Potential impacts of climate change on international tourism

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ABSTRACT

Global temperatures rose by over 0.5°C during the 20th century and current estimates suggest that they will continue to rise at between 0.2 and 0.3°C per decade during the course of the 21st century. This increasing trend towards warmer temperatures could have major consequences for the tourism industry, which is heavily dependent on present climatic and environmental conditions. The ecosystems of many international holiday destinations are potentially vulnerable to climate change. This paper reviews the potential impacts of climate change for ten international tourist destinations. The most serious impacts will result from the effects of sea-level rise on small island states. Other impacts likely to affect tourism include coral bleaching, outbreaks of fire, changed migration patterns of animals and birds, flooding, the spread of vector-borne diseases and shorter skiing seasons. Without appropriate adaptive measures, climate change could produce a shift in the comparative attractiveness of tourist destinations around the globe.

KEYWORDS: climate change, impacts, international tourism, sea-level rise, ecosystems

INTRODUCTION

International tourism is the largest and most rapidly expanding economic activity in the world. In 1999, travel and tourism involved 663 million people internationally and generated US$450m in receipts (TTI, 2000). The global tourism industry is expected to grow significantly in the future as personal income and leisure time increase, and transportation networks improve.

The climate system is dynamic and varies at all time scales. However, over the previous century there has been an increase of over 0.5°C in the mean global temperature (Figure 1). The warming in the 20th century has been more rapid than for any other period for which there are data, and the 1990s were the warmest decade of the last millennium. Since the start of the industrial revolution vast quantities of carbon dioxide and other 'greenhouse' gases have been released into the atmosphere by the burning of fossil fuels, most notably coal and oil, and to a lesser extent

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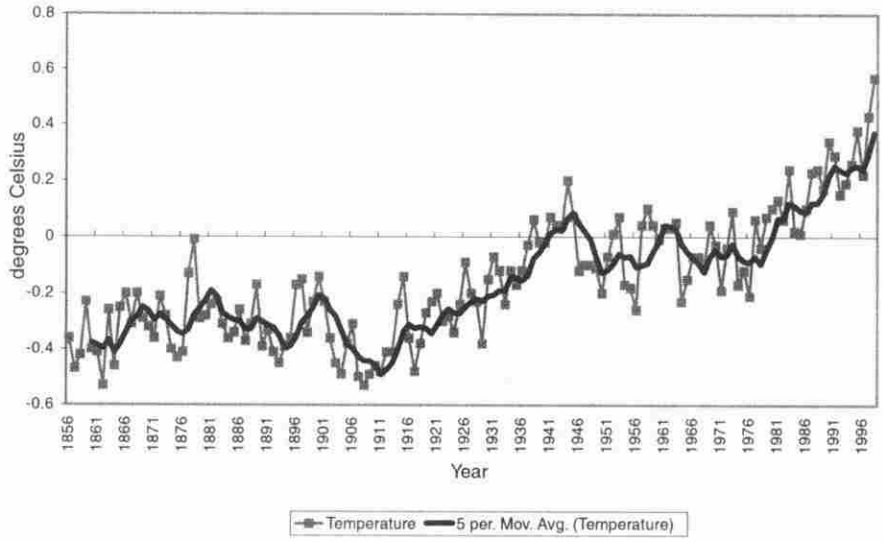
Figure 1 Global mean temperature anomalies, 1860–1998, with respect to 1961–1990 (Jones et al., *1998)*



gas. Estimates of future emissions are used in mathematical climate models (Wigley *et al.*, 1997) to explore how this will affect global temperatures and regional climates. Detailed analysis of the output from these models provides further evidence of the impacts of the enhanced 'greenhouse' effect upon the climate. Extreme climate events (such as droughts and prolonged 'heat-waves') may increase in frequency. What is perceived as an usually hot period (eg August 1997 in the UK) in the present, may become a common occurrence by the middle of the next century, and what might be considered to be an exceptional period of weather in the future will lie beyond present experience (Table 1). The table shows anomalies that have a return period of one in 20 years for the present the 2020s and 2050s. For comparison, in the central England temperature record, August 1997 had an anomaly of +3.4°C and the year 1997 had an anomaly of +1.06°C.

Table 1: Temperature anomalies of warm years and hot months in the UK

	1961–90	*2010–39*	*2040–69*
August	+3.15°C	+5.41°C	+7.14°C
Year	+1.10°C	+2.36°C	+3.08°C

The natural environment and climate conditions are very important in determining the attractiveness of a region as a holiday destination (Smith, 1990). Although research into the impacts of climate change for tourism is still at a primitive stage, it is generally acknowledged that there would be major consequences for the tourist industry (Wall and Badke, 1994). The continued success of international tourism is closely and symbiotically related to the preservation and enhancement of environmental resources. Environmental management considerations are wide and highly variable: from the prevention of coastal flooding and erosion and the conservation of water resources, to the control of forest and bush fires and the preservation of vulnerable flora and fauna. Unchecked growth in tourism will inevitably lead to modification of the environment. For

Table 2: Tourist arrivals and mean annual temperature for the countries/regions considered

	Country/region	*Resorts*	*International arrivals* (000) 1999		*Mean annual temperature* (°C) 1961–90
1	The Maldives	Beach resorts and coral reefs	Maldives	436	27.2
2	The European Alps	Garmisch-Parten Kirchen, Germany Kitzbuhel, Austria	Germany Austria	16,511 17,352	2.3
3	The Eastern Mediterranean	Greece; Turkey	Greece Turkey	10,916 9,200	16.0
4	Southern Spain	The Costas	Spain	47,749	15.0
5	UK	Scottish ski resorts; coastal golf links	UK	25,475	7.5
6	East and South Africa	Lake Manyara National Park, Tanzania Masai Mara, Kenya South Africa	Kenya South Africa	80 5,898	21.2
7	European lakes	Lake Zurich; Lake Balaton	Switzerland Hungary	10,900 15,000	10.0
8	Australia	Snowy mountains, Great Barrier Reef, interior bush, beaches and coast	Australia	4,326	20.0
9	Florida and mid-eastern coastline, US	Assateague National Seashore, Maryland; Florida Keys	USA	46,983	10.6
10	Brazil	Rainforest	Brazil	5,059	26.0

Sources: UN, 1998; Europa, 1998; Euromonitor, 1998.

example, the expansion in air travel is increasing emissions of greenhouse gases and enhancing the risk of continued global warming (IPCC, 1999).

This paper reviews the impacts of climate change on ten international tourist destinations, chosen to reflect differences in climate, environment and socio-economic conditions. The key climate and tourist characteristics for each country considered are given in Table 2. The climate change scenarios used in this paper have been constructed from state-of-the-art climate change experiments performed with HadCM2 (Mitchell *et al.*, 1995) and HadCM3 (Gordon *et al.*, 2000) that have been widely employed in impact assessments.

THE MALDIVES, INDIAN OCEAN

Environment and climate

The Maldives are located in the Indian Ocean to the south-west of the Indian subcontinent. They consist of an archipelago of 1,190 coral atolls with a total population of 220000. Many of the islands are less than one metre above sea level and their total land area is less than 300km^2. The chain of islands was formed from natural coral reefs that have built up around the rim of a chain of ancient volcanoes. These reefs ensure that the islands remain intact. The Maldives' climate is tropical, hot and humid. The mean annual temperature is 27°C with little daily or seasonal variation. Annual rainfall is between 2,540 and 3,800mm, and a large proportion of this arrives in the form of the south-west monsoon or 'hulhangu', which lasts from May to October. For the Maldives, the impact of climate change on sea level is critical. As the oceans heat up they expand, causing sea levels around the world to rise at an estimated rate of 4–10cm per decade (IPCC, 1995). Figure 2 shows the estimated rise in sea level caused by thermal expansion and small glacier melt based upon the IPCC SRES emissions scenarios.

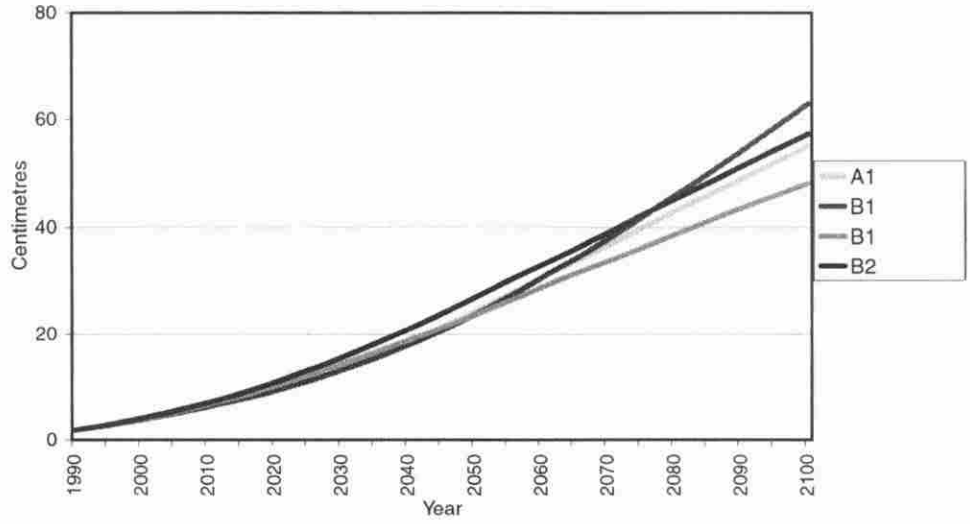
Tourism

During the 1980s tourism in the Maldives became one of the most important and highest-growth sectors of the economy. Tourism is now the backbone of the Maldives' economy, accounting for about 18 per cent of GDP and 74 per cent of foreign exchange receipts in 1994 (Nurse, 1996). In 1998, 395,725 tourists visited the islands and of this number 85 per cent were from Western Europe. Providing protection and stability to the islands, the coral reefs represent a rich biological diversity of marine communities and have become a very important tourist attraction. The Maldives Tourism Promotion Board reports that 40 per cent of the tourists who visit the Maldives do so for diving purposes (Maldives Tourism Promotion Board personal communication, 1999).

Potential impacts

The low elevation of the Maldives archipelago makes it particularly vulnerable to

Figure 2 Estimated rise in sea level caused by thermal expansion and small glacier melt based upon preliminary SRES emissions scenarios using MAGICC (Wigley et al., 1997)



sea-level rise (Abegg *et al.*, 1998; Wall, 1993a). At best, a rise in sea level would cause coastal erosion and at worst, a sizeable proportion of the landmass could become submerged over the next 30 years. The dangers of salt-water intrusion into the islands' aquifers, combined with sea-level rise, may lead to many of the islands becoming uninhabitable in the future (Nicholls and Mimura, 1998; Pernetta, 1992). Other small island states at risk from sea-level rise include Kiribati with a population of 75,000 scattered over 300 islands in 2 million km^2 of the Pacific (two of these islands have already been submerged), and the Marshall Islands with a population of 50,000 covering 1,200 islands in 700,000km^2 of the Pacific.

Coral 'bleaching' (the degradation of the coral) could be induced by a warming of only 1 or 2°C. An international team of coral experts reported that the 1997–98 sea surface temperatures were the warmest in the observed record. The coral bleaching associated with this event had an impact on almost all species of corals and many other invertebrates, and had a devastating effect on reefs in the Maldives (NOAA, 1998). Byrant *et al.* (1998) estimated that 58 per cent of the world's coral reefs are threatened by human activity, and if seriously damaged, could lead to a loss in tourist revenue of US$140bn.

THE EUROPEAN ALPS

Environment and climate

The European Alps are located in a double border area between the temperate latitudes and the Mediterranean subtropics, and between oceanic and continental Europe. Due to their complex topography, the European Alps demonstrate a wide range of climatic conditions, with virtually every valley experiencing a unique local climate. Table 3 gives the mean climate values (January to March) for Innsbruck, at an elevation of 582m.

Table 3: Temperature and rainfall values for Innsbruck in winter

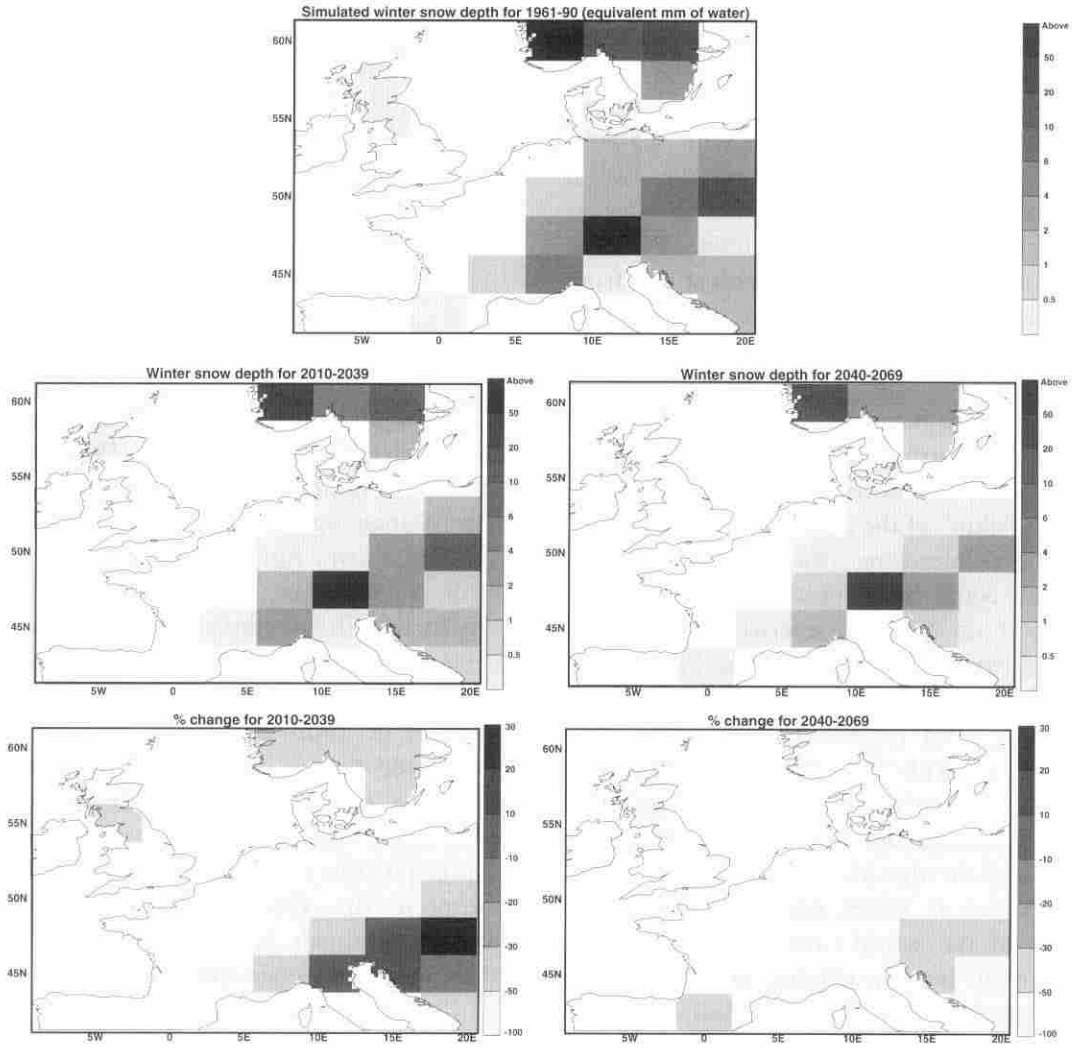
	Max. temperature	*Min. temperature*	*Rainfall*
Jan	1°C	–7°C	54 mm
Feb	4°C	–5°C	49 mm
Mar	11°C	0°C	41 mm

An analysis of climate records in Switzerland has shown a temperature warming of greater magnitude than the global trend (Beniston, 1994; Beniston *et al.*, 1994) suggesting an amplification of the global climate change signal in the Alpine region. Figure 3 shows future scenarios of snow depth, for the years 2010–49 and 2040–69, constructed from climate-change experiments performed at the Hadley Centre (Mitchell *et al.*, 1995). Projections are also provided of future changes in snowfall. It is expected that as temperatures rise there will be a considerable shortening of the snow season and a reduction in the amount of precipitation that falls as snow. For the European Alps, this reduction in snowfall may be as much as 30 per cent by the 2020s and over 50 per cent by the 2050s.

Tourism

Tourism in the European Alps is dominated by winter sports, which are in turn highly dependent on adequate snow cover (Abegg and Froesch, 1994). Approximately 23 per cent of GNP is indirectly generated by tourist activities, of which 80 per cent is attributed to tourism in mountain areas (Breiling and Charamza, 1994). However, the winter tourism industry has endured several consecutive years of losses with low-altitude sites the most vulnerable due to a greater variability in snow cover. Several of these low-elevation sites are among the more famous. Garmisch-Partenkirchen,

Figure 3 Evolution of snow cover for the European region, as estimated by the HadCM2 GCM with the IS92a emissions scenario



located in the Bavarian Alps at the foot of the Zugspitze, is Germany's best-known ski resort. The resort is situated at an elevation of 702m and is the venue for the famous annual ski jumping and World Cup descents each year. Kitzbuhel in Austria is another low-elevation (800m) ski resort that could be vulnerable to climate change.

Potential impacts

Mountain areas provide important landscapes for tourism and recreation (Price, 1998) but are particularly sensitive to climate change (Parish and Funnell, 1999). During the 20th century climate change in the European Alps was characterised by a warming of about 2°C in the minimum temperatures (Haeberli and Beniston, 1998). A warming of this magnitude has profound effects on glacial and periglacial zones; the European Alps have lost about 50 per cent of their glacial volume and 30–40 per cent of the glacial surface area since the middle of the 19th century. Regional climate scenarios suggest that within dec-

ades the Alps could lose major areas of glacial cover and the lower limit of permafrost could rise by several hundred metres (Haeberli and Beniston, 1998). These changes would have major implications for the alpine vegetation and wildlife. The loss or replacement of aesthetically valued species could alter the tourist attractiveness of these regions, particularly in the summer (Beniston and Holten, 2000). For example, Müller (1997) suggests that the loss of the *névé* on the Eiger, Mönch and Jungfrau could cause substantial damage to the tourist industry. Permafrost thaw could have a profound impact on the essential infrastructure (such as roads, cable car stations and chalets) upon which tourism depends and could lead to problems of slope stability resulting in potentially hazardous situations (Perry, 2000; Haeberli *et al.*, 1997). In warmer conditions there could also be a greater risk of avalanches and debris flows in the Alps (Perry, 2000).

The detrimental effects of global warming on the skiing industry are relatively well documented (McBoyle and Wall, 1987; Abegg and Froesch, 1994; Abegg, 1996). Models of snow-cover duration that use regional climate-change scenarios show a decline in the number of days of snow cover, especially for those resorts at low-altitude (below 1,400m) sites (Bultot *et al.*, 1994; Whetton *et al.*, 1996). Assuming a rise in mean temperature of 3°C it has been estimated that the winter snowline would rise by 300m in the Central Alps and by 500m in the Pre-Alps, and the skiing season would be shortened by one month (Messerli, 1990). In addition, Bultot *et al.* (1994) have estimated that, with a warming of 1–3°C, the number of days suitable for creating artificial snow in Switzerland could be substantially fewer. The spatial area suitable for skiing could be significantly reduced and it is anticipated that higher-altitude ski resorts will experience increasing pressure if their lower-lying counterparts become less commercially viable (Koch and Rudel, 1990; Breiling, 1993).

THE EASTERN MEDITERRANEAN

Environment and climate

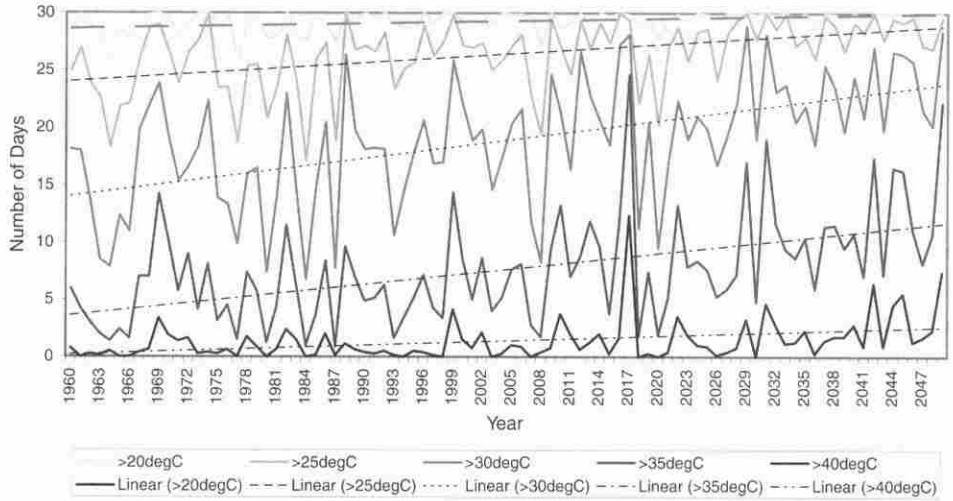
Greece and Turkey were selected to represent tourist destinations in the eastern Mediterranean. Greece is a mountainous and peninsular country, possessing an archipelago of about 2,000 islands. Turkey has an extensive coastline bordering the Black Sea, the Aegean Sea and the Mediterranean and has land borders with Greece, Bulgaria, Syria, Iraq, Georgia and Armenia. The terrain is primarily mountainous, with a high central plateau (Anatolia) and a narrow coastal plain.

The Mediterranean climate is characterised by mild winters and long hot summers, with maximum temperatures often exceeding 40°C. Projections of future climate suggest that the mean summer temperature increase for some parts of the eastern Mediterranean could be in excess of 4°C by the middle of this century (Goodess *et al.*, 1997). The interior of Turkey has a climate exemplified by extremes in temperature, with hot dry summers and cold snowy winters on the plateau. Mean daily temperatures in Ankara vary from 4–30°C. The Mediterranean coast is more equable, with mild winters and warm summers. As climate changes, summer heat waves could become more common, with temperatures well above the thresholds of human comfort (Figure 4).

Tourism

The tourist industry is facing mixed fortunes in the countries of the eastern Mediterranean. Traditionally, tourism has been one of the biggest foreign exchange earners in Greece and contributes 6 per cent to GDP (Moussios, 1999). However, because of competition from newer and more exotic resorts elsewhere in the world, the

Figure 4 Estimated changes in the frequency of days above certain temperature key thresholds for the eastern Mediterranean; estimates derived from the HadCM2 GCM using the IS92a emissions scenario



number of visitors started to fall in 1996 and 1997. To counteract this downturn in revenue, the government is improving the tourist infrastructure, particularly in the Aegean where tourism continues to flourish, and the Hellenic Tourism Organisation has recently approved a budget of DR10bn (US$28.9m) to encourage tourism to the country in future years (TTI, 2000). In contrast, tourism has expanded rapidly in Turkey in recent years and a 30 per cent increase in the number of visitors was forecast for the year 2000 (European Commission, 1999).

Potential impacts

A rise in summer temperatures to above 40°C would reduce personal comfort and could cause an increased incidence of heat stress and mortality (Perry, 1987; Gawith *et al.*, 1999). At present, August is the most popular month for tourist travel to Greece and Turkey. However, it is anticipated that with increasing temperatures many tourists may be discouraged from visiting at this time of the year. Instead, holidaymakers may choose to visit at an earlier or later time of the year to avoid the hottest months or they may switch to alternative destinations in other countries. Even during the last two decades, Athens has endured uncomfortably high temperatures that have led to a large number of heat-related health incidents (Giles and Balafoutis, 1990). Other environmental impacts of climate change are likely to include an increasing risk of water supply restrictions, forest fires and urban smogs. Very high levels of pollution have been recorded during hot spells in some of the eastern Mediterranean resorts (Giles and Balafoutis, 1990; Goldberg, 1996; Abatzoglou *et al.*, 1996). An increase in the frequency of these extreme environmental events may result in the eastern Mediterranean becoming a less attractive tourist destination.

SOUTHERN SPAIN

Environment and climate

Spain's landmass predominantly consists of the Meseta Central, a large highland plateau surrounded by mountain ranges. Low-

land areas include narrow coastal plains such as the Andalusian plain in the south-west and the Ebro basin. For most of the country the climate is continental with hot dry summers and cold winters. However, the Andalusian plain experiences a Mediterranean climate, with mild winters and warm dry summers. Models of climate change indicate temperature increases for this area. For example, it is suggested that September in 2050 will be as warm as July is today. The indications are that rainfall will not change significantly, so that summer months will remain dry but become warmer.

Tourism

In 1999, travel and tourism employed 24.3 per cent of the workforce in Spain (approximately 3.3 million people) and accounted for approximately 22.7 per cent of GNP (World Travel and Tourism Council, 1999). South-eastern Spain is one of the major destinations for tourists from the UK and other European countries. Resorts such as Benidorm, Malaga and Marbella (the Costas region) are popular in the summer months for families, singles and the under 30s, and are frequented by longer-stay holidaymakers in the winter months, attracted by year-round sun and warmth.

Potential impacts

Spain is viewed as a friendly, easily accessible, no-risk destination. For example, there is no need for any immunisation against insect-borne diseases such as malaria and yellow fever. However, more recently malaria has resurfaced in Spain and it is estimated that climate warming will result in this region becoming a more suitable habitat for certain species of mosquito (eg *Anopheles labranchiae*) by the 2050s (Martin and Lefebvre, 1995).

Other impacts are likely to include flash floods, an increased incidence of forest fires and heat stress following periods of extreme temperature. A greater frequency of days of extreme heat in the summer may cause a further shift towards winter holidays (Harlfinger, 1991). Forest fires already constitute a serious problem within the area of the Mediterranean basin. The worst situation is precipitated by hot, dry and windy conditions, when fires spread rapidly (Merillon, 1991). In recent years, there has been a tendency for the number of forest fires to increase following periods of extreme dryness (LUCC, 1998).

SCOTLAND

Environment and climate

Scotland occupies the northern portion of Great Britain and is traditionally divided into three geographic regions from north to south: the Highlands, the Lowlands, and the Southern Uplands. The country is well known for its mountainous and beautiful scenery. Most of upland Britain, including the highest peaks, is contained within the borders of Scotland.

The Scottish weather is unlikely to be high on the list of factors that attract tourists to Scotland. Indeed, in a Scottish Tourist Board survey the weather was listed as a major source of complaint. However, temperatures are milder than might be expected given Scotland's northerly latitude, being moderated by the surrounding oceans (Table 4). Annual precipitation ranges from 3,810mm in the Highlands to about 635mm in the eastern areas. Snowfall in Scotland is extremely variable from year to year. In recent years, there has been an increase in the vigour and frequency of westerly airflow, which has meant a reduction in the annual frequency of winter frosts and snow days. Climate models indicate that winters and summers will become warmer in the future; however, this will be accompanied by a more active hydrological cycle and increased precipitation (Hulme and Jenkins, 1998). Temperature

Table 4: Mean January and July temperatures in Scotland

	Mean January temperature	*Mean July temperature*
Eastern coastal region	3.9°C	13.8°C
Western coastal region	3.1°C	15.0°C
Edinburgh	3.5°C	14.5°C

trends will determine whether precipitation falls as snow or rain in the next few decades (see Figure 3).

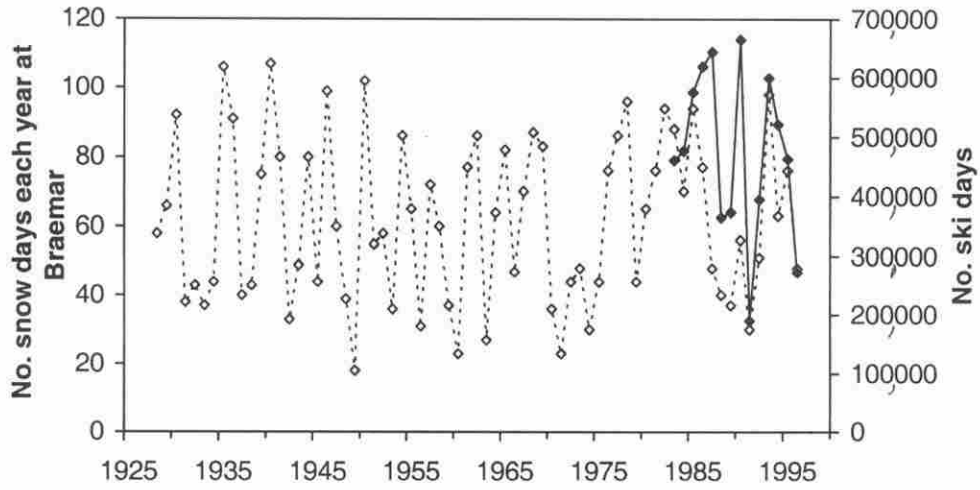
Tourism

Tourism is an important industry in Scotland and directly provides over 155,000 jobs. Two of the tourist activities most sensitive to climate change in Scotland are skiing and golf. There are 550 golf courses in Scotland (Scottish Tourist Board personal communication, 1999). Some of the world's leading golf courses are located in Scotland: the Old Course at St Andrews and other Open Championship courses at Carnoustie, Muirfield, Royal Troon and Turnberry. Skiing is the second major tourist activity that is potentially sensitive to climate change. Although the Scottish skiing industry is a small and specialised market, it is very important to the local economy. During the period 1993–95 around 0.1 million skiing trips were taken annually. Expenditure on these trips is estimated at about £16m per year, bringing valuable income and jobs to the local area.

Potential impacts

The domestic holiday market is influenced by short-term weather fluctuations, with warmer temperatures encouraging more British residents to take holiday trips to Scotland, especially for outdoor pursuits. In the long term, a better guarantee of warm weather should lead to a growth in both short breaks and main holiday markets (CCIRG, 1996; Giles and Perry, 1998) but could be adversely affected by an increase in precipitation. The UK will also

Figure 5 Number of days with lying snow each year at Braemar (dashed line) since 1927, and the more recent record of ski days at the five main Scottish skiing centres (solid line)



Source: Palutikof, 1999

grow in popularity as a holiday destination in the international scene if traditional overseas resorts become unpleasantly hot (Agnew, 1999). Coastal golf links could be threatened by an increase in storm frequency, rising sea levels and accelerated coastal erosion (Perry, 1997) and an increase in the incidence of flooding. The skiing industry is sensitive to climate variability; there is a clear relationship between the number of days with snow lying and the number of ski days (Figure 5). Increasing temperatures could reduce the number of days with snow lying, and hence the viability of the skiing industry (Smith, 1990; Palutikof, 1999; Harrison *et al.*, 1999). There may be a greater risk of snow avalanches (Perry, 1997).

EUROPEAN LAKES

Environment and climate

The European lakes, such as Lake Zurich in Switzerland and Lake Balaton in Hungary, are important tourist attractions for water-based recreation activities. However, European lakes are suffering from cumulative environmental stresses. For example, the overuse of nitrate fertilisers in agriculture has caused groundwater to become contaminated with phosphates and is threatening the aquatic environment of Lake Balaton. Problems are exacerbated in shallow lakes such as Lake Balaton, which covers an area of 598km^2 but has an average depth of only 2–3 metres.

The climate in Hungary is continental, with long, dry summers and severe winters, but is moderated by oceanic influences. The annual mean temperature is 10°C; however, in the hottest month, July, it is 21.7°C and in the coldest month, January, it is −1.2°C. Switzerland has a central European mild continental climate, with temperatures typically 20–25°C in summer and 2–6°C in winter. Climate statistics for three Swiss lakes are given in Table 5.

Temperature, rainfall and wind are the key climate parameters driving the physical behaviour of a lake. Any changes in these variables will have significant consequences for the hydro-ecology of the lakes. Output from general circulation models project an increase in temperature (Figure 6) and a drier precipitation regime for the Lake Balaton basin (Bartholy *et al.*, 1995) and for central Europe in the summer. Lakes at high altitudes and high latitudes are particularly sensitive to climate warming (Sommaruga *et al.*, 1997). Some lacustrine systems such as Lake Zurich comprise an approximately balanced input-output system and are better able to cope with climatic variability. However, the response of such complex catchments to long-term climate change remains unclear.

Tourism

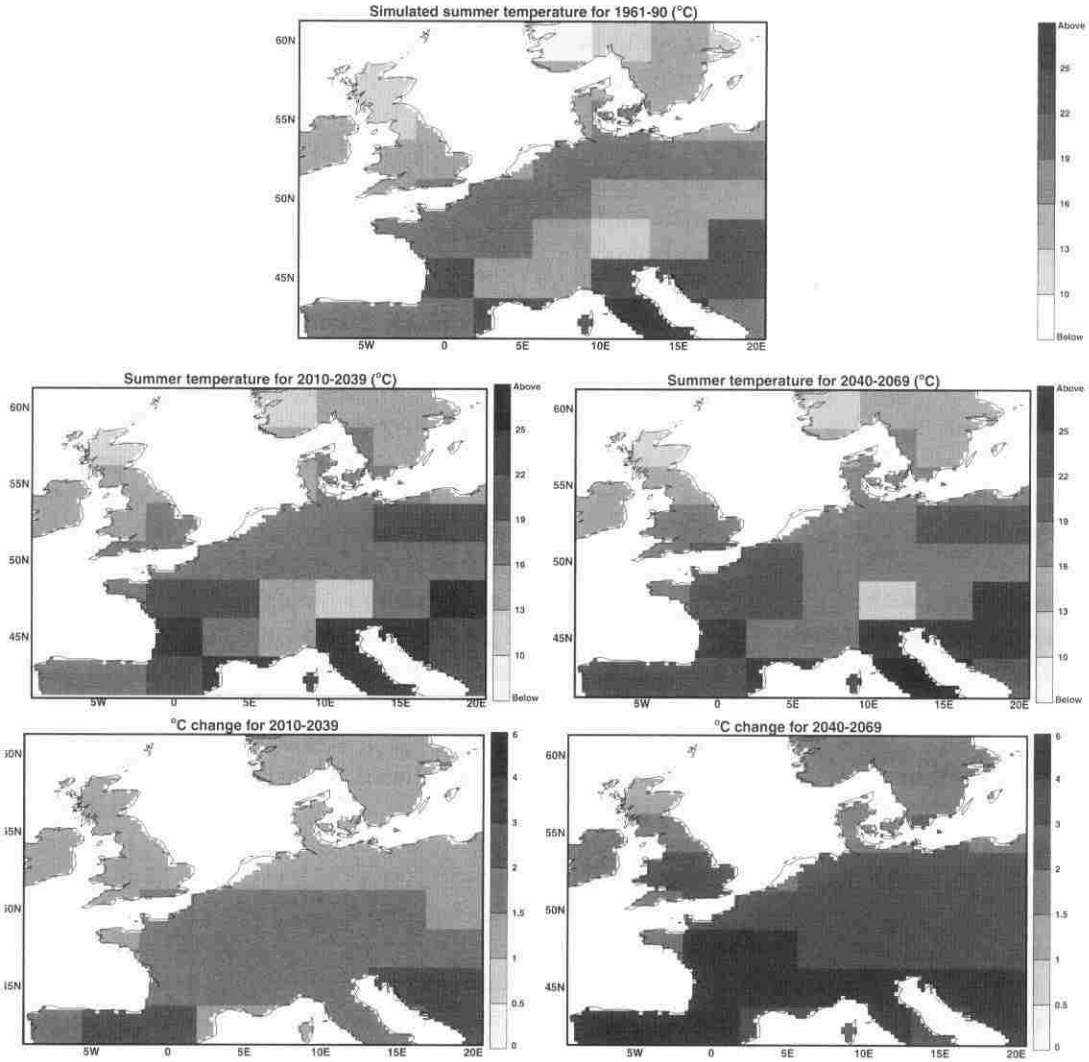
Switzerland's principal tourist attractions are the lakes and the mountains. In 1998, a total of 3.2 million people visited Zurich (Swiss Federal Statistical Office, 1999). In Hungary, tourism has developed rapidly

Table 5: Climate statistics for three Swiss lakes, 1998

Lake (elevation)	*Mean temperature* (°C)	*Total rainfall* (mm)	*Total sunshine* (hrs)
Geneva (420m)	10.8	826	2,014
Lausanne (461m)	11.3	1,046	2,031
Zurich (556m)	9.6	1,044	1,609

Source: Swiss Meteorological Institute, 1999

Figure 6 Evolution of summer temperatures (JJA) for the European region as estimated by HadCM2 GCM with the IS92a emissions scenario



and is an important source of foreign exchange. Lake Balaton is the largest freshwater lake in Central and Eastern Europe and is the second most important tourist destination in Hungary, after Budapest. In 1994, nearly 2.5 million tourists visited the lake, purchasing goods and services worth approximately US$540,000 (Ratz, 1998).

Potential impacts

Global warming threatens the freshwater ecosystems upon which many outdoor recreational activities depend (Wall, 1998). Ephemeral streams and small rivers are particularly vulnerable to climate variability, and any reduction in runoff could curtail recreational fishing. Increasing temperatures and higher evaporation rates will lower lake levels and may change the tourist potential of the shorelines (Smith, 1990). Fixed waterfront facilities, such as marinas, will be particularly vulnerable to any change in lake levels. Without appropriate action, lower water levels combined with

higher temperatures could increase concentrations of pollution close to shorelines and encourage the formation of algal blooms (Ostendorp *et al.*, 1995).

EAST AND SOUTH AFRICA

Environment and climate

Kenya, Tanzania and South Africa each support abundant and varied wildlife of immense scientific and economic value. More than 21,000km^2 have been set aside as national parks in East and South Africa, harbouring one of the world's last and greatest wildlife populations. The Serengeti alone is home to more than a million wild animals. Lake Manyara National Park, lying at the foot of the Great Rift Valley, is a popular haven for a variety of animals and birds, and the Masai Mara Game Reserve contains large populations of wildebeest, antelopes, zebras and lion.

Southern African temperatures warmed by about 0.05°C per decade in the 20th century, consistent with the average temperature for the continent as a whole. Rainfall has decreased during the past two decades, and there were several serious droughts in the 1990s (Hulme *et al.*, 1996). Climate model results suggest that temperatures will continue to increase, although the effect on rainfall is uncertain. The temperature increase is likely to be highest in arid zones in southern Africa, and slightly less intense in the equatorial zone of eastern Africa.

Tourism

Travel and tourism is one of Kenya's top two foreign exchange earners and is estimated to have generated 12 per cent of Kenya's GDP in 1999 (TTI, 2000). Visitors are attracted to the equable Indian Ocean beaches, and the 25 national parks and 23 game reserves. It is estimated that eight out of ten visitors come to Kenya for the wildlife. However, ethnic unrest and political uncertainties in 1997, coupled with the devastating effect of the El Niño rains, have contributed to the recent poor performance in tourism (TTI, 2000). Tanzania has a huge potential for tourism and has set aside 23,000km^2, nearly 26 per cent of the total land area, as protected and conservation areas. Tourism is increasing annually, although Tanzania still earns less in tourist receipts than Kenya (WTO, 2000). In South Africa, tourism is the sector benefiting most from the end of apartheid. Tourism accounts for only 2.6 per cent of South African GDP (the global mean is 4.2 per cent); however, international arrivals have more than doubled since 1992 (Seekings, 1999). The chief tourist attractions are the 'pleasant' climate, the scenery and the wildlife reserves, such as Kruger National Park.

Potential impacts

Climate change may increase the frequency of flooding (IPCC, 1996), drought (Benson and Clay, 1994) and land degradation (Bonkoungou, 1996), and subsequently reduce the viability of recreation activities and wildlife safaris (Zinyowera *et al.*, 1997). The distribution of wildlife in Lake Manyara National Park and the Masai Mara Game Reserve is closely connected to the climatic seasons. Changes in climate and hydrological conditions could alter breeding and migration patterns of birds and other wildlife (Walker, 1991). Flamingos, for example, have deserted their lake habitats due to their sensitivity to changed environmental conditions. The annual migration of wildebeest, zebra and antelope from the Serengeti is one of the main attractions of the Masai Mara Game Reserve. As the growth of grass and vegetation changes with altered rainfall patterns, there will be corresponding shifts in migration patterns (Hernes *et al.*, 1995). Any redistribution in wildlife could threaten population numbers, which may in turn reduce the appeal for tourists. More

frequent droughts would also increase the pressure on the reserve by pastoralists.

Infrastructure is crucial for tourism, but could be adversely affected by climate change. Heavy rainstorms and flooding can cause temporary closure of tracks and bridges (Zinyowera *et al.*, 1997), making the national reserves inaccessible. Periods of intense rainfall, such as the 1997–98 El Niño rains, can leave the park roads impassable for prolonged periods and result in reduced tourist visits and loss of revenue.

AUSTRALIA

Environment and climate

Australia, covering an area of 7,682,300km^2, is the sixth largest country in the world and has a coastline 36,735km long. The fertile coastal strip provides a sharp contrast to the dry and inhospitable interior of the Australian 'outback'. In the interior, large expanses of scrubland are interspersed by salt lakes, mountains like the MacDonnell Ranges near Alice Springs, and rock formations such as Ayers Rock/Uluru.

Australia has a very variable climate, ranging from the subtropical north to the significantly colder regions of the south. In the northern regions there are tropical monsoons in summer (November–February) while winters (July–August) are dry. In the southern regions, winter is the wet season although rainfall decreases rapidly inland. In the arid interior, extremely high temperatures, sometimes exceeding 50°C, are experienced during the summer months.

Climate models indicate an average summer (December to February) temperature increase of over 1.5°C by the 2020s and a summer temperature increase of 3–4°C by the 2050s for Australia. Model results also suggest that by the 2050s Australia will experience a reduction in cloud cover of 10–15 per cent (Figure 7), and a corresponding reduction in seasonal rainfall of 10–20 per cent.

Tourism

Tourism is one of Australia's largest and fastest-growing industries. Climatically it is a country conducive to outdoor holidays. The main attractions are the Great Barrier Reef, the Blue Mountains, water-based recreation activities (eg white-water rafting) and winter sports in the Australian Alps. Approximately 4 million tourists visited Australia in 1997. The Australian tourist industry generated an estimated total foreign-exchange earnings of US$16.1bn in 1997–1998 and directly accounts for more than 5 per cent of Australia's GDP (King and McVey, 1999). In many mountainous regions, the winter tourism industry is a major contributor to the local economy and creates about 12,000 full-time jobs during the skiing season (Buckby *et al.*, 1993), while in coastal regions, tourism to the Great Barrier Reef generates US$1.5bn annually for Queensland, Australia (Done *et al.*, 1996; Richmond, 1993).

Potential impacts

A continuing warming trend could have several knock-on adverse effects for the Australian tourist industry through a decrease in snow cover, an increased risk of bushfires, sea-level rise, coral bleaching and an increased risk of malaria. The Australian Alps have a winter snow cover lasting from a few weeks at the lower-elevation sites to up to four months at the higher-elevation ski resorts (Whetton *et al.*, 1996). As a result of global warming the skiing season may be shortened (Galloway, 1988). In the 'worst-case scenario', by 2030 the average snow cover could contract by 66 per cent (Table 6), suggesting that there would be insufficient natural snow for viable commercial ski operations (Whetton, 1998). König (1998) has estimated that Australian ski resorts may lose 44 per cent of their skiers if winters with little natural snow became more common, and winter sports may concentrate in the higher alti-

Figure 7 Evolution of summer cloud cover (DJF) for Australia as estimated by HadCM2 GCM with the IS92a emissions scenario

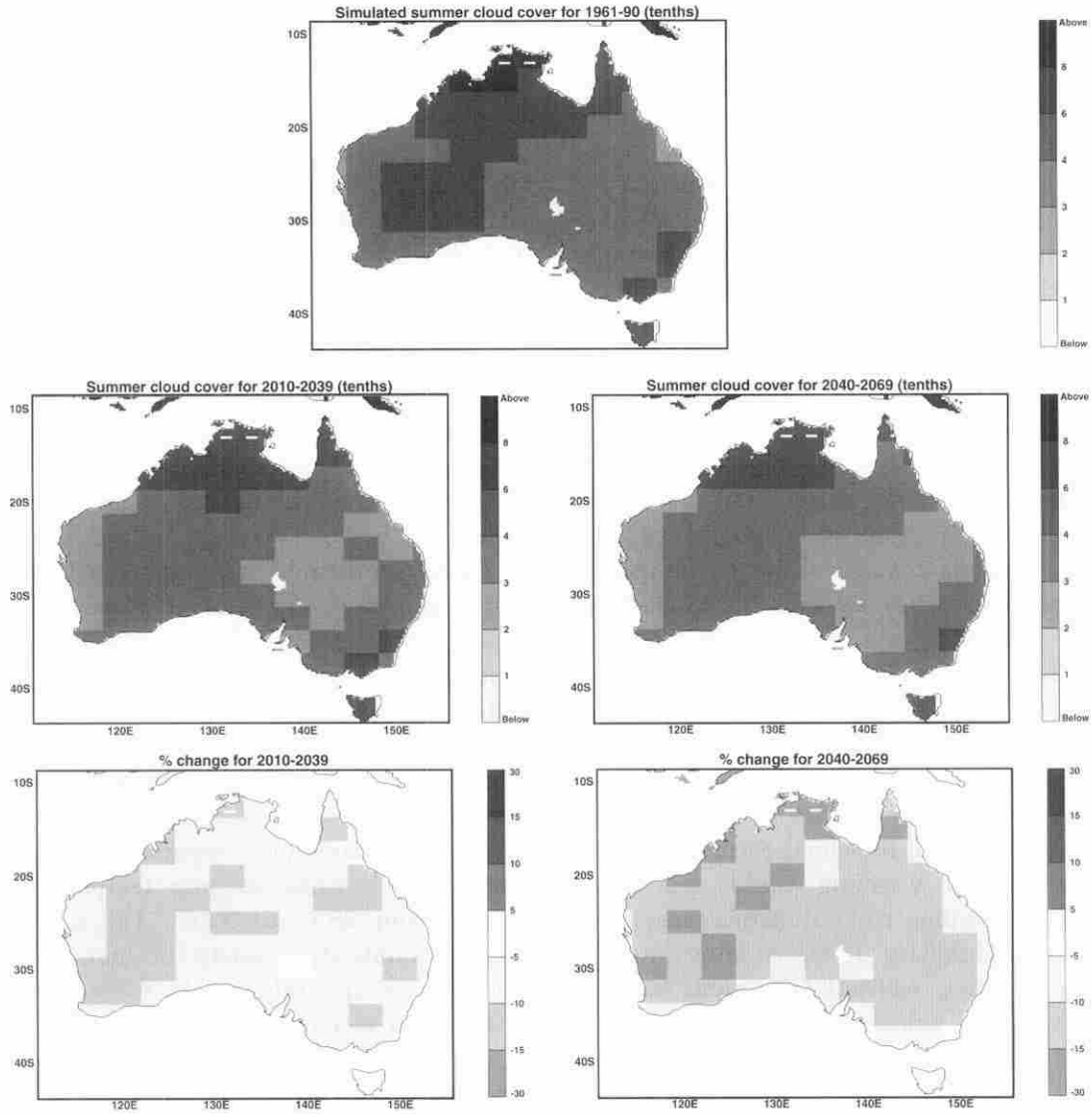


Table 6: Simulated snow-cover duration for selected sites in Australia (Whetton, 1998)

Location	*Elevation (m)*	*Current snow-cover duration (days)*	*Simulated snow-cover duration (days), CIG scenarios (1996)*	
			2030	2070
Lake Mountain	1,400	29	0–17	0–12
Falls Creek	1,643	113	64–100	0–92
Mt Buller	1,805	127	80–115	5–107
Mt Bogong	1,986	159	123–150	45–144
Mt Kosiciusko	2,228	187	152–177	92–172

tude resorts. The most vulnerable low-altitude resorts are Mt Buller, Mt Buffalo, Selwyn Snow Fields and Mt Baw Baw.

An increase in temperature and precipitation is expected to influence the seasonal and geographical abundance of the major malaria vector species and vertebrate hosts. In turn, this would raise the potential for transmission of mosquito-borne diseases in both tropical and temperate Australia (Liehne, 1988). Another potential health risk is the increased likelihood of developing skin cancer, as decreasing cloud cover increases exposure to harmful ultra-violet radiation (WMO, 1995).

Australia's coastline includes 12,000 islands and extensive estuarine and wetland areas, which could be inundated by sea-level rise. In a warmer climate the risk of storm surges may increase due to sea-level rise and changes in the intensity and frequency of tropical cyclones (McInnes *et al.*, 1999). This would adversely affect tourism in leading resorts such as Cairns, North Queensland. Coral reefs are a crucial source of tourist income (Carte, 1996; Wilkinson, 1996), but coral-bleaching events associated with global warming could spell catastrophe for these tropical marine ecosystems (Hoegh-Guldberg, 1999). At above normal temperatures, reef-building corals become increasingly vulnerable to damage by light and die in large numbers (Birkeland, 1997). It has been estimated that in the next 20–40 years, the Great Barrier Reef will be severely damaged by increasing sea temperatures, seriously reducing its tourist appeal (Hoegh-Guldberg, 1999).

SOUTH-EASTERN AND MID-ATLANTIC US COASTLINE

Environment and climate

Florida and Assateague Island, Maryland, are two popular tourist destinations on the south-eastern and mid-Atlantic coastline of the USA which are sensitive to climate change. Florida is the most south-eastern state of the USA. It covers a total area of 150,520km^2, which includes over 166 rivers, more than 30,000 lakes and a tidal shoreline totalling 3,648km in length. The southernmost point in Florida is 2,700km from the equator, closer than any other part of continental USA. Florida's mild and humid climate derives from the fact that the state is a subtropical peninsula surrounded by the moderating waters of the Gulf of Mexico and the Atlantic Ocean. Average January temperature ranges from approximately 12°C in the north-west to 21°C in the Keys. Summer temperatures average between 27°C and 29°C, while summer rainfall averages from 170mm in the central region to 150mm in the north-west.

Assateague Island is an uninhabited barrier island built by sand that has been raised from the ocean floor by the persistent force of waves. The island is 59km long, extending southwards from Ocean City, Maryland to Chincoteague, Virginia, and is 5km across at its widest part. Maryland has a more seasonal climate than Florida. Winter maximum temperatures are on average 6°C, while summer temperature ranges from 28°C to 30°C. The region receives moderate amounts of rain, with the highest monthly totals in summer (100mm on average).

Tourism

In 1998, domestic and international tourism expenditure amounted to US$525.4bn in the USA (Ross, 1999). Tourism is the second largest sector in the economy and the largest employer, providing 14.4 million jobs annually. Tourism in the USA is largely coastal-motivated, with 85 per cent of all US tourist revenues being generated by the coastal states (Houston, 1996). Florida is the most popular international destination state for tourists. The US market share and number of annual visitors to Maryland and Florida are given in Table 7.

Table 7: US market share and number of visitors for Maryland and Florida

State/territory	*1997 market share (%)*	*1997 visitation (000)*	*1996 market share (%)*	*1996 visitation (000)*	*Volume change (%)*
Maryland	1.1	266	1.2	272	–2.1
Florida	25.1	6,073	25.2	5,710	+6.4

Source: Tourism Industries, International Trade Administration 5/98

The main coastal tourist attractions are beach activities, surf and deep-sea fishing, boating, surfing, dolphin watching, walking and the coral reefs. Florida's reefs alone contribute $1.6bn to the US GDP.

Potential impacts

Sea-level rise is of particular concern to Florida since many recreational and tourist activities are concentrated along the state's beaches, which are of low gradient and are especially vulnerable to erosion (Leatherman, 1989). For the tourist resorts of south-east USA, the greatest threats of climate change will be to the geomorphology and ecology of the coastal zones. Wall (1993b) estimated that a rise in sea level of 30cm could cause a retreat in the beaches of Florida of 31–305m. Ecologically important wetlands, such as the Everglades, are potentially under considerable threat (Wall, 1998). Evidence from the past century indicates that coral-bleaching events may become more frequent and severe as global warming continues. Changes in these ecosystems could have a major adverse impact on tourism activities (US Department of State, 1999). There is some evidence that there may be an increase in the frequency and intensity of severe storms which may discourage holiday-makers from travelling to at-risk destinations (Smith, 1993). The mid-Atlantic and south-eastern coastal marshes and barrier islands, including the Assateague National Seashore in Maryland, are threatened by sea-level rise, erosion and storm damage. Coastal wetlands are already eroding in the state of Maryland and beach renourishment has been prominent in heavily developed areas, such as Ocean City (Leonard *et al.*, 1990).

BRAZIL

Environment and climate

Brazil is the largest country in South America with a total land area of 8.5 million km^2 and 7.5,000km of coastline. Dense tropical forest covers 47 per cent of the landmass. The Amazon rainforest contains 30 per cent of the world's remaining forest and is the world's largest repository of biological diversity (Bazzaz, 1998). Brazil can be divided into six major geographic regions delimited by vegetation: tropical rainforest in the Amazon basin; the semi-deciduous forest of the eastern coastal lowlands and plateau; the '*caatinga*' (dry bush) of the semi-arid north-east; the '*cerrado*' (woodland savannah) of the central regions; the needle-leafed pine woods of the southern highlands; and the Mato Grosso swamplands of the western central plains.

The country experiences a wide range of climatic conditions, from the humid equatorial states of the north (22–26°C) to the cooler and drier savannah grasslands of the central and southern uplands (18–21°C). In the upper regions of Amazonia, 2,000mm

of rain falls annually. However, most of Brazil has moderate rainfall (1,000–1,500mm a year), with summer (December–April) the wettest season.

Tourism

Although tourism accounts for only 2.5 per cent of GDP in Brazil, this economic sector is regarded as the one with the most promising prospects for future development. The number of foreign tourists visiting Brazil is growing annually by 7 per cent. Rio de Janeiro, with its famous beaches, is the centre of the tourist trade. Other attractions are the Iguacu Falls, the Amazonian rainforest, the wildlife of the Pantaal and the beaches of the north-east coastal region. Future plans are to promote ecotourism (via the SEBRAE programme of Rural Ecological Tourism) which only accounts for 1 per cent of the present tourist market in Brazil (report from Reuters for Environmental News Network, 15th December, 1997).

Potential impacts

INPE (National Institute of Space Research, Brazil) estimated that in 1997, deforestation of the Brazilian Amazonia had reached 530,000km^2, an area corresponding to the size of France (Fearnside, 1999). Hulme and Sheard (1999) have shown that future climate changes could have a severe impact on South America's ecosystems. Models indicate a considerable reduction in the Amazonian rainforest (Figure 8) caused by rising temperature and decreasing rainfall. This experiment does not account for forest dieback caused by the direct impacts of human activity. A disturbance to the natural ecosystem of this magnitude may lead to further biodiversity losses, reduced rainfall and runoff (through a decrease in evapotranspiration), and impacts on the global carbon cycle (White *et al.*, 1999).

Accelerated sea-level rise could have serious impacts on the tourist activities of coastal cities. Muehe and Neves (1995) list 10–15 coastal cities in Brazil that are at risk from sea-level rise. Collectively, these cities have a coastal frontage of 1,300km, or 17 per cent of the shoreline. At Recife, where there is a population of 2 million people, tide-gauge measurements from 1946 to 1988 indicate a sea-level rise of 5.6mm/year (Muehe and Neves, 1995). With increased beach erosion, shoreline recession may exceed 20m at Boa Viagem Beach, the most valued beachfront property in the city.

Figure 8 Predicted vegetation types for the present day and the 2050s (2040–2069)

Source: Hadley Centre, 1998; diagram supplied by Dr A. White (ITE, Edinburgh)

CONCLUSIONS

Climate change presents a multifaceted challenge to the tourist industry. The potential impacts of climate change have been reviewed for ten key holiday destinations. These effects are shown to be extremely wide ranging and may have far-reaching implications for international tourism. Climate impacts can be classified into two types: direct and indirect.

Climate change may directly influence tourism via the decision-making process. For decisions such as '*when* to go on holiday?' and '*where* to go on holiday?', weather and climate have an influence at both the destination resort and the source region. Some resorts are likely to become less attractive as temperature and humidity increase above comfort levels (such as in the eastern Mediterranean); other destinations (for example the UK) may become more attractive as warm summer weather becomes a greater certainty.

Indirect impacts arise mainly as a result of the impact of climate change on the local environment. For example, without intervention, sea-level rise and its effects on coastal erosion will severely threaten the recreation and tourist activities associated with coastal resorts. Decreasing snow cover may adversely affect low-elevation ski-resorts in the European and Australian Alps. A reduction in air quality associated with an increase in the incidence of photochemical smogs is already noticeable in many large metropolitan areas. With an increase in the frequency of anticyclonic (calm) conditions, concentrations of pollutants may increase to dangerous levels and further threaten tourist activities in large cities such as Athens and Los Angeles. Other potential health threats include an increase in the transmission of insect- and water-borne diseases, and a greater risk of skin cancer with reduced cloud cover. Many regions have become popular tourist destinations because of some unique environmental feature, such as the Great Barrier Reef in Australia and the Amazon forest in Brazil. However, recent scientific research suggests that a continued warming trend could have a detrimental impact upon these ecosystems in the form of coral bleaching and forest die-back.

The most vulnerable tourist resorts and regions are a function of (i) the likely magnitude and extent of the climate impact, (ii) the importance of tourism to the local economy and (iii) the capacity to adapt. For example, tourism in Brazil currently accounts for a minor component of GDP but the adverse effects of climate change upon the Brazilian ecosystems, on which much tourism depends, may be widespread. In Spain, the climate impacts are likely to be less extensive but tourism is a vital component of the national economy. Some tourist destinations are extremely vulnerable to climate change. For example, in the Maldives there exists a very fine balance between the environment and human activity, and the capacity to adapt to climate change is low. Any further increase in sea level will threaten not only local tourism but also the very existence of these islands.

Nevertheless, the tremendous capacity of humans to respond and adapt to their changing environment must not be negated. Indeed, some of the consequences of climate change may present opportunities for the tourist industry to capitalise upon. Thus, the future balance of international destinations will be influenced by climate change, the environmental and human response to climate change, and interactions with other market forces.

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