (Rebetez, 1996). At the same time snow exhibits an even stronger negative correlation with air pressure and a positive correlation with precipitation (Table 1).
Table 1: Correlation coefficients for various snow parameters and air temperature, air pressure and precipitation in winter (D, J, F) at Zavižan, period 1953/54-2001/02

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Air pressure</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow cover &gt;= 1 cm</td>
<td>-0.326</td>
<td>-0.328</td>
<td>0.403</td>
</tr>
<tr>
<td>Snow cover &gt;= 30 cm</td>
<td>-0.387</td>
<td>-0.397</td>
<td>0.474</td>
</tr>
<tr>
<td>Snowfall</td>
<td>-0.444</td>
<td>-0.705</td>
<td>0.666</td>
</tr>
<tr>
<td>Snow depth</td>
<td>-0.462</td>
<td>-0.450</td>
<td>0.511</td>
</tr>
</tbody>
</table>

Figure 4: Variations of mean number of days with snowfall (daily precipitation ≥ 0.1 mm) - above, mean daily snow depth - middle and mean winter temperature – below, their 11-year binomial moving average series and linear trends at Zavižan during the period 1953/54 – 2001/02

Due to the obtained high correlation of snow and some meteorological parameters it seemed reasonable to calculate trends in temperatures (average, mean maximum and mean minimum),
precipitation (amounts and days), cloudiness and air pressure, as indicators of possible causes of changes in snow regime (Table 2).

During the second half of the 20th century air pressure has increased in annual and seasonal values (except autumn). At the same time cloudiness decreased, significantly in winter and annual values. Winter precipitation shows increasing tendency, while number of precipitation days decreases, indicating that increase in precipitation totals is a result of rarer but more intensive precipitation weather situations. Because in winter months 83% of these days are those with snow, such a regime of precipitation changes reflects in shorter duration of snowfall but more abundant. Temperature trend is increasing in both, maximum and minimum temperatures, resulting in positive diurnal temperature range. These changes are the consequence of increase in frequency of anticyclonic weather types with high diurnal temperature range over the Northern Adriatic (Gajić-Čapka and Zaninović, 1997). During these winter anticyclonic situations, the temperature inversions are characteristic. This means low temperatures in valleys and higher ones at higher altitudes. Because of this, winter anticyclones bring also higher temperatures at Zavižan.

**DISCUSSION**

The appearance of snow and its stay on ground depends on general circulation of the atmosphere (weather types), and the meteorological parameters characteristic for snow season, primarily temperature, as well as the exposition of the location and the characteristics of the ground.

During winter months (December, January and February) the potential skiing district of the Velebit Mountain, western Dinaric Alps, situated along the eastern Adriatic coast, has on average 69 days with snow cover ≥ 30 cm, that are required for alpine skiing and snowboarding. The average refers to the period 1961-1990, which is the last World Meteorological Organisation (WMO) standard period for climate analysis.

Available data for the second half of the 20th century show large inter-annual variability, especially pronounced since mid eighties. From poor snow winter 1953/1954 till winter 1984/1985 there were more ski reliable snow days (moving average curve above the average 1961-1990) than in ninetiens when it fluctuates under the climatological mean due mainly to the two winters without snow (1989/1990 and 1990/1991).
Table 2: Trends of average (T), mean maximum (T<sub>max</sub>), mean minimum air temperature (T<sub>min</sub>) and diurnal temperature range (DTR) - °C/10 years, precipitation (R) - mm/10 years, precipitation days (n<sub>RD</sub>) – days/10 years, cloudiness (N) - tenth/10 years and air pressure (p) - hPa/10 years for Zavižan, period 1954-2001 (air pressure 1956-2001). Shading denotes trends significant at α=0.05 level

<table>
<thead>
<tr>
<th>Seasons</th>
<th>T</th>
<th>T&lt;sub&gt;max&lt;/sub&gt;</th>
<th>T&lt;sub&gt;min&lt;/sub&gt;</th>
<th>DTR</th>
<th>R</th>
<th>n&lt;sub&gt;RD&lt;/sub&gt;</th>
<th>N</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Spring</td>
<td>0.23</td>
<td>0.31</td>
<td>0.20</td>
<td>0.12</td>
<td>-4.6</td>
<td>-0.16</td>
<td>-0.10</td>
<td>0.25</td>
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<tr>
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<td>0.21</td>
<td>0.33</td>
<td>0.18</td>
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<td>-12.4</td>
<td>-0.09</td>
<td>-0.10</td>
<td>0.07</td>
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<tr>
<td>Autumn</td>
<td>0.02</td>
<td>0.08</td>
<td>-0.02</td>
<td>0.10</td>
<td>49.2</td>
<td>-0.05</td>
<td>-0.01</td>
<td>-0.04</td>
</tr>
<tr>
<td>Winter</td>
<td>0.20</td>
<td>0.27</td>
<td>0.17</td>
<td>0.10</td>
<td>21.1</td>
<td>-4.0</td>
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<td>0.92</td>
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<tr>
<td>Annual</td>
<td>0.18</td>
<td>0.26</td>
<td>0.14</td>
<td>0.12</td>
<td>58.5</td>
<td>-6.8</td>
<td>-0.10</td>
<td>0.34</td>
</tr>
</tbody>
</table>

More frequent lack of snow winters at the end of eighties and in nineties are accompanied by more rapid increase in temperature. This points at the future potential significant changes in snow regime due to the projections for highest expected changes in temperature in Croatian highland: winter temperature increase would be ranged between 0.8 and 1.0°C by 2030, between 1.6 and 1.8°C by 2050 and between 4.2 and 4.9°C by 2100. These results have been obtained according to the climate change scenarios for Croatia. They have been made on the basis of IPCC alternative scenarios (1992a-1992f), assuming the present CO<sub>2</sub> concentration increase policy (“business as usual”) as well as regional circulation scenario for the Mediterranean developed at East Anglia University. Two projections of global social and economic growth have been chosen: 1992a and 1992e. Scenario 1992a is a scenario on the lower limit of the expected changes, while scenario 1992e is on the upper limit. In both cases, the parameters of these projections were derived applying the hypothesis of cooling effect of aerosols. Global and regional projections have been examined and compared with long-term data series for three different climate regions in Croatia. The estimates have been made for temperature, precipitation amounts and sea level rise for Croatian lowland, mountainous region and coastland for three time horizons 2030, 2050 and 2100.

The observed trend of 1°C during last fifty years over the Velebit Mountain is the same one as the projected change for the first horizon (2030). Simultaneously, trend of number of days with snow cover ≥ 30 cm showed an increase of 1 day in 50 years, what would be not relevant for ski season. The projections of temperature increase, which are predicted to be five times higher by the end of
the 21st century, could have more consequence on snow regime depending further on precipitation changes. The scenarios of precipitation change by season's show an increase between 6% to 10% in mountainous parts of Croatia, having an opposite influence on snow cover than temperature.

So, the magnitude of changes in snow parameters remains uncertain, especially because of high inter-annual variability of snow parameters as a result not only of temperature changes but also precipitation changes and frequency of weather types.

Further research would demand analysis of snow cover relevant not only for alpine skiing at higher altitudes (snow cover ≥ 30 cm), but also those (snow cover ≥ 10 cm) necessary for development of winter skiing tourism (cross-country skiing or snow mobiling) at lower altitudes. Its correlation to temperature and precipitation in relation to altitude for a whole winter ski season and for particular school holiday weeks would enable further estimates of snow changes that should be incorporated in tourism plans.

Application of IPCC scenarios and regional models brings further uncertainties, because they refer to mean temperatures, not distinguishing seasons, and there are considerations that warming is higher in the northern hemisphere and during winter.

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THE RELATIONSHIP BETWEEN WEATHER CONDITIONS AND TOURISTS' PERCEPTION OF COMFORT: THE CASE OF THE WINTER SUN RESORT OF EILAT

Yoel Mansfeld¹, Ariel Freundlich² and Haim Kutiel²

1. Center for Tourism, Pilgrimage & Recreation Research, and Department of Geography, University of Haifa, 31905 Israel
2. Department of Geography, University of Haifa, 31905 Israel
E-mail addresses: yoel@geo.haifa.ac.il; kutiel@geo.haifa.ac.il; ariel-fr@bezeqint.net

ABSTRACT
This chapter examines the interplay between weather conditions and tourists' perception of comfort. This relationship is examined based on the assumption that perceived weather comfort is one of the key constraints that shape tourists' propensity and motivation to travel. Using the case of Israel's winter sun resort - Eilat, the study measured actual climatic factors and, through a structured questionnaire, interviewed beach tourists on their perceived climatic comfort. The results show that optimal climatic conditions for beach tourists can be detected. Also, wind velocity and cloudiness, having such variable characteristics in terms of time and space, exert a crucial influence on tourists' levels of satisfaction. Subsequently the study found that domestic tourists are more sensitive to weather conditions than tourists from overseas. Furthermore, apparently, travel motivations have bearing on the way tourists perceive weather, mainly when weather conditions are poor. As a consequent of the above results, the study concluded that, from a policymaking perspective, there must be an effective cooperation between all stakeholders of a given tourist destination if we truly seek improving the functional relations between weather forecasting and tourists' propensity to travel.

KEYWORDS: weather perception of comfort, climatic conditions, PET, travel motivation, beach tourism

INTRODUCTION
Tourism has been characterized in the past half century as one of the world's most rapidly developing economic activities (Lanfant, 1995). Furthermore, it is predicted that it will lead the
service industry sectors, together with telecommunications and information technology, deep into the 21st century (Poon, 1988; Bar On, 1997; Fretchting, 1996; Perry, 1997, 1998). In tourism, weather and climatic conditions are important considerations in tourists' destination-choice behavior. Since most tourist activities take place outdoors, and since the very essence of the tourist phenomenon is to have close encounters with the outdoor environment, these conditions can either work as major constraints or alternatively major "pull" factors. Some researchers even claim that climatic conditions are among the most dominant factors that shape global tourist flows (Burton, 1995; Boniface & Cooper, 1987; Coltman, 1989; Mings, 1997).

Despite awareness of the major role of the climatic factor in tourism, surprisingly the number of researchers studying the relationship between weather conditions and tourism is very small. Thus, the number of cross-disciplinary studies published on these relationships from climatic, meteorological, bio-meteorological and tourism perspectives are very limited.

Marine and seaside activities are among the most popular yet weather-dependent tourist activities. Tourists normally wear light clothes, and are exposed to various weather conditions such as wind, sun radiation, and air and sea temperatures. Furthermore, often the desire to be exposed to weather condition factors (especially sunshine) can be a leading travel motivation for some tourists (Mansfeld, 1992). Tour operators and hoteliers are counting on simple thumb rules regarding the so-called "guaranteed weather" they promise to their customers. However, in a market that spends millions of US Dollars every season, and with weather conditions being such central components of sun & sea tourism packages, it is possible that as a result of inappropriate weather tourists will experience very poor value for their money. Such a wide gap between expected and real weather conditions will negatively affect their quality perception of a given destination and thus impinge upon their future destination-choice behavior. A wide negative gap between expected (and promised) and real climatic attributes is thus a destructive factor to the tourism industry as well.

In order to avoid such unconstructive outcomes, there is a need to study the way tourists perceive and experience weather. It is necessary to find out which weather factors contribute more and which less to their overall feeling of comfort and satisfaction. Moreover, there is a need to explore how different micro-climatic conditions in various locations in a given destination play their role in shaping weather satisfaction and climatic comfort among tourists. This is a crucial issue since the weather forecast is often based on one meteorological station located in a given destination, yet it is known from various studies that the human-thermal micro-climate may change quite substantially
within very short distances (Barradas, 1991; Hoppe & Hermann, 1991). Thus, the micro-climate on a beach might differ from that in a shopping strip along the seaside. It is also important to note that meteorological stations normally measure weather conditions 2-10 meters above ground. Such measures might not be relevant to tourists sitting or lying on the beach. Furthermore, it is important to note that standard weather forecasts normally do not issue tourist specific weather interpretations to local holiday-makers. Without detecting the relevance of different weather components to customers' satisfaction it is impossible to adjust such forecasts and tailor them according to tourists' information needs.

Based on the above arguments, this study's aim is to use the case of Israel's most highly developed sun, sand & sea resort of Eilat on the red Sea, in order to investigate the following research questions:

1. What is the perception of weather condition among beach tourists in Eilat?
2. What are the gaps between perceived and actual (objective) weather conditions measured on those beaches?
3. Which weather factors contributed more to the overall perception of weather conditions in the time of the field survey?
4. Are there any micro-meteorological effects that might substantially shape tourists' perception of weather?
5. Are their significant variations in the way domestic (Israeli) tourists and international (mainly Europeans) tourists perceiving weather?
6. Do different travel motivations have bearing on weather perceptions?

Answering the above research questions will help mitigate the risks involved in choosing a destination and facilitate tourists' decision about where to go and at what time of the year. Moreover, it will allow operators of various tourism facilities along the seashore to improve the micro-climate of their services and amenities, hence narrowing the gap between expected and real weather conditions.

THEORETICAL BACKGROUND

Air temperature, solar and terrestrial radiation, relative humidity and wind velocity together with personal variables, i.e. clothing and metabolism level, are considered the factors that shape the energy balance between man and his environment. This balance influences the personal thermal
comfort feeling. Using these variables, in the past seventy years research has generated various biometric models and indices which weigh part or all of them using synthetic indices or series of equations. Different indices were developed for different purposes. Among them are the "effective temperature index" (ET) and the "discomfort index" (DI, THI) which are both effective, mainly in hot weather conditions (Thom, 1959; Tenenboum et.al., 1961). The "wind chill" index (WCI) was also developed mainly for measuring in cold climatic conditions (Siple & Passel, 1945; Steadman, 1971, 1984). All three indices are still widely used even today. In the 1970s, as part of computerization, more comprehensive bio-meteorological models were developed which calculate the overall man-environment energy transfer balance (Fanger, 1970; Auliciems & Kalma, 1979; de Freitas, 1985, 1990; Höppe, 1993, 1999).

Apart from the factors mentioned above, there is another related to the climatic adaptation phenomenon which might have bearing on the human reaction to thermal environment. Climatic adaptation is a general term depicting various phenomena of human adaptation to weather and temperature changes. Such adaptations take place when moving from different climatic regions, in times of seasonal climatic changes and as a result of repeated exposure to extreme temperatures. This process has two components: a physiological component and a socio-behavioral component (Givoni, 1974; MacFarelane, 1974; Tromp, 1979, 1980). The physiological component stems out of the growing physiological efficiency of the heat control mechanisms in the human body. It lasts between a few days to a few weeks while the length and the efficiency of the process is dependent on the person's physical condition and on the number of previous exposures to heat or cold conditions. Frequent past exposures to hot and cold weather improves and fastens the acclimatization process. The socio-behavioral component stems out of the human adaptation to new thermal environment. It is done by adopting new behaviors in terms of clothing, food and drinking habits and rest and activity lifestyles. It is an individual process that might last for years or even a decade.

Both the thermal and the bio-meteorological indices mentioned above have been applied in various ways: e.g. in determining school and university heating, in adjusting physical work to weather conditions, in making clothing recommendations in extreme weather conditions, in determining thresholds of acceptable heat stress, etc. Only a few researchers have so far tried to use the existing thermal indices in tourism applications. Among them are Terjung (1966), Leech (1985), Boniface & Cooper (1987), Barradas (1991) and Höppe & Hermann (1991).
In 1985, Mieczkowski went one step further and developed a tourist-climatic index. Its aim was to measure to what extent world climate fits tourism? Using monthly average climatic variables, he constructed ranking scales for those variables according to levels of comfort and utility they offer to tourists. The ranking of these variables was arbitrary, according to his subjective yet professional judgment.

De Freitas (1985, 1990) adopted a more comprehensive and interdisciplinary approach than other researchers in the bio-meteorological field. He used two bio-meteorological models (HIBIDEX and STEBIDEX) to calculate the man-environment energy balance for tourists using the beach. He compared the results of his calculations and the reported thermal feelings, based on questionnaires that had been distributed among those beach tourists. The observed thermal feelings were used by him to calibrate the models and to interpret their statistical results.

It is argued here that the relevance of the models and indices discussed hitherto is questionable. First, different weather conditions might affect tourists differently in open environments – not just in the way of thermal affects. For example, strong wind may cause the tourist physical discomfort. Grey sky, poor visibility and dust may negatively affect tourists' esthetic experience of the open environment even if the thermal conditions are acceptable. However, models based on thermal conditions cannot relate to such factors. Moreover, the bio-meteorological models were developed in most cases in controlled laboratory conditions and were tested on homogeneous research groups that had no relation to tourism and tourist activity. Second, in most of the cases, the developed models were applicable to micro- as well as macro climatic conditions. Also, in most cases there was no distinction between the actual and immediate weather conditions and average climate existing in a studied region. Third, none of the studies referred to the variable tourist activities, to tourists' differential travel motivations and to the different socio-economic characteristics of tourists. All these neglected factors surely have an impact on the way tourists perceive weather conditions. Moreover, many researchers claim that human reaction to climate is dependent not only on climatic variables but also on socio-psychological factors (Mieczkowski, 1985). Thus, Ambler (1968) for example, found that people may feel "warmer" when entering a place exposed directly to the sun even before the physical impact of the solar radiation started. Likewise, solar radiation is more appreciated after a long period of grey and gloomy weather (Auliciems & de Freitas, 1976). It is also argued here that tourists coming from cold countries (such as Scandinavia) will place more
importance on the availability of sunny days and blue skies than locals in Mediterranean or subtropical countries.

From the review of the studies in this section it becomes apparent that the impact of weather conditions on tourists and tourist activities is highly complex and dependent on many factors. It is also evident that the interface between climatology and tourism has not been adequately studied and, to date, we lack sound empirical evidence on the relationship between them. As Perry (1997) concluded, we urgently need research initiatives on the interrelations between climatology and tourism based on collaboration between researchers from both tourism studies and applied climatology. The challenge, as he states, will be to create a direct linkage between the study of climatic conditions and tourism planning, development and operation on the one hand, and between climatic conditions and tourists' needs, expectations, travel motivations and their socio-behavioral background on the other. If such interdisciplinary studies do become available, tourist experiences and satisfaction and the economic performance of tourism businesses will be substantially improved. The study presented here adheres to Perry's (1997) proposition.

METHODOLOGY

The Studied Area:
The city of Eilat is located in the southernmost point of Israel and in the north tip of the Eilat-Aqaba Red Sea gulf. The surrounding arid desert takes an annual average of no more than 25 mm of precipitation and there are only five rainy days per year on average. Because of the very dry conditions in the region there is a wide gap between day and night temperatures. In August, the mean temperature ranges between 39°C in mid day and 26°C at night. In January, these values range between 22°C in mid day and 11°C at night. The prevailing winds are influenced by the local topography and usually are coming from the north. The sea temperature never goes below 18°C and the water is very clear allowing the existence of coral reefs and rich underwater fauna and flora. This underwater scenery forms one of Eilat's main tourist attractions. The bay of Eilat is surrounded from the west by close steep granite and sandstone mountains, leaving a very narrow seaside strip. Eilat climatic characteristics, together with the combination of sea and desert, high mountains and rich underwater world makes it a highly attractive sea and sun resort – mainly during the winter. Eilat caters for both domestic and international tourists. The latter come mostly from Western and Northern European countries.
The field work for the study presented here took place in three declared beaches in Eilat: the "Sheraton Beach" in the northern part of the bay, the "Herod's Beach" located further to the east and the "Aqua Sport Beach" located 4 kilometers south of the city (see Figure 1). The field work lasted four consecutive days during the winter (in March).

![A map of Eilat](image)

**Figure 1: A map of Eilat**

**Research methods**

**Data collection:**

As part of the field work Ultimeter 2000 meteorological measurement devices were located at each beach. Air temperatures, relative humidity and wind velocity measurements were taken systematically every 20 minutes. Using these measurements the study calculated two widely used thermal indices: discomfort index (DI) and wind chill equivalent temperature. Cloud coverage was also estimated as part of the measurements and solar radiation data was obtained from the Eilat Weather Station. All meteorological data was collected at 1.5 meters above ground level which seems to represent better the conditions experienced by tourists. The index DI (also known as THI) was calculated using the following formula:
DI = \(1/2 \cdot (Ta + Tw)\)

Where \(Ta\) = dry bulb temperature \(^{\circ}C\) and \(Tw\) = wet bulb temperature \(^{\circ}C\).

On the basis of experiments done in the past (Tenenboum et. al, 1961; Zohar, 1980) it was decided that if the value of this index is below 22\(^{\circ}C\) units there is no heat stress at all. If the measured values are 22 – 24\(^{\circ}C\) it means that the current weather represents a light heat stress. Values between 25 and 28\(^{\circ}C\) indicate medium heat stress and values exceeding 28 units represent heavy heat stress. It must be noted that this index is meant to be used only under warm conditions.

WCI index (Wind Chill Equivalent Temperature) demonstrates human heat loss caused by the wind as a result of intensified transfer of heat from the body surface to the colder air surrounding it. It must be noted that this index does not take into account the heat loss caused by intensified evaporation from the body by the wind. This index is normally used in cold situations when the perspiration process does not occur and evaporation from the body surface is redundant (Brauner & Shacham, 1995). The index was calculated based on the following formula (Siple & Passal, 1945; Brauner & Shacham, 1995):

\[ WCI = \left( \sqrt{100v + 10.45} - v \right) \cdot (33 - Ta) \]

Where: \(Ta\) = \(^{\circ}C\) air temperature; \(v\) = \(m/s\) wind velocity - the index is using units of Kcal/m\(^2\)/hour; WCT = (Wind Chill equivalent Temperature) is calculated by using the value of light wind (3mph = 1.34m/s) in the WCI formula and calculation of the obtained temperature in a way that

\[ WCT = 33 - (WCI/12) \]

this index is in \(^{\circ}C\) units.

The two aforementioned indices are widely used but have some disadvantages: The Discomfort Index was developed mainly for an indoor environment and thus takes into account only temperature and humidity. It is not sensitive to sun-shade and wind differences prevailing in outdoor situations. It is effective mainly for measuring in warm environments. The Wind Chill Index takes into account temperature and wind velocity only and is more effective in cold conditions. However, in this study, which looks at the outdoor environment and into differential thermal conditions, there is a need for a more modern index that will take into consideration all four weather variables influencing human thermal comfort. These are air temperature, solar and terrestrial radiation, wind velocity and relative humidity. The PET index developed by Höppe & Hermann (1991) and Höppe (1993, 1999) is, therefore, appropriate for such conditions.
PET index cannot be calculated using one or several formula but is derived from the MEMI bio-
meteorological model which is based on a set of equations (see Hoppe, 1993). In the study
presented here, PET was calculated using the RayMan model which was developed by Matzarakis et
al. (1999; 2000). This model is aimed specifically for calculating complex thermal indices in urban
open space using simulations of energy transfer between man and the open environment. The input
data required for RayMan model are the dry air temperature (°C), the relative humidity (%), wind
velocity (m/s) and mean radiant temperature (°C), describing the effect of the solar and terrestrial
radiation. The model can be processed on a regular PC and can be downloaded from the developers'
website (www.mif.uni-freiburg.de/rayman).

Parallel to the meteorological calculations the study interviewed tourists vacationing on the three
beaches, using a structure questionnaire. They were asked about their perceptions of the current
weather. The study used questionnaires in four different languages: Hebrew, English, French and
Spanish, to obtain the widest possible representation of international and domestic tourists. The
questionnaire included 16 multiple choice type questions on four different issues: evaluation and
ranking of perceived weather conditions; description of weather components; description of thermal
feeling; and socio-behavioral background characteristics of each respondent. All questions related
to weather perceptions used a 7 point scale running from highly negative perception (-3) to highly
positive perception (+3) of weather components. Respondents were instructed to evaluate their
subjective perception of weather conditions based on the existing weather conditions during the time
of the interview.

**Sampling**

The sample size used in this study was 241. 91 tourists were Israelis (domestic tourism) and 150
were international tourists. Among the domestic tourists 42 (about 46%) declared that their prime
tourist motivation to come to Eilat was the sea and the beach activities. The rest claimed that sea
and beach activities were only part of an overall set of motivations. Among the international
tourists, only 30% (45 tourists) claimed that their leading travel motivation was the sea and beach
experiences. Tourist were randomly selected and interviewed while engaged in passive activities in
all areas of each particular beach.
Data Analysis

Tourists' rankings were statistically analyzed using various scales and averages, standard deviations and variances were calculated for each data series. Additionally, the coefficient of variability (CoV hereafter) was calculated to evaluate the homogeneity of each series. In doing so, ranking scales were transformed from (-3) to (+3) into 1 to 7 scales using the following formula: \( X_{\text{new}} = X_{\text{old}} + 4 \) where \( X_{\text{old}} \) is the ranking each respondent indicated when filling out the questionnaire.

The meteorological data was analyzed also using averages, standard deviations, variances and coefficient of variability.

The data was analyzed first on a general level encompassing all the respondents. Further, respondents were split into two groups – Israeli tourists and international tourists. Subsequently, the data was rearranged to allow comparison between those tourists' whose prime travel motivation was beach and sea activities and those who had other leading travel motivations.

RESULTS

First field work day

The first field work day took place on the Sheraton Beach between 09:45 – 14:00 LST (see Map 1). The beach is around 40 meters wide with several sun shades scattered about. During the field work, the sky was partially cloudy (between 60%-100%). The wind velocity was quite strong with an average of 4 m/s. Its direction was north-easterly. Air temperatures were between 20°C at 10:00 LST to 24°C at 14:00 LST. The wind chill index was 15.8°C at 10:00 LST and reached 21.3°C by 13:45 LST. The calculated PET value was 22.4°C at 10:00 LST and increased to above 33°C as the solar radiation went up. The relative humidity in the early morning was 40% and towards 14:00 LST it diminished to 34%.

Second field work day

The second field work day took place in two beaches; the Sheraton Beach and the Herodes Beach (see Figure 1). In the morning hours it was cold, windy and dust winds came particularly from the north-east. The sky was completely covered with clouds and the weather deteriorated towards noon. At a certain stage light rain started, a very unusual situation in Eilat. The wind became stronger with gusts of about 8-9 m/s. The morning temperature reached 18°C but never passed 21°C by lunch time. Wind Chill Index reached 16 degrees by 11:00 LST and decreased to 13.5-14.5 degrees as the winds became stronger. The average PET value ranged around 18-19°C. Surprisingly, despite the
poor weather some tourists did stay on the beach and some of them even bathed in the sea. As weather conditions deteriorated in the early afternoon most of them left the beaches.

Third field work day
This day was dedicated to data collection in Aqua Sport Beach 4 kilometers south of Eilat city. This beach has two sections: one northern and one southern. In between there was a whole array of beach facilities, including a diving club, restrooms and arrangements for various aqua sports (see Figure 1). This 3 – 4 meters high built-up complex created a distinct micro-climate. Meteorological measurements were taken in both sections between 10:20 LST and 14:45 LST. In the beginning it was quite cloudy (50% coverage) but the clouds gradually disappeared leaving clear sky by 14:45 LST. In the morning, temperatures reached 20°C and increased to 23-24°C by noon. Relative humidity decreased from 52% in the morning to 40% by noon. These measurements were similar in both sections of the beach. However, with regard to the wind velocity, in the southern section it reached 3-4 m/s and in the northern section it did not fall below 6-7 m/s with occasional gusts reaching 8-9 m/s and even more. The reason for this difference is the building complex which divides the two beach sections and partially blocks the wind coming from the north-east.

Fourth field work day
Also took place in the Aqua Sport Beach. This time data collection was made only in the southern section. Measurements were taken between 10:40 LST to 14:15 LST. It was mostly a clear day with about 15% cloud coverage. There was a light wind and the air was clear, excellent visibility and with no dust at all. Temperatures ranged between 20°C in the morning to 23°C in the afternoon. PET value was 20.8°C in a sunny location (16.5°C in the shade) in the morning and went up to 30-38°C in a sunny location at 14:00 LST. The relative humidity diminished from 33% to 23%. Wind velocity also diminished from 4m/s at 10:40 LST to 1 m/s at 14:15 LST. This time the wind came from the south south-easterly direction.

General observations
Among all tourists interviewed for this study, 49% perceived the weather in Eilat, while vacationing on the beach, as quite appropriate and very appropriate (rank 6 or 7 on the measurement scale). 54% ranked the quality of the weather as good and very good (rank 6 or 7 on the measurement scale). Only 30% of the tourists ranked the overall weather conditions as "ideal" (not hot and not cold, rank
4 on the scale). 26.5% ranked the wind as appropriate and 52% were highly satisfied with the sun exposure. It should be noted that these finding are averages reflecting on the aggregated findings from all four sampling days. However, since the weather conditions on those days varied, this is just a general observation, which needs to be further explored also on a daily basis.

**Weather perceptions: Israeli versus international tourists:**

When comparing the average ranking of weather perceptions between Israeli and international tourists, the results show that all Israeli tourists' rankings were slightly lower than those of international tourists. This is despite similarities in their socio-demographic background characteristics and the fact that all were exposed to the same weather conditions. These findings were quite persistent for the overall data set and also when the analysis was made on a daily basis and on leading/non-leading motivation basis. More substantial differences were found with regard to specific evaluations based on scales of appropriate/non-appropriate weather, good/bad weather, comfortable/not comfortable weather and nice/dull weather. Less substantial differences were found between Israelis and international tourists when weather factors (wind, sun, humidity and cloudiness) were compared separately. Variable and minor differences were found when weather description factors (hot/cold and thermal feelings) were analyzed.

In order to examine if differences between Israeli and international tourists were significant a two-tailed t-test with 5% level of significance was performed for the four days aggregated data. The H_0 hypothesis was that there are no significant differences between the two samples. Table 1 shows the results of this test. The results show that significant differences were found in the appropriate/inappropriate, good/bad, comfortable/not comfortable and the nice/dull ranking scales. In all these scales, the differences between the two groups stemmed from Israelis ranking those perceptions lower than international tourists. Interestingly, the two groups were significantly different also with regard to the hot/cold
Table 1: Comparison between Israeli tourists and international tourists (all days, all travel motivations)

<table>
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<tr>
<th>Category</th>
<th>Israeli Tourists</th>
<th>International Tourists</th>
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<td>CoV (%)</td>
<td>Average Ranking</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>%</td>
<td>SD</td>
</tr>
<tr>
<td>Appropriate/ inappropriate</td>
<td>4.07</td>
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<td>47</td>
</tr>
<tr>
<td>Good/bad</td>
<td>4.57</td>
<td>1.63</td>
<td>36</td>
</tr>
<tr>
<td>Comfortable/ not comfortable</td>
<td>4.55</td>
<td>1.71</td>
<td>38</td>
</tr>
<tr>
<td>Nice/ugly</td>
<td>4.83</td>
<td>1.68</td>
<td>35</td>
</tr>
<tr>
<td>Hot/cold</td>
<td>0.05+</td>
<td>1.09</td>
<td>27</td>
</tr>
<tr>
<td>Wind ranking</td>
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<tr>
<td>Sun ranking</td>
<td>-0.86</td>
<td>1.21</td>
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<tr>
<td>Cloudiness ranking</td>
<td>+0.75</td>
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<td>Light and radiation</td>
<td>R.</td>
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</tr>
<tr>
<td>Humidity ranking</td>
<td>-0.16</td>
<td>0.91</td>
<td>24</td>
</tr>
<tr>
<td>Thermal feeling R.</td>
<td>-0.13</td>
<td>0.85</td>
<td>22</td>
</tr>
<tr>
<td>Age (years)</td>
<td>31</td>
<td>14</td>
<td>45</td>
</tr>
<tr>
<td>Dry temp. (C°)</td>
<td>21.7</td>
<td>1.2</td>
<td>5</td>
</tr>
<tr>
<td>Wet temp. (C°)</td>
<td>13.6</td>
<td>1.0</td>
<td>7</td>
</tr>
<tr>
<td>R. Humidity (%)</td>
<td>35</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Wind (m/s)</td>
<td>4.2</td>
<td>1.9</td>
<td>44</td>
</tr>
<tr>
<td>Cloudiness (%)</td>
<td>55</td>
<td>38</td>
<td>69</td>
</tr>
<tr>
<td>DI index (C°) **</td>
<td>17.62</td>
<td>0.8</td>
<td>5</td>
</tr>
<tr>
<td>WCT index (C°)</td>
<td>18.6</td>
<td>2.1</td>
<td>11</td>
</tr>
<tr>
<td>PET index (C°)</td>
<td>25.0</td>
<td>5.4</td>
<td>22</td>
</tr>
</tbody>
</table>

1. Significant differences between Israeli tourists and international tourists appear in bold
   * Significant in single – tail test
   ** There is no meaning to the index if value is less than 22
   *** Variability coefficient is calculated by dividing the standard deviation with the mean. (0% = highly homogeneous series and 100% = highly in-homogeneous series)

The impact of travel motivation on weather

It was assumed in this study that each tourist's character of travel motivation has bearing on the way he perceives weather conditions. The data collected on this issue was analyzed using two main categories: tourists whose leading motivation was engaging in some kind of activity(s) connected to
the sea and/or the beach, and tourists who came to Eilat as a result of various motivations, excluding any kind of sea/beach activities. Analysis also differentiated between Israeli and international tourists in order to avoid any bias resulting from their socio-cultural backgrounds. Results show that both for the international and the Israeli tourists travel motivation characteristics did not play any significant role. This trend was found true both for the overall data set (aggregated data for the 4 sampling days) and for each separate day. The only exception to these findings is that of the second day, which was characterized by extreme unpleasant weather conditions. On that day, the average ranking of the group motivated primarily by sea/beach activities was significantly lower. This exceptional finding was true both for Israeli and international tourists.

**General comparison between "fine" day and "dull" day**

An important task is to relate the subjective weather rankings obtained through the questionnaire with the objective weather conditions that prevailed in each sampling day. In order to put these rankings in a weather context two distinct days were compared: the second day, which was characterized by extremely bad weather and the last day, which was a very fine day with light wind, blue sky, very good visibility and almost no clouds. The average rankings obtained for each of those days appear in Table 2.

When looking at rankings obtained for the "dull" day it appears that those depicting the overall weather perception (appropriate/inappropriate, good/bad etc.) ranged between 2.9 to 3.25. That means quite inappropriate, quite bad, or quite dull. On the other hand, those rankings of the "fine" day were all above 6, meaning quite good, quite appropriate etc. The average ranking for the hot/cold scale on the "dull" day was -0.860, i.e., close to quite cold, while that of the "fine" day was +1.032 which means quite hot. In the "dull" day tourists claimed that the wind was too strong (+1.627) that it was too cloudy (+2.02) and that it was not sunny enough (-2.232) and not clear enough (-1.297). The parallel indices obtained for the "fine" day had positive values but very close to zero, meaning ideal and pleasant weather.

The average temperature that prevailed when interviewing the tourists on the "dull" day was 19.9\(^\circ\)C, PET index was 18.86\(^\circ\), the relative humidity was 45%, the wind 4.5 m/s, cloudiness 100% all day and the average wind chill index was 16.1\(^\circ\)C only because of the strong wind. On the "fine" day the average temperature reached 21.4\(^\circ\), PET index reached 25.7\(^\circ\), the relative humidity was 29%, the
wind 2.1 m/s, cloud coverage 17% and the wind chill index increased to 20°C due to higher temperatures and lower wind velocity.

Table 2: Comparison between weather rankings during "fine" day and "ugly" day

<table>
<thead>
<tr>
<th>Ranking Category</th>
<th>Fine Day Average Ranking</th>
<th>CoV (%)</th>
<th>Bad Day Average Ranking</th>
<th>CoV (%)</th>
<th>α (α = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate/inappropriate</td>
<td>6.02</td>
<td>1.19</td>
<td>20</td>
<td>3.25</td>
<td>1.84</td>
</tr>
<tr>
<td>Good/bad</td>
<td>6.33</td>
<td>0.81</td>
<td>13</td>
<td>3.07</td>
<td>1.42</td>
</tr>
<tr>
<td>Comfortable/not comfortable</td>
<td>6.21</td>
<td>0.81</td>
<td>13</td>
<td>3.23</td>
<td>1.40</td>
</tr>
<tr>
<td>Nice/ugly</td>
<td>6.28</td>
<td>0.93</td>
<td>15</td>
<td>2.93</td>
<td>1.55</td>
</tr>
<tr>
<td>Hot/cold</td>
<td>1.03</td>
<td>0.97</td>
<td>19</td>
<td>0.86-</td>
<td>0.68</td>
</tr>
<tr>
<td>Wind ranking</td>
<td>0.31+</td>
<td>0.74</td>
<td>17</td>
<td>1.67+</td>
<td>0.98</td>
</tr>
<tr>
<td>Sun ranking</td>
<td>0.016+</td>
<td>0.53</td>
<td>13</td>
<td>2.23-</td>
<td>1.07</td>
</tr>
<tr>
<td>Cloudiness ranking</td>
<td>0.016+</td>
<td>0.70</td>
<td>17</td>
<td>2.02+</td>
<td>1.01</td>
</tr>
<tr>
<td>Light and radiation R.</td>
<td>0.31+</td>
<td>0.59</td>
<td>14</td>
<td>1.28-</td>
<td>0.88</td>
</tr>
<tr>
<td>Humidity ranking</td>
<td>0.17-</td>
<td>0.72</td>
<td>19</td>
<td>0.33-</td>
<td>0.89</td>
</tr>
<tr>
<td>Thermal feeling R.</td>
<td>0.43+</td>
<td>0.84</td>
<td>19</td>
<td>0.86-</td>
<td>0.77</td>
</tr>
<tr>
<td>Age (years)</td>
<td>34</td>
<td>11</td>
<td>33</td>
<td>37</td>
<td>15</td>
</tr>
<tr>
<td>Dry temp. (C°)</td>
<td>21.4</td>
<td>0.7</td>
<td>3</td>
<td>19.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Wet temp. (C°)</td>
<td>12.5</td>
<td>0.3</td>
<td>2</td>
<td>13.6</td>
<td>0.1</td>
</tr>
<tr>
<td>R. Humidity (%)</td>
<td>29</td>
<td>2</td>
<td>7</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Wind (m/s)</td>
<td>2.1</td>
<td>0.7</td>
<td>31</td>
<td>4.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Cloudiness (%)</td>
<td>17</td>
<td>12</td>
<td>70</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>DI index (C°) **</td>
<td>16.9</td>
<td>0.5</td>
<td>3</td>
<td>16.8</td>
<td>0.10</td>
</tr>
<tr>
<td>WCT index (C°)</td>
<td>20.0</td>
<td>1.3</td>
<td>6</td>
<td>16.1</td>
<td>0.92</td>
</tr>
<tr>
<td>PET index (C°)</td>
<td>25.66</td>
<td>3.95</td>
<td>15</td>
<td>18.86</td>
<td>2.34</td>
</tr>
</tbody>
</table>

2. Significant differences between Israeli tourists and international tourists appear in bold
* Significant in one tail test
** There is no meaning to the index if value is less than 22
*** Variability coefficient is calculated by dividing the standard deviation with the mean. (0% = highly homogeneous series and 100% = highly in-homogeneous series)
A t-test executed to reveal possible average ranking differences between "fine" and "dull" days proved that such significant differences do exist (see table 2).

**The reflection of Coefficients of Variability**

As explained earlier, the CoV measures the level of homogeneity of a given series. The higher it is, the less homogeneous is the series. In this study it was important to examine to what extent rankings of weather perceptions are homogeneous and if there are any significant differences between the levels of homogeneity of tourists' rankings. In all the analyses done in this direction it was found that CoVs of the meteorological variables were relatively the lowest and ranged between 5%-10% by average. However, there were significant differences between the various meteorological variables. Thus, the temperature and humidity were found to be highly stable with CoVs of 3%-7% only. On the other hand, wind and cloudiness were found to be quite non-homogeneous with CoVs of between 30%-40%.

Average rankings of tourists were by far less homogeneous because of the subjective nature of their responses. However, even in this case, there were differences. Thus, four of the major ranked variables (appropriate/inappropriate, good/bad etc. were less homogeneous with CoVs between 30%-40% by average. However, the thermal rankings (hot/cold rankings) obtained lesser CoVs of 17%-23% by average. It is interesting to note that the later CoVs were quite stable and did not change substantially over the sampling days and through the various socio-demographic axes. Alternatively, the CoVs of the good/bad rankings tended to change with the weather. The better weather conditions were, the lower the CoVs are (meaning more homogeneous). Thus, for example, the CoVs of the "bad" day reached 55%-60% and even more, whilst those of the "fine" day obtained only 14%-19% values, meaning highly homogeneous.

**Locational impact on weather perception and ranking**

The wind velocity in the northern section of the Aqua Sport Beach was a distinct weather phenomenon on the third day (see table 3).

It was twice as strong as that in the southern section. However, all other meteorological variables were quite similar. This raises a question as to what extent locational differences on the same beach, and consequent different weather conditions, yield different weather perception and ranking by tourists?
Table 3: Comparison between weather rankings in the northern and southern sections of Aqua Sport Beach

<table>
<thead>
<tr>
<th>Ranking Category</th>
<th>AQUA SPORT BEACH – NORTHERN SECTION</th>
<th>AQUA SPORT BEACH – SOUTHERN SECTION</th>
<th>( \alpha ) (( \alpha = 0.05 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Ranking</td>
<td>SD</td>
<td>CoV (( % ))</td>
</tr>
<tr>
<td>Appropriate/ inapprop.</td>
<td>4.20</td>
<td>1.74</td>
<td>41</td>
</tr>
<tr>
<td>Good/bad</td>
<td>4.84</td>
<td>1.46</td>
<td>30</td>
</tr>
<tr>
<td>Comfortable/ not comfort.</td>
<td>4.10</td>
<td>1.66</td>
<td>40</td>
</tr>
<tr>
<td>Nice/ugly</td>
<td>5.02</td>
<td>1.26</td>
<td>25</td>
</tr>
<tr>
<td>Hot/cold</td>
<td>0.38+</td>
<td>1.07</td>
<td>24</td>
</tr>
<tr>
<td>Wind ranking</td>
<td>1.60+</td>
<td>0.81</td>
<td>14</td>
</tr>
<tr>
<td>Sun ranking</td>
<td>0.24-</td>
<td>0.85</td>
<td>23</td>
</tr>
<tr>
<td>Cloudiness ranking</td>
<td>0.22-</td>
<td>1.13</td>
<td>30</td>
</tr>
<tr>
<td>Light and radiation R.</td>
<td>0.04+</td>
<td>0.67</td>
<td>17</td>
</tr>
<tr>
<td>Humidity ranking</td>
<td>0.25-</td>
<td>0.86</td>
<td>23</td>
</tr>
<tr>
<td>Thermal feeling R.</td>
<td>0.16-</td>
<td>0.98</td>
<td>25</td>
</tr>
<tr>
<td>Age (years)</td>
<td>35</td>
<td>12</td>
<td>34</td>
</tr>
<tr>
<td>Dry temp. (( \text{C}^\circ ))</td>
<td>22.3</td>
<td>0.6</td>
<td>3</td>
</tr>
<tr>
<td>Wet temp. (( \text{C}^\circ ))</td>
<td>15.3</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>R. Humidity (%)</td>
<td>43</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Wind (m/s)</td>
<td>7.2</td>
<td>0.7</td>
<td>10</td>
</tr>
<tr>
<td>Cloudiness (%)</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DI index (( \text{C}^h )) **</td>
<td>18.8</td>
<td>0.4</td>
<td>2</td>
</tr>
<tr>
<td>WCT index (( \text{C}^h ))</td>
<td>17.5</td>
<td>1.1</td>
<td>7</td>
</tr>
<tr>
<td>PET index (( \text{C}^h ))</td>
<td>21.04</td>
<td>0.66</td>
<td>3</td>
</tr>
</tbody>
</table>

1. Significant differences between Israeli tourists and international tourists appear in bold
* Significant in one tail test
** There is no meaning to the index if value is less than 22
*** Variability coefficient is calculated by dividing the standard deviation with the mean. (0% = highly homogeneous series and 100% = highly in-homogeneous series)
The study found that in the southern beach average ranking of the appropriate/inappropriate, good/bad comfortable/uncomfortable and nice/dull were higher than those of the northern beach. These differences were found significant using a t-test. Alternatively, the average rankings of the thermal scales (describing the weather using hot/cold and thermal feelings scales) showed that tourists on the southern beach felt only slightly warmer (although even this difference was statistically significant). It must be noted here that some of the tourists interviewed on the southern beach claimed they moved there from the northern beach to avoid the strong wind. On the other hand, tourists interviewed in the northern section pointed out that they would not move to the southern section despite the strong wind since the southern section is already too crowded with other tourists.

**DISCUSSION**

A key question in this study was which weather factors impinge mostly on tourists' weather perception and to what extent? The findings of this study showed that on a bad weather day, generally, tourists' rankings of these weather factors were consistently low. However, on a fine day, all indices used to measure their weather perceptions were high. This raises the question: what is the reason for these kinds of findings? A comparison of these two days shows that the variables contributing mostly to the perception differences were wind velocity and cloudiness. The differences in these two variables were large and significant. Temperature differences were also significant, yet much smaller. The cloudiness and the wind velocity differences also shaped the differences in the wind chill index and in the global and direct solar radiation. The comparison between the two sections of the Aqua Sport Beach supports these conclusions as in this case, only the wind velocity managed to change tourists' perceptions as reflected in their average rankings. These differences were obtained despite lack of any cloudiness and plenty of sun at both sections of the beach. It seems, therefore, that the two weather factors, cloudiness (which expresses reduction of solar radiation) and wind velocity, have crucial (and negative) impacts on the comfort feelings of tourists. It must be noted, though, that this conclusion is apparently true for temperature ranges that prevailed during the field work days (20 – 24°C). It is possible that in summer conditions, when it is generally much warmer, both wind velocity and cloudiness may act as positive rather than negative factors.
Another important question in this study was asking if there exist micro meteorological effects that might distinctively shape tourists' perceptions of weather, and if so, why? Comparison between the two sections of the Aqua Sport Beach showed a high level of dissatisfaction with conditions in the northern section of the beach, primarily due to its over exposure to the wind. There are two possible reasons why strong wind can disrupt beach activity: First, wind fosters feelings of cold by increasing the transfer of heat from the body surface to the air surrounding it. In other words it speeds up evaporation from the human body. Second, strong wind might create physical discomfort as it blows directly onto the body. It could also be a nuisance since it moves dust, sand and other particles. In this respect, Mieczkowski (1985) and de Freitas, (1990) estimated that wind exceeding more than 6m/s will always creates a feeling of physical discomfort.

In this case, was the wind perceived as a negative weather factor because of its wind chill effect, or rather due to the physical discomfort it created among the respondents? When examining the data it seems as if there was only minor difference between the wind chill index of the southern and the northern section of the Aqua Sport Beach. This means that the discomfort expressed by tourists in the northern – exposed section of the beach stemmed mainly from physical discomfort rather than the thermal effect caused by the wind. These conclusions are much in line with Mieczkowski (1985) and de Freitas, (1990) claims about the 6 m/s velocity threshold mentioned above.

Another interesting issue is the different perception of weather as reflected by the comparison between domestic and international tourists. As was indicated in the findings section, Israelis' rankings were consistently lower than those of the international tourists. The questions is obviously why? Two possible explanations for these differences may be offered here: First, there is a possibility that differences in mentality and background characteristics between the two tourist groups generated variations in the way they perceived the weather. Second, a more reasonable explanation stems from the fact that the majority of the international tourists interviewed in this study came from North and Western Europe and also from North America. These regions receive precipitation all year round and thus for tourists coming from such areas lack of rain, partially blue sky and sun are enough to perceive the weather as pleasant. On the other hand, for Israeli tourists this is not the case since Israel has between seven to eight dry months every year. As a result, domestic tourists placed more importance on other climatic factors, i.e. temperature and wind. This explanation is supported by Auliciems & de Freitas (1976) who claimed that solar radiation is much more appreciated by people after a period of grey and gloomy seasons. In any event, in order to
come to a firmer conclusion on this question it seems that in future studies socio-cultural and psychological influence as weather perception determinants must also be examined.

Another aspect that calls for discussion is the question of why diverse travel motivations did not reflect differently on tourists' weather perception. Initially, it was hypothesized that tourists coming to Eilat and motivated primarily by beach and sea activities would be more concerned with weather conditions. However, when investigating the results it appears that in the three "reasonable weather" days there were no significant differences between the two motivation groups. However, in the "bad weather" day significant differences were detected. Those tourists with distinct sea/beach motivations ranked the weather variables substantially lower. These findings support the above hypothesis, but this difference is marked only when the weather perceived is substantially bad.

On another matter, there is also the question as to why coefficients of the thermal variables were quite low variability vis a vis when compared to the variables depicting weather on a good/bad scales. In other words, why were the thermal variables found to be more homogeneous? In order to discuss this question we have to refer to the bio-meteorological studies. In these studies "thermal comfort" is defined as a situation where a person reports on high level of satisfaction from his current thermal environment (ASHRAE, 1966; Fanger, 1970; Givoni, 1974; Tromp, 1979). In many such studies it was found that criteria for thermal comfort are somewhat and only marginally influenced by age, gender, and socio-cultural differences (Fanger, 1972; Tromp, 1980). Givoni (1974) explains this by claiming that despite thermal feeling being a subjective evaluation of the thermal environment; it is still based on objective physiological grounds. According to him, it stems from temperature control mechanisms in our body. An optimal thermal feeling is attained in a situation where the thermal control mechanisms are in minimal activity. Alternatively, discomfort thermal feeling will be dependent on deviation of these mechanisms from the minimal activity level. Because human physiology is similar among most human beings, it is not surprising that most of them rank their thermal environment similarly. However, when using the bad/good scales their rankings were far more subjective.

In light of the above discussion, it is possible to explain why the homogeneity (mainly of the good/bad scales) was relatively low in the "bad" day and high in the "fine" day. In the latter day, the weather conditions were ideal and as a result there was wide agreement on the weather conditions among the tourists. However, on the "bad" day, weather conditions were extreme and since every
person has his own tolerance and sensitivity thresholds, it is expected that there will be far less homogeneity of weather perceptions.

**SUMMARY AND CONCLUSIONS**

This study made an integrated use of meteorological and tourists' perception data in order to evaluate to what extent weather conditions in beach/sea areas are perceived as appropriate to tourists. The main conclusions of this study are:

- Temperature range between 22-25°C and PET values ranging from 22-30°C together with 29-30% of relative humidity levels, wind velocity not exceeding 2-3m/s and light cloud coverage of up to 1/8 were found to create the optimal weather condition for beach tourists in Eilat. However, these findings are relevant to the period of only four days in March. Therefore, there is a need to further extend the study to other seasons in order to conclude which are the most appropriate times for such tourism activity in Eilat.

- It seems that wind velocity and cloudiness, having such variable characteristics in terms of time and space, exert a crucial influence on tourists' levels of satisfaction while using Eilat's beaches. With regards to the wind, it is relatively easy to adjust the beach facilities and supply wind shields and thus create a micro-climate that will improve tourists' satisfaction. In Eilat, because of the topographical structure and the synoptic conditions, the prevailing wind comes from the north. Hence, it is possible to detect those beaches more exposed to northerly wind and adjust them accordingly. This is common practice already in many beaches around the world that suffer from exposure to strong winds.

- It appears from the study that domestic tourists are more sensitive to weather conditions than tourists from overseas. This finding is reflected in their significantly lower rankings of weather factors. A few hypotheses were raised to explain this difference, yet in order to further substantiate them there is a need to look also at sociological factors.

- Travel motivations have bearing on the way tourists perceive weather, mainly when weather conditions are poor. Those who came to Eilat primarily for beach and sea activities were more sensitive to poor weather. This conclusion should lead to two recommendations. The first, on a tourism planning level, is that all stakeholders involved in beach development should carefully examine weather conditions on the beach. The data they collect through such examination will be applied in structuring optimal micro-climates and thus will improve the level of satisfaction amongst
tourists. The second refers to the role of weather forecasts in shaping destination-choice. The weather forecast conveyed to tourists must be by far more detailed and market-segment specific. In other words, it should be tailored according to those weather variables taken into account when tourists evaluate prospect destination alternatives. A more tourist oriented weather forecast should include: A) a local and more spatially detailed forecast on a given destination. This is especially important to destinations such as Eilat that "sell" weather as an important ingredient of its tourist product and which enjoy such unique weather conditions. B) Weather forecasts must be based also on an interpretative approach. If adopting this policy, tourists will be also given information on what are the best beach/sea activities to be taken under the forecasted weather conditions. C) weather forecasts must be available and, therefore, be distributed locally and in languages spoken by international and not just domestic tourists. In only a few countries and tourist destinations (such as in the US) are such weather forecasts available. However, the majority of sea and beach destinations around the world still need to provide this amenity.

- In order to improve the functional linkages between weather forecast and tourism activities there must be an effective cooperation between all stakeholders of a given tourist destination. Developers, operators and marketers of the destination should all cooperate to mitigate the gap between tourists' expectations and needs and actual weather conditions.

ACKNOWLEDGEMENTS
The authors wish to thank the Israeli Ministry of Tourism for allocating a grant to support this study.

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ASHRAE (American Society of Heating, Refrigerating, and Air conditioning Engineers) (1966)
CLIMATE, THERMAL COMFORT AND TOURISM

A. Matzarakis
Meteorological Institute, University of Freiburg, D-79085 Freiburg, Germany
andreas.matzarakis@meteo.uni-freiburg.de

ABSTRACT
Methods of human-biometeorology can be applied for the assessment of atmospheric impacts on human beings. The thermal effective complex is the most important factor for tourism among the human-biometeorological effective complexes. A procedure for the physiologically significant assessment of the thermal environment is presented. It is based on thermal indices, which are derived from the human energy balance. It is important to know the mean climatic conditions of the area of vacations and recreation for tourism climatology. As an exemplary result a bioclimate map of Greece for the summer month of August is presented which shows the pronounced spatial distribution of mean monthly values of the thermal index Physiological Equivalent Temperature (PET). Additionally, extreme conditions i.e. heat waves and its possible implications to human health were analyzed.

KEYWORDS: Tourism climate indices, thermal indices, PET, Freiburg, thermal stress

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 the health. Fevers vary seasonally and also mood and various psychological disturbances. Aches and pains in joints flare up in winter and summertime heat waves may debilitate and kill (WMO, 1999). Travel to climate-stressed locations may also, result in health problems (e.g. caused by heat stress, UV-radiation, air pollution and heat strokes). Causes and effect impact relations between the atmospheric environment and human health or comfort can be analyzed by means of a human-biometeorological classification (Matzarakis and Mayer 1996, VDI, 1998) which takes into consideration:
In this paper, only the thermal complex is the subject of interest. It includes the meteorological factors air temperature, air humidity and wind velocity, and in addition short and long wave radiation, which affect thermo-physiologically humans in indoor and outdoor climates. This complex is relevant to human health because of a close relationship between the thermoregulatory mechanisms and the circulatory system.

The climatic indices, which are primary used for tourism climate assessments and thermal comfort studies, present a certain number of crucial points. From the point of view of human-biometeorology they do not include the effects of short and long wave radiation fluxes which are generally not available in climate records. The required, for the human energy balance, short and long wave radiation fluxes are calculated using synoptic/climatological and astronomical data (VDI 1998, Matzarakis et al 2000). A full application of thermal indices of the energy balance of the human body gives detailed information on the effect of the thermal environment of humans (VDI, 1998). Common applications are PMV (Predicted Mean Vote), PET (Physiological Equivalent Temperature) (Matzarakis and Mayer 1997, VDI, 1998, Höppe, 1999, Matzarakis et al, 1999), SET* (Standard Effective Temperature) (Gagge et al., 1986) or Outdoor Standard Effective Temperature (Out_SET*) (Spangolo and de Dear, 2003) and Perceived Temperature (Tinz and Jendritzky, 2003).

All this thermal indices are well documented and include important meteorological and thermo-physiological parameters (Matzarakis, 2001a, b). The advantage of these thermal indices is that they require the same meteorological input parameters: air temperature, air humidity, wind speed, short and long wave radiation fluxes. In Table 1, threshold values of the thermal indices Predicted Mean Vote (PMV) and Physiological Equivalent Temperature (PET) are presented for different thermal perception levels and physiological stress on humans.

In order, to get answers about the interactions between tourism and the atmosphere methods of human-biometeorology can be applied. Applying methods from human-biometeorology the effects
of atmospheric environment to humans can be accessed. The same methods can also be used in the construction of optimised and less climatic tourism resorts. The objective of this article is twofold: (1) to give a brief overview of assessment methods and (2) to discuss some exemplary results.

**HUMAN-BIOMETEOROLOGICAL ASSESSMENT METHODS**

**Thermal environment**

Additional and detailed information is provided using climate indices (e.g. from applied climatology and human-biometeorology). In general, the tourism climate indices can be classified into three categories (Abegg, 1996): elementary, combined and bioclimatic indices. Elementary indices (a.e. summer index by Davies, 1968), are synthetic values without any thermo-physiological relevance. They are unproven in general. The bio-climatic and combined tourism climate indices are based on more climatological parameters, considering effects of parameter combination (Mieczkowski, 1985).

The thermal effective complex describes the influences of the thermal environment on the well-being and health of human beings. It is related to the close relationship between the human thermoregulatory mechanism and the human circulatory system. For the physiologically significant assessment of the thermal environment (Fig. 1), thermal indices are available derived from the human energy balance (Höppe, 1999, Matzarakis et al., 1999, Mayer and Matzarakis, 2003). Since the 1960s, heat-balance models of the human body are more and more accepted in the assessment of thermal comfort. The basis for these models is the energy balance equation for the human body (1):

\[ M + W + R + C + E_D + E_{Re} + E_{Sw} + S = 0 \]  

(1)

Where, $M$: the metabolic rate (internal energy production), $W$: the physical work output, $R$: the net radiation of the body, $C$: the convective heat flow, $E_D$: the latent heat flow to evaporate water diffusing through the skin (imperceptible perspiration), $E_{Re}$: the sum of heat flows for heating and humidifying the inspired air, $E_{Sw}$: the heat flow due to evaporation of sweat, and $S$: the storage heat flow for heating or cooling the body mass. The individual terms in this equation have positive signs if they result in an energy gain for the body and negative signs in the case of an energy loss ($M$ is
always positive; \( W, E_D \) and \( E_{sw} \) are always negative). The unit of all heat flows is in Watt (Höppe, 1999).

The individual heat flows in Eq. 1, are controlled by the following meteorological parameters (VDI, 1998, Höppe, 1999):

- air temperature: \( C, E_{Re} \)
- air humidity: \( E_D, E_{Re}, E_{Sw} \)
- wind velocity: \( C, E_{Sw} \)
- radiant temperature: \( R \)

Thermo-physiological parameters are required in addition:

- heat resistance of clothing (clo units) and
- activity of humans (in W).

The human body does not have any selective sensors for the perception of individual climatic parameters, but can only register (by thermoreceptors) and make a thermoregulatory response to the temperature (and any changes) of the skin and blood flow passing the hypothalamus (Höppe, 1993, 1999). These temperatures, however, are influenced by the integrated effect of all climatic parameters, which are in some kind of interrelation, i.e. affect each other. In weather situations with less wind speed, for instance, the mean radiant temperature has roughly the same importance for the heat balance of the human body as the air temperature. At days with higher wind speeds, air temperature is more important than the mean radiant temperature because it dominates now the increased enhanced convective heat exchange. These interactions are only quantifiable in a realistic way by means of heat balance models (VDI, 1998, Höppe, 1999).

One of the first and still very popular heat-balance models is the comfort equation defined by Fanger (1972). Fanger introduced the thermal indices “Predicted Mean Vote” (PMV) and “Predicted Percentage Dissatisfied” (PPD), which were thought mainly to help air-conditioning engineers to create a thermally comfortable indoor climates. After the much more complex outdoor radiation conditions had been taken into account and assigned appropriate parameters by Jendritzky et al. (1979, 1990), this approach has increasingly been applied to outdoor conditions and is now also known as the “Klima Michel Model”. Since this model was designed only to estimate an integral index for the thermal component of climate and not to represent a realistic description of the thermal human body conditions, it is able to work without the consideration of fundamental thermo-physiological regulatory processes. For example, in Fanger’s approach the mean skin temperature
and sweat rate are quantified as “comfort values”, being only dependent on activity and not on climatic conditions (Höppe, 1999).

More universally applicable than these models, which are primarily designed for the calculation of a thermal index like PMV, are those which enable the user to predict “real values” of thermal quantities of the body, i.e. skin temperature, core temperature, sweat rate or skin wetness. For this purpose it is necessary to take into account all basic thermoregulatory processes, like the constriction or dilation of peripheral blood vessels and the physiological sweat rate (Höppe 1993, 1999). Such a thermophysiological heat-balance model is the Munich energy balance model for individuals” (MEMI) (Höppe 1984, 1993), which is the basis for the calculation of the physiological equivalent temperature, PET.

![Flowchart of the human-biometeorological assessment of the thermal environment](image)

*Figure 1: Flowchart of the human-biometeorological assessment of the thermal environment (Mayer and Matzarakis, 2003)*

The heat-balance model MEMI is based on the energy-balance equation of the human body (Eq. 1) and some of the parameters of the Gagge two-node model (Gagge et al. 1971). In Eq. 1, some terms are dependent on the mean clothing surface temperature, the mean skin temperature or the sweat rate, all of which are affected by the ambient conditions – the physiological sweat rate (the basis for the calculation of $E_{sw}$) is also a function of the core temperature, which depends on both, ambient conditions and activity. Therefore, in order to solve Eq. 1, the three unknown quantities have to be
evaluated first, i.e. the mean surface temperature of the clothing \( T_{cl} \), the mean skin temperature \( T_{sk} \) and the core temperature \( T_c \). For the quantification of these unknown quantities, two more equations are required to describe the heat flows from the body core to the skin surface and from the skin surface through the clothing layer to the clothing surface (Höppe, 1984, 1999).

Solving the human energy balance and under the inclusion of some thermo-physiological considerations (details in Höppe 1984) it is possible to estimate the resulting thermal state of the body for any given combination of climatic parameters, activity and type of clothing, characterized by the heat flows, body temperatures and sweat rate. MEMI therefore presents a basis for the thermo-physiologically relevant evaluation of the thermal component of the climate.

The most important differences to the Gagge two-node model are the procedures of calculating the physiological sweat rate (as a function of \( T_{sk} \) and \( T_c \)) and the separate calculation of heat flows from parts of the body surface, which are clothing covered or bare. For people not familiar with the fields of thermophysiology or biometeorology, the expected body temperatures or heat flows may not be very meaningful. This fact is certainly one of the reasons why Gagge et al. (1971) developed the new effective temperature (ET*), an index based on their two-node model. Using ET* the thermal effects of complex meteorological ambient conditions can be compared to the conditions in a standardized room with a mean radiant temperature not differing from the air temperature and a constant relative humidity of the air 50%.

Similar in the definition of ET* (Gagge et al., 1971), but based on the MEMI, the PET was introduced by Höppe and Mayer (Höppe and Mayer, 1987, Mayer and Höppe, 1987).

The characteristics of the methods for the determination of the human-biometeorological assessment of the thermal environment are illustrated in Figure 1.

**Physiologically Equivalent Temperature**

However, at the present, there are some more popular physiological thermal indices derived from the human energy balance (Höppe, 1993, Jendritzky and Tinz, 2003, Spagnolo and de Dear, 2003). One of these is the Physiological Equivalent Temperature (PET). PET is defined to be the physiological equivalent temperature at any given place (outdoors or indoors). It is equivalent to the air temperature at which, in a typical indoor setting, the heat balance of the human body (work metabolism 80 W of light activity, added to basic metabolism; heat resistance of clothing 0.9 clo) is
maintained with core and skin temperatures equal to those under the conditions being assessed (VDI, 1998, Höppe, 1999).

The following assumptions are made for the indoor reference climate:

- Mean radiant temperature equals air temperature \((T_{\text{mrt}}=T_a)\).
- Air velocity (wind speed) is fixed at \(v = 0.1 \text{ m/s}\).
- Water vapour pressure is set to 12 hPa (approximately, equivalent to a relative humidity of 50\% at \(T_a = 20{}^\circ\text{C}\)).

The procedure for the calculation of PET contains the following steps:

- Calculation of the thermal conditions of the body with MEMI for a given combination of meteorological parameters.
- Insertion of the calculated values for mean skin temperature and core temperature into the model MEMI and solving the energy balance equation system for the air temperature \(T_a\) (with \(v =0.1 \text{ m/s}, \ VP = 12 \text{ hPa} \) and \(T_{\text{mrt}} = T_a\)).
- The resulting air temperature is equivalent to PET.

Compared to other thermal indices, which are likewise obtained from the human energy balance, e.g., the predicted mean vote PMV, PET offers the advantage of a widely known unit (degrees Celsius), which makes results more comprehensible to regional or tourism planners, who may be not so familiar with the modern human-biometeorological terminology (Matzarakis et al., 1999).

Similar to the frequently used PMV index (Fanger, 1972, Jendritzky et al., 1990), PET is one universal index to characterise the thermal bioclimate. It allows the evaluation of thermal conditions in a physiologically significant manner, too. With respect to this, Matzarakis and Mayer (1996) transferred ranges of PMV for thermal perception and grade of physiological stress on human beings (Fanger 1972, Mayer 1993) into corresponding PET ranges (Table 1). They are valid only for the assumed values of internal heat production and thermal resistance of the clothing.

It is worth mentioning that the VDI-guideline 3787 part 2 “methods for the human-biometeorological evaluation of climate and air quality for urban and regional planning, part I: climate“ (VDI, 1998) recommends the application of PET for the evaluation of the thermal component of different climates to emphasize the significance of PET more further. This guideline is edited by the German Association of Engineers (‘Verein Deutscher Ingenieure’ VDI).
Table 1: Ranges of the physiological equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo (according to Matzarakis and Mayer 1996)

<table>
<thead>
<tr>
<th>PET</th>
<th>Thermal Perception</th>
<th>Grade of Physiological Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 °C</td>
<td>very cold</td>
<td>extreme cold stress</td>
</tr>
<tr>
<td>8 °C</td>
<td>cold</td>
<td>strong cold stress</td>
</tr>
<tr>
<td>13 °C</td>
<td>cool</td>
<td>moderate cold stress</td>
</tr>
<tr>
<td>18 °C</td>
<td>slightly cool</td>
<td>slight cold stress</td>
</tr>
<tr>
<td>23 °C</td>
<td>comfortable</td>
<td>no thermal stress</td>
</tr>
<tr>
<td>29 °C</td>
<td>slightly warm</td>
<td>slight heat stress</td>
</tr>
<tr>
<td>35 °C</td>
<td>warm</td>
<td>moderate heat stress</td>
</tr>
<tr>
<td>41 °C</td>
<td>very hot</td>
<td>extreme heat stress</td>
</tr>
</tbody>
</table>

In order to calculate PET, it is necessary to determine the meteorological parameters which are important for the human energy balance at a human-biometeorologically significant height, e.g. 1.1 m above ground (average height of a standing person’s gravity center in Europe). Dominant meteorological parameters influencing the human energy balance include air temperature, vapour pressure, wind velocity and mean radiant temperature of the surroundings. Depending on the objectives of the evaluation, these meteorological parameters can be measured or calculated in a grid-net by numerical models (Matzarakis et al., 1999, Matzarakis, 2001c).

RESULTS OF THE HUMAN-BIOMETEOROLOGICAL ASSESSMENT OF THE THERMAL ENVIRONMENT

The human-biometeorological radiation model RayMan was developed by Matzarakis et al. (2000) in order to calculate the mean radiant temperature. It is well suited for the application in different environments, esp. urban structures, because it is able to take into account various complex horizons. In addition, thermal indices like PMV, PET or SET* are output variables of RayMan.
Analysis of mean conditions and extreme events

Human-biometeorological analysis regarding tourism purposes can be carried out based on daily, monthly or annual conditions. Several possibilities for the assessment of climate and thermal comfort in tourism are existing. Some results of mean conditions and extreme events are presented in the following.

First, the physiologically equivalent temperature PET (Matzarakis et al., 1999), at the Urban Climate Station of the Meteorological Institute of the University of Freiburg/Germany is calculated as an example for the assessment of the thermal environment of people in a medium sized European city. The site is located at the top of a 50 m height building in the centre of Freiburg. Wind speeds have been reduced to the gravity center of humans (1.1 m). The calculations of PET were carried out by means of the radiation and thermal bioclimate Model RayMan (Matzarakis et al., 2000).

Frequencies of PET in % of PET classes, according to Matzarakis and Mayer (1996), based on hourly data for the whole year, above the urban canopy layer (UCL) in Freiburg in the year of 2002 are shown in Fig. 2. In 6.4 % of all hours of the year (including winter time) we detect warm or even hot conditions, according to PET classes or conditions. This is an example for the yielding of ground information on thermal bioclimatic-tourism conditions of an area.

Extreme events, which may have negative consequences to the local populations and visitors, can be analyzed in addition. Heat waves affect human health and can result in implications e.g. deaths or heat strokes. The air temperature and PET conditions during the period May, 1 to September, 30, 2003 in Freiburg, Germany, a period with untypical summer conditions followed by extremely hot conditions is presented in Fig. 3. The wind speed is reduced to the level of the gravity center of humans (1.1 m). It is shown:

- daily maximum air temperature \( (T_{a,\text{max}}) \),
- daily minimum \( (T_{a,\text{min}}) \) air temperature,
- daily maximum PET \( (PET_{\text{max}}) \),
- daily minimum PET \( (PET_{\text{min}}) \)

in Freiburg for the period May, 1 to September, 30, 2003.

Additionally the frequency of days with:

- minimum air temperature \( (T_{a,\text{min}} > 20) \),
- maximum air temperature \( (T_{a,\text{max}} > 30) \),
- minimum PET \( (PET_{\text{min}} > 20) \),
• maximum PET ($PET_{max} > 30$) and
• maximum PET ($PET_{max} > 35$)

for the same period is shown. From Fig. 3 the extreme conditions for this specific period can be detected.

Figure 2: Hourly frequencies distribution of Physiological Equivalent Temperature (PET) in Freiburg for 2002

Figure 3: Daily maximum ($T_{a,max}$) (°C) and minimum ($T_{a,min}$) air temperature (°C), daily maximum ($PET_{max}$) (°C) and minimum ($PET_{min}$) Physiological Equivalent Temperature (°C) in Freiburg for the period May, 1 to September 30, 2003 and additional the frequency of days with min air temperature ($T_{a,min} > 20$), maximum air temperature ($T_{a,max} > 30$), minimum PET ($PET_{min} > 20$), maximum PET ($PET_{max} > 30$) and maximum PET ($PET_{max} > 35$), for the same period
Figure 4: Pattern of hourly values of Physiological Equivalent Temperature (PET), in Freiburg for August 2003

Figure 4 presents the temporal pattern of PET values in Freiburg for August 2003. During the first 15 days of August 2003 only a few hours with thermal comfort values (PET < 20 °C) occurred. The second part of August was characterised by conditions, which are typical for Freiburg. During the first 15 days of August 2003, less little neutral thermal conditions for humans, especially during the nighttime have been observed in the vicinity of Freiburg. Results in high temporal and spatial resolution are helpful for risk assessments espc. to avoid negative implication on humans.

Mapping

In the meantime, some investigations which use thermal indices like PMV or PET for the human-biometeorological assessment of the thermal environment in different scales were performed. Results from a case study (Matzarakis et al., 1999) enables a process analyses, e.g. in the form of regressions between PET as thermal index and meteorological input parameters like single radiative fluxes, mean radiant temperature, air temperature, or vapour pressure. Maps can be drawn using geo-statistical methods converting point results to spatial distributions (Matzarakis and Mayer, 1997).
As an example for bioclimate maps, the spatial distribution of mean daily *PET* values in Greece at 12 UTC in August (Figure 5) shows the influences of different site factors (site elevation or distance to the coast) which are coming out well pronounced. The month of August in Greece is one of the summer months with the highest heat stress conditions for the population. For example, all regions below 600 m a.s.l. show high heat stress. Nevertheless, there are comparatively large spatial differences between the areas with high heat stress. On the islands of the Aegean and Ionian Sea, the heat stress conditions are somewhat lower than those obtained in the interior land parts of the country. Extreme heat stress is observed in the lower elevated regions of Greece (e.g. in Thessaly, Macedonia, in the western part of Sterea Ellada and the southern part of Epirus). We find similar conditions in the coastal areas which are covered with land masses or protected bays. In this category most of the islands are to be found. Although, conditions with strong heat stress are lesser...
in relation to the continental mainland there. This is due to the influence of the Etesian winds in the Aegean Sea and a development of regional sea breeze wind systems in the Ionian Sea (Matzarakis and Mayer, 1997, Matzarakis et al., 1999).

The presented information can be helpful in the identification of stressed areas or suitable areas and in the extension or reduction of tourism period.

CONCLUSIONS

Human-biometeorology provides well-suited thermal indices on the basis of the human energy balance for the assessment of the thermal environment on human beings on a regional and local scale. This information can be implemented in planning and construction of tourism areas and facilities.

A range of climate information is required for tourism climatology. But simple meteorological or climatological parameters in the form of means (Fig. 5), extremes, frequencies (Fig. 3 and 4) and possibilities may not be useful unprocessed. Tourism climatology information has to be assessed and demands quantitative results and not only qualitative statements.

Scientific generated tourism climate indices, and in general, thermal climate indices are not tested at humans (tourists) and they don’t include the climate adaptation of them.

Combined variables of atmospheric parameters like thermal comfort are of special interest. Nevertheless, they do not provide absolute integrated assessments and guidelines of atmospheric effects on humans, or assessment with the purpose of planning tourism resorts, etc. Physical factors like e.g. for instance ultraviolet radiation or air quality have to be further included in the assessments.

Finally, looking at the existing deficits and observing critical points at the thermal indices and their use in applied climatological studies, it has to be mentioned, that the efforts in developing scientific tools is advancing ahead. An international expert group, covered by the umbrella of the International Society of Biometeorology, the World Health Organisation and the World Meteorological Organisation is working in the development of one universal thermal climate index, based on the state of the art in human-biometeorology.

From an aestethical point of view, sunshine or visibility is important. Information on climate (including all its atmospheric and physical terms) requires well-prepared, well-presented and accessible information in order to be broadly used in tourism climatology (de Freitas, 1990, 2001,
2003). In addition, other interactions between the different facets, including recreational behaviour and socio-economic factors have to be also considered.

Many of the above mentioned questions are part of the work of the Commission Climate, Tourism and Recreation of the International Society of Biometeorology (http://www.mif.uni-freiburg.de/isb).

REFERENCES


CLIMATIC CHANGES IN THERMAL COMFORT AT THE ADRIATIC COAST

K. Zaninović¹, A. Matzarakis²

¹Meteorological and hydrological Service of Croatia
²Meteorological Institute, University of Freiburg

E-mail addresses: zaninovic@cirus.dhz.hr, andreas.matzarakis@meteo.uni-freiburg.de

ABSTRACT
The knowledge about thermal comfort of humans plays an important role in human health and activities, especially in tourism, recreation and sport. In spite of the efforts that have been made to investigate temperature changes during the last century, these results cannot completely clarify their impacts on humans. This paper analyses the variations and trends of the PET (Physiologically Equivalent Temperature) and PMV (Predicted Mean Vote), the thermal bioclimate indices based on the human energy balance models. The climatic changes are analyzed during the period 1901-2000 for all seasons and for the annual values at the meteorological stations Crikvenica and Hvar. Both are very attractive tourist destinations at the eastern Adriatic coast. Crikvenica is situated in the northern Adriatic Sea and Hvar is situated on island of Hvar in the middle Adriatic Sea.

In spite of some missing data in time series, they were subject to trend analysis. In order to remove short-term fluctuations in data series, they have been smoothed by means of the 11-year binomial moving average filter. The linear trends have been tested for significance by means of nonparametric Mann-Kendall rank statistics. For the series, which showed the significant trend identified by the Mann-Kendall coefficient \( t \), a progressive analysis of the time series by means of the statistic \( u(t) \) was performed in order to determine the beginning of this phenomenon.

KEYWORDS: thermal comfort, physiologically equivalent temperature, trend

INTRODUCTION
The knowledge about thermal comfort of humans plays an important role in human health and activities, especially in tourism, recreation and sport. In spite of the efforts that have been made to investigate temperature changes during the last century, these results cannot completely clarify their impacts on humans. The goal of this article is to study the variations and trends of PET (Physiologically Equivalent Temperature) and PMV (Predicted Mean Vote), the thermal bioclimate indices based on the human energy balance models (VDI, 1998).
The climatic changes are analysed during the period 1901-2000 for all seasons and for the annual values at the meteorological station Hvar, a very attractive tourist destination situated on island of Hvar in the middle Adriatic Sea (Fig. 1).

Concerning the meteorological parameters that can be important for tourism, the climate changes in Croatia have been investigated for the minimum and maximum temperatures, daily temperature range and precipitation at the inland lowland and coastal stations. The results indicated at the decreasing maximum temperatures and increasing minimum temperatures resulting with the significant decrease in daily temperature range (Zaninović, Gajić-Čapka, 1995). Besides, the changes in thermal comfort for Hvar for the period 1858-1995, from the beginning of meteorological measurements in Hvar were investigated (Zaninovic, 1995). The results pointed at the increasing thermal comfort trends significant in winter, autumn and annual values as the result of positive temperature trends and negative wind speed trends. Increasing trends in thermal comfort for the period 1955-2004 were found also in Croatian and Slovenian mountains, but caused mainly by the temperature increase in spring and summer (Zaninović, 1996, Zaninović et al., 2006).

According to Köppen’s classification of climate, Hvar has a moderately warm rainy climate, with the warmest month of July, with the mean temperature 24.7°C and the coldest month of January with the mean temperature 8.8°C. The daily mean temperature above 20°C can be expected from early June to late September. The swimming is convenient from mid June to the end of October when the sea temperatures are above 20°C. Cold days with sub-zero temperatures are very rare,
appearing mainly in December and January. On the contrary, warm days with the highest daily temperature above 25 °C appear between May and October, and in July and August nearly all days are warm. During July and August the highest daily temperature often exceeds 30°C (hot days), while the night temperature does not drop below 20°C (warm nights). The mean annual cloudiness is about four tenths, and over half the sky is overcast from November until April. In spring the amount of cloudiness decreases, and in the summer it reaches the lowest values - in July and August only two to three tenths of the sky are overcast. With over 2700 hours of insolation a year, or an average of more than 7 hours per day, Hvar belongs to the sunniest areas of Croatia. From November to March it has an average of 4-5 hours of sunshine a day, and in the sunniest season, in the summer, the sun shines on the average about 11 hours a day. Clear days when the mean daily cloudiness is under two tenths, are twice as frequent as cloudy days, when over eight tenths of the sky are overcast. During July and August about 20 days in the month are clear. Most cloudy days occur between November and March, but even then there are not more than 9 cloudy days and only in December about 11 cloudy days a month on average.

The mean annual precipitation in Hvar is about 730 millimetres. Most precipitation occurs in winter, which is a characteristic of the maritime precipitation regime. About 65% of the total precipitation occurs between October and March, and in that period there are about 7 to 9 rainy days per month. The warm season has less precipitation and fewer rainy days, while in the summer there are only 3 to 4 rainy days per month.

In the annual wind rose mild winds prevail. The most frequent winds come from the north and north-north-east and south-east. This winds regime is characteristic of the whole coastal area, indicating the appearances of the bora and the jugo (scirroco). In the summer, about midday, a characteristic flow comes from the west quadrant, the well-known mistral.

The average thermal sensation ranges from cold to hot. On average from the end of December to the end of February it is cold all day. However, concerning the probability of different thermal sensation, the sensations of cold and fresh have similar probabilities in winter, while the feeling of very cold and extremely cold are very rare. Early spring and late autumn are fresh, but pleasant days are not rare. In May and in autumn from mid-September until the end of October, it is pleasant and sometimes warm. Spring and autumn are very favourable for active holidays with walks and sports.

In the summer, warm weather prevails, and from mid-July to mid-August it can be hot during the afternoon. A favourable characteristic of the Hvar bioclimate is that the sensation of very hot is very
rare and is felt nearly exclusively in the afternoon hours. Due to the fair and warm weather in that season, it is possible to stay in the open nearly all day, and in the warmest part of the day a refreshing sea bath will mitigate the feeling of warmth.

METHODS

Thermal environment

The thermal effective complex deals with the influences of the thermal environment on the well-being and health of human beings. The basis is the close relationship between the human thermoregulatory mechanism and the human circulatory system. For the physiologically significant assessment of the thermal environment, some thermal indices are available which are derived from the human energy balance (Mayer, 1993, Matzarakis and Mayer, 1997, Höppe, 1999, Matzarakis et al., 1999).

In the meantime, several investigations were performed which use thermal indices like PMV or PET for the human-biometeorological assessment of the thermal environment in different scales. Results from case studies (Matzarakis et al., 1999) enables a process analysis, e.g. in the form of regressions between PET as thermal index and meteorological input parameters such as single radiative fluxes, mean radiant temperature, air temperature, or vapour pressure. For calculating the mean radiant temperature, the human-biometeorological radiation model RayMan was developed by Matzarakis et al. (Matzarakis et. al., 2000), which is well suited for the application in different environments, esp. within urban structures, because it considers various complex horizons. In addition, thermal indices like PMV, PET or SET* are output variables of RayMan.

Trend analysis

The fluctuations and trends of seasonal and annual values of thermal comfort indices PET and PMV as well as the meteorological parameters that influence at the thermal comfort as air temperature, relative humidity, wind speed and cloudiness have been determined. Variations and trends have been analysed during the last 100-year period (1901-2000) in spite of some missing data in 20’s and 40’s.

In order to remove the short-term fluctuations the data series were smoothed by means of the weighted 11-year binominal moving average filter. The weighted moving average can be expressed by means of the term:
in which $\bar{x}_i$ is the filtered value of the series corresponding to the $t$th term, and $w_i$ is the weight by which the value of the series $i$ units removed from $t$ is multiplied. The length of the moving average defined in this way is $2n+1$ time units, and in our case $n$ is 11. The weight in our case is binomial coefficient:

$$c_k = \frac{n!}{k!(n-k)!}$$

Linear trend has been tested for significance with the Mann-Kendall rank statistics $t$ (Mitchell et al., 1966, Sneyers, 1990). For each element $x_i$, or for each rang $y_i$ which is given to them when they are arranged in increasing order of magnitude, the number $n_i$ of elements $y_j$ preceding it ($i>j$) is calculated such that $y_i>y_j$. The test statistic $t$ is given by the equation:

$$t = \sum_i n_i$$

For the series, which showed the significant trend identified by the Mann-Kendall coefficient $t$, a progressive analysis of the time series by means of the statistic $u(t)$ was performed in order to determine the beginning of this phenomenon (Sneyers, 1990). The $t_i$ test values are normally distributed for a long series and their mean and variance are:

$$E(t) = \frac{n(n-1)}{4}$$

$$var(t) = \frac{n(n-1)(2n+5)}{72}$$

They make possible the determination of standardized values:

$$u = \frac{t - E(t)}{\sqrt{var(t)}}$$

When the values $u$ exceed the stated significance limit for more than one point, the trend can be recognized. Where $u$’s are positive, they point at an increasing trend, and where they are negative they point at a decreasing trend. In order to identify the beginning of the possible trend, $u$ is calculated for all $i$’s, from the first to the last datum, forming the progressive onward test series. The backward test series $u'$ is formed in the same manner, calculating it from the last to the first term. Their intersection points designate the beginning of the trend.
RESULTS AND DISCUSSION

According to the mean annual and seasonal PET and PMV values, the mean annual thermal sensation in Hvar is slightly cool (17.3°C PET, -0.8 PMV), varying from cool winter (8.3°C PET, -2.8 PMV) and slightly warm summer (28.5°C PET, 1.3 PMV). Because of the maritime influence, autumn is warmer (18.6°C PET, -0.5 PMV) than spring (14.8°C PET, -1.3 PMV).

The PET and PMV fluctuations show a visible warming about 50’s, even more pronounced than in the temperature (Fig. 2). That is the result of smaller wind speed in the same period. After that, the cooling period until the beginning of 80’s occurred, as the result of the decrease in temperature and simultaneous increase in wind speed. At the same time the decrease in water vapour occurred as well. The warming in PET and PMV from the beginning of 80’s until the end of century is the result of increase in the air temperature and decrease in wind speed, but also the decrease in the cloudiness from the end of 70’s until the end of 80’s.

Table 1: Seasonal and annual trends (per 100 years) of mean physiologically equivalent temperature (PET in °C) and predicted mean vote (PMV), temperature (t in °C), vapour pressure (VP in hPa), wind speed (v in m/s) and cloudiness (in tenths). Shading denotes trends significant at the 0.05 level according to Mann-Kendall rank statistics

<table>
<thead>
<tr>
<th>Seasons</th>
<th>PET</th>
<th>PMV</th>
<th>t</th>
<th>VP</th>
<th>v</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>-0.62</td>
<td>-0.12</td>
<td>0.38</td>
<td>-0.57</td>
<td>0.59</td>
<td>-0.14</td>
</tr>
<tr>
<td>Spring</td>
<td>-0.75</td>
<td>-0.10</td>
<td>0.19</td>
<td>-1.13</td>
<td>0.43</td>
<td>0.62</td>
</tr>
<tr>
<td>Summer</td>
<td>-0.56</td>
<td>-0.09</td>
<td>0.32</td>
<td>-2.08</td>
<td>0.27</td>
<td>0.55</td>
</tr>
<tr>
<td>Autumn</td>
<td>-0.24</td>
<td>-0.01</td>
<td>0.54</td>
<td>-1.01</td>
<td>0.46</td>
<td>0.03</td>
</tr>
<tr>
<td>Annual</td>
<td>-0.61</td>
<td>-0.09</td>
<td>0.39</td>
<td>-1.12</td>
<td>0.40</td>
<td>0.26</td>
</tr>
</tbody>
</table>
Figure 2: Variations of the mean physiologically equivalent temperature (PET in °C), the mean predicted mean vote (PMV), relative humidity (RH in %), wind speed (v in m/s) and cloudiness (in tenths), their weighted 11-year binomial moving average series and linear trends during the period 1901-2000 at Hvar

The trend analysis showed the increasing trend of temperature at Hvar in all seasons. The greatest changes suffered temperature in autumn (around 0.5°C/100 years) and the smallest in spring (0.2°C/100 years), but only the increasing trend of mean annual values of 0.4°C per 100 years is significant (Tab. 1). However, the both human-biometeorological indices, PET and PMV show decreasing trends in all seasons, moreover significant for the annual values of PET (-0.6°C/100 years). The negative trend was the greatest in spring (-0.8°C/100 years) and the slightest in autumn, as the effect of the opposite temperature trends in those seasons. Analysis of possible causes for the opposite trends in temperature and thermal comfort shows that all of them contributed partly for such result. The main influence at the decreasing trend of biometeorological indices has probably
the wind. Namely, the wind speed increased in all seasons during last century, even significant for
the annual values and in all seasons except winter. As the wind speed in Hvar was observed, but not
measured, it was much more sensitive to errors than other meteorological parameters. Therefore, it
is very difficult to establish if the increasing trend of wind speed is real or is a result of
inhomogeneity. The water vapour pressure gave also the contribution to the decreasing trend in
thermal sensation because of significant negative trends in all seasons as well as in annual values.
However, the trends of temperature and water vapour pressure are in a kind of contradiction,
because, as it is well known, the water vapour pressure is positively correlated with temperature. If
the negative trends of water vapour pressure are the result of errors in input data, the decrease in
thermal comfort is also unreal. Finally, the cloudiness suffered the positive trends in all seasons
except winter contributing also to the decrease of thermal sensation.

The progressive trend test has been applied to the annual values of PET, which had significant
decreasing trend, as well as for the parameters influencing thermal comfort - temperature, wind
speed and water vapour pressure (Fig. 3). From the courses of the onward (u) and backward (u’) test
series it can be seen that during the analysed period PET had three intersection points. The first one
was in 1946 pointing at the beginning of the increasing trend in PET, while the second intersection
point in 1971 marks the beginning of decreasing trend. None of these trends became significant,
because the u value didn’t exceed the limit value 1.96. In the last decade (since 1991) PET began to
increase again, even reaching the significant values at the end of the observing period of PET, and
the forthcoming years will show if the increasing trend will continue. The progressive trend test for
temperature shows that the increasing trend in temperature began in 1946, corresponding with the
beginning of the increasing trend in PET. The increasing trend of temperature became significant in
1959, and stayed significant until the end of observing period. Because of such temperature trend
characteristic it is obvious that the variations in PET trend are the result of other meteorological
parameters important for the thermal comfort. The annual values of wind speed showed the
beginning of the increasing trend in 1951.
The wind speed increased until the end of century and since 1962 it was significant. Comparing the progressive trend tests for PET and wind speed, one can see that the beginning of increasing trend in wind speed in 1951 corresponds with the beginning of the retard in increase of PET. From the beginning of 60’s the decrease in water vapour began contributing together wind the increase in wind speed to the decrease in PET, in spite of increasing temperature trend. Finally, the increase of PET in the last decade of the century is the result of simultaneous sharp increase in temperature and water vapour and decrease of wind speed.

The obtained negative trends in thermal indices in 20th century in all seasons in spite of positive temperature trends are the result of the increasing trend in wind speed and cloudiness. The
differences with the results from the earlier investigation for the same station (Zaninović, 1998) are probably the result of different periods of investigation.

REFERENCES
ABSTRACT

For many alpine areas in Switzerland, winter tourism is the most important source of income, and snow-reliability is one of the key elements of the offers made by tourism in the Alps. 85% of Switzerland’s current ski resorts can be designated as snow-reliable. If climate change occurs, the level of snow-reliability will rise from 1200 m up to 1800 m over the next few decades. Only 44% of the ski resorts would then still be snow-reliable. While some regions may be able to maintain their winter tourism with suitable adaptation strategies, others would lose winter tourism due to a diminishing snow pack. Climate change must be viewed as a catalyst that is reinforcing and accelerating the pace of structural changes in tourism. Today, adaptation strategies are predominant in tourism (e.g. artificial snow production). As an industry that will be severely affected by climate change, however, tourism will increasingly have to focus on mitigation strategies (e.g. less greenhouse gas emissions by tourism traffic).

KEYWORDS: Alps, Climate change, Skiing, Snow, Switzerland, Tourism

INTRODUCTION

For many alpine areas in Switzerland winter tourism is the most important source of income, and snow-reliability is one of the key elements of the touristic offers. Skiing and snowboarding, but also snow related activities like cross-country skiing or snow hiking depend on enough snow. Hence, the financial viability of the winter tourism industry depends on sufficient snow conditions. It was the winters with little snow at the end of the Eighties (1987/88 – 1989/90) that caused a stir in the Swiss Alps. The big difference to the situations at earlier periods with little snow is that the capital intensity of ski tourism had considerably increased.

Since 1850, Swiss Glaciers have lost more than a quarter of their surface. In 2030, 20 to 70% of
Swiss glaciers will have disappeared. This is not only a severe lost of mountain aesthetic, but also a problem for ski slopes on glaciers in winter and summer skiing. Global warming increases melting of permafrost and makes many mountain areas vulnerable to landslides. Mountain cableway stations lift masts and other buildings in permafrost soil become instable. To brace such buildings in melting permafrost causes high costs. However, warming in mountain areas also makes hiking and climbing more dangerous due to increasing rock fall. On the one hand, the future climate will be warmer on the other hand the future climate will change its pattern. More precipitation or a higher fog level will lead to new conditions for mountain summer tourism such as hiking, trekking or biking. More and stronger extreme events are another threat for tourism activities and tourism infrastructure.

Because of the strong links of tourism and agriculture, direct impacts of climate change on tourism or agriculture are likely to have additional indirect impacts on the other sector. Depending on the region, farmers rely to a variable degree on off-farm income. In the Swiss Alps, an important number of the farmers depend on winter tourism. This is important because government subsidies and the total gross margin could change in the future independent of climate change, whereas additional income from activities in other sectors, such as winter tourism, may change because of climate change. Direct impacts of climate change on the tourism industry may have serious indirect effects on agriculture. Climate change is not only a severe threat for winter tourism, but for alpine agriculture too.

**CLIMATE CHANGE AND SNOW-DEFICIENT WINTERS**

The Swiss economy is highly dependent on tourism. If the assumptions of the impacts of climate change hold true, snow cover in the Swiss Alps will diminish which will, in turn, jeopardise the tourism industry. The crucial factor for the long-term survival of mountain cableway companies is the frequency and regularity of winters with good snow conditions, or, put the other way round, the number of snow-deficient winters that can be withstood. It is not possible to give a definitive answer here, since the economic situation of the companies varies too much. The experience acquired by Swiss ski resorts, however, shows that a ski resort can be considered snow-reliable if, in 7 out of 10 winters, a sufficient snow covering of at least 30 to 50 cm is available for ski sport on at least 100 days between December 1 and April 15.

Today, 85% of Switzerland's 230 ski resorts can be considered to be snow-reliable (tab. 1).
However, even today a lot of ski resorts in the Prealps are not snow-reliable. If the line of snow reliability were to rise to 1'500 m as a result of climate change (year 2030 – 2050), the number of snow-reliable ski resorts would drop to 63%. The Jura, Eastern and Central Switzerland, Ticino, and the Alps in the cantons of Vaud and Fribourg will be particularly jeopardised by global warming. The ski regions of Valais and the Grisons will experience virtually no major problems, since the mean altitude of the cableway terminals in these regions is higher than 2500 m above sea level. If the line of snow-reliability were to rise to 1800 m, which is a possible scenario, there would be a further serious deterioration in conditions: only 44% of skiing regions could be designated as snow-reliable. Even in the cantons of Grisons and Valais, approximately a quarter of the ski resorts would no longer be snow-reliable.

Table 1: Snow-reliability of Swiss ski resorts (Abegg 1996, Buerki 2000)

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of ski resorts</th>
<th>1200 masl No. %</th>
<th>1500 masl No. %</th>
<th>1800 masl No. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jura</td>
<td>15</td>
<td>4</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>Alps (Vaud + Frib.)</td>
<td>19</td>
<td>16</td>
<td>84</td>
<td>7</td>
</tr>
<tr>
<td>Valais</td>
<td>54</td>
<td>54</td>
<td>100</td>
<td>52</td>
</tr>
<tr>
<td>Bern (ex. Jura)</td>
<td>35</td>
<td>30</td>
<td>86</td>
<td>20</td>
</tr>
<tr>
<td>Central Switzerland</td>
<td>35</td>
<td>26</td>
<td>74</td>
<td>13</td>
</tr>
<tr>
<td>Ticino</td>
<td>8</td>
<td>8</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>Eastern Switzerland</td>
<td>18</td>
<td>11</td>
<td>61</td>
<td>6</td>
</tr>
<tr>
<td>Grisons</td>
<td>46</td>
<td>46</td>
<td>100</td>
<td>42</td>
</tr>
<tr>
<td>Switzerland</td>
<td>230</td>
<td>195</td>
<td>85</td>
<td>144</td>
</tr>
</tbody>
</table>

Climate change will lead to a new pattern of favoured and disadvantaged ski tourism regions. If all other influencing factors remain the same, ski tourism will concentrate in the high-altitude areas that are snow-reliable in the future too, e.g. most of the ski runs in the cantons of Valais and Grisons. Ski resorts at lower altitudes will withdraw from the market sooner or later because of the lack of snow.
The only areas with good prospects will be those with transport facilities that provide access to altitudes higher than 2000 m. The regions at higher altitudes may experience greater demand, prompting a further expansion in quantitative terms. The pressure on ecologically sensitive high-mountain regions will increase. The call for snow-reliable ski resorts constitutes the main reason for the current boom in concept studies and plans for opening up high-mountain regions, or, expressed in different terms: climate change is an argument for opening up high-mountain regions to tourism. A survey among tourists shows, that skiers will respond flexibly to changing snow conditions. During a period of snow-poor seasons, as expected more often under a changing climate, 49% of the skiers would change to a ski resort that is more snow-reliable. 32 % of the skiers would ski less often. Although only 4% of the respondents would give up skiing, it can be concluded that climate change would have serious impacts on the number of skier days. The most vulnerable ski resorts in the lower regions of the Alps have to deal with a significant decrease of younger guests, day tourists and novice skiers, which is exactly the target group of these resorts (Buerki 2000).

Meier (1998) calculated the potential annual costs of climate change in Switzerland at CHF 2.3 to 3.2 billion (US $ 1.5 to 2.1 billion) by the year 2050, which is 0.6 to 0.8% of the Swiss gross national product for 1995. CHF 1.8 to 2.3 billion (US $ 1.2 to 1.6 billion) would be accounted for by tourism. Even if there are many reservations that can be voiced regarding this calculation, it nevertheless shows that tourism is the economic sector that would be most affected by climate change in Switzerland and that this influence is of an order of magnitude that cannot be neglected. The impacts of climate change on winter tourism may be even more severe in countries such as Germany or Austria due to lower altitudes of their ski resorts.

However, the winter of 1998/99, in particular, February 1999, showed that the possibility of winters with a great deal of snow can not be excluded in the future. In a study of the ‘avalanche winter’ of 1999, the direct losses incurred by mountain cable-ways as a result of avalanches and the large quantities of snow were estimated at CHF 17 million (US $ 12 million). In total, 44 facilities were damaged, including 20 skilifts, 11 chair-lifts, 4 cable railways and 2 funicular. The mountain railway companies had to spend an extra 77% on snow clearing, compared with previous years. Roughly 25% more than in normal winters was spent on securing the ski slopes. All in all, the avalanche winter of 1999 probably caused losses of CHF 332 million (US $ 240 million), the major portion of these having been indirect losses of CHF 302 million (US $ 215 million) (Nöthiger 2004 & SLF 2000).
ADAPTATIONS OF TOURISM REPRESENTATIVES

In Switzerland the tourism representatives at a political, entrepreneurial, operational and organisational level are not sitting back idly contemplating the consequences of a climate change. They are adapting right now in the expectation of climate change. The experiences with snow deficient winters have shown them that the climate does not determine their economic activities, but, instead, constitutes a key resource and framework condition. The results of a focus group study among tourism representatives in Switzerland can be summed up as follows:

- Climate change has been recognised as a problem for winter tourism. Those responsible for tourism know that what they can offer is highly dependent on snow and that they are at risk from snow-deficient winters. They are familiar with the potential consequences of climate change for winter tourism. While achieving snow-reliability constitutes a central topic, potential climatic change is seen as being only of relatively minor importance.

- Climate change is not regarded as a catastrophe for winter tourism. The tourism representatives think that climatic change is presented in a highly exaggerated form by the media – and also in science and politics. Although climate change could intensify the problems that already exist in ski areas at lower altitudes and speed up structural changes in the sector, the majority of ski resorts at medium and high altitudes, however, would scarcely be affected.

- Climate change is already affecting the strategies and plans of the winter sport resorts today. The discussions held in the focus groups clearly revealed an ambivalent relationship to climate change. On the one hand, the representatives strongly distrust the information disseminated about climate change and play down its potential consequences, but on the other hand, they use climate change to legitimate forward strategies. Climate change and global warming, together with international competition, have been used as the key arguments for constructing artificial snowmaking facilities, as well as for extending existing ski runs and opening new ones in high-alpine regions (at above 3000 m).

- The tourism representatives all agree that winter sports can only survive in the Alps if snow-reliability is guaranteed. Precisely, the smaller ski fields at lower altitudes either have their hands bound or can scarcely finance the necessary investments (e.g. snow cannons, levelling out ski slopes, opening higher-altitude chambers in skiing areas). On the one hand, they do not have financial resources of their own, and on the other hand, banks are (now) only
prepared to grant very restrictive loans to ski resorts at altitudes below 1500 m which are not particularly profitable. Nevertheless, the representatives believe that smaller ski fields in the Alpine foothills play a key role in promoting the importance of skiing. Opinions frequently differ a great deal, however, on whether nonprofitable ski regions of this type should be retained and how their financing can be guaranteed. While a number of people are in favour of dismantling non-profitable cableway and ski-lift operations and regard a certain ‘healthy shrinkage’ of the sector as necessary, others believe that there is an obligation to retain these ski fields for regional economic reasons. This is also increasing pressure for cable-way companies to receive subsidies.

STRATEGIES
Climate change represents a new challenge for tourism, and particularly for winter tourism in mountain areas. It is not, however, the case that tourism’s initial position will undergo a sudden, radical change. Instead, climate change has to be viewed as a catalyst that will reinforce and accelerate the pace of structural change in the tourist industry and more clearly highlight the risks and opportunities inherent in tourist developments even now. The emergence of a 2-tier society in the tourist sector will not be due to climate change alone, but to the general change in structure as well. On the one hand, we have the top resorts with their already varied and attractive offers and high snow-reliability and, on the other hand, we have the smaller locations with their less extensive developments, less-refined offers and restricted opportunities for further development. Since climate change is a relatively long-term development in comparison to other trends in tourism, tourism managers and tourists will have every opportunity to adjust to the different constraints and adopt the corresponding strategies and measures (fig. 1):
One of the most familiar measures in the struggle against snow-deficient winters is the construction of high cost artificial snowmaking facilities.
Adopting a fatalistic attitude towards climate change and its impacts should not be considered as a true strategy in this respect. Such attitudes are manifested by the fact that neither suppliers nor consumers alter their behaviour. This could also be described by using the term ‘business as usual’. Another approach that can be classified under the heading of ‘fatalism’ is when tourist transport facilities that were used for winter sports are closed down and dismantled without any attempt at promoting and reinforcing other types of tourism – in other words, when withdrawal from ski
tourism is not actively planned. A fatalistic attitude of this type is most readily evident amongst the operators of small, isolated ski-lifts at lower altitudes who experienced severe financial difficulties as a result of the snow-deficient winters.

CONCLUSIONS
At first sight, global warming seems to be a chance for the tourism industry in alpine areas. But warmer temperatures and a longer summer season are of minor importance. Over all, climate change is a threat for alpine tourism due to less snow, less glaciers, but more extreme events (e.g. landslides).

Winter tourism depends on good snow conditions and is highly sensitive to snow-deficient winters. Climate research findings show that there will be an increase in the number of winters with little snow on account of climate change. The tourism representatives will not just sit back idly in the face of climate change. They are reacting to the deteriorating snow conditions and the changes in demand. Technical measures, especially artificial snowmaking, to maintain ski tourism rank at the forefront. Tourists demand good snow conditions, and hence, this is what has to be offered by the ski resorts. In any case, the impacts of climate change will involve significant costs for tourism. One
of the most important questions will be, how young people would start skiing/snowboarding, if there is only little snow in the big towns and if the little and cheap ski lifts for families at small distances to these towns will be dismantled due to climate change. Although indoor skiing is a growing industry in European towns, it is uncertain that indoor ski domes can replace the role of little ski resorts for beginners in the foothills.

As a sector of the economy that is severely affected by climate change, however, tourism needs to focus more on mitigation strategies in its own best interests. This holds particularly true for the traffic generated by national and international tourism and, above all, for air traffic. Tourist development and tourist projects not only need to be verified and evaluated in terms of their social and environmental compatibility but must also be assessed from the climate-compatibility angle.

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CLIMATE CHANGE AND MOLDOVA’S TOURISM: SOME INDIRECT CONSEQUENCES

R. Corobov

Modern Institute for Humanities, MD 2005, Chisinau, Moldova
E-mail address: rcorobov@sanepid.md

ABSTRACT
Warm climate and rich soils are main natural recourses of Moldova that determine its economics and attractiveness for tourism. The basic branch of Moldova economics is agriculture. Agriculture products, especially grapes and wines, not only prevail in the export, but are national pride and the face of tourism industry. Therefore, any unfavorable climatic changes impact negatively on the country’s tourism potential. The regional response of key climatic variables to SRES emission scenarios based on the results of three GCM experiments (HadCM3, CGCM2 and CSIRO-Mk2) was estimated. Temperature and precipitation changes were transformed in their possible impacts on cereals and grapevine productivity. It is shown that in Moldova the main contribution into expected warming is done by winter months: on average 60-80% by the 2020s and more than twice – by the 2080s. Projected summer warming is from 8-12% in the beginning to 20-30% – by the end of the century. Maximal precipitation increase is also expected in wintertime; the summer precipitation tendencies are mainly negative (20-30% decrease by the 2080s). On the whole, Moldova moves towards a dryer climate, from insufficiently wet and wet subhumid zones to dry subhumid and semiarid zones. New climatic conditions will be worse for Moldova agriculture. In particular, grape-yield decrease can amount up to 4-5, 6-7 and 8-10% by the 20s, 50s and 80s accordingly; the decrease in sugar content – to about 3, 5 and 7%, especially for table wines species. Thus, the likely climatic changes are not favorable for Moldova’s natural and semi-natural environment with some negative potential for regional tourism.

KEYWORDS: climate change, viticulture, international tourism
INTRODUCTION

A short literature review

Tourism is one of the world’s largest industries. According to information generalized by Colin (2002), in 1999 the tourism industry accounted for some 11% of global GDP and approximately for 8% of total global employment (about 200 million jobs). The rate of average annual growth in international tourist arrivals was about 5.2% between 1985 and 1999, ranging from 4.5% in Europe to 7.5% in Africa. It is also widely accepted that tourism plays a heavy part in encouraging more consumerist lifestyles and, consequently, its sustainable development is an important issue. This recognition has formed the conception of ‘sustainable tourism’ (Colin, 2002). Clearly, as one of the extremely important engine of economic growth and as the large sector of world trade, tourism is in need of understanding its future perspectives under climate change impacts. Climate is influential for international tourism, which being situation-specific is responsive to its variability and change.

Most of tourism environmental impacts studies are focused on the aspects relating either to the reasons for choosing the destination point for concrete traveling (‘attractor’) or to particular conditions promoting the development of a local tourism industry (Colin, 2002; Gössling, 2002). For example, Colin (2002) used the ecological footprint analysis to understand societal demands of sustainable tourism upon the biosphere, including management approaches and tools designed to better integrate tourism development and natural environment protection at tourist destination areas. However, there is some increase in recent year’s studies that link tourism and climate change. Maddison (2001) investigated the importance of climate as a determinant of the destinations choice made by British tourists. Attractors included climate variables, travel and accommodation costs; the trade-offs between climate and holiday expenditure identified the ‘optimal’ climate for generating a tourism flow. These findings could be used to predict the impact of various climate change scenarios on popular tourist destinations. Maddison’s pooled travel-cost model (PTCM) was adapted for Dutch tourism (Lise and Tol, 2002). These authors investigated the sensitivity of tourists demand for vacation destinations with respect to climate and drew some conclusions on the possible impact of climate change in the long term. A cross-section analysis was conducted on destinations of OECD tourists on the whole and on holiday activities of Dutch tourists to find optimal temperatures at travel destination for different tourists and tourist activities. Globally, OECD tourists prefer a temperature of 21°C (average of the hottest month of the year) in their holiday destination choice. On the authors’ opinion, this temperature is ‘ideal for the large bulk of international tourists’, and
because this preference is largely independent of the tourist’s origin, the climate change will have a strong effect on tourism demands. Summing their own and available surveys of empirical researches, Lise and Tol (2002) concluded that although the tourism industry is accustomed to rapid change due to political stability, price changes, fashion and social trends, the climate change could have additional implications, for instance, by making currently popular areas less attractive or bringing new competitors to the tourism market.

However, although it is not surprise for anyone that climate is an important consideration for tourists’ choice, some narrowness is seen in the scope and scale of tourism studies caused by climate change concerns: the available researches rarely look beyond direct impacts of temperature-precipitation changes on the choice of destination area. The substantive recognition of the wider indirect consequences of climate change, as a new global phenomenon, for tourism industry is necessary.

Interpretation of sustainable tourism as the derivative of climatic conditions only is adoption of a narrow view on tourism-related demands, limiting them to the human-comfort aspects of local environment. Considerations should be given to the entire spectra of new challenges for tourism caused by climatic changes, allowing a truly holistic appreciation of the problem. Broadly speaking, the emphasis should be made not only on the changes in traditional tourism destination areas due to new local climatic conditions, but also on the support of tourism-related economic growth for its own sake. The wider demands on natural and economic resources should be considered because tourism embraces various and other than the recreation only stimulating motives. Moreover, if it is possible to “adjust” the tourist demands to gradual climatic changes through seeking new destinations or other dates for holidays, then the change of non-climatic attractors is more drastic. In this case, the tourists, usually very responsive to the environment, probably do not care much about possible changes in weather.

Indeed, when the choice of destination made by tourists reflects the desire to experience a particular country, its culture or traditions, the statement ‘a major factor in both choice of destination and time of departure is surely climate’ (Maddison, 2001) can be called in question. Of course, a warm dry weather is of no small importance for sight seeing in foreign places or enjoying the splendor of London or St. Petersburg, but it is unlikely that expected climate change enables to diminish the number of tourists visiting these cities. It seems therefore, that discussing this question, we should distinguish ‘tourism’ in classical meaning of this world from merely ‘recreation’ travels when the
high chance of optimal temperature, duration of sunshine or beach length are first-order attractors. The broad goals of sustainable tourism could be further addressed by specifying the degree of vulnerability to climate change of those national resources that base a country’s attractiveness for international tourist flow, treating this natural capital as ‘critical’ (Owens, 1994).

The tourism demands are situation-specific, and it is not possible to build a single model, which could be appropriate for all origin-destination pairs. For example, it is shown, that tourists of all nationalities prefer to travel to richer countries; apparently, relative poverty deters too, sometimes being stronger than the cost of living effect (Lise and Toll, 2002). As an illustration in point, Fig. 1 demonstrates the dynamic of a tourist flow to Moldova in the 1990s. The economic crisis and unstable political situation of the transition period resulted in sharp decrease of the international tourist arrivals: from almost 360 thousands in 1991 to less than 11 thousands in 1993. Negative balance of international arrivals and citizens of Moldova visiting other countries is lasting out up to date.

We should also agree with Lise and Toll (2002) that while tourists and probably tourist operators are more adaptable to cope with climate change consequences, the same couldn’t be said about local economies and local providers of tourist services. The lasts should keep the attractiveness of their region for tourists. Local losses may be dramatic, particularly in regions with few alternatives; here the climate change is likely to lead to drastic changes in the tourists flow.

Figure 1: Dynamic of tourism flow in the Republic of Moldova, thousands persons (Based on Moldova’s Year-books 1990-2002)
From this viewpoint, there are very important conclusions of the IPCC Third Assessment Report as well as of other works (Bruce et al., 1995; McCarthy et al., 2001; Pittok, 2002) that climatic changes will impact a society differently to the present, including differences in degrees of exposure, adaptive capacity, and potential for change. Some societal changes will make society more resilient, less exposed, more adaptable to climate change and more able to adopt mitigation measures, but in many countries and regions this will not be the case. Evidences show that the most adverse effects will be in developing countries and countries with economics in transition, where populations are most vulnerable and least likely to easily adapt (Michaelova and Dutschke, 2000). The climate change will further affect their potential for development. The relative regional vulnerability is largely determined by the stability and effectiveness of political institutions, by the access to resources, information, and technology. Obviously, the climate change will also affect possibilities to promote sustainable tourism industry more negatively in these countries. However, one cannot predict such tendencies without concrete social and climatic scenarios of future changes.

**The main objective of this article is to show**, using Moldova viticulture as a case study, how climate change consequences for the vital branch of national economy can affect the country’s tourist potential.

**The Republic of Moldova as a destination area for international tourism**

Warm climate, rich soils, beautiful and various landscapes are main natural resources of Moldova, used mainly for steady raising of agriculture production in the former years. As a result, the development of territory in the early 1990s amounted to 85%, and anthropogenic loadings exceeded critical limits. Such a situation stimulated urgent measures for expansion of protected territories, which areas in different regions will be carried to 2-6%. The problem of their competent using has aroused and become the actual. One way to solve the task is increase of regional recreation potential through the development of modern infrastructure for medical cure, rest, and **tourism**, considering recreation industry as an equal branch of national economy. As an example one could name the GEF/WB Project aimed at biodiversity conservation in delta ecosystems of the Dnestr River (GEF Project, 2003).

The best introduction to Moldova, its ‘visiting card’, is viticulture and winemaking. From ancient times Moldova’s unique wines have made it well known in the world, and the same is true today. The Moldovans’ skill in producing grapes and finest wines that meet all tastes is the integral part of
national culture; grapevine growing is one of the most ancient activities. Even the shape of the country, when to see on a map, resembles a bunch of grapes.

The culture of winemaking in the region has its origins in prehistory. Prints of Vitus Teutonica leaves, found near Naslavcea on the Dnestr riverbank, are of millions-years age. The ancient Dacians discovered how to make wine out of grapes long before then most other peoples. In the first millennium B.C. the Greek colonies on the Lower Danube, Dnestr and Prut Rivers exported large quantities of wine to Greek cities. After conquering Dacia (1st century A.D.) the Romans transformed the region into vineyard and cornfield lands. The well-known Moldavian governor and scholar Dimitri Cantemir emphasized the significance of viticulture for the country’s economy in the 18th century; later, Basarabia (the territory between the Prut and Dnestr Rivers) became one of the biggest wine exporters. If initially Moldavian wine production was based on the cultivation of domestic types, then from the second half of the 19th century it has been specialized on mass planting of foreign cultivars, especially French ones. Today around 15% of the Republic’s annual budget is formed by the income from viticulture. The total vineyards’ area covers 150 thousand ha, practically satisfying the internal and external markets demand. With annual gathering 350-500 thousand tons of grapes, Moldova produces 12-15 million decalitres of the most prestigious local and European wines. 15% of the entire production is consumed within the country, 85% is exported. The annual wine exports amounts to $130-150 million. Moldova has adapted to market requirements and is in the list of the world top ten wine- and grape-producing countries. There is a refrigerated storage for about five thousand tons of table grapes boasting a range of valuable dietary and curative qualities of local vineyards.

Therefore, although a tourist can get to know Moldova in many ways, the best one to discover its essence is tour by the Wine Road, or Wine Routes spreading out like a web over the country (http://www.turism.md/eng/content/204/). Along with European wines (Chardonnay, Pinot, Riesling, Cabernet or Aligote), the tourists appreciate the local high quality wines preserving the natural purity of grapes and vigorous richness of Moldavian soils. The names of many famous wines, appreciated both by royalty and other prestigious consumers, come from the names of places where corresponding wineries are located: Purcari, Cricova, Ciumai, Romanesti, Cojusna, Milestii Mici, etc. Among the world famous the Moldavian sparkling wines are. This drink originated in France has found a second home in Moldova. The champagne phenomenon, many centuries ago discovered by a French monk Perignon, has been successfully adapted by Moldavian wine makers. Moreover,
Moldova was one of the world pioneers in producing red sparkling wines, whose brands received numerous awards at international competitions. Many visitors assert that sparkling wines are the best Moldavian drunk that permits to appreciate fully the miraculous charm of the country. According to local climatic conditions, Moldova is divided into four wine producing regions, where their unique vines are growing (Cheban, 2000):

1. **Central or Codru Region**, where more than 50% of all vines grow. The forest and hill landscapes, typical for this region, protect the vineyards from winter frosts and dry summer winds. The Romanesti microclimatic zone, the former winemaking colony of Romanov dynasty, is a place for the best white and sparkling wines, as well as for so-called "divines" (fortified wines) and sherries.

2. **South East (Purcari) Region** – a narrow strip of land stretching along the western bank of the Dnestr River is the home of Purcari winery. Purcari estate has become famous for producing, using German vines and winemaking technologies, the high quality red wines comparable to Russillions-Landnedoc.

3. **Southern Region** is famous for its French vine varieties, have been adapted successfully to this area’s climatic conditions. Due to high quality red wines grown here the region is compared with France Bordeaux region.

4. In **Northern Region** much of local grape harvest is destined for brandy production. Climatic conditions, combined with gentle hill and valley landscapes, create very favorable growing conditions in the so-called circular "cups" on sunny slopes that catch the sun heat, saving it overnight. The "cups" also shield effectively the vineyards from winds, both hot and cold, helping to plants normal growth.

Local traditions idolize wines and that is why every countryside house has a "wine tasting room", usually at an entrance to the cellar where wine is kept. All Moldavian wineries are renowned by their skillfully decorated wine tasting rooms, which are real works of art. Impressive architecture of wineries and tasting rooms admires gests; cellars and wine collections are among the country’s main “attractors”, being excellent illustration to the long-term history of national grapevine growing and wine production and remaining the invariable symbol of the country’s main property (Fig. 2). Tourists and visitors can visit any of 15 collections of vintage wines and "divines" with tens to thousands millions bottles stored in their cellars. The most famous and tremendous is Cricova wine
collection. This 30-150 m deep underground world that features over 100 kilometers of galleries caves and niches is an ideal environment for maturing all sorts of sparkling and other wines; it is also the biggest (above 30 mil. litres) wine cellar in the world (Fig. 3). After visiting this place the first cosmonaut Yuri Gagarin said: "It was harder to come off Cricova then to take off the Earth".

![Figure 2: Some examples of grapevine and wine motives in Moldavian décor](image1)

![Figure 3: A part of Cricova’s wine collection (rightmost picture)](image2)

A second insight into Moldova and its traditions is wine exhibitions. In the last years Chisinau became a great international exhibition center. "Moldova Wine" exhibition, held annually in February, and the October Wine Festival have excellent reputation and are visited by thousands of peoples. Wine, sparkling wine, cognacs, liquors, exhibited at competitions, are the products from France, Germany, Italy, Slovakia, Romania, Russia, Ukraine and other countries. Excursions to famous vineyards and wineries, monasteries and medieval castles are organized for foreign guests. Without a doubt, such exhibitions are possible only in a country with the high-level culture of sustainable winemaking.

However, being situated at the northern border of world viticulture, Moldova’s vines are very sensitive to climatic conditions on the whole and to the weather conditions of a year, in particular (Cheban, 2000). It is necessary to add that a perennial vine plant may remain economically productive during 50-60 years, exposing to inevitable climate variability. Therefore, Moldavian wine production, as a main ‘attraction’ for international tourism, is extremely vulnerable to any changes in regional climate.
METHODS

It was decided to assess the possible vulnerability of Moldavian viticulture to the likely climate change through the assessment of its today sensitivity to climate variability.

As initial data on vine productivity and grapes quality, their yields and sugar content (sugariness) were used. 180 technical varieties, cultivated at the different by soil and environment vineyard plots of “Cricova” joint-stock company, were classified in two data sets depending on the direction of their use: for production of sparkling or table wines (Table 1). Vine productivity was estimated by 1986-1995 annual yields at each plot included in the analysis. The coefficients of variation \((CV)\) of studied parameters are considered as some measure for initial coarse estimation of cultivars sensitivity to annual weather conditions. If to take soils and pattern of locations as invariable environmental factors in a short-term study, the weather conditions are the main source of grapevine production interannual variability. \(CVs\) show that such variability of yields is approximately twice higher than of sugariness; cultivars for sparkling wines production are more sensitive to weather conditions than cultivars for table wines.

<table>
<thead>
<tr>
<th>Table wine cultivars</th>
<th>N</th>
<th>Area, ha</th>
<th>Yield c/ha</th>
<th>Sugariness, %</th>
<th>CV, %</th>
<th>Sparkling wine cultivars</th>
<th>N</th>
<th>Area, ha</th>
<th>Yield c/ha</th>
<th>Sugariness, %</th>
<th>CV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feteasca</td>
<td>16</td>
<td>218</td>
<td>75.9</td>
<td>8.1</td>
<td>17.4</td>
<td>4.0</td>
<td>Chardonnay</td>
<td>14</td>
<td>411</td>
<td>66.5</td>
<td>4.79</td>
</tr>
<tr>
<td>Muscat</td>
<td>4</td>
<td>68</td>
<td>67.8</td>
<td>4.1</td>
<td>17.6</td>
<td>3.8</td>
<td>Pinot</td>
<td>22</td>
<td>635</td>
<td>68.6</td>
<td>5.48</td>
</tr>
<tr>
<td>Traminer</td>
<td>5</td>
<td>105</td>
<td>68.1</td>
<td>6.2</td>
<td>17.7</td>
<td>4.1</td>
<td>Riesling</td>
<td>6</td>
<td>183</td>
<td>69.2</td>
<td>9.03</td>
</tr>
<tr>
<td>Rkatsители</td>
<td>41</td>
<td>579</td>
<td>72.6</td>
<td>6.8</td>
<td>17.5</td>
<td>4.2</td>
<td>Sauvignon</td>
<td>10</td>
<td>150</td>
<td>76.6</td>
<td>9.97</td>
</tr>
<tr>
<td>Cabernet</td>
<td>10</td>
<td>145</td>
<td>71.8</td>
<td>6.3</td>
<td>17.4</td>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merlot</td>
<td>8</td>
<td>145</td>
<td>72.3</td>
<td>7.5</td>
<td>17.5</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aligote</td>
<td>44</td>
<td>1034</td>
<td>70.8</td>
<td>6.2</td>
<td>17.4</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>128</td>
<td>2294</td>
<td><strong>71.3</strong></td>
<td><strong>6.3</strong></td>
<td><strong>17.5</strong></td>
<td><strong>4.0</strong></td>
<td><strong>Total</strong></td>
<td>52</td>
<td>1379</td>
<td><strong>70.2</strong></td>
<td><strong>7.23</strong></td>
</tr>
</tbody>
</table>

Surface air temperature and precipitation records at Bața weather station, located in 15 km from the studied plots, were used for the description of this period’s meteorological conditions. As air temperature variables were selected: mean monthly temperature; mean minimum monthly temperature of a cold (November-March) period \((CP)\); absolute minimum temperature of a cold period; mean maximum monthly temperature of a warm (April-October) period \((WP)\); absolute maximum monthly temperature of a warm period. As precipitation variables, \(WP\) monthly sums as well as \(CP\) and \(WP\) sums were considered.
The advanced procedures of multiple regression analysis (Afifi and Azen, 1979) were applied for the assessment of grape productivity dependence on monthly meteorological conditions (2,7). The analysis was carried out both for each cultivar and for each grapevine group on average.

RESULTS AND DISCUSSION
Dependence of grapevine productivity on climatic conditions

Fig. 4 shows the graphs of 1986-1995 yearly yields and sugariness of grapes and their approximations by linear trends. During this period the grapevine yields were decreasing steadily that is confirmed by statistically significant negative trends. Correlation coefficient $r$ of yields with a calendar year is above 0.8-0.9 practically for all cultivars. Some more decrease is typical for the cultivars of a champagne use direction (the trend coefficient is equal -1.53 against -1.44 for table wine cultivars). At the same time, there was no statistically significant trend in grape sugar content: in most cases $r$ is less 0.3.

Table 2. Parameters of the linear trends ($y = a_0 + a_1\tau$) of vine productivity, 1986-1995

Note:
- $r$—correlation coefficient of productivity with calendar month
  - $0.01 < p \leq 0.05$;
  - $0.001 < p \leq 0.01$;
  - $p \leq 0.001$—statistical significance of trend
- $a_0$—interception; $a_1$—coefficient of trend; $\tau$—calendar year.

From a physiological viewpoint, the observed fact is explained (Corobov et al., 2002) by the bigger dependence of yields on so-called “earthly” ecological factors (soil fertility, farming practices, etc.), while grape sugar content is mainly determined by “cosmic” factors (temperature-precipitation regime and solar radiation). That is why, the considerable decrease in organic and mineral fertilizes application, plant protection, and agrotechnics, caused by economic difficulties of the transition period in Moldova economy, more negatively affects the grape yields than sugariness.

The trend component imposes certain restrictions on the statistical analysis because in this case the real productivity reflects not only a year weather conditions but also the trend change of other impact factors. Proceeding from this, the deviations from trends were considered as a climatically
conditioned part of productivity. As we see in Fig. 4, the deviations, reflecting weather caused origin, were both positive and negative, and *their values were taken as independent variables for the regression analysis.*

![Fig. 1. The graphs of annual grape yields and sugariness and their linear trend approximation](image)

The dependence of grape productivity on monthly air temperature and precipitation was studied in detail by Corobov et al. (2002). Here, only some statistical models for the productivity prognosis will be repeated. Because of the multipleness and sometimes (depending on the period of growth) different directions of temperature and precipitation influences on final vine productivity, such a prognosis could be received only through complex examination of their individual influences brought together in one model. Of such a kind tasks are best addressed by multiple regression techniques that estimate statistically significant relationships between one dependent variable (predictant) and a suite of independent variables, or predictors (Afifi and Azen, 1979).

In Table 2 and 3 the statistical models of grape yield and sugariness dependence on the temperature-precipitation conditions of a preceding period are cited. The coefficient of determination \( R^2 \) shows a proportion of year-to-year variability in productivity that is explained by the subset of selected variables. *P*-value \( (p) \) estimates statistical significance of a model. In our case, this parameter is everywhere over 95% confidence level \( (p < 0.05) \) accepted in biology; frequently it is over 99% level \( (p < 0.01) \). It should be also noted that all equations estimate the expected climatically conditioned deviations from the long-term trends.
Figure 4: The graphs of annual grape yield and sugariness and their linear trend approximation

$Y_t = 2932.7 - 1.44t; r = -0.89; p = 0.0006$

$Y_s = 3111.6 - 1.53t; r = -0.91; p = 0.0003$

$S_t = -65.7 + 0.04t; r = 0.18; p = 0.6203$

$S_s = 56.4 - 0.02t; r = -0.07; p = 0.8315$

Let us don’t analyze in details the equations for individual periods of vine vegetation, which could be considered as statistical models for productivity prognosis at these phases of plant development. Below there are some general conclusions only:

1. Weather impacts on grapevine yield and quality are highly dependent on the stage of vine plant development. During winter dormancy the most crucial for productivity are meteorological conditions of February for yields and December and February for sugar content.

2. The influence of meteorological conditions during grapevine vegetation can be divided on two stages: the first – period of sprout and berry growth; the second – period of yield ripening. In the first period the increase of air temperature over optimum by 1°C results in yield decrease by 1.2 centners per ha and more; precipitation, on the contrary, favors to yields. In the second period the most crucial month is September.
This period precipitations are again useful for yields, but unfavorable for sugariness. High August-September temperatures have adverse impacts on yields, especially of table vines.

3. The dependence of grapevine productivity on meteorological conditions of plant growing gives an opportunity to address two most important from viewpoint of this article tasks: (1) to quantify the degree of grapevine yield and sugariness dependence on annual meteorological conditions; (2) to quantify the likely climate change impacts on Moldova grapevine production.

Some projections of likely climate change in Moldova

In the development of climate change regional projections we used the results of coupled atmosphere-ocean general circulation model (AOGCM) simulations (McCarthy et al., 2001). By the time of the research (late 2002), the results of three AOGCM runs based on SRES A2 and B2 emission scenarios were archived at the IPCC Data Distribution Centre (DDC, 2003): HadCM3, CSIRO-Mk2, and CGCM2 (Canadian Center for Climate Modeling and Analysis). The appropriate references documenting each model can be found at the DDC’s website (IPCC DDC, 2003). The results from these integrations, below sometimes shortened as Had, CSIRO and CGCM, served as a basis for further regionalization. A2 and B2 marker anthropogenic forcing scenarios are considered respectively (in terms of cumulative GHG emissions) as “high” and “medium low” (Nakicenovic and Swart, 2000).
### Table 2: The statistical models of grape yield prognosis at different phases of plant growth

<table>
<thead>
<tr>
<th>Groups</th>
<th>Phenology phase</th>
<th>$R^2$, %</th>
<th>$R$-value</th>
<th>Error</th>
<th>Coefficients of regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>St. Abs.</td>
<td>$a_0$</td>
</tr>
<tr>
<td>For sparkling wines</td>
<td>Winter dormancy</td>
<td>60.1</td>
<td>0.698</td>
<td>0.040</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>Sap movement</td>
<td>73.1</td>
<td>0.773</td>
<td>0.038</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Blossom - berry growth</td>
<td>98.0</td>
<td>0.977</td>
<td>0.002</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Berry ripening</td>
<td>99.0</td>
<td>0.985</td>
<td>0.004</td>
<td>0.36</td>
</tr>
<tr>
<td>For table wines</td>
<td>Winter dormancy</td>
<td>48.3</td>
<td>0.580</td>
<td>0.099</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>Sap movement</td>
<td>66.2</td>
<td>0.702</td>
<td>0.073</td>
<td>1.58</td>
</tr>
<tr>
<td></td>
<td>Blossom - berry growth</td>
<td>94.2</td>
<td>0.932</td>
<td>0.014</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>Berry ripening</td>
<td>99.0</td>
<td>0.985</td>
<td>0.004</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Conventional signs:
1. $R^2$ – coefficient of determination; $R$ – coefficient of multiple regression;
2. Lower indexes: $T_i$ – $i$-month mean temperature; $T_{max}$ – absolute maximum temperature; $P_i$ – $i$-month precipitation; $P_{cp}$ – cold period precipitations total.
3. $p$ – statistical significance of a model; St., Abs. – standard and absolute errors respectively.

### Table 3: The statistical models of grape sugariness prognosis at the different phases of plant growth

<table>
<thead>
<tr>
<th>Groups</th>
<th>Phenology phase</th>
<th>$R^2$, %</th>
<th>$R$-value</th>
<th>Error</th>
<th>Coefficients of regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>St. Abs.</td>
<td>$a_0$</td>
</tr>
<tr>
<td>For sparkling wines</td>
<td>Winter dormancy</td>
<td>87.4</td>
<td>0.900</td>
<td>0.004</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Sap movement</td>
<td>87.6</td>
<td>0.881</td>
<td>0.017</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Blossom - berry growth</td>
<td>97.1</td>
<td>0.973</td>
<td>0.005</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Berry ripening</td>
<td>99.0</td>
<td>0.988</td>
<td>0.0004</td>
<td>0.12</td>
</tr>
<tr>
<td>For table wines</td>
<td>Winter dormancy</td>
<td>84.5</td>
<td>0.876</td>
<td>0.008</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Sap movement</td>
<td>78.9</td>
<td>0.826</td>
<td>0.018</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Blossom - berry growth</td>
<td>95.2</td>
<td>0.956</td>
<td>0.002</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Berry ripening</td>
<td>97.8</td>
<td>0.975</td>
<td>0.002</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Conventional signs:
1. $R^2$ – coefficient of determination; $R$ – coefficient of multiple regression;
2. Lower indexes: $T_i$ – $i$-month mean temperature; $T_{max}$ – absolute maximum temperature; $P_i$ – $i$-month precipitation; $P_{cp}$ – cold period precipitations total.
3. $p$ – statistical significance of a model; St., Abs. – standard and absolute errors respectively.
The likely changes of temperature and precipitation are shown in Table 4 for the ensemble models means. For both emission scenarios the annual air temperature in Moldova will increase: respectively up to 4.7°C with “high” and up to 3.4°C with “medium low” greenhouse gas emissions. As to annual precipitation, some decrease is expected practically by all simulations. Maximal warming is expected in winter months, minimal warming – in summer. If to take into account precipitation changes, Moldova will face warmer and wetter winters, but hotter and dryer summers with 20-30% precipitation decrease by the end of 21 century.

Table 4: Ensemble mean projections of Moldova monthly temperature and precipitation changes as to 1961-1990

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature, °C</th>
<th>Precipitation, мм</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010-2039</td>
<td>2040-2069</td>
</tr>
<tr>
<td>1</td>
<td>A2</td>
<td>1,53</td>
</tr>
<tr>
<td>2</td>
<td>A2</td>
<td>1,7</td>
</tr>
<tr>
<td>3</td>
<td>A2</td>
<td>1,34</td>
</tr>
<tr>
<td>4</td>
<td>A2</td>
<td>0,79</td>
</tr>
<tr>
<td>5</td>
<td>A2</td>
<td>0,73</td>
</tr>
<tr>
<td>6</td>
<td>A2</td>
<td>1,46</td>
</tr>
<tr>
<td>7</td>
<td>A2</td>
<td>2,12</td>
</tr>
<tr>
<td>8</td>
<td>A2</td>
<td>2,15</td>
</tr>
<tr>
<td>9</td>
<td>A2</td>
<td>2,05</td>
</tr>
<tr>
<td>10</td>
<td>A2</td>
<td>0,97</td>
</tr>
<tr>
<td>11</td>
<td>A2</td>
<td>1,16</td>
</tr>
<tr>
<td>12</td>
<td>A2</td>
<td>0,36</td>
</tr>
</tbody>
</table>

Year | 1,36 | 1,9 | 2,95 | 2,56 | 4,73 | 3,38 | -9,59 | -15,66 | -24,93 | 1,82 | -42,37 | -5,99 |

Climate changes impacts on Moldova viticulture

The possible changes in Moldova grapevine productivity, calculated in accordance with regression dependence on temperature and precipitation, are shown in Table 5. As we see from the results, new climate will be less favourable for Moldova viticulture, especially for total yields that can decrease from about 3-5% in the 2020s to 6-12% in the 2080s. Grape cultivars for sparkling wines are slightly more vulnerable. Sugar content in grapes can decrease in table cultivars, but to keep practically its present volume in sparkling cultivars.

Of course, these estimations are somewhat rough because they are based on the one case study, and don’t take into account the effect of CO2 fertilisation. According to some researches (Harrison et al., 1995), under doubled CO2 abundance (700 ppmv) one could expect increase of vine photosynthetic activity resulting in 35% increase of total dry matter and about 20% increase of fruit weight. It is also expected that elevated atmospheric CO2 would influence the quality of wines. The lower sugar concentration and increased acidity under elevated CO2 would improve the quality of light or
**sparkling** wines, but will harm the **high quality** wines. Thus, two main factors of anthropogenic climate change – increase of air temperature and CO2 concentration – affect grapevine growth and development in opposing ways. This moment should be necessarily taken into account when to transit from such a pilot research to the sound assessment that could be assumed as a base for decision-making.

**Table 5: Possible absolute (Abs, c/ha) and relative (%) changes in Moldova grapevine productivity**

<table>
<thead>
<tr>
<th>SRES scenario</th>
<th>Time-slice</th>
<th>Table cultivars</th>
<th>Sparkling cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yield</td>
<td>Sugariness, %</td>
</tr>
<tr>
<td></td>
<td>Abs</td>
<td>%</td>
<td>Abs</td>
</tr>
<tr>
<td>A2</td>
<td>2010-2039</td>
<td>-2.84</td>
<td>-3.95</td>
</tr>
<tr>
<td></td>
<td>2040-2069</td>
<td>-5.35</td>
<td>-7.45</td>
</tr>
<tr>
<td></td>
<td>2070-2099</td>
<td>-8.79</td>
<td>-12.24</td>
</tr>
<tr>
<td>B2</td>
<td>2010-2039</td>
<td>-3.48</td>
<td>-4.85</td>
</tr>
<tr>
<td></td>
<td>2040-2069</td>
<td>-4.85</td>
<td>-6.75</td>
</tr>
<tr>
<td></td>
<td>2070-2099</td>
<td>-6.09</td>
<td>-8.48</td>
</tr>
</tbody>
</table>

**CONCLUSION**

This paper attempted to connect the realms of the Republic of Moldova as a destination tourism point and its agriculture sustainable development in new climatic conditions. In so doing, an economical approach to the assessment of indirect climate change impacts on tourism potential is discussed, along with the Moldova viticulture case study as an example of its practical application. Possible changes in effectiveness of the leading branch of national economy under climate change helps to predict changes in the potential of the country for international tourists attraction.

The complex research of grapevine productivity dependence on the meteorological conditions showed that climate influences upon viticulture in a **regular** way, which can be **quantified**. This gave an opportunity to address two most important from viewpoint of the discussed problem tasks: (1) to quantify the degree of grapevine yield and sugariness dependence on annual meteorological conditions; (2) to receive qualitative and quantitative estimations of likely climate change impacts on Moldova grapevine production.

It was shown, that Moldova expects significantly new, mainly less favorable climatic conditions for vine growing. These projections should be taken into account when to plan future tourist activities at the territory, using famous Moldavian wines and winemaking traditions as a main attraction for international tourists.
ACKNOWLEDGEMENTS

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TOURISM, LIVELIHOODS, BIODIVERSITY, CONSERVATION AND THE CLIMATE CHANGE FACTOR IN DEVELOPING COUNTRIES
With Special Reference to Africa and the Republic of South Africa

Murray C. Simpson

Oxford University Centre for the Environment, University of Oxford

ABSTRACT Limited attention has been paid to the impacts of climate change on tourism in developing countries. This paper considers the interdependent links between tourism and biodiversity and tourism and livelihoods in developing countries, with particular focus on Africa and the Republic of South Africa. The paper discusses the importance of tourism to Africa and developing countries, the role that biodiversity plays in tourism, the relationship between tourism and community based conservation, the role that tourism can play in poverty alleviation and in the delivery of net benefits to livelihoods and discusses the impacts of climate change on these relationships.

KEYWORDS: tourism, livelihods, biodiversity, conservation, climate change, Africa, developing countries

INTRODUCTION
In 2006 the travel and tourism industry will confirm its position as the world’s largest employer with over 11% of the globe’s employees and the world’s largest industry with gross output of over US$7 trillion and GDP of 11.5% (World Travel and Tourism Council 2003). The World Tourism Organization (WTO) estimates that by 2020 there will be 1.6 billion international travellers. Africa’s share of the world tourism market is growing at an average annual growth rate of 5.9%, this is in comparison to a world average rate of 3.3%. In the year 2000 Africa’s annual international tourism receipts reached 477 billion US Dollars (WTO 2002a). Tourists are forever reaching more remote and fragile places on the planet and visitation to existing high volume sites is increasing dramatically, the potential impacts on the world’s biodiversity and natural and cultural heritage may be equally dramatic, this growth in the industry is expected to continue, particularly to destinations in developing countries (Goodwin et al 1998). The impacts of increased visitation if understood and directed responsibly, have the potential to deliver net benefits to the environments affected by
tourism and to the communities living within and adjacent to them. An increasing numbers of tourists would like more meaningful contact with developing country communities, offering potential diversification of economic opportunities for local people and contributing to poverty alleviation (Ashley and Roe 1998; Ceballos-Lascurain 1996; Chalker 1994; Eadington & Smith 1994; Mowforth & Munt 1998; DFID 1999; Goodwin et al 1998; Swanson 1992). Climate change and the resulting impacts add an additional and considerably important variable to the delicate balance of factors contributing to the positive and negative impacts of tourism on destinations and communities around the world and there will be significant differentiation in the extent of the variable’s importance depending on geographic location.

The impacts of climate change on tourism, its stakeholders, adjacent communities and related industries at both a macro and a micro level cannot be understated, the key impacts fall into two broad categories:

1) Increased frequency and magnitude of extreme events including; flash floods, hurricanes/tornados/cyclones, drought, fire and storm surge and;

2) Cumulative changes including; sea level rise, sea temperature increase, retrieving glaciers, desertification, water salinisation, silting and degradation, ground and air temperature changes, increased wave height, fluctuation of precipitation levels and loss of seasonal distinctions (IPCC 2001).

The resulting issues impacting on tourism will include: coastline degradation and flooding, a decline in public health and safety and an increase in disease, forestry degradation, water quality vulnerability, threats to coastal infrastructure, increased poverty, unstable food security and an insecure agricultural sector. In addition there will be dangers in river access, species degradation, heightened water resource management issues, threats to hydroelectric power generation, threats to biodiversity and natural and cultural heritage assets, changes in visitation flows, unstable and threatened physical infrastructure including buildings, roads and communications, coral bleaching and a reduction in wildlife abundance. These impacts clearly cannot be taken lightly, and may threaten the very existence of tourism in some destinations.

According to the Intergovernmental Panel on Climate Change (IPCC) Africa is particularly vulnerable to climate change. In its’ Climate Change 2001 report; Working Group II: Impacts, Adaptation and Vulnerability the IPCC emphasises the particular vulnerability of Africa to the impacts of climate change and outlines ten key background factors to consider when assessing the
African scenario (see list below adapted from IPCC 2001 report), in light of the vastness of the continent and variety of scenarios present the following generalities should be read in context. The following factors will, in turn, also contribute to the vulnerability of the tourism sector in Africa, particularly when viewed collectively:

1) Diversity: One of the key factors for visitors to the region is the range of attractions available created by the diversity of climate, landform, biota and culture. These features are coupled with a wide variety of economic circumstances making African Governments’ task of responding proactively to changes that are largely not of their making or under their control even more difficult.

2) Climate: This factor is a major influence on tourists’ decision making as to their choice of destination (Pizam 1999). Africa is predominately tropical and hot and dry with large areas north and south that are subhumid providing substantial rainfall during the wet season and almost no rainfall during an extended dry season. Large areas exist of semi-arid climates, which are characterized by extreme unreliability of rainfall and few permanent surface-water sources. Other areas in Africa, located on the tropics of Capricorn and Cancer are the vast desert regions of the Kalahari and the Sahara, changes in the climate in all of these regions will affect visitation.

3) Development Status: “Measured by almost any index of human well-being, Africa contains the poorest and least-developed nations of the world…Per capita gross domestic product (GDP), life expectancy, infant mortality, and adult literacy are all in the bottom quartile globally when averaged across Africa…” (IPCC 2001) See Figure 1.

4) Food Supply: Contrary to the global trend, per capita food production in Africa has been declining over the past two decades. With more than half of the African population rural and directly dependent on locally grown foods or those harvested from the immediate environment there is already widespread malnutrition and dependence on food aid and food grown outside the region (World Bank 1996).

5) Dependence on Natural Resources: Ecotourism, agriculture, pastoralism, mining and logging are strong sectors in the formal and informal economies of many African countries. Changes in climate that affect the viability of these industries will have an extensive influence on those same countries economies and the livelihoods of their communities.
Biodiversity: West, east and southern Africa all contain major “hotspots” of biodiversity (Myers et al 2000) and around one fifth of the world’s plants, birds and mammals originate or have major areas of conservation in Africa. As discussed later in this paper biodiversity is key to a vast number of tourism initiatives and attractions in Africa.

Low Capacity for State-Initiated Interventions: Centralised, post-colonial political economies are relatively recent in most of Africa. Due to a range of destabilising factors including military coups, despotism, tribalism, corruption, maladministration and economic programs imposed by the international financial community, many governance structures are under-funded and under-capacity. Additionally, to compound these problems of governance, lines of communication from nations’ capitals to their regions and rural areas are often unreliable and slow.

Disease Burden: “Insect-vector diseases such as malaria and tryanosomiasis; water-borne diseases such as typhoid, cholera, and schistosomiasis; and poverty-related diseases such as tuberculosis are prevalent in Africa. The HIV/AIDS pandemic is placing great strain on the health infrastructure.” (IPCC 2001) With climate change comes the threat of an increase in the ‘disease burden’ making affected destinations less attractive to tourists who consider health as a factor in their decision making process.

Armed Conflict: Large refugee movement and populations to be supported as a result of persistent armed conflict in several regions of Africa further weakens the ability of nations to respond to climate change. Issues of safety and security are, of course, also vital factors for consideration by tourists when choosing destination.

High External Trade and Aid Dependence: As a result of issues such as a lack of strong internal demand, relatively low value goods dominating export economies, the servicing of large international debt, and trade linkages that maintain patterns established by former colonial relationships, many African countries have a negative trade balance and are dependent on financial aid limiting government resources and their ability to respond to climate change.
LIVELIHOODS AND TOURISM

Visitation to developing countries, such as those in Africa, has increased dramatically over the past two decades. As illustrated in Table 1, between 1980 and 1997 tourist arrivals in developing countries increased by nearly 136 million. This increase is due to a range of factors including increased interest from travellers in experiential and educational holidays, a greater awareness of green issues, a desire for knowledge when travelling which goes beyond the attractions of ‘sun, sand and sea’ and an understanding of the need for more ‘responsible’ travel (Mann 2000; Page and Dowling 2002; Goodwin et al 1998).

<table>
<thead>
<tr>
<th>YEAR</th>
<th>World Tourist Arrivals (Millions)</th>
<th>Tourist Arrivals in Developing Countries (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>25.3</td>
<td>-</td>
</tr>
<tr>
<td>1960</td>
<td>69.3</td>
<td>50.3</td>
</tr>
<tr>
<td>1970</td>
<td>159.7</td>
<td>-</td>
</tr>
<tr>
<td>1980</td>
<td>284.8</td>
<td>50.3</td>
</tr>
<tr>
<td>1990</td>
<td>425</td>
<td>-</td>
</tr>
<tr>
<td>1997</td>
<td>610</td>
<td>186</td>
</tr>
</tbody>
</table>

Adapted from World Tourism Organization cited in Mann 2000: The community tourism guide

Tourism is a principal export for 83% of developing countries and the principal export for one third of developing countries. 80% of the world’s poor, those living on less than 1US$ per day, live in 12 countries, in 11 of these countries tourism is a significant sector and growing (see Table 2 for populations by region living on less than 1US$ per day). In the year 2000 developing countries
received 292.6 million arrivals which represented 42% of global international tourist arrivals in that year (WTO 2002b).

Table 2: Population living on less than one US dollar a day (at 1993 purchasing power parity)

<table>
<thead>
<tr>
<th>Region</th>
<th>1987 %</th>
<th>1987 millions</th>
<th>1998 %</th>
<th>1998 millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. Asia</td>
<td>26.6</td>
<td>417.5</td>
<td>14.7</td>
<td>267.1</td>
</tr>
<tr>
<td>E. Europe/Central Asia</td>
<td>0.2</td>
<td>1.1</td>
<td>3.7</td>
<td>17.6</td>
</tr>
<tr>
<td>Latin Amer./Caribbean</td>
<td>15.3</td>
<td>63.7</td>
<td>12.1</td>
<td>60.7</td>
</tr>
<tr>
<td>Middle East/N. Africa</td>
<td>4.3</td>
<td>9.3</td>
<td>2.1</td>
<td>6.0</td>
</tr>
<tr>
<td>S. Asia</td>
<td>44.9</td>
<td>474.4</td>
<td>40.0</td>
<td>521.8</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>46.6</td>
<td>217.2</td>
<td>48.1</td>
<td>301.6</td>
</tr>
</tbody>
</table>

Source: World Bank

Partly due to inadequacies of environmental law and their enforcement, preoccupations with economic problems and, in some cases, the absence of environmental pressure groups/organizations, tourism and recreation in some developing countries has been developing at a more rapid pace than the eco-consciousness of the government officials involved in the process (Mieczkowski 1995). However, it is also the case that international tourism is one of the few economic sectors through which developing countries have increased their participation in the global economy (WTO 2001) this increase is highlighted in Table 3.

Table 3: Tourism Expenditure Sorted by Country Group

| ABSOLUTE VALUE (US$ MILLIONS) OF TOURISM EXPENDITURE SORTED BY COUNTRY GROUP |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|
| COUNTRY GROUPS                | 1990            | 2000            | INCREASE        | %INCREASE       |
| OECD                          | 201,082         | 330,464         | 129,382         | 64.3%           |
| EU                            | 119,998         | 179,041         | 59,043          | 49.2%           |
| OTHER COUNTRIES               | 1,366           | 2,388           | 1,022           | 74.8%           |
| DEVELOPING COUNTRIES          | 59,645          | 138,937         | 79,292          | 132.9%          |
| LEAST DEVELOPED COUNTRIES     | 1,021           | 2,594           | 1,573           | 154.1%          |
| OTHER DEVELOPING COUNTRIES    | 11,045          | 17,041          | 5,996           | 54.3%           |

Adapted from Source: World Tourism Organization: Tourism and Poverty Alleviation 2002
Developing countries are sensitive to the importance and potential of tourism to their nations’ economies, their local communities’ livelihoods and the biodiversity present in their countries (Ashley & Roe 1998). Tourism can assist in poverty alleviation and in the reduction of gender inequality; it can contribute to the reduction of economic instability and vulnerability and assist in the protection of natural and cultural heritage (Goodwin, Kent, Parker & Walpole 1998; WTO 2001). In addition the benefits that can flow from tourism have a great impact on other sectors, especially agriculture and can lead to the upgrading of infrastructure and links to other markets often taken for granted in developed countries.

Development agencies including the World Bank, the United Nations and the UK Government Department for International Development (DFID) recognise tourism as one route to development in poorer countries (Roe et al 1997; DFID 1997). Pro-poor tourism strategies can ‘tilt’ tourism at the margin generating new opportunities and benefits for the poor, this is demonstrated by a number of case studies, including amongst others; Poultney and Spenceley (2001); Mahoney & Van Zyl (2001); Saville (2001); Nicanor (2001); Williams, White & Spenceley (2001); Renard (2001); Braman & Amazonia (2001) and Cattarnich (2001).

In 2000, South Africa accounted for 6,026,000 international tourist arrivals and US$2,707 million receipts; Tanzania 459000 international tourists, $739 million receipts; and Ghana received 399000 international tourist arrivals and US$386 million international tourism receipts (WTO 2002a). The contribution of tourism to foreign exchange earnings is extremely important to governments, elites and entrepreneurs, but the extent to which tourist revenue works for the livelihoods of poor people is also vital. Maximising impacts on poverty elimination includes expanding the use of local labour, goods and services and also developing infrastructure, supportive policies and environmental strategies (DFID1999).

Positive livelihood impacts of tourism include not only the creation of economic opportunities and benefits for individuals, households and the collective community. In addition they include a wide range of non-financial livelihood impacts that decrease vulnerability; the development of skills, improved access to information, enhanced and new infrastructure, credit and markets, food security and the strengthening of community organizations. Less tangible changes such as renewed pride, empowerment, physical security, cultural benefits, optimism and more participation in decision-making also contribute greatly to the overall enhancement of livelihoods (Ashley 1997; Ashley, Goodwin & Roe 2001; Ashley 2000; DFID 1999).
Many African governments have recognised the potential for not only the national economic benefits from tourism but also the livelihood benefits and assistance in conservation initiatives that can be derived from community tourism in regional and rural areas of their countries. The relatively late emergence of travel and tourism in South Africa due to the isolationism of the old ‘apartheid’ system in some ways has protected its resources from excessive exploitation and inferior development, in other ways however, it has limited the potentially positive economic and social impacts that tourism may have delivered (WTTC 2002).

The South African Government, understandably, places a range of issues higher on its agenda than tourism including transformation, black empowerment, HIV/AIDS, poverty elimination, housing, education and training. The government has, however, recognised the enormous potential of the tourism industry as a catalyst for successful development across the country and has taken measures such as the Integrated Ecotourism Development Plan and the development of Generic Guidelines for Responsible Tourism Development. It has established funding initiatives and provided a support network for the sustainable and ‘responsible’ development of tourism with a view to achieving a balance between business imperatives, the protection of natural and cultural heritage, and the well-being of local communities (WTTC 2002; DEAT 2002a; DEAT 2002b; Provincial Government Western Cape, RSA 2002). Since 1999 the Department of Environmental Affairs and Tourism (DEAT) has spent 260 million South African Rand funding over 150 community-based tourism projects. According to the department’s figures this has resulted in more than 400,000 temporary jobs in the community-based tourism sector, 2,300 permanent jobs and 4,000 people being trained in other associated development projects delivering livelihood benefits to communities and households throughout the country. In 2002, South Africa’s travel and tourism economy directly and indirectly accounted for approximately 1,148,000 jobs and 12.5% of total exports. Around 65% of new jobs created by tourism annually are found in the developing world, many of these positions go to women, contributing to the reduction of gender inequality and the empowerment of women. 46% of workers in accommodation and catering are women; a much higher share than in labour markets overall (DEAT 2002a). Africa was the only region in the world where economic growth in 2001 exceeded the 2000 figure and tourism is expected to grow at a rate of over 5% per year to 2020, compared to a world average of 4.1% (WTO 2002a). In 1999 the World Tourism Organization (WTO) designated 2000 to 2010 as the Decade for Tourism Development in Africa.
TOURISM, BIODIVERSITY AND CONSERVATION

The terms ‘nature tourism’ and ‘ecotourism’ have been used interchangeably and synonymously by many (Lindberg 1991; Aylward and Freedman 1992; WTTERC 1993; Cater & Lowman 1994; Goodwin 1996; Page & Dowling 2002). The International Ecotourism Society (TIES) defines ecotourism as “Responsible travel to natural areas that conserves the environment and sustains the well-being of local people”. In an attempt to establish a common concept for the purposes of its research, the WTO devotes 130 words to defining the sector in their series of seven market studies on ecotourism generating markets. However, perhaps most simply, and certainly most concisely, in the foreword to ‘Ecotourism: A sustainable option?’ edited by Cater and Lowman 1994, Sir Crispin Tickell, formerly President of the Royal Geographical Society and former chairman of the Climate Institute of Washington DC, stated that in his view ecotourism should mean “...travel to enjoy the world’s amazing diversity of natural life and human culture without damage to either.”

Whatever definition of ecotourism one chooses, if indeed one does, there can be little doubt that tourism in Africa is predominantly based around the natural and cultural heritage that coexists in the region (Ngugi et al 2003). In southern and eastern Africa, particularly, most tourism is based on wildlife viewing and/or hunting (Leader Williams 2000). There exists a crucial interdependence between tourism, the environment and communities adjacent and within the tourism destination. Biodiversity and the physical and social environment constitute the resource base for tourism in Africa. The Industry and Environment Office of the United Nations Environment Programme (UNEP/IE) in 1995 stated in its Global Biodiversity Assessment Report that the environment is the most essential resource for the growth of tourism; “Tourism is extremely sensitive to the environment and should negative environmental effects diminish the tourism experience, tourism growth and sustainability are seriously jeopardised.” Biodiversity attracts tourists, the success and sustainability of tourism in developing countries depends on the continued well-being of the environment, tourism has a vested interest not only in maintaining its resource base but also in enhancing it, the conservation and strengthening of biodiversity is therefore essential. Whilst the importance of biodiversity conservation is now recognised worldwide, in Africa, especially, the conservation of both terrestrial and aquatic biodiversity is clearly vital to the sustainable development of the tourism industry and the livelihoods of those communities involved. Of concern, is that the existing biodiversity in Africa is also recognised as particularly vulnerable and susceptible to climate change (IPCC 2001).
Wildlife tourism is closely bound up with wildlife conservation and community livelihoods (Hulme and Murphree 2001) this concept is supported by a number of available case studies concerning community conservation tourism. In Kenya and Tanzania; Barrow et al 2000; Leader-Williams et al 1996; and Wøien and Lama 1997, in Namibia; WWF 2001; Roe et al 2001; Roe et al 1997; and Ashley 1997, and in Zimbabwe; Goodwin 1997; McIvor 1997; and Bird 1997. Policy analyses and more general overviews are illustrated in Roe et al 2000; and Barrow et al 2000. Over the past decade there has been a shift in conservation approaches from ‘top-down’ towards a variety of ‘people-centred’ approaches (IIED 1994, Western & Wright 1994, Hulme & Murphree 2001). Community-based conservation seeks synergies between wildlife or environmental conservation and rural development through empowering local communities to use and benefit from their natural resources and enlisting their support for conservation (Ghimire & Pimbert 1997; Swanson and Barbier 1992; Ashley & Roe 1998; Roe et al 1997). Pro-poor tourism (PPT) and pro-poor wildlife tourism goes further to focus explicitly on maximising benefits for the poor (DFID 1999; LWAG 2002). Similarly the shift in conservation policy over the last decade has changed the focus from one of maintaining the habitat and species towards also improving the social and economic well-being of communities (Songorwa 1999). Incorporating local participation in decision-making and benefit distribution is now seen as an essential component of a successful community based conservation programme.

At the 1992 United Nations Conference on Environment and Development in Rio, it was recognised that the tourism industry could contribute towards both conservation of resources and development of the community. It is however, not merely financial earnings resulting from community based tourism that can contribute towards conservation, equally important is the increased pride and recognition of cultural and natural assets by the local communities (Ashley & Roe 1998). Often, tourism can act as a catalyst in strengthening local attitudes towards these assets thereby increasing the likelihood of better conservation practices. The earth’s natural resources plays host to a number of conflicting interests and conflicts will always exist around tourism, conservation and sustainable development, though if managed properly and responsibly, the three should benefit each other. “The World Tourism Organization estimates that 7% of all international travel expenditure is related to nature tourism and that the nature tourism industry is therefore worth US$83 billion p.a. This is the fastest growing segment within the international tourism market, and continued growth of 5-10% is anticipated” (WTO 1999, cited in Livestock and Wildlife Advisory Group (LWAG) DFID 2002).
The Wildlife and Poverty Study carried out by the LWAG highlights some of the possible livelihood benefits that wildlife can deliver; these are illustrated in Figure 2.

**Figure 2: Wildlife and Possible Positive Livelihood Outcomes**
Adapted from Source: LWAG Wildlife and Poverty Study

**CLIMATE CHANGE, BIODIVERSITY AND TOURISM**
Climate plays an overwhelming role in biodiversity and changes in biodiversity and species distribution are, therefore, often correlated with climatic variables. Given that much of Africa’s tourism is based on the existing biodiversity in the continent, any degradation in that biodiversity is potentially extremely serious for the industry, the livelihoods of many of the region’s communities and national economies. The University of Cape Town’s Energy and Development Research Centre report on the economic consequences of global warming in South Africa (2002) was based on secondary data from the findings of the Vulnerability and Adaptation Study for the South African Country Study on Climate Change (1999). Tourism was identified as the sector representing the biggest potential economic loss to South Africa as a result of climate change, as tourism contributes around 10% of GDP to the country. The report stated that tourism will be affected by a loss of habitats and biodiversity, and also by changes to temperature, humidity and an increased risk of malaria (Turpie et al 2002). Climate change is having an impact on all living organisms, on their environment and on the interactions between them. The major categories of climate change impacts
on biodiversity can be said to fall into three broad areas (IPCC 2001; IPCC 2002; UNEP 2002; UNEP 2003):

1) Impacts at different spatial scales; ecological communities, along environmental gradients, at the regional level.

2) Impacts on different environments: soil, rivers and estuaries, sea and coastal zones, terrestrial ecosystems.

3) Impacts on specific areas such as protected areas.

Following are examples of some of the impacts on biodiversity that may occur as a result of climate change, which in turn will impact on tourism in Africa (Chaplin et al 2000; Myers et al 2000; IPCC 2001; IPCC 2002; UNEP 2002; UNEP 2003; Thomas et al 2004):

1) The survival of rare and isolated populations in fragmented habitats may directly or indirectly be affected by climate change, some may quickly become extinct.

2) Endemic species are highly sensitive to change and therefore more vulnerable

3) Animal populations may be affected by environmental stress or indirectly through changes in vegetation; migration may occur, however, where populations are unable to migrate, local extinction will probably occur.

4) Coastal areas are especially vulnerable to natural disturbances; habitat fragmentation and biological invasions may occur.

5) Rising sea levels will have impacts on coastal ecosystems including the potential squeezing out of habitats especially where coastal margins are backed by areas of intense human use.

6) Rising sea levels will result in land loss, particularly in low lying islands and will impact on coastal salt marshes displacing them inland resulting in increased salinity.

7) Ecosystems that are already under stress will be the most likely to be severely affected by climate change.

8) Shifting and changes in seasons may increase the ranges of insects and diseases, and affect birdsong and the flowering of plants.

9) The number of invasive species and their dissemination is likely to increase and already existing invasive species are expected to expand their areas.

10) Corals have shown a high sensitivity to minor increases in temperature, rising sea temperatures will further affect the distribution and survival of particular marine resources.
Drought and desertification may occur in tropical and sub-tropical zones, changing patterns of precipitation and evaporation are of critical importance, and extreme flooding will have implications for large areas.

Increased frequency and magnitude of extreme events such as cyclones and storm surges will result in loss of land area and impacts on seabird nesting colonies and the migratory patterns of species.

Of the twenty five biodiversity hotspots for conservation priorities, shown in Figure 3, (Myers et al. 2000), five lie within Africa and around half are located in regions of the world that also contain developing countries. Factors such as widespread poverty, recurrent droughts, a dependence on natural resources and biodiversity make Africa more acutely vulnerable to the impacts of climate change than many other regions in the world (Hulme 1996; Nugugi 2003; IPCC 1998 & 2001). Inequitable land distribution, an over dependence on rain fed agriculture, its disease burden and an inability to action timely responses due to economic or governance issues also combine to ensure that the consequences of changing biodiversity in Africa will have inevitable ‘knock-on effects’ on the tourism sector and the livelihoods of the communities that rely on tourism and its secondary industries. Scenarios generated, in comparison to historical data, by climate change researchers depicting regional changes into the future and scenarios examining issues of seasonal changes indicate serious consequences for biodiversity globally and Africa in particular (Thomas et al. 2004; Calculations and maps by Amelung (2003), based on the CRU CL 1.0 climatological dataset (New et al., 1999), and HadCM3 future projections (Johns et al., 2003)). The projected impacts on biodiversity, of course, vary depending on the extremity of the climate change scenario depicted. However, even on the basis of mid-range climate warming scenarios, projected for 2050 (Thomas et al 2004), 15-37% of species, in sample regions, including South Africa, will be ‘committed to extinction’.

South Africa is just one example of a developing country where tourism plays a major part in its economy, the sector relies on the biodiversity prevalent within the country and heavy investment has been made into community based tourism initiatives designed to assist in the alleviation of poverty and to increase net benefits to the livelihoods of its people. The Vulnerability and Adaptation Study carried out in 1999 by the Department of Environment and Tourism in South Africa indicates that a loss in biodiversity and ecosystem function will be brought about by shifts in temperature and precipitation, an increase of 2.5 degrees centigrade by 2050 will bring about a general aridification...
of conditions in the western half of the country leading to a significant decrease in river flow in the southern and western catchments and a shrinkage of areas amenable to the country’s biomes to about half of their current extent resulting in huge losses in biodiversity (Du Plessis 2003; Turpie et al 2002; DEAT 1999).

The loss in biodiversity will affect supply of product to the tourism industry by the change in habitats e.g. estuaries and coastal zones. Demand from tourists will decrease due to increases in temperature, humidity and incidences of malaria and both supply and demand will be affected by the loss of species in the national parks and changes in the landscape of tourism (Krippendorf 1984; Turpie et al 2002). Various scenarios of climate change reveal different degrees of impact, with a more rapid global warming scenario large areas of Africa will experience changes in rainfall and temperature in December-February and June-August far beyond natural variability leading to the heightened vulnerability of coastal zones, water resources and food security, an exacerbation of desertification, an increase in vector-borne and water-borne diseases and the potential irreversible loss of natural resources and biodiversity (Viner & Agnew 1999; Chaplin et al 2000; IPCC 2001; Turpie et al 2002; Ngugi 2003; Thomas et al 2004). Climate change and desertification are
inextricably linked; dead vegetation, increased frequency and severity of drought and flooding, loss of animal and plant species and an increased risk to human health will not attract tourists.

CONCLUSION

Wildlife, biodiversity and nature-based tourism underpin the tourism industry in developing countries, and tourism to developing countries is among the fastest growing sectors of the industry (Cellabos-Lascuarin 1996; Wells 1997). The potential impacts of climate change on tourism in developing countries will not be restricted to changing visitation flows, seasonal visitation changes, unstable or threatened physical infrastructure, coastal degradation and beach erosion. The more dramatic impacts of climate change including flood, drought, loss of biodiversity and water degradation will increase the vulnerability of already vulnerable regions resulting in increased poverty in already impoverished areas. Added to these impacts will be unstable food security as a result of agricultural instability, a reduction in wildlife abundance and a decrease in public health in already disease prevalent regions. The combination of these and other effects will reduce or completely remove the net benefits that flow from tourism to developing countries and their communities, leading to the dramatic undermining and possible destruction of a fledging and important source of income, foreign exchange, employment and a wide range of other livelihood benefits.

The economies, the environment and the livelihoods of Africa’s nations and its people are vulnerable in the face of climate change. Most developing nations do not have sufficient human, financial and technical capital to effectively address climate change, particularly those countries with a wide range of socio-economic and environmental conditions. While Africa as a continent may be more vulnerable than others, climate change is a global problem requiring global solutions. African nations and the developing countries of the world will require assistance from developed countries to build both their human and technical capacity to adapt to climate change.

“Improvements in national and regional data and capacity to predict impacts is essential. Developing African capacity in environmental assessment will increase the effectiveness of aid. Regional assessments of vulnerability, impacts, and adaptation should be pursued to fill in the many gaps in information” (IPCC, 2001 chp.10 p3).
Pragmatic research in African and developing countries is urgently required into the interactions of climate change, the environment and tourism including the evaluation of existing and potential impacts from both a macro and a micro destinalional perspective. Consideration of potential adaptation and mitigation strategies should play a significant role in the research not only taking account of industry, tourists, government and secondary industry perspectives but also including serious consideration of the factors that may impact on poverty, the sustainable livelihoods of communities and in particular, the rural poor.

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VULNERABILITY OF WINTER RECREATION TO CLIMATE CHANGE
A Case Study Of The Lakelands Tourism Region (Southern Ontario, Canada)

Daniel Scott¹, Brenda Jones², Christopher Lemieux², Geoff McBoyle², Brian Mills¹, Stephen Svenson² and Geoff Wall²
¹- Adaptation and Impacts Research Group, Meteorological Service of Canada
²-Faculty of Environmental Studies, University of Waterloo

Abstract: A number of researchers have identified alpine skiing as being particularly sensitive to climate change, but no study has explored its vulnerability relative to other winter-related recreational activities. This study presents the findings of the first comparative assessment of the potential effects of climate change on four winter recreation activities (alpine and Nordic skiing, snowmobiling and ice fishing) in a single tourism region. The case study of the Lakelands Tourism Region (Southern Ontario, Canada) was used to explore current vulnerability to climate variability and future vulnerability under a range of climate change scenarios. Climate-related variability in the current season length differed among the four activities examined. Although the season length of each activity was projected to diminish under climate change, the findings suggest that in this region alpine skiing is the least vulnerable winter recreation activity, due largely to climate adaptations. Notably, the snowmobiling industry was projected to be at greater risk to climate change, as was recreational ice fishing. Similar analyses conducted in other regions of North America are required to explore the potential impact of climate change for winter tourism and implications for competitive relationships between destinations.

KEYWORDS: winter recreation, tourism, climate change

INTRODUCTION
Climate has a strong influence on the winter tourism and recreation sector. It affects the physical resources that are the foundation for many recreational activities (e.g., snow and ice) and the length and quality of tourism and recreation seasons. Despite the importance of climate to winter tourism, and tourism in general, there have been comparatively few investigations into the relationships between climate and tourism. The vulnerability of individual winter recreation industries and tourism regions to climate variability and change has not been adequately assessed.
One winter-related recreational industry cited as particularly vulnerable to climate change is alpine skiing. Climate change assessments of alpine skiing in Australia (Galloway, 1988, König, 1998), Austria (Breiling et al., 1997), Scotland (Harrison et al., 1999) and Switzerland (König and Abegg, 1997) all project negative consequences for the industry and associated businesses, including shortened operating seasons. In North America, Lamothe and Periard (1988) and McBoyle and Wall (1992), using the climate change scenarios of the period, estimated that the lower Laurentian Mountains in Quebec would experience a 34 to 49% and 42 to 87% reduction in ski seasons, respectively. McBoyle and Wall (1992) projected that the ski season in northern Ontario would be reduced by 30 to 40%, while a similar study projected a reduction of 30 to 55% in northern Michigan and 59% to 100% in southern Michigan (Lipski and McBoyle, 1991). Using the results of a recent economic study of skier expenditures in Michigan (Leisure Trends Group, 1995), economic losses, if proportional to minimum season length reductions (30%) could exceed $122 million (US).

Emphasis on the vulnerability of the alpine ski industry to climate change is understandable given its economic significance to winter tourism, particularly outside of North America where the snowmobile industry (with an estimated annual economic impact of $10.6 billion (US) in the United States and Canada (ISMA, 1999)) does not rival the economic significance of alpine skiing. The potential vulnerability of other winter recreation industries, such as snowmobiling and recreational ice fishing, has yet to be examined. Furthermore, no comparative assessment of the winter tourism and recreation sector has been undertaken in any region of the world, including Canada. The lack of systematic sector-wide assessments in major tourism regions remains a significant barrier to our understanding of the net impact of climate change on the recreation and tourism sector and competitive relationships between tourism regions. It also creates uncertainties with respect to relevant management decisions that will encourage the future sustainability and profitability of these industries in a particular location.

This study undertook a comparative assessment of the winter recreation and tourism sector in one region of Ontario, Canada where the tourism industry is integral to the local economy – the Lakelands Tourism Region. This paper examines the current sensitivity of four core winter recreation industries (alpine and Nordic skiing, snowmobiling and ice fishing) to climate variability and how the projected impacts on these winter recreation industries differ under a range of climate change scenarios. The importance of climate adaptations and management implications is also discussed.
STUDY AREA

The Lakelands Tourism Region was selected for this case study because climate is a known limiting factor for winter recreation in the area. Located in southcentral Ontario approximately 100 to 300 kilometres north of the Greater Toronto Area (GTA), the Lakelands Region is comprised of parts of four counties (Bruce, Grey, Simcoe and Haliburton) and one district (Muskoka) (Figure 1).

Figure 1: Study Area

Recreation and tourism are vital components of the region’s economy. In 1999, direct and indirect economic contributions from tourism amounted to $814 million (CDN), with approximately 29,000 full-time equivalent jobs associated with the industry (OMTCR, 2001). In Bruce County, tourism is the second largest industry (Bruce County 2001). With respect to individual recreational industries, the study area contains over one-half of the province’s 41 alpine ski areas registered with the Ontario Snow Resorts Association (OSRA). Most of the large ski areas in the province including those that make the largest annual investments in snowmaking and terrain enhancements are situated in the study area (Lebrecht, 1994; MacDonald, 1988). The region also encompasses four of the eight OSRA-registered Nordic ski areas, with a number of other alpine ski resorts and conservation areas also offering Nordic opportunities. There are approximately 9,200 kilometres of snowmobiling trails in the region, representing 19% of all trails operated by the Ontario Federation of Snowmobile Clubs (OFSC) province-wide. Over 30% of the 36,000 trail permits sold in Ontario during the 1998/99 winter season were sold in the Lakelands Region (OFSC 2000). The region’s recreational ice fishing is also a multi-million dollar industry. In 1998, 862,000 domestic person visits out of a
provincial total of 3,225,000 were engaged in recreational fishing in the region. The local fishery supports more than 30 commercial ice hut operators and generates approximately $28 million (CDN) in recreation-related expenditures for the local economy (LSEMS, 1998).

DATA AND METHODS
The nature of recreational activities examined in this study necessitated two different methodologies to assess their current vulnerability to climate variability and their future vulnerability under projected climate change. The scenarios-based modelling approach was used for the three snow-based recreational activities (alpine skiing, Nordic skiing and snowmobiling) and is outlined in Figure 2. The only difference between the three snow-based activities was the inclusion of snowmaking capacity into the alpine skiing analysis. A climate analogue approach was used for the ice fishing analysis.

Figure 2: Methodological Framework for Snow-based Recreation Activities

Snow-based Recreational Activities
Seven climate stations in the study area were selected based on their proximity to major ski resorts and snowmobile trail networks, the length and quality of their climate record, and their ability to provide representative spatial coverage of the region. Daily temperature and precipitation data for these stations were obtained from the Meteorological Service of Canada for the 1961-90 period.
Climate change scenarios used in this study were obtained from the Canadian Climate Impacts and Scenarios (CCIS) Project. The scenarios provided by CCIS are constructed in accordance with recommendations of the Intergovernmental Panel on Climate Change (IPCC) Task Group of Scenarios and are derived from 30-year means (2010-39 corresponding to the 2020s scenario; 2040-69 to the 2050s scenario; and 2070-99 to the 2080s) with respect to the 1961-90 period. The two climate change scenarios used, the first generation Canadian Global Coupled Model (CGCM1) and the third generation Hadley Climate Model (HadCM3), were selected from seven available scenarios to represent a range of projected winter temperature and precipitation increases. The HadCM3 scenario generally projects less warming and the largest increase in precipitation, while the CGCM1 scenario represents one of the warmer and drier scenarios. To produce daily temperature and precipitation values for each of the three time periods, climate change scenarios were downscaled using the Long Ashton Research Station (LARS) stochastic weather generator (Semenov et al., 1998) parameterized to local climate stations and the 1961-90 period. More details regarding the selection of climate change scenarios; downscaling of the GCM output; and validation of the LARS output for this study are described elsewhere (Scott et al., 2002).

Temperature and precipitation variables were used to develop a locally parameterized snow depth model, based largely on methods used to develop the Canadian Daily Snow Depth Database (Brown and Bratten, 1999) and the Water Balance Tabulations for Canadian Climate Stations (Johnstone and Louie, 1983). The method involved estimating three parameters: amount of precipitation that falls as snow and rain; snow accumulation; and snowmelt. The approach was validated by comparing modelled and observed snow depth at three separate thresholds (2 cm, 10 cm and 30 cm).

A snowmaking module was integrated with the snow cover model to complete the methods for alpine skiing. The goal of this module was to maintain a 50-centimetre snow base between November 26th and March 30th for each year. The 50-centimetre snow base threshold was based on an analysis of the reported snow base depth at the same ski areas during the 1990s (the period when snowmaking systems were largely in place). The dates were established by reviewing opening and closing dates for ski areas in the study area during the past 20 years using data provided by the Ontario Ministry of Tourism, Culture and Recreation (OMTCR). Technical capacity and decision rules regarding snowmaking were derived from interviews with stakeholders and related literature. Anticipating technological advancements in snowmaking, the study also parameterized the
snowmaking module with improved capacities (i.e., ability to economically make snow at warmer temperatures and make more snow per day).

An important methodological component of this case study was the establishment of climatic thresholds for the winter recreational activities. A number of climatic thresholds are available in the literature regarding suitable conditions and delineation of recreation seasons. For example, Crowe et al. (1973) defined a favourable ski day as one with at least 2.5 centimetres of snow on the ground and air temperatures between –2°C and +5°C, while Lamothe and Periard (1988) defined it as having a minimum 30-centimetre snow depth and air temperatures between –13°C and –25°C. These types of climatic thresholds have been used previously in a number of climate change sensitivity analyses of winter recreation (Breiling et al., 1997; König, 1998; Lipski and McBoyle, 1991; McBoyle and Wall, 1987, 1992; Wall, 1988).

Climatic thresholds used to parameterize the recreation season simulation models were refined through examination of observed ski area operations’ data and communication with ski industry stakeholders. Alpine ski operations in the study area, for example, seldom closed because of cold temperatures and a 2.5-centimetre base was deemed unsuitable for skiing, particularly in areas of rough terrain. For the purpose of this study, a minimum 30-centimetre snow base was used to define whether a ski area was open. Alpine ski areas were modelled to close when maximum temperatures exceeded 10°C for two consecutive days and were accompanied by liquid precipitation or the two-day liquid precipitation exceeded 20 millimetres. The economic goal of one of the prominent ski areas in the study region is to operate for at least 12 weeks, encompassing the major winter holiday periods (Christmas and New Year – late December; Spring Break – mid March). Climate thresholds for the two trail-based recreation industries (Nordic skiing and snowmobiling) were similar to that of alpine skiing, but modifications to the snow depth threshold allowed a minimum snow depth for snowmobiling that was near the lower bound of that recommended by the OFSC, which is 10 centimetres.

**Recreational Ice Fishing**

Ice conditions are the primary determinant for ice fishing activity. The lack of suitable ice modelling results and ice thickness data for the study area consequently required a different methodological approach from the three snow-based winter recreation activities described earlier. Ice fishing season data available from the OMTCR facilitated a climate analogue approach, by contrasting the
difference in season length between a climatically normal winter for the 1961-90 period (winter of 2000/01) and a winter with temperatures similar to those projected for an average winter in the 2050s (winter of 1997/98). Additional insights into ice conditions in the study area were obtained from Fang and Stefan’s (1998) modelling results for small lakes at similar latitudes in nearby US states (Michigan and New York).

RESULTS
This section is divided into two parts. The first summarizes the current vulnerability of the four winter recreation activities (alpine and Nordic skiing, snowmobiling and ice fishing) to climate variability in the Lakelands Region. The second section examines how the vulnerability of the four winter recreation activities could change under climate scenarios projected by CGCM1 and HadCM3 (2020s, 2050s and 2080s).

Vulnerability to Current Climate Variability
There is substantial inter-annual variability in the season length among the five areas (Figure 3). Horseshoe ski area consistently has the longest ski season, averaging approximately 124 days, while Sir Sam’s ski area consistently has the shortest, averaging only 79 days.

Although Sir Sam’s is climatically better suited for a longer ski season (i.e., further north, higher elevation, north facing slopes), it is the proximity of these two ski areas to major skiing markets (principally the GTA) and consequent business models that explains the different average ski seasons. Horseshoe is located just over 100 kilometres from the City of Toronto and is suitable for ‘day trippers’ (ski for the day and return home in the evening); Horseshoe is known for its efforts to be the first ski resort to open and the last one to close in the region. Sir Sam’s ski area is a three-hour drive from the City of Toronto and tends to serve skiers who stay in the area (weekends and holiday periods). This ski area closes in midweek during the winter season because of insufficient demand, even though ski conditions may be ideal.

Two other important observations can be drawn from Figure 3. First, the average ski season in the 1990s was surprisingly as long or longer than the 1980s at four of the five alpine ski areas even though the winters during the 1990s were on average warmer (the 1990s were the warmest decade in the observational record). Second, alpine ski areas in the Lakelands Region appear to be less vulnerable to climate variability now than in the previous decade. The explanation for this is the
multi-million dollar investments in snowmaking technology that occurred at these ski areas during the late 1980s and 1990s as response to the poor ski seasons of 1979/80 and 1982/83. By the mid-1990s, extensive snowmaking systems (100% coverage) were in place at all five of the alpine ski areas examined in this study. As a former director of the OSRA (MacDonald 1988) clearly stated “if we had to rely on snow from the heavens, the ski industry would be bankrupt.” During the period of analysis, snowmaking was estimated to have extended the ski season between 38% (1995/96) and 80% (1994/95) at Horseshoe ski area verses natural snow cover alone. Nonetheless, despite the tremendous investment in snowmaking, the record warm winter of 2001/02 again revealed the vulnerability of the ski industry to climate variability. The ski season at Horseshoe declined 25% verses the previous winter (Figure 3) and Blue Mountain opened after Christmas Day for the first time in 20 years.

![Figure 3: Comparison of Observed Alpine Skiing Season Length in the Lakelands Region](image)

Climate variability also has important impacts on the snowmobiling industry, but quantifying the impact was more difficult due to data limitations. The OFSC estimates average snowmobile season length in its 17 districts based on local observations, but does not archive weekly trail conditions or even yearly season length. Media reports and communications with OFSC representatives and local snowmobile clubs indicate the inter-annual season length variability is substantial in the region. Unlike alpine skiing, the linear nature and large distances (often 100s of kilometres) of snowmobile
Amelung B., Blaziejczyk K., Matzarakis A., 2007: Climate Change and Tourism – Assessment and Coping Strategies

trails pose technical and economic barriers to the widespread and efficient implementation of snowmaking, leaving the industry reliant on natural snow and vulnerable to climate variability.

![Figure 4: Comparison of Observed Nordic Skiing Season Length in the Lakelands Region](image)

Like snowmobiling, Nordic skiing trails are almost entirely reliant on natural snow conditions. A comparison of Nordic ski season lengths (Figure 4) with alpine skiing (Figure 3) reveals substantially more variability. For many of the Nordic ski trails in the Lakelands Region, the longest ski season is more than three times that of the shortest season, suggesting that this industry is also more vulnerable to climate variability than alpine skiing.

The shorter distances of most Nordic ski trails in the Lakelands Region relative to snowmobiling trails, however, makes snowmaking a more feasible technical adaptation strategy. Some Nordic ski areas in the study area have limited snowmaking capabilities, but this tends to be restricted to high-traffic open areas where snow conditions often deteriorate more quickly. Of the six Nordic ski areas in Figure 4, only Hardwood Hills has a snowmaking system that covers its entire trail network. Not surprisingly, it also had the longest ski season in every year where comparable data were available.

Ice fishing in the Lakelands Region, particularly on Lake Simcoe, has also been severely impacted by climate variability. Pressure cracks on Lake Simcoe are a common occurrence during the winter, but rarely cause problems. In 1997, a 100-metre wide by 70-kilometre long crack developed stranding 250 ice-fishers on the ice (Van Rijn, 1997). Local business owners believe that it is possible that the frequency and severity of pressure cracks may be increasing on Lake Simcoe, perhaps because of climate variability. As one ice hut operator stated, “The temperature used to be
steadier. Now it seems to be a real roller coaster ride” (Jackson’s Point operator, 2001). Relatively warm winters during the 1990s contributed to a shortened ice-fishing season (Table 1). Comparing the ice fishing length at four locations on Lake Simcoe where data were available for 1997/98 (the second warmest winter on record in the region) and 2000/01 (a climatically normal winter for the 1961-90 period) indicated the industry’s vulnerability to climate variability. On average, the ice fishing season during the warm winter of 1997/98 was reduced by 50%. During the record warm winter of 2001/02, some commercial ice hut businesses did not operate at all because of unsafe conditions.

Table 1: Variability in the Ice Fishing Season Lengths

<table>
<thead>
<tr>
<th>Location on Lake Simcoe</th>
<th>Season Length (days)</th>
<th>% Change wrt to 2000/01 Season Length (days)</th>
<th>% Change wrt to 2000/01</th>
<th>Season Length (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midland</td>
<td>45</td>
<td>-46%</td>
<td>50</td>
<td>-40%</td>
</tr>
<tr>
<td>Jackson’s Point</td>
<td>35</td>
<td>-52%</td>
<td>46</td>
<td>-37%</td>
</tr>
<tr>
<td>Kempenfelt Bay</td>
<td>25</td>
<td>-64%</td>
<td>61</td>
<td>-46%</td>
</tr>
<tr>
<td>Lake Couchiching</td>
<td>43</td>
<td>-45%</td>
<td>48</td>
<td>-29%</td>
</tr>
</tbody>
</table>

Note: wrt – with respect to

Climate Change Impact Assessment

Alpine Skiing

Comparison of the projected season lengths for the five alpine ski areas in the Lakelands Region under the two climate change scenarios using current and improved snowmaking technology consistently indicates a trend toward shorter average ski seasons in the region, although there are some differences in the magnitude of change among the climate change scenarios and among the five ski areas (Table 2). The more northerly ski areas that are at higher elevations (i.e., Sir Sam’s and Hidden Valley) are the least vulnerable to climate change in all three time frames analyzed (2020s, 2050s, 2080s). In terms of individual ski areas, Blue Mountain appeared to be the most
vulnerable overall, with average season lengths being reduced by 18-30% in the 2020s, 30-52% in the 2050s and 54-66% in the 2080s. This finding is consistent with its geographical location near the shores of Lake Huron, where lower elevations, higher average humidity levels, and the moderating effect of Lake Huron provide a warmer climate that is less conducive to snowmaking. At all five ski areas, it is possible that improvements to snowmaking could reduce season losses. Improved snowmaking is most valuable at Blue Mountain, where season losses could be reduced by 10-20% in the 2050s and 2080s.

Table 2: Simulated Alpine Ski Seasons Under Climate Change Using Current and Improved Snowmaking Technology

<table>
<thead>
<tr>
<th>Ski Area &amp; Snowmaking Technology</th>
<th>Simulated Baseline (days) 1961-90</th>
<th>Change in Season Length (%)</th>
<th>CGCM1</th>
<th>HadCM3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2020s</td>
<td>2050s</td>
<td>2080s</td>
</tr>
<tr>
<td>Hidden Valley</td>
<td>126</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>-14%</td>
<td>-26%</td>
<td>-39%</td>
</tr>
<tr>
<td>Improved</td>
<td></td>
<td>-10%</td>
<td>-20%</td>
<td>-30%</td>
</tr>
<tr>
<td>Sir Sam’s</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>-14%</td>
<td>-24%</td>
<td>-38%</td>
</tr>
<tr>
<td>Improved</td>
<td></td>
<td>-10%</td>
<td>-18%</td>
<td>-29%</td>
</tr>
<tr>
<td>Horseshoe</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>-15%</td>
<td>-31%</td>
<td>-47%</td>
</tr>
<tr>
<td>Improved</td>
<td></td>
<td>-7%</td>
<td>-20%</td>
<td>-34%</td>
</tr>
<tr>
<td>Blue Mountain</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>-30%</td>
<td>-52%</td>
<td>-66%</td>
</tr>
<tr>
<td>Improved</td>
<td></td>
<td>-17%</td>
<td>-32%</td>
<td>-49%</td>
</tr>
<tr>
<td>Talisman</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>-22%</td>
<td>-38%</td>
<td>-54%</td>
</tr>
<tr>
<td>Improved</td>
<td></td>
<td>-14%</td>
<td>-26%</td>
<td>-38%</td>
</tr>
<tr>
<td>Average % ∆</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>-19%</td>
<td>-34%</td>
<td>-49%</td>
</tr>
<tr>
<td>Improved</td>
<td></td>
<td>-12%</td>
<td>-23%</td>
<td>-36%</td>
</tr>
</tbody>
</table>

Maintaining the length of alpine ski seasons in the Lakelands Region under increasing climate change will come with a cost - increased snowmaking. Assuming no change in modelled current snowmaking capacities, the amount of snowmaking required (with respect to the 1961-90 period) to limit the ski season losses could range from approximately 150% to 200% in the 2020s. By the 2050s, snowmaking requirements could range from 175% to 300% of the 1961-90 baseline.
Determining the additional costs of making more snow at warmer average temperatures (which requires more energy) remains an important future research question. When snowmaking is integrated into the climate change impact assessment, the magnitude of the impact of climate change is substantially diminished relative to earlier studies that did not incorporate it. A doubled-atmospheric CO₂ equivalent scenario (~2050s) with current snowmaking technology reduces the alpine seasons among the ski areas in the study area by only between 24-52% (CGCM1) and 16-30% (HadCM3). These scenarios are more optimistic than earlier studies that estimated a 40-100% loss of the alpine ski season in the region under doubled-CO₂ conditions (McBoyle and Wall, 1992; Ordower, 1995) and clearly demonstrate the importance of incorporating adaptation in climate change assessments.

**Trail-based Activities**

Trail-based activities were identified in the previous section as being more sensitive to climate variability than alpine skiing, largely because of differences in adaptive capacities (i.e., snowmaking). The results of the climate change impact assessment reveal that trail-based activities are also more likely to be impacted by the climate change scenarios considered. As might be expected, snowmobiling areas located in the northern part of the study area (e.g., Haliburton district) are projected to experience less change in season length than those at lower elevations (Tables 3 and 4). The average projected decline in season length in the Lakelands snowmobiling areas is quite substantial, ranging from 29% (HadCM3) to 49% (CGCM1) as early as the 2020s. By the 2050s, the average snowmobiling season in the Lakelands Region is projected to be reduced by approximately 50%, with further reductions of 70% (HadCM3) and 79% (CGCM1) in the 2080s.

Complicating projections of snowmobiling season length are lake ice cover projections. Long snowmobile trails in the study area are often linked by ice-crossings, and poor snow conditions on snowmobile trails also encourage some snowmobilers to use lakes instead. Projections of reduced ice cover and average thickness (Fang and Stefan, 1998) will adversely impact the connectivity of some trail networks and likely increase the exposure of snowmobilers to dangerous ice conditions. In the Lakelands Region, the duration of ice cover is projected to decline on average by 45 to 60 days and average maximum thickness to decline by 30 to 40 centimetres (Fang and Stefan, 1998). While this case study identifies marginal ice conditions as an important safety hazard and a
consideration for trail connections, ice conditions have not been incorporated into this climate change assessment.

Table 3: Observed and Simulated Snowmobiling Season Length (Days) in the Lakelands Region

<table>
<thead>
<tr>
<th>Snowmobile Area</th>
<th>Observed 1980-90s</th>
<th>Simulated Seasons (Crowe et al. 1977)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haliburton (District 6)</td>
<td>91</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huntsville (District 7)</td>
<td>91</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muskoka (District 7)</td>
<td>91</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orillia (District 8)</td>
<td>70</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collingwood (District 8)</td>
<td>70</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chatsworth (District 9)</td>
<td>70</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wiarton (District 9)</td>
<td>70</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average % △</td>
<td></td>
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</tr>
</tbody>
</table>
Table 4: Observed and Simulated Nordic Ski Season Length (days) in the Lakelands Region

<table>
<thead>
<tr>
<th>Nordic Ski Area</th>
<th>Observed 1980-90s</th>
<th>Simulated Seasons</th>
<th>1961-90</th>
<th>2020s</th>
<th>2050s</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean % △</td>
<td>Mean % △</td>
<td>Mean % △</td>
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</tr>
<tr>
<td>Horseshoe¹</td>
<td>65</td>
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<tr>
<td>CGCM1</td>
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<td>59%</td>
<td>14</td>
<td>84%</td>
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<td>91%</td>
</tr>
<tr>
<td>HadCM3</td>
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<td>73%</td>
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1. Analysis for Horseshoe, Mansfield and Hardwood Hills Nordic ski areas were based on a common climate station and thus the projected season lengths for each climate change scenario were identical at all three locations; 2 Hardwood Hills is the only Nordic ski area with snowmaking capacity for the entire trail network.

Nordic skiing was also found to be more vulnerable to climate change than alpine skiing (Table 4). Similar to snowmobiling, the average projected reduction in season length for Nordic skiing in the study area is substantial, ranging from 40% (HadCM3) to 56% (CGCM1) by the 2020s and 79% (HadCM3) and 86% (CGCM1) by the 2080s. Again, Nordic ski areas at higher elevations (e.g., Haliburton) are projected to experience less change.

**Ice Fishing**

As mentioned earlier, the 1997/98 ice-fishing season provides an analogue for the potential impact of climate change on recreational ice fishing in the Lakelands Region. The winter of 1997/98 was...
the second warmest on record in the Great Lakes Region, averaging 3.7°C above the 1960-91 average. During this winter period, the Lake Simcoe ice fishing season was on average (based on four sites) 52% shorter than the winter of 2000/01, which was 0.3°C below average.

The projected winter temperature change in the CGCM1 2050s scenario is more than 1°C warmer (+4.83°C) than 1997/98, suggesting that the ice fishing season will likely be further reduced. Projections of ice thickness by Fang and Stefan (1998) indicate that, under average conditions, the threshold for safe ice thickness (15-25 centimetres) would be rarely achieved in some locations in the study area. The ability of ice hut businesses to operate year-to-year under such conditions would be compromised, with those operating in areas on Lake Simcoe with the lowest annual ice thickness being impacted first. In addition, climate change is projected to affect the range of fish species in the Great Lakes basin. While changes in fish species composition have not been incorporated into this analysis of ice fishing, they will likely have implications for the sport fishery (availability of desired species, lake stocking requirements, fisheries management) in the Lakelands Region.

CONCLUSIONS AND DISCUSSION

This study explored the relative vulnerability of four key winter recreation industries in the Lakelands Tourism Region in southcentral Ontario to current climate variability and projected climate change under a range of scenarios.

Vulnerability to current climate variability varied among the four recreational activities examined. Of the four activities, alpine skiing was the least vulnerable to current climate variability, while the two trail-based activities were generally more vulnerable, experiencing reductions in season lengths of well over 50% in some years. The main reason for this difference in vulnerability was snowmaking capacity (between the snow-based activities). The fourth industry, recreational ice fishing, showed even greater vulnerability to current climate variability.

In terms of climate change, the findings of the impact assessment suggest that the vulnerability of alpine skiing is similar to previous studies that suggest a high likelihood of diminished season lengths. The scenarios in this study, however, are more optimistic than earlier studies, due largely to the inclusion of snowmaking in the impact assessment. 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 and could alter the
competitive relationships between individual ski resorts and between the Lakelands and other ski regions (e.g., Michigan, Quebec) that have climatic advantages. Trail-based activities in the study region are projected to experience substantial reductions in average season lengths. Reductions in average season length in the range of 29-49% and 40-56% are likely as early as the 2020s for snowmobiling and Nordic skiing, respectively. Nordic skiers generally have less invested in equipment than snowmobilers and therefore substantially reduced season lengths may not have as significant an impact on participation and activity substitution.

The climate change impact assessment research community has largely focused on the vulnerability of the alpine ski industry, thereby overlooking the apparent greater vulnerability of the snowmobile industry in North America (ISMA, 1999). Season reductions of approximately three (CGCM1) to five (HadCM3) weeks are possible for the snowmobile industry in the Lakelands Region by the 2050s. Given such reductions to an already relatively short season, it is possible that snowmobilers may choose not to continue investing thousands of dollars in recreational vehicles and supporting equipment. However, this outcome is difficult to predict without further research. It is also possible that the decreased availability of suitable snow conditions could motivate snowmobilers to substitute one type of recreational vehicle for another that is not limited by snow conditions (i.e., from snowmobiles to ATVs). Although potential adaptations exist (e.g., implementation of snowmaking, activity substitution – snowmobile to ATV), these strategies would require important changes by recreation suppliers and participants alike. Further investments by government agencies in trail development for winter tourism needs to be re-evaluated based on the expected return on investment and their adaptability for multiple recreational uses. Notably, climate change was also not considered in Canada’s recent National Snowmobiling Tourism Plan (Pannell Kerr Forster, 2000), despite the potentially important implications for the sustainability of snowmobile-based tourism in the plan’s long-term time frame (starting in 2008).

This study revealed that of the four activities examined, recreational ice fishing was the most vulnerable to climate change. The average ice fishing season on Lake Simcoe was reduced by approximately 50% during the winter of 1997/98 and the average winter temperature in the 2050s is projected to be 1°C warmer the CGCM1 scenario. Ice fishing as an activity (without the added weight of an ice hut) would persist, but there is the potential for increased lake ice hazards for fishers and snowmobilers including more ice fishers falling through the ice with attendant rescue requirements and costs. Similarly, there is a potentially dangerous feedback between poor snow
conditions and increased lake ice hazard, as some snowmobilers substitute lake ice surfaces for land-based trails when conditions are poor. Finally, it is also possible that as ice conditions in other key ice fishing regions in the Great Lakes Region deteriorate to a greater extent with a possible net transfer of fishing pressure to the Lakelands Region.

This study is the first comparative assessment of the winter recreation and tourism sector in Canada or internationally. It is hoped that the approach taken and the issues raised will enhance research into the relationships between climate and tourism, and improve climate change impact assessment in the tourism and recreation sector. However, several additional advances are required that will stimulate collaboration between climate change and tourism researchers that is essential for progress in this area of research to developing a more comprehensive understanding of the implications of climate change for tourism destinations. Assessing the response of recreationists and tourists to climate variability and change, examining potential impacts on summer recreation seasons and tourist flows (both anticipated to increase in the Lakelands region and Canada as a whole (Scott 2003), and exploring the interplay of climate change with other major factors influencing the recreation and tourism sector (e.g., demographic change, technology, energy costs, globalization, economic development) are also important. It is hoped that recent workshops and conferences on climate change and tourism hosted by the World Tourism Organization (Tunisia, April, 2003), the Environmental Science Foundation (Milan, June 2003), and this NATO Advanced Research Workshop will stimulate collaboration between climate change and tourism communities that is essential for progress in this area of research.

References


Lamothe and Periard Consultants (1988) Implications Of Climate Change For Downhill Skiing In Quebec. Climate Change Digest, CCD 88-03.


