CLIMATE CHANGE: THE IMPACT ON TOURISM COMFORT AT THREE ITALIAN TOURIST SITES

Marco Morabito[1], Alfonso Crisci[2], Giacomo Barcaioli[2], Giampiero Maracchi[2]

1. Interdepartmental Centre of Bioclimatology - University of Florence - Piazzale delle Cascine18 Florence, 50144, Florence, Italy
2. Institute of Biometeorology, CNR, Via Caproni 8, 50145, Florence, Italy

E-mail address: m.morabito@ibimet.cnr.it (M. Morabito)

ABSTRACT

A large number of studies have shown that climate change has a great impact on human health, and on other living organisms. In the Mediterranean area, in particular, the fact that heat-waves are frequent and persistent, often associated with low water availability, and that winter precipitation has undergone modification related to the rising altitude of the thermal zero, highlights concerns that such change could have an increasing impact on tourism. Rather than studying the Mediterranean as a whole, this paper focused on Italy. Many Italian cities are characterised by a mild climate, generally without temperature extremes. Together with other attractive attributes, such as history, architecture and favourable geographical position, climate helps to make Italy an important destination for tourists. This study was based on a biometeorological approach to tourist activities in all seasons by using climatological scenarios in three Central Italian tourist sites: Firenze, an important city for cultural and architectural tourism, Grosseto, a city involved in summer tourism and connected with environmental activities during all seasons, such as agro-tourism, and Monte Cimone, an important site for sports in winter and mountain holidays in summer. Local climatic scenarios, derived from a downscaled HadCM3 Global Model series for the period 2001-2080, were carried out for these three localities. Local scenarios consisted of: a daily series of maximum and minimum temperatures, amount of precipitation, average relative humidity, average wind velocity and global radiation. A biometeorological index based on the human energy balance, the PET, was applied. Trend analysis of seasonal precipitation was also performed for each site. The main results were represented by favourable winter conditions for tourist activity, but a large and unexpected increase in extreme discomfort caused by hot conditions for summer tourist activity. This was particularly true for tourists that were not acclimatized to such weather conditions.

KEYWORDS: *Climate, Tourism, PET, Biometeorological index*

INTRODUCTION

One of the major concerns about the potential for climate change is that variation in extreme climatic events will occur. Climatic change due to the enhanced greenhouse effect is likely to have substantial impacts on human beings, other living organisms, and activities such as tourism (1, 2, 3). This is especially true regarding the choice of destination for seasonal activities. For example, traditional beach resorts may become too hot and humid for summer holidays, because they will cause climatic stress on tourists. On the other hand, insufficient snow precipitation on mountain sites may severely affect winter sport resorts.

Most studies have shown climatic changes on historical series in terms of increases in extreme high temperatures, decreases in extreme low temperatures and increases in intense precipitation events (4, 5, 6, 7, 8). These results are unable to evaluate the real influence of the atmospheric environment on humans, in particular on tourists who need information about physiological strain, especially when they are not acclimatized to specific local weather conditions. Relatively little is known about the effects of climate on tourism or the role it plays (9). Only a few studies (10, 11) have investigated the climate change effect from a biometeorological point of view, mostly by using simple biometeorological indices, such as the Apparent Temperature index (12, 13). Also, studies on the application of biometeorological indices on climatological scenarios are also few and far between (14).

The aim of this study was to evaluate the future seasonal variations of extreme biometeorological discomfort, caused by hot and cold conditions, in three Italian sites that are characterized by a great reliance on tourism. Since tourists respond to the integrated effects of the atmospheric environment rather than to climatic averages (9), a thermal index based on the energy balance model for humans was employed. The three areas studied are situated in Central Italy: Firenze (λ = 11°11' E; Φ = 43°47' N) at 76m a.s.l, Grosseto (λ = 11°70' E; Φ = 42°45' N) at 10m a.s.l., and Monte Cimone (λ = 10°42' E; Φ = 44°11' N) at 2,165m a.s.l. The first two sites are located in the Region of Tuscany, while the third site is situated in the Apennine Mountains in the Region of Emilia Romagna, on the border with Tuscany.

METHODS

Climatological scenarios

A climatological series of daily maximum and minimum air temperatures (°C), daily average relative humidity (%), wind velocity (ms^{-1}), global radiation (Wm^{-2}) and daily cumulative precipitation (mm) were derived by a downscaling technique from the Hadley Centre's HadCM3 scenario series (15). This series corresponds to the Summary for policymakers-Emission Scenarios (SRES) (16) classes A2 and B2, obtained under the CLIMAGRI project (*www.climagri.it*). The

HadCM3 GCM model is able to represent the main physical and chemical atmospheric processes, taking into consideration both economic development and the emission rate of greenhouse gases (Fig. 1).

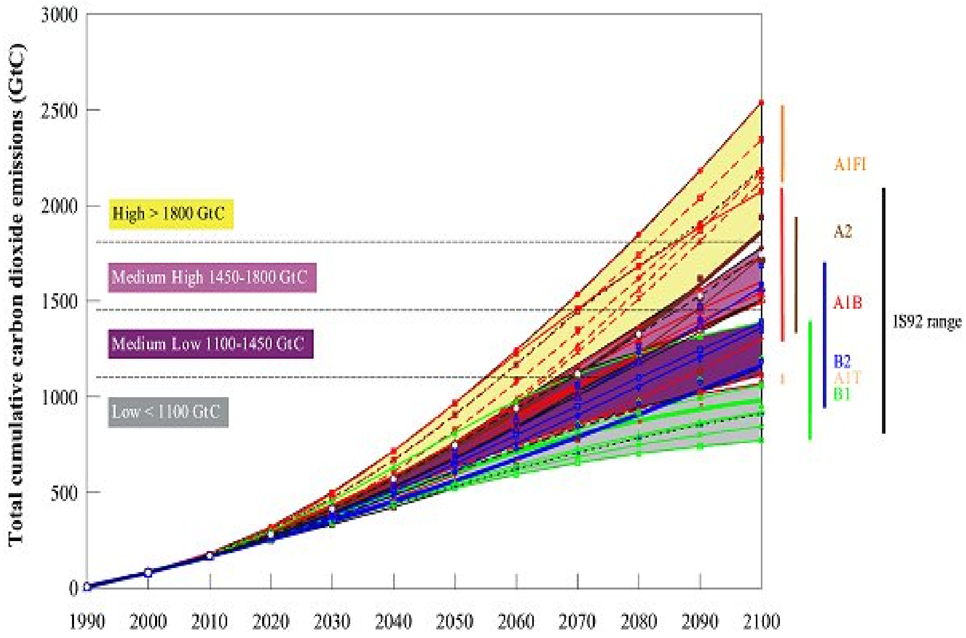

Figure 1: Scenarios's emission SRES hypothesis (16)

The main advantage of using the HadCM3 model was its consideration of the interaction between atmosphere and ocean (Atmosphere-Ocean General Circulation Model: AOGCM).

The downscaled series concerned the three sites in the Region of Tuscany. The methodology adopted to produce the local series, relative to atmospheric variables, was carried out by the following steps:

- A linear interpolation was calculated on the HadCM3 daily series using irregular triangulation, TIN. The results were represented by the series which has the geographical location of the specific sites, and corresponds to a real observed meteorological series. The products of interpolation kept the statistical proprieties of the original series of scenarios owing to the linearity of this interpolator.
- A numerical calibration of the obtained series was applied using a historical series recorded in each specific site. Among the innumerable techniques which could be used, the most effective seems to be the application of a linear regression model for each month, where the daily values were selected. Each monthly model was able to assess the relation among the quantile of the distribution of the series of scenarios interpolated, and also the observed series for each parameter involved. This kind of analysis was time invariant

because the regression model works on selected series. Finally the models were applied to the unselected series of scenarios. The results were a series of calibrated scenarios that have a daily variability similar to real observations, but have maintained the information about trend provided by the GCM model.

Local climatic scenario data so obtained was used for climatological inference for the local sites. The calibration procedures are written in PERL language, and are an internal product of CLIMAGRI project.

Biometeorological index

Both climatological data scenarios (A2 and B2) were utilized to assess the Physiological Equivalent Temperature (PET) (17, 18) by using the RayMan model (19). The male average used was: 35 years old; 1.75 m in height; 75 kg in weight; with moderate clothing (0.9 clo); standing and with a metabolic level corresponding to light activities (80 W). This index was applied to assess two daily conditions:

1. Diurnal PET (at 16:00 hours), by using the daily maximum air temperature (°C); the corresponding relative humidity (%), assessed by using the empirical formula provided by the National Weather Service-Alabama University (http://www.srh.noaa.gov/bmx/tables/rh.html), replacing the dew point temperature with the available daily minimum air temperature; the daily average wind velocity (ms^{-1}); the daily global radiation (Wm^{-2}); and the daily average cloud cover (in eighths) assessed by the percentage of solar radiation extinction.
2. Nocturnal PET (at 08:00 hours), by using the daily minimum air temperature (°C); the daily average relative humidity (%); the daily average wind velocity (ms^{-1}); the daily global radiation (Wm^{-2}); and the daily average cloud cover (in eighths) assessed as by the percentage of solar radiation extinction.

Statistical analyses

A statistical analyses was made for each site and for each season for the period 2001-2080. The seasons were considered as follows: winter (December, January and February); spring (March, April and May); summer (June, July and August); autumn (September, October and November). The diurnal and nocturnal daily PET were assessed on a decadal basis (8 decades) and the relative frequencies as compared to the first decade were assessed. For winter and summer all days with diurnal or nocturnal extreme discomfort caused by cold (PET ≤ 4°C), or hot (PET > 41°C), conditions were considered. For spring and autumn all days with extreme discomfort caused by cold, or hot, conditions were considered using slightly less severe criteria (cold= PET ≤ 8°C, and hot= PET > 34°C). Also, the number of days per decade with a daily amount of precipitation over 0.2 mm (rainy days) was assessed on a seasonal basis and relative frequencies, to the first decade, were calculated. With the aim of the detection of trends in the time series, a parametric method of linear correlation analyses was applied. The Pearson product moment correlation coefficient (r) was assessed and the statistical significance (P) was tested by using the Student t-test.

RESULTS

Winter

All sites showed negative and significant linear trends of diurnal (Tab. 1) and nocturnal (Tab. 2) extreme discomfort caused by cold conditions. The decrease in the number of days with uncomfortable conditions was higher during the diurnal period than during the nocturnal period. The maximum diurnal decrease for the three sites was observed for Grosseto (A2: 13.2% per decade; B2: 7.3% per decade), followed by Firenze, while the minimum was observed for M. Cimone (Fig. 2). Regarding the trends of the number of days with an amount of precipitation over 0.2 mm, Grosseto showed a significant ($P<0.001$) linear decrease of 2.5% per decade. The other sites showed negative but not significant trends.

Table 1: Correlation coefficients of the seasonal trends of diurnal extreme discomfort conditions evaluated by using the Physiological Equivalent Temperature (PET) in the three sites of interest for tourism. Legend: * Statistically significant P<0.05; ** Statistically significant P<0.01; Statistically significant P<0.001; No D.: No extreme discomfort conditions measured

Discomfort	Sites	Pearson's correlation coefficients for diurnal discomfort conditions							
		Winter		Spring		Summer		Autumn	
		A2	B2	A2	B2	A2	B2	A2	B2
Cold conditions	M.Cimone	-0.86**	-0.79**	-0.88***	-0.88***	-0.91***	-0.91***	-0.97***	-0.84**
	Grosseto	-0.90***	-0.71*	-0.75*	-0.82**	No D.	No D.	-0.71*	-0.80**
	Firenze	-0.81**	-0.70*	-0.71*	-0.42	No D.	No D.	-0.87***	-0.93**
Hot conditions	M.Cimone	No D.	No D.	No D.	No D.	No D.	No D.	No D.	No D.
	Grosseto	No D.	No D.	0.91***	0.91***	0.98***	0.96***	0.96***	0.83**
	Firenze	No D.	No D.	0.88***	0.96***	0.98***	0.97***	0.96***	0.74*

Spring

Diurnal extreme discomfort caused by cold conditions showed a prevalence towards significant linear decrease in all sites (Tab. 1). The same situation was also observed regarding nocturnal discomfort conditions (Tab. 2), where a slight linear decrease (A2 4% per decade; B2 3% per decade), which was statistically significant for Grosseto and Firenze ($P<0.001$), was observed. On the other hand, high significant increases ($P<0.001$) in diurnal discomfort caused by hot conditions were observed for Grosseto (A2: 66.3% per decade; B2: 69.5% per decade) and for Firenze (A2:

73.5% per decade; B2: 77.6% per decade) (Fig. 3). The mountain site, M. Cimone, showed a significant negative trend (P<0.01) for rainy days. The only site which showed a positive trend was Firenze, which showed a significant increase (P<0.05) in days with precipitation, mostly evident in the second half of the 21st century.

Table 2: Correlation coefficients of the seasonal trends of nocturnal extreme discomfort conditions evaluated by using the Physiological Equivalent Temperature (PET) in the three sites of interest for tourism. Legend: * Statistically significant P<0.05; ** Statistically significant P<0.01; Statistically significant P<0.001; No D.: No extreme discomfort conditions measured

Discomfort	Sites	Pearson's correlation coefficients for nocturnal discomfort conditions							
		Winter		Spring		Summer		Autumn	
		A2	B2	A2	B2	A2	B2	A2	B2
Cold conditions	M.Cimone	-0.35	-0.43	-0.55	-0.63	-0.99***	-0.96***	-0.94***	-0.69*
	Grosseto	-0.94***	-0.92***	-0.91***	-0.95***	No D.	No D.	-0.94***	-0.89**
	Firenze	-0.85**	-0.73*	-0.90***	-0.91***	No D.	No D.	-0.93***	-0.82**
Hot conditions	M.Cimone	No D.	No D.	No D.	No D.	No D.	No D.	No D.	No D.
	Grosseto	No D.	No D.	No D.	No D.	No D.	No D.	No D.	No D.
	Firenze	No D.	No D.	No D.	No D.	No D.	No D.	No D.	No D.

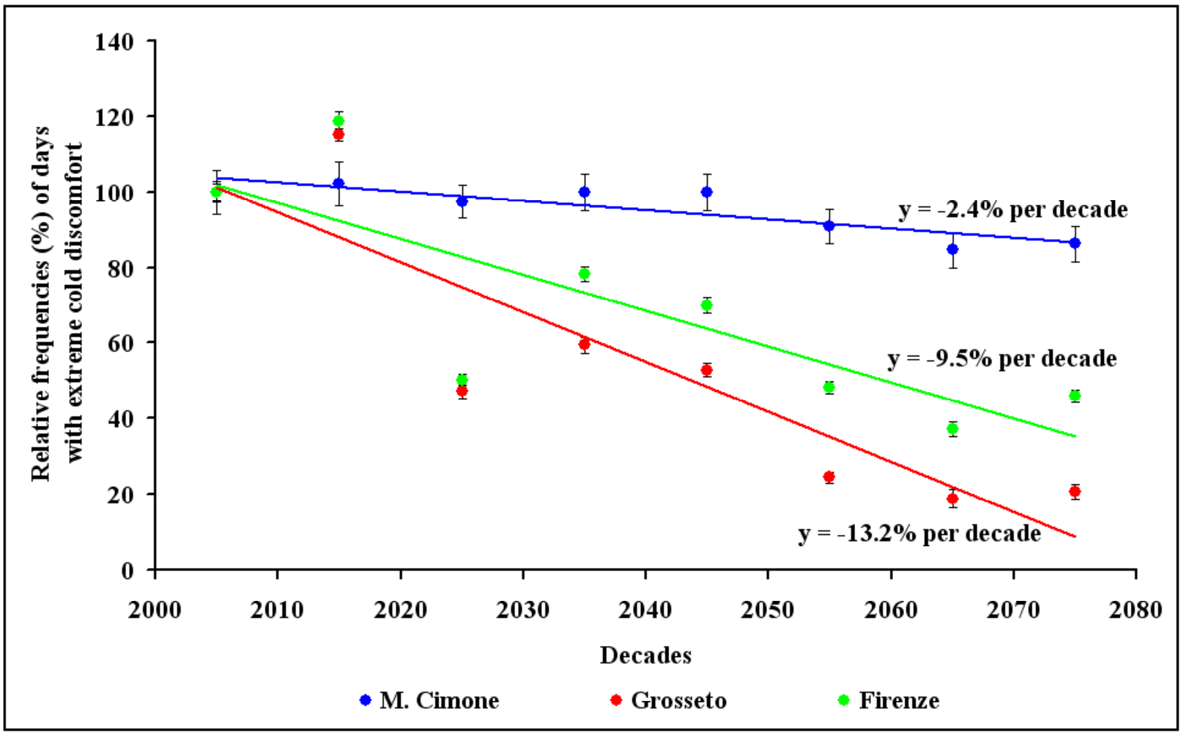

Figure 2: Relative frequencies of winter days with extreme diurnal discomfort caused by cold conditions evaluated by using the Physiological Equivalent Temperature (PET) to the climatological series of scenarios of class A2 evaluated with the HadCM3

Summer

A highly significant (P<0.001) decadal increase in extreme diurnal discomfort (Tab. 1), caused by hot conditions, was observed for Grosseto, ranging from 83.0% (B2) to 99.2% (A2) per decade, and for Firenze, ranging from 41.8% (B2) to 88.5% (A2) per decade. On the other hand a significant decrease (P<0.001) of extreme diurnal (Tab. 1) and nocturnal (Tab. 2) discomfort caused by cold conditions was only observed for M. Cimone. Negative trends for rainy days were observed in all sites. Linearly significant trends were observed for Firenze (P<0.05), with a decrease of 3.8% per decade, and for M. Cimone (P<0.05), with a decrease of 3.0% per decade (Fig. 4).

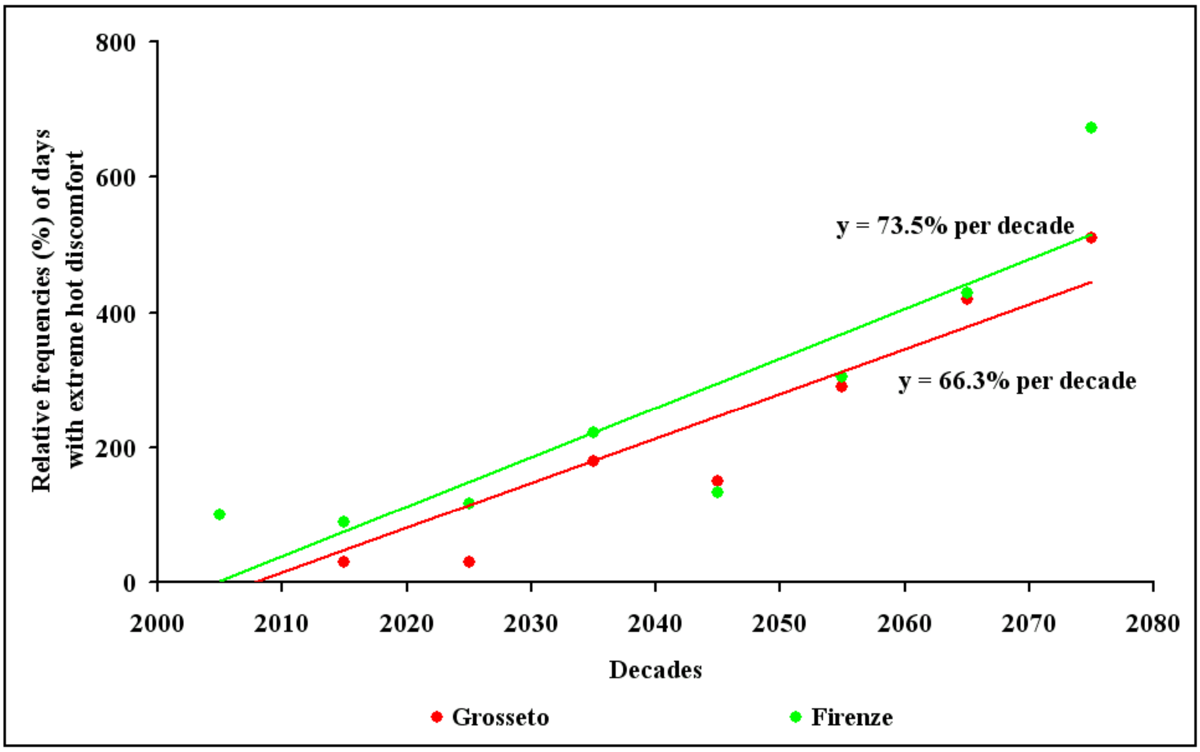

Figure 3: Relative frequencies of spring days with extreme diurnal discomfort caused by hot conditions evaluated by using the Physiological Equivalent Temperature (PET) to the climatological series of scenarios of class A2 evaluated with the HadCM3

Autumn

Significant linear decreases of diurnal (Tab. 1) and nocturnal (Tab. 2) discomfort caused by cold conditions were observed in all sites. On the other hand great increases in diurnal discomfort caused by hot conditions were observed for Firenze (A2: 122.1% per decade; B2: 23.2% per decade) and especially for Grosseto (A2: 170.4% per decade; B2: 62.9% per decade). The trends for rainy days were prevalently positive and statistically significant only for M. Cimone (P<0.05), with an increase of 1.2% per decade.

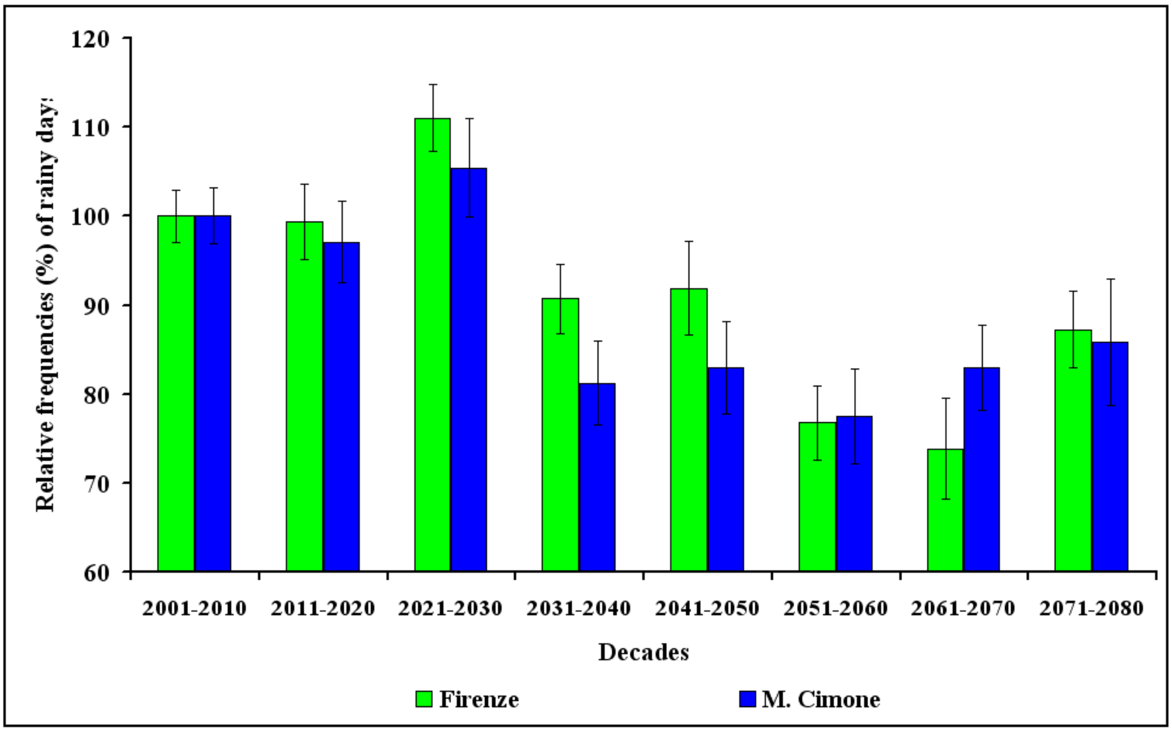

Figure 4: Relative frequencies of rainy days in summer obtained by using the climatological series of scenarios of class A2 evaluated with the HadCM3 for the city of Firenze and for M. Cimone

DISCUSSION

These surveys will be useful to explore perceptions of seasonal extremes of weather, and for their potential impacts on vacation planning. The reduction of extreme discomfort caused by cold conditions shows that winter will be favourable for tourist activity. On the other hand, summers will show more frequent extreme discomfort conditions, especially in urban environments. These results confirm those pointed out by the Third Assessment Report of IPCC (20), which showed an increase in the frequency of days with very high maximum temperatures during the 21st century. They also corroborate another study (21), carried out in Thessaloniki, in Northern Greece, which demonstrated that the temperature-humidity index (THI) will rise above a value for which everyone feels uncomfortable, for more than twice as long as present, by 2050. All of these conditions are very dangerous for the health of tourists who tend to be more vulnerable than locals, as they are not acclimatized to the place they are visiting (9). If summer became warmer and/or drier, tourists might suffer great discomfort and may be encouraged to remain closer to home.

The tourists that visit cities in Tuscany during the seasons of transition, such as spring and autumn, generally characterized by mild weather, will more often find extreme and unexpected hot conditions. Several authors (3), in a recent preliminary study, have already shown that the decisions of tourists are affected by weather fluctuations, especially with regard to short breaks in spring and autumn.

The present study shows that autumn, caused by the fact that the mountain site will present an increasing number of days with precipitation, will be favourable for tourists who practise sports on snow. On the other hand, the reduction in spring precipitation will anticipate the dry and hot summer season.

It will be necessary to extend these surveys to other sites, which will be fundamental for the identification and the evaluation of environmental information for business planning and decision-making in the recreation and tourism industry (9).

ACKNOWLEDGEMENTS

The authors wish to thank Dr. P. Bonasoni of the National Research Council (CNR) of the Institute of Atmospheric Sciences and Climate (ISAC) for the precious collaboration, and Dr F. Giovannini of ARPAT-Firenze (Agenzia Regionale per la Protezione Ambientale della Toscana) for providing meteorological data.

REFERENCES

1. Viner, D. and Agnew, M. 1999. Climate Change and its Impacts on Tourism. Climatic Research Unit, UEA. Report commissioned for WWF UK, WWF. http://www.wwf.org.uk/filelibrary/pdf/ tourism_and_cc_full.pdf.
2. Agnew, M.D. and Viner, D. 2001. Potential impacts of climate change on international tourism. Int. J. Tour. Hosp. Res. 3:37-60(R).
3. Palutikof, J.P. and Agnew, M.D. 2002. Climate change and the potential impacts on tourism. Proc. of the 15th Conference on Biometeorology and Aerobiology. 27 Oct./1 Nov. Kansas City, Missoury.
4. Easterling, D.R., et al. 1997. Maximum and minimum temperature trends for the globe. Science. 277:364-367.
5. Karl, T.R. and Knight, R.W. 1998. Secular trends of precipitation amount, frequency, and intensity in the USA. Bull. Amer. Meteor. Soc. 79:231-241.
6. Heino, R., et al. 1999. Progress in the study of climatic extremes in Northern and Central Europe. Clim. Change. 42:151-181.
7. Easterling, D.R., et al. 2000. Climate Extremes: Observations, Modelling, and Impacts. Science. 289:2068-74.
8. DeGaetano, A.T. and Robert J.A. 2002. Trends in Twentieth-Century Temperature Extremes across the United States. J. Climate. 15:3188-3205.

9. de Freitas, C.R. 2003. Tourism climatology: evaluating environmental information for decision making and business planning in the recreation and tourism sector. Int. J. Biometeorol. 48:45-54.

10. Gaffen, D.J. and Ross, R.J. 1998. Increased summertime heat stress in the U.S. Nature. 396:529-530.

11. Wang, X.L. and Gaffen D.J. 2001. Trends in extremes of surface humidity, temperature and summertime heat stress in China. Advances in Atmospheric Sciences. 18:742-751.

12. Steadman, R.G. 1979. The assessment of sultriness. Part I: A temperature-humidity index based on human physiology and clothing science; Part II: Effect of wind, extra radiation and barometric pressure on apparent temperature. Journal of Applied Meteorology. 18:863-885.

13. Steadman, R.G. 1984. A universal scale of apparent temperature. Journal of Climate and Applied Meteorology. 23:1674-1687.

14. Delworth, T.L., Mahlman, J.D. and Knutson, T.R. 1999. Changes in heat index associated with CO2-induced global warming. Climatic Change. 43:369-386.

15. Johns, T.C., et al. 2003. Anthropogenic climate change for 1860 to 2100 simulated with the HadCM3 model under updated emissions scenarios. Climate Dynamics. (Online First, 18 Feb 2003), DOI 10.1007/s00382-002-0296-y.

16. IPCC. 2000. Summary for policymakers-Emission Scenarios, Special Report of IPCC Working Group III, ISBN:92-9169-113-5.

17. Höppe, P. 1999. The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment. Int. J. Biometeorol. 43:71-75.

18. Matzarakis, A., Mayer, H. and Iziomon, M. 1999. Applications of a universal thermal index: physiological equivalent temperature. Int. J. Biometeor. 43:76-84.

19. Matzarakis, A., Rutz, F. and Mayer, H. 2000. Estimation and calculation of the mean radiant temperature within urban structures. Biometeorology and Urban Climatology at the Turn of the Millenium, edited by R.J. de Dear, et al. Selected Papers from the Conference ICB-ICUC'99, Sydney, WCASP-50, WMO/TD No. 1026:273-278.

20. IPCC3. 2001. Third Assessment Report - Climate Change 2001 http://www.ipcc.ch/pub/online.htm (last access 15 April 2004).

21. Gawith, M.K., Downing, T. and Karacostas. 1999. Heatwaves in a changing climate. Climate, Change and Risk, edited by T. Downing, A. Oissthoorn and R.Toll, Routledge, 279-307.