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Bridging the gap between science and the stakeholder: the case of climate change research

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ABSTRACT: This paper provides an overview of the EU-funded project 'Modelling the Impact of Climate Extremes' (MICE) and, specifically, the stakeholder collaboration and dissemination activities undertaken during the 3 year project. MICE was a pan-European end-to-end assessment of the potential impacts of climate change on a range of economic sectors important to the region. MICE actively encouraged the promotion of dialogue between the research and stakeholder communities in order to ensure that the research activities undertaken within the project were useful to the wider user community. Five workshops were held during the final 18 months of the project. In addition to these, a workshop report and a non-technical stakeholder-focussed brochure were produced to ensure that results do not remain solely within the academic community. The present paper provides a brief overview of the aims and objectives of the MICE project and describes the 5 workshops, including the rationale behind the structure of the final pan-European workshop, and selected results produced by the MICE Consortium. The main outcomes of the final workshop were (1) that the next 10 to 20 yr are important to stakeholders, whilst projections for the 2080s have limited relevance for decision-makers (2) the reliability of climate models needs to be increased and uncertainties decreased; (3) scientific results should be made accessible to the non-specialist, and stakeholders should be involved in relevant projects, preferably from the design stage; (4) there is the need to recognise and work to bridge the gap between what scientists can realistically achieve and what stakeholders require.

KEY WORDS: MICE · Climate extremes · Dissemination activities · Stakeholders · Impacts

1. INTRODUCTION

1.1. Climate change and impact sectors

It is widely accepted that climate change will have substantial impacts on the natural environment, and on human activities. Increasing concentrations of greenhouse gases in the atmosphere are expected to cause changes in climate at all spatial scales, from global to local. The impacts of climate change are likely to be more severe due to changes in the occurrence of extreme events such as windstorm and flood, than due to a change in the mean climate. As a result, many of our current estimates of the potential impacts of climate change may be conservative. Possible reasons follow.

1.1.1. The statistics of extremes

A change in the mean can have a disproportionate and non-linear effect on the fraction of extremes beyond critical thresholds (Meehl et al. 2000). Furthermore, there may be a non-linear relationship between a change in the mean of a distribution and behaviour at the extremes, because the other moments of the distribution (the variance, kurtosis etc.) have also changed. Fig. 1 shows that the distribution of temperatures often resembles a normal distribution, where non-stationarity of the distribution implies changes in mean or variance. An increase in the mean leads to new record high temperatures (Fig. 1a), but no change in variability. An increase in variability without a change

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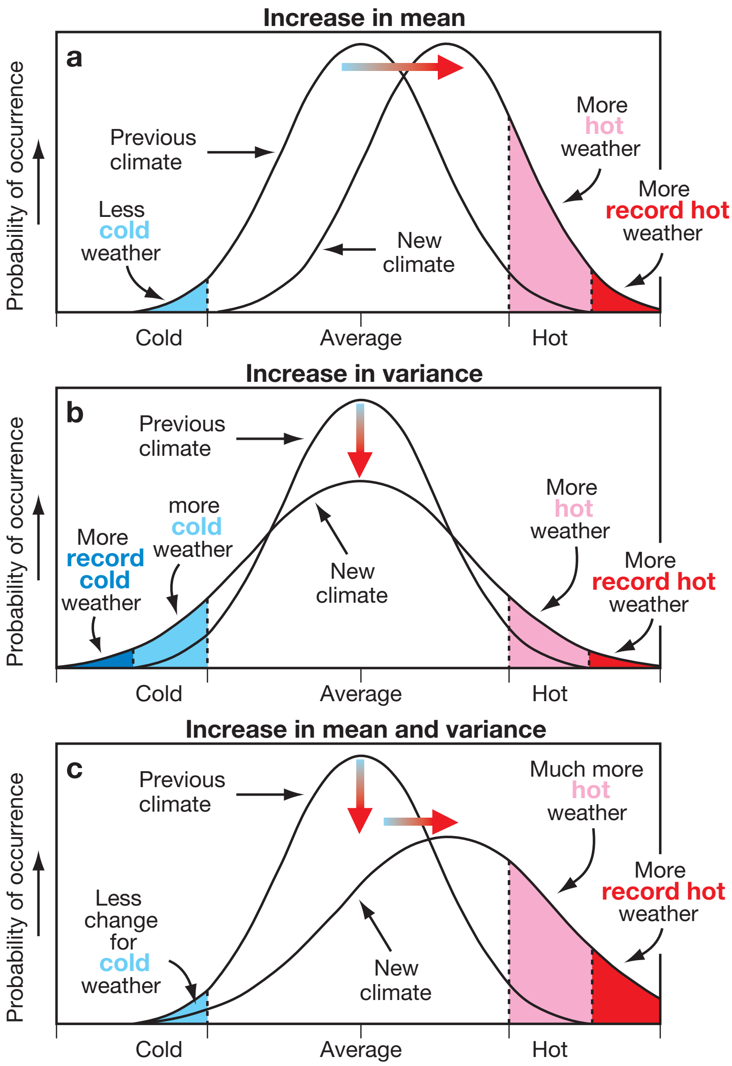

Fig. 1. Effect on extreme temperatures when (a) mean temperature increases, (b) variance increases, and (c) when both mean and variance increase for a normal distribution of temperature (from Folland et al. 2001, their Fig. 2.32)

in the mean results in an increase in the probability of both hot and cold extremes as well as the absolute value of the extremes (Fig. 1b). Increases in both the mean and the variability are also possible (Fig. 1c), and could affect the probability of hot and cold extremes, with more frequent hot events with more extreme high temperatures, and fewer cold events.

1.1.2. The response of the environment and human activities to climate

The response to extremes such as wind storms, floods and droughts is different from the response to a change in the mean climate. The response time is shorter, and arguably the response is greater. As an example, a change in the mean rainfall of a region, on the scale that is predicted by most general circulation models (GCMs), is likely to lead to slowly-evolving changes in the natural environment and agricultural practices, which can be relatively easily managed. However, if floods or droughts become more severe and/or more frequent, the impacts may extend to include crop failures, damage to property and loss of human life. This introduces the possibility of also examining the likelihood that predetermined critical thresholds will be exceeded. For example, extreme temperature may cause crop failure in a single year but if the frequency of failures increased dramatically, the land may become economically unviable which could result in a total loss of productivity rather than a gradual degradation of yields.

1.2. The MICE project

The project MICE—Modelling the Impact of Climate Extremes—began in January 2002 and ended in December 2004. MICE was a European-wide collaboration with partners from Germany, Greece, Italy, Poland, Portugal, Sweden, Switzerland, and the UK. The project was funded by the European Commission (EC) under the 5th Framework Programme. MICE had 2 main goals: (1) to identify potential changes in the occurrence of climate extremes of rainfall, temperature and windstorm in Europe due to global warming, and (2) to identify the impacts these changes may have on specific sectors—agriculture, commercial and natural forestry, energy use, tourism and civil protection/insurance.

The MICE research programme involved 3 main stages:

(1) The collection of information about future changes in climate extremes from climate models. These were first evaluated regarding their ability to simulate the present-day occurrence of extremes using observed gridded and station data.

(2) The analysis of model output to assess future changes in the occurrence of extremes. At this stage return periods, joint probabilities, sequential events and the spatial patterns of extremes were analysed.

(3) The determination of the impacts of changes in extremes. Some well-founded and extensively-tested models already existed for sectors such as forest fire and windthrow, and in other cases models were either non-existent, or existed but had to be improved or adapted.

MICE studied changes in extreme event occurrence across the European landmass as predicted by a suite of global and regional climate models, and evaluated the impacts of predicted changes on selected categories of the human environment and activities. The analyses carried out in MICE were based on the Hadley Centre's third generation climate models HadCM3, HadAM3H/P and HadRM3H/P (Hulme et al. 2002, Met Office 2002, Johns et al. 2003). Data from these models are available at the following latitude by longitude resolutions: $2.5 \times 3.75°$, $1.25 \times 1.875°$ and $0.44 \times 0.44°$, respectively. The region of interest was the European landmass but, where necessary, e.g. storm tracking, the study area was extended to include the North Atlantic basin. Much of the impacts work required high resolution input data and, as a result, the majority of analyses utilised the HadAM3H/P and HadRM3H/P models, data from which are available for two 30 yr time periods (1961–1990 and 2070–2099). MICE was aware that this would limit the usefulness of impacts information to stakeholders, but was restricted by the limited time-slices available. Data from HadCM3 for the 1961–2100 period were utilised where it was possible to apply the coarse resolution data. The impact categories investigated by MICE are shown in Table 1, together with the climate extremes of importance for these categories and their parent climate variables. Not all MICE partners studied all impacts—the 4th column in Table 1 shows the countries involved in examining each impact sector.

These impacts categories were chosen to provide examples of both primary (forestry and agriculture) and tertiary (tourism, insurance) activities. Whereas the impact of climate change on primary activities such as forestry and agriculture is well recognized and has been extensively studied, MICE has also studied activities where the impacts of climate change are less well recognized and documented, e.g. tourism. MICE sought to determine the extent to which substantial impacts from climate change could be expected in these sectors, especially with respect to changes in the occurrence of extremes.

1.3. Importance of stakeholder involvement

Scientists are increasingly required to carry out applicable research that can be effectively communicated to the wider community of stakeholders and the general public. In order to meet this need, the MICE Consortium placed a high priority on stakeholder involvement throughout the entire project, to ensure that the research being carried out would provide useful results to the end-users. At each stage of the project, stakeholder/end-user input played a significant role. For example, at each 6-month progress meeting, stakeholders local to the region hosting the meetings were invited to discuss their concerns and highlight the information they would require to make policy decisions regarding their adaptation to climate change. In addition to this, 4 local workshops were hosted by MICE partners to discuss single-issue climate change impacts relevant to the location. These related to civil protection from floods, snow-based tourism, beach-based tourism and the forestry industries. These 4 workshops will be described in more detail in Section 2.

Efforts by MICE to engage the stakeholder community culminated in a final pan-European workshop hosted by the Italian partner in Florence. The stakeholders were drawn from the 6 sectors studied by the MICE Consortium (Table 1). Representatives from these 6 sectors attended the workshop along with

Table 1. Impact categories, related climate extremes (and parent variables) analysed, and partners involved in examination by the MICE project of climate extreme impacts on economic sectors

Impact category	Climate extreme	Parent variable	MICE partners
Forestry			
Windthrow	Windstorm	Sea level pressure (used for storm tracking)	Germany & Sweden
Forest fire	Heat stress & drought	Temperature & rainfall	Portugal & Italy
Ecological damage	Flood, drought & heat stress	Temperature & rainfall	Sweden
Mediterranean agriculture	Heat stress & drought	Temperature & rainfall	Portugal, Italy & Greece
Energy use	Summer heat waves & winter cold waves	Temperature	UK & Greece
Tourism			
Mediterranean beach holidays	Heat stress & human comfort	Temperature	Greece
Winter sports	Deficit or excess of snow	Precipitation & temperature	Switzerland
Insurance & civil protection			
Property damage	Windstorm	Storm tracking	UK & Germany
Loss of life	Flood	Rainfall & snow	Poland
Water	Flood & drought	Precipitation	Poland

climate scientists and government representatives. In total there were 44 participants with 24 stakeholders, 14 MICE partners and 6 additional climate scientists. Further details of the European workshop can be found in Section 3. The main aim of this meeting was to inform stakeholders of the major results found through MICE for their sectors. A second goal was to explore, with stakeholders, their reactions to these results, especially regarding their views on adaptive capacity and adaptation strategies in light of these results. Thus, the final stakeholder workshop was not only for the purpose of dissemination but, equally important, the 2-way exchange of ideas with stakeholders with the purpose of establishing further research needs.

2. LOCAL WORKSHOPS

In this section a brief overview of the 4 local workshops is provided, including the dates and locations of the meetings and a description of the attendees (Table 2). All 4 workshops followed a similar format focussing on topics relevant to the local industries and community. First, presentations by scientists and stakeholders were made. These were followed by breakout sessions designed to answer specific, impact-related questions, and plenary sessions to disseminate discussion results to the audience. Detailed information regarding the results of these workshops can be found in Giannakopoulos (2004), Schwarb (2004), Stjernquist (2004) and Kundzewicz (2004a).

To illustrate some of the techniques applied to ensure the local workshops remained focussed, during the Greek workshop (held on 10 June 2004), a series of practical exercises focussed the discussion of the meeting and helped to ensure that specific answers were elicited to specific questions. The first exercise was to familiarise participants with the projected changes in climate variables globally and for individual regions, the summary of which is shown in Table 3. Table 4 summarises the information from the exercise designed to identify the possible impact of climate changes on major international travel flows.

3. EUROPEAN STAKEHOLDER WORKSHOP

The 4 local workshops described in Section 2 provided valuable insights into the issues associated with workshop organisation, and enabled the MICE Consortium to identify the most effective methods/techniques to use when aiming to maximise stakeholder input. These techniques include

- Targeting the right audience. It is important to make sure the audience is correctly targeted. Stakeholders have busy schedules and attending workshops that are not relevant is a waste of time and money for both the stakeholder and the hosts. Most stakeholders will

Table 2. Dates, location, main topic and attendees of the 4 local MICE workshops

Dates	Location	Topic	Representatives and representative bodies
4 November 2003	Lucerne, Switzerland	Climate change and winter tourism	Tourism organizations, cable car companies, ski and snow-making industries and climate scientists
25 March 2004	Poznań, Poland	Climate change and flooding in central Europe	Researchers, educators, public administrators at different levels, water managers, spatial planners, representatives of insurance and reinsurance industry, civil society (NGOs), and the media
6 May 2004	Helsingborg, Sweden	Climate change and future risks—weather extremes and forest damage	Swedish National Board of Forestry, regional forestry boards, independent forest managers and other forest companies, Swedish Environmental Protection Agency, Swedish Meteorological and Hydrological Institute, energy companies, Swedish University of Agriculture, Lund University, Danish Forest and Landscape Research Institute, Danish National Environmental Research Institute
10 June 2004	Orthodox Academy of Crete, Greece	Impacts of climate extreme events on Mediterranean tourism and beach holidays	Greek National Tourism Organisation (main governmental body that directs tourism policy in Greece), Association of Greek Tourism Enterprises, Hellenic Association of Travel and Tourism Agencies, Hellenic Chamber of Hotels, Hellenic Federation of Professional Congress Organisers, Pan-Hellenic Federation of Tourism Enterprises, Women in Tourism Association, Crete Regional Civil Protection Bureau

Table 3. Climate change predictions for global and region specific tourist destinations. SLR = sea level rise. Source: World Tourism Organisation (2003)

Region	Temperature	Precipitation	Other key variables
Global	0.2–0.6°C rise in temperature per decade. Decrease in diurnal temperature range	Increase in rainfall by 3–10% by 2050. Increase in droughts over continental areas	4–10 cm SLR per decade
Northern Europe	0.4–0.8°C rise in temperature per decade. Increase in winter and summer temperatures. Decrease in frost days	Increase in amount and intensity of winter rainfall. Decrease in summer rainfall	Summers become 'better' and appear 'more reliable'
European Alps	Increase in winter temperatures. Snowline increases in altitude by up to 100 m per decade	Increase in winter snowfall	Increased risk of avalanches due to combination of higher temperature and increase in snow. Shorter ski season
Mediterranean Basin	0.3–0.7°C rise in temperature per decade. Increase in heat index and no. of days over 40°C	Decrease in summer rainfall (15%). Increase in desertification, winter rainfall, erosion and run-off	Increased risk of forest fires and flash floods. Water resource pressures increase. Coastal areas and infrastructure vulnerable to SLR
Middle East/ North Africa	0.3–0.7°C rise in temperature per decade. Increase in number of very hot days	Slight decrease in annual rainfall. Rainfall and convective activity become more intense	Water resource pressures increase. Increased risk of flash floods and erosion. SLR threatens beaches. Increase sea surface temperatures
Sub-Saharan Africa	0.3–0.7°C rise in temperature per decade	10–15% increase in winter rainfall	Wetter warmer winters. Drier, more intensely-hot summers
North America	0.3–0.7°C rise in temperature per decade	Slight increase in annual rainfall. Rainfall and convective activity become more intense	Increased rainfall and hurricane activity over Pacific states associated with El Niño events
Caribbean	0.2–0.6°C rise in temperature per decade	Slight increase in annual rainfall. Rainfall and convective activity become more intense	Increased rainfall and hurricane activity associated with La Niña events
Central/ Southern America	0.2–0.6°C rise in temperature per decade	3% decrease in annual rainfall	Decreased hurricane activity associated with El Niño events
North East Asia	0.4–0.8°C rise in temperature per decade. Increase in winter and summer temperatures. Decrease in frost days	Increase in amount and intensity of winter rainfall. Decrease in summer rainfall	Summers become 'better' and appear 'more reliable'
South Asia	0.1–0.5°C rise in temperature per decade	Little change in rainfall	Coastal areas vulnerable to erosion
Far East/Pacific	0.1–0.5°C rise in temperature per decade	Little change in rainfall	Small island states and coastal areas vulnerable to SLR

not commit their time without plenty of advanced information including the agenda and other potential participants. Furthermore, targeted stakeholders should also be able to influence investment decisions, policy and/or research agendas

- Structuring the programme to ensure a focussed discussion. It is easy to become distracted by side issues. Specific questions have to be asked in order to ensure useful and relevant answers and to ensure that the time available is utilized to its maximum potential. While stakeholders find some general background information interesting, the attention must focus on issues and aspects that are directly relevant to them—key impacts on operations or profit within their planning horizons. The objectives and desired outcomes should be specified at the start of the process in order to ensure that discussions are focussed and that participants are aware of what is expected of them
- Providing stakeholders with an opportunity to put forward their point of view. At Florence, around half of the 2-day workshop was given over to soliciting stakeholder comments and opinions through formal presentations and informal discussion and debate
- To facilitate discussion, small groups are desirable. However, it is essential that members of sub-groups

share common characteristics. In this way, useful and relevant discussions are facilitated

- To further facilitate discussion it is advisable to communicate results in clear and concise language. Common terms used in research are not necessarily used in the outside world. To maximise the interaction between stakeholders and scientists, discussion should be carried out in everyday language, easily understandable by the lay-person
- The above objectives are more likely to be achieved if a stakeholder is involved in the planning process.

The MICE European workshop took place in Florence, Italy, on 28 and 29 October 2004. The 2-day event was split into 2 parts. Day 1 was concerned with presentations that set the context of the MICE project and workshop, and also outlined the major impacts identified for each sector. Both MICE partners and invited speakers (including selected stakeholders) took the floor to speak about different aspects of climate change and associated impacts. On Day 2, the participants were split into break-out groups to discuss specific issues associated with the research undertaken by MICE and to address several major questions. The remainder of this section will outline the structure of the European workshop.

3.1. Setting the context

It is important to set the context of the project being presented, the aims of the workshop, and the intended outcomes. Prior to the workshop, participants were provided with a set of briefing documents. These included a description of the MICE project, the reasons for and aims of the workshop, a description of the 4 preceding local workshops, and a concise description of some of the results produced by the MICE Consortium. In this way, participants were prepared for the structure and content of the workshop.

With the aim of stressing that MICE activities were part of a larger research effort, it was explained that MICE was part of a co-operative cluster of projects exploring future changes in extreme events in response to global warming. The other members of the cluster are STARDEX (STAtistical and Regional dynamical Downscaling of EXtremes for European regions) and PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects). These 3 projects were all supported by the EC under the 5th Framework Programme 'Global change, climate and biodiversity'. They were designed to bring together expertise from across Europe in the fields of climate modelling, regional downscaling, statistical analyses of climate data and impacts analysis to explore future changes in extreme events (such as floods, droughts, cold spells, heat waves and wind storms) in response to global warming. Neither STARDEX nor PRUDENCE had strong interaction with the stakeholder community and, as a result, MICE informally acted as the communication gateway for the 3 projects. In order to highlight this cluster of projects and emphasise the EC's climate change programme, representatives from the EC, STARDEX and PRUDENCE were invited to the workshop to talk about their respective research agendas. This opening session also emphasised that the MICE project and workshops were very much a first step in a continuing process of encouragement and enhancement of science/stakeholder collaboration in the field of the assessment of potential impacts of climate change.

3.2. Invited speakers

Although a primary aim of the workshop was to discuss the impacts of changes in climate extremes on certain activity sectors, the majority of participants did not come from a scientific background and it was therefore necessary to provide information on the tools used to understand and analyse climate change (especially at the regional scale), to provide some examples of the detected changes in climate extremes identified by MICE, and to generally engage the audience. The workshop opened with a number of scene-setting presentations.

A brief description of climate models outlined their main components and how they were utilised in MICE. Emphasis was placed on the shortcomings of these models, e.g. limitations created by inadequacies in our understanding of the physical systems they seek to model and by computing power, and hence inherent uncertainties in model results. However, it was also stressed that these models are the best tools available at the current time and that they are continually being developed and improved and becoming more complex. The output from these models is used to build scenarios of regional climate change that can then be used in impact studies.

It is also important to provide a historical context. A brief review of historical climate data and results of analyses based on these was presented. Potential sources of error in the observed record, recent trends and spatial patterns, and the extension of the recent instrumental record with palaeo and early instrumental data for pre-1850 periods were all discussed. Three key messages were presented

- The 6 warmest years have all occurred since 1997 (they are, in rank order, 1998, 2002, 2003, 2004, 2001 and 1997)

Table 4. Summary of climate changes and their probable impact on major international travel flows. SLR = sea level rise. Source: World Tourism Organisation (2003)

Major tourism flow	Climate change in region of origin	Climate change in region of destination	Implications for destination region	Possible market reactions
Northern Europe to Mediterranean	Warmer, wetter winters Warmer, drier summers More reliable summers	Warmer, wetter winters Much warmer, drier summers Changes more marked in Eastern Meditteranean Increased heat index More days > 40°C More arid landscape Small tidal range results in a greater SLR impact	Increased drought & fire risk Increased water shortages Increased personal heat stress Beach degradation & habitat loss due to SLR Increase vulnerability to more tropical diseases (e.g. malaria) More flash floods Poor urban air quality in cities	Improved northern European summers leads to more domestic holidays Decreased incentive for Mediterranean summer holidays Increased incentive for shoulder-month Mediterranean holidays Increased incentive for southerners to go north
North America to Europe	Warmer winters Warmer summers Slight rainfall increases SE USA (Florida) at risk from beach erosion & greater storm risk Pacific coast greater storm risk and higher rainfall	Northern Europe Much warmer, wetter winters Warmer, drier summers More reliable summers Southern Europe Warmer, wetter winters Much warmer, drier summers Increased heat index More days > 40°C SLR	Northern Europe (80% of flow) More attractive climate for summer holidays Possibly greater congestion at key sites and cities Southern Europe (20% of flow) Greater drought risk Increased water shortages Greater fire risk More beach degradation due to SLR	Too hot for peak summer cultural visits to southern Europe Shoulder-month travel may increase Little change foreseen for travel to northern Europe
Europe to North America	Northern Europe Much warmer, wetter winters Warmer, drier summers More reliable summers Southern Europe Warmer, wetter winters Much warmer, drier summers Increased heat index More days > 40°C SLR	Warmer winters Warmer summers Slight rainfall increases SE USA (Florida) at risk from beach erosion & greater storm risk Pacific coast greater storm risk and higher rainfall	SLR damages Florida coast and Everglades Risk of Pacific coastal damage Geomorphic damage to southeastern coast Increased heat index Coastal erosion and storm damage risk on east coast Rising health costs as tropical disease risk rises	Main destinations: Florida, California and New York Florida may become less attractive at peak times Possibly greater attraction of Carolina coast? East coast US and Canadian cities too hot in summer Stronger winter ski market due to reduced capacity in Europe
North East Asia to South East Asia	Warmer all year round Small year-round rainfall increase	Little change in rainfall Relatively little change in temperature Coastal areas vulnerable to SLR	No dramatic climatic changes foreseen Islands and tourist coasts vulnerable Coral bleaching	Climatic factors unlikely to influence travel patterns greatly Possible decline in dive and beach markets
North East Asia to North America	Warmer all year round Small year-round rainfall increase	Warmer winters Warmer summers Slight rainfall increases SE USA (Florida) at risk from beach erosion & greater storm risk Pacific coast greater storm risk and higher rainfall	Risk of Pacific coastal damage Geomorphic damage to south-eastern coast Increased heat index Coastal erosion and storm damage risk on east coast Rising health costs as tropical disease risk rises	East coast US and Canadian cities too hot in summer? Sightseeing travel not likely to be greatly affected by climate change
North America to Caribbean	Warmer winters Warmer summers Slight rainfall increases SE USA (Florida) at risk from beach erosion & greater storm risk Pacific coast greater storm risk and higher rainfall	Warmer winters Warmer summers SLR	Particularly vulnerable to SLR Increased beach erosion Coral bleaching & reef damage Salinisation of aquifers Higher energy costs for air conditioning Greater need for sea defences & flood control More tropical diseases (e.g. malaria) Increased pressure on natural resources & ecosystems	Beach holidays become less attractive (heat index, beach erosion, sea and coral quality) Less need to escape northern climate Loss of confidence in health risk levels at destination

- The warmest-ever summer since 1500 in Europe was in 2003
- Palaeo data indicate that the 20th century was the warmest century of the second millennium, and experienced the greatest warming within a century.

These 2 presentations were important for setting the context of the project and the workshop, and in providing background information to facilitate useful discussions during the remainder of the meeting.

3.3. Results from MICE

Moving on from the general to the specific, results generated by MICE and relevant to the 6 impact sectors were then presented. These included results based on the analysis of changes in extremes of temperature, rainfall, windstorm and floods. Some of these results, based on the SRES A2 scenario (Nakicenovic & Swart 2001) for the 2070–2099 period, are briefly summarized below

- Heat waves may become more pronounced and severe in Europe, particularly outside the UK and Scandinavia
- The cold season may shorten and the number of very cold days may decrease by up to 4 mo in Northern Europe
- Southern Europe may become drier whilst Northern Europe may become wetter
- The frequency of heavy (intense) precipitation events could increase in the future. As a result, flooding is likely to increase across most of Europe as winter precipitation increases (Kundzewicz et al. 2006, this issue)
- In general, wind storms are expected to decrease but the number of severe storms is likely to increase (Leckebusch et al. 2006, this issue).

3.4. Sectoral impacts

Following the Day 1 morning presentation, each of the 6 impact sectors were examined in turn. A presentation was first made by the MICE partner concerned with the assessments of climate change impacts for each sector. This was followed by a presentation by selected stakeholder(s). A brief description of the impacts identified for each sector is detailed below.

3.4.1. Agriculture and Forest Fires

MICE focussed on the impacts of climate change on summer and winter crops (sunflower and durum wheat, respectively) over the Mediterranean Basin and for a small sub-region of Tuscany, Italy. For the Basin-wide study, HadRM3 model data were used at a resolution of 0.44°, whilst for Tuscany the data were downscaled to a 5 km resolution (Moriondo et al. 2006, this issue). The SRES A2 and B2 scenarios were used for the 2070–2099 future period.

The CropSyst crop simulation model (Stockle et al. 2003) was used to analyse the impact of changing climate extremes on crop development. The main conclusions for the Mediterranean Basin are

- There is likely to be a reduction in the length of the growing season by up to 2 wk
- There is likely to be an increase in the risk of heat stress during flowering stages (greatest in plain and hill areas)
- There is likely to be a general increase (higher in northern areas) in the risk of rain days during the sowing stage
- There is likely to be a marked reduction in yield of summer crops (with some exceptions for northern Mediterranean areas)
- There is also likely to be increased rainfall intensity and longer dry spells. These effects are expected to be greatest over the southern Mediterranean and North Africa.

MICE also examined the changes in the risk of forest fires, which are a significant threat in Mediterranean countries. MICE analyses found that in the future there is likely to be an increase in the risk of forest fires in response to global warming. This greater risk is attributed to an increase in the number of dry and hot days and longer hot and dry spells, which result in a longer fire risk season. The increased risk of forest fire is greatest in continental and upland areas.

3.4.2. Forestry

MICE focussed particularly on Scandinavian forestry and the impacts of windstorm activity and biological agents i.e. bark beetle infestation. The main effects of climate change on Swedish forests identified to the stakeholders were

- Warmer climates (leading to longer vegetation periods)
- Increased precipitation in autumn and winter
- Decreased precipitation in summer (mainly in southern Sweden)
- Increased runoff in central and northern Sweden
- Decreased snow coverage

MICE found that Swedish forests are most at risk from damage due to storm activity if trees are planted outside the natural distribution of the species; for example, in the case of Spruce, this distribution is beyond the boundary marked by the –2°C isotherm.

MICE also found that bark beetle infestation may increase in the future as a result of climate change. Windthrow and summer dry spells and spring frosts promote bark beetle increase whilst winter frosts discourage its propagation. A warmer world may result in an earlier spring swarming and increase the possibility of a second swarming later in the year.

In general, climate change may result in the following effects

- An increased risk of the combined negative effects of raised mean and extreme temperatures
- An increased risk of tree damage due to early spring frosts and more summer droughts
- Spruce, the most economically important tree species in Europe, would face an increased risk of damage from bark beetle and an increased windthrow risk outside its natural distribution.

Further results from MICE analyses of the impacts of climate extremes on European forestry can be found in Jönsson et al. (2004), Nilsson et al. (2004) and Schlyter et al. (2006, this issue).

3.4.3. Water

With regards to the water industry, MICE focused particularly on changes in relation to intense precipitation. The results, based on HadCM3 and HadRM3H/P model simulations, indicate that the water-holding capacity of the atmosphere, and hence the potential for intense precipitation, increases with increasing temperature. Therefore, even if mean summer precipitation over central Europe decreases, a reduction in the frequency of more intense daily precipitation events does not necessarily follow. Increases in intense precipitation may aggravate summer flood hazard, particularly if falling on parched soils. In addition, wetter and warmer winters, with increasingly frequent rain and increasingly infrequent snow, may result in an increase in flood hazard. Conversely, ice-jam floods are likely to be less frequent and less severe, and snowmelt is likely to be earlier and less abundant, reducing the risk of spring floods.

Water management has to deal with 3 main concerns: (1) water shortages, (2) flooding, and (3) pollution. All 3 can be exacerbated by climate change. Water is indispensable to human activity: shortages affect human mortality and health, and incapacitate industrial activity. Water managers face issues of managing fluxes and stocks of water under uncertainty: water supply vs. water demand management; the protection of infrastructure; water availability for humans and for ecosystems; and water storage as a possible remedy for floods and droughts. In addition to climate change and the aforementioned challenges, the water industry has to deal with non-climate-related multiple stresses of increased demand, population growth, overexploitation, pollution and land-use change.

The overall conclusions are that floods and droughts are likely to become more severe in the future, resulting in adverse effects on many sectors of the human and natural environment. Further information can be found in Kundzewicz (2004b) and Szwed et al. (2004).

3.4.4. Energy

The main focus of the Florence workshop was on Mediterranean energy usage. However, details of MICE activities focussing on European-wide impacts of climate change on energy consumption can be found in Livermore (2005) and Giannakopoulos & Psiloglou (2006, this issue). A case study based on Athens residential energy consumption was presented. The key findings of this study are

- The historical increasing trend in energy demand is due to economic growth
- Energy demand is lower during spring and autumn and holidays/weekends
- Peak demand is in December and July
- There is a definable temperature at which energy demand is at a minimum (in Athens this is 22°C). Temperatures above or below this threshold result in increases in energy consumption due to increased use of air-conditioning and space heating, respectively
- The seasonal cycle of demand will change in response to global warming, e.g. with a reduction in consumption in winter, and an increase in consumption in summer through the increased use of air conditioning systems.

From subsequent discussions the energy industry has 2 timescales upon which it works and implements policy: first, the short-term outlook, within the next 30 yr, focuses on currently established facilities; second, the long-term perspective, looking at implications for future facilities. The French energy industry uses 3 temperature dimensions: (1) the long duration maximal temperature (exceeding the 98th percentile temperature); (2) the short duration maximal temperature (100 yr return level of daily maximum running 12 h means) and (3) the instant maximal temperature (the 100 yr return level of daily maximum temperature) to assist in the planning of new facilities and management of existing plants.

3.4.5. Insurance

Examples of recent severe European wind storms, including Lothar, Martin, Daria and Wiebke, were provided in order to emphasise the economic importance of these events. Insured losses are still only a relatively small proportion of total economic loss produced by wind storms (around 50% in developed countries, but much less elsewhere). However, over the past 3 decades, the size of insured losses has increased dramatically—from €2.65 billion in the 1970s to €7.4 billion in the 1990s. The vulnerability of an area to windstorm damage depends on the localised gust speed and the concentration of insured property in that area. The key messages from this research are that, with adaptation, insured losses are likely to increase in the future; e.g. across the UK the projected increase is 15%, and will be much higher if adaptation strategies are not implemented. Such adaptation strategies include the identification of regions vulnerable to damage e.g. floodplains; as a result, policy premiums could be increased to offset excessive losses or insurance may not be offered for these areas. Further information regarding the modelling of storm losses can be found in Klawa & Ulbrich (2003).

3.4.6. Tourism

Results from the analysis of impacts of climate change on the Alpine winter sports and Mediterranean summer beach tourist industries were presented. Possible future trends of temperature and precipitation and, consequently, changes in snow cover across the Alps were described. Major conclusions included: the change in future snow cover is a function of altitude; the most sensitive altitudinal range is between 1000 and 1500 m. In this altitude range, the projected decrease in snow cover in January and March by the 2020s is between 20 and 30%. In the future, it is expected that for every 1°C increase in temperature, the ski season will shorten by up to 14 d.

For the Mediterranean, it is not possible to explicitly model changes in tourism due to climate change. Only the likely changes in climate and associated infrastructure pressures could be presented, as follows

- Increased risk of drought, especially in summer
- Increased desertification through a decrease in total rainfall
- Increased pressure on water resources, especially in summer
- Increase in the risk of heat stress and human discomfort
- Intensification of rainfall and convective activity
- Increase in flash floods and erosion
- Increased vulnerability of coastal areas and infrastructure due to sea level rise
- Poor air quality in cities
- Increased vulnerability to tropical diseases.

The expected changes in the flow of tourists to and from the Mediterranean include

- More domestic holidays in northern Europe due to improved summers
- Mediterranean summer holidays become less attractive
- Spring and autumn become the new Mediterranean holiday seasons
- Southerners prefer to holiday further north during the summer.

For further information on MICE efforts regarding the impacts of climate change on tourism see Schwarb & Kundzewicz (2004) and Agnew & Palutikof (2006, this issue).

3.5. Break-out groups and plenary sessions

Break-out groups are a common technique used in order to stimulate and encourage discussion in small groups by removing any feelings of apprehension often experienced when faced with a large group of people. In this workshop, 3 consecutive break-out sessions were organised, the aim of each to answer 1 of 3 major questions:

(1) What is the relevance and importance of climate change in Europe ranked against other risks?

(2) What is the potential for adaptation? On the basis of your own experience, and in the light of the presentations on Day 1, what is the potential for adaptation in your area?

(3) In light of discussions so far, what are the research needs? How can they be addressed?

In Break-out Sessions 1 and 3, stakeholders were divided into 3 groups (insurance and tourism, energy and water, and forestry and agriculture). For Break-out Session 2, the participants were divided among the 6 impact sectors based on their expertise. Small, single-sector, groups were used in Session 2 to reflect the nature of Question (2). It was considered by the organisers that there was little to be gained by cross-sector information-sharing with respect to this critical question, and that more information would be elucidated in these small groups. In retrospect, this logic might also have applied to Sessions 1 and 2.

The following section will outline the results of discussions of the 3 questions posed to the workshop participants.

3.5.1. What is the relevance and importance of climate change in Europe ranked against other risks?

The main outcomes from these discussions revealed issues common to all sectors. First, the lack of high spatial resolution climate models producing data relating to the intermediate periods between the baseline and 2070–2099 time-periods means that, because projections are into the very distant future, climate change is ranked low by stakeholders in comparison with other risks. For example, the insurance industry requires risk assessments over the next decade or two, but climate change over this period is considered to be relatively small and unimportant in relation to other, non-climate hazards. Taking the energy and water sectors as a further example, stakeholders felt that socio-economic changes, such as population growth and urbanisation, have a higher priority than climate change. Near-future periods such as the 2020s suffer from a low climate signal-to-noise ratio, where the climate change signal is not easily differentiated from natural climate variability. This issue was not explicitly addressed in MICE due to the reliance on time-period output from HadAM3H/P and HadRM3H/P. Suggestions on how to deal with this issue can be found in the IPCC Working Group I Third Assessment Report (Mitchell et al. 2001).

Second, the uncertainties associated with climate modelling are too large for certain key variables e.g. precipitation and storminess. All acknowledged that future climate change is an important issue but, when developing management strategies, organisations require more reliable information as a basis for decision-making.

3.5.2. What is the potential for adaptation? On the basis of your own experience, and in the light of the presentations on Day 1, what is the potential for adaptation in your area?

Each sector was asked separately about their desire and ability to adapt to a changing climate. Several common approaches were raised

- Legislation: e.g. hose pipe bans, building codes (structural integrity and energy efficiency), and regulation of agricultural practices in order to promote a sustainable system
- Education: educate the general public on the need to, and how to, conserve energy and water and prevent forest fires
- Technological improvements: improve the energy efficiency of white goods, improve the efficiency and robustness of supply and distribution networks
- Risk assessments: these would be useful to both the insurance and water industries to identify areas at highest risk from various climate-related hazards, e.g. floodplains, coastal zones.

In addition to these common adaptation strategies there were many others specific to each sector. Table 5 includes examples to illustrate some of the possible adaptation strategies available to each sector.

Table 5. Potential adaptation strategies for each MICE sector

Sector	Strategy
Insurance	Increase responsibility of the policy holder to ensure he/she does not locate in vulnerable areas and that property is properly maintained, e.g. through deductibles and co-insurance Identify thresholds above which damage cannot be insured Spread the risk Risk mapping
Tourism	Diversify: establish new holiday seasons, e.g. in the Mediterranean focus on spring and autumn seasons Weather-proof through creation of indoor environment-controlled facilities for water sports etc. Encourage non-weather dependent activities such as cultural tourism
Energy	Encourage a new energy paradigm—move away from fossil fuels
Water	Flash flooding cannot be entirely avoided but forecasts and response times can be improved To adapt to an increased risk of flooding, strategies include use of storage dams, dykes and mobile defences Against drought, strategies include storage dams, irrigation and de-salination Risk mapping
Forestry	Adaptation strategies are very specific to the hazard in question To adapt to increased windstorm frequency, mixed stands should be planted, thinning techniques should be adapted to specific regions and species, and more broadleaf trees should be cultivated Increases in precipitation can be adapted to by improving drainage, strengthening roads and dams and changing from non-native to native species. This latter strategy is also applicable to adapting to drought
Agriculture	Adaptation strategies can originate from 3 sources—the farmer, insurance companies and government Farmers can adapt by cultivating hardy species and by modifying microclimates Insurers can provide information about risks Governments can establish support systems designed to provide information and financial support for damage recovery

3.5.3. In light of discussions so far, what are the research needs? How can they be addressed?

All sectors stressed the need to (1) improve climate model reliability, (2) reduce uncertainty, and (3) output future projections for the next 50 yr as opposed to the next 100. Projections should also be produced at different, higher spatial scales so that more localised risk modelling can be undertaken. Research results should be disseminated in a simple and easily understandable way. And finally, stakeholders expect to be informed on the range of impacts of climate change, associated uncertainties, and what could be possible adaptation measures and strategies to cope with/prevent/avoid the impacts of climate change, in a continuing dialogue with the science and policy-making communities.

4. SUMMARY AND CONCLUSIONS

This paper has briefly outlined the strategies used within the MICE project to encourage and improve stakeholder-scientist interaction. At each stage of the project, stakeholders/end-users were invited to 6-monthly project progress meetings, thus ensuring that the project addressed the concerns and requirements expressed by the stakeholders to the best of the Consortium's abilities. Attempts were made to address specific concerns highlighted during these meetings, e.g. bark beetle infestation of Swedish forests.

In addition to the project meetings, 4 local workshops were held to discuss the impacts of climate change on Alpine tourism, civil protection and insurance losses from flooding in central Europe, forest damage in Sweden and Mediterranean tourism. This facilitated the expert judgement-based approach used to investigate the implications of climate change in these 4 activity sectors — areas that are generally not explicitly modelled in a quantitative way. Not only did these workshops provide an insight into the possible impacts of climate change on these sectors, but they also enabled the MICE partners to construct a framework upon which to organise the final European stakeholder workshop. The main aims of this final workshop were, first, to disseminate the results of impact analyses carried out in MICE to the broader stakeholder community and, second, to promote the interaction between stakeholders/policy makers and the research community. This was achieved by correctly targeting the audience, by designing a focussed workshop programme, by identifying specific questions to be addressed in break-out sessions, by providing sufficient background material both before and during the meeting and, finally, by ensuring adequate time and facilities for stakeholders/end-users to voice their views and opinions.

The European stakeholder workshop was a 2-way learning process whereby scientists and end-users have interacted and communicated for mutual benefit. It was a conduit for the interchange of information and views, and a forum for the development of understanding of the respective needs and capabilities of the climate change stakeholder and research communities.

Discussions identified several common needs across the 6 impact sectors

- The need for near-future as opposed to distant-future scenarios of climate change: the 2020s and at most the 2050s, instead of the 2080s. The issue of climate change tends to be ignored or downplayed in decision-making because of the timescale of projections. Statistical downscaling methods, such as those developed by STARDEX (www.cru.uea.ac.uk/cru/projects/stardex), should be used alongside conventional dynamical downscaling techniques in order to address this issue
- The need for more reliable climate modelling: the need to reduce uncertainty and hence provide more accurate and consistent (inter-model) information. The confidence limits in projections of future climate change are too wide to permit climate change issues to be factored into decision-making, especially at the regional and local level
- The need to make the results of research more accessible to the lay-person. Researchers should involve stakeholders in the planning of research, they should disseminate information at interim stages, and they should work to ensure that presentation of results is attractive and understandable to the non-specialist
- The need to recognise and work to bridge the gap between what scientists can produce and what end-users require. Some concern was expressed by stakeholders that the continuity of this process was difficult to maintain between different Framework Programmes.

The MICE project and its focus on the dissemination of scientific information to stakeholders and the encouragement of the 2-way dialogue between the 2 communities was a first step in a continuing process aimed at enhancing collaboration between these groups. It was clear from interactions with the stakeholders, from those involved in the project meetings to those in the final workshop in Florence, that the process was both interesting and useful. Many expressed a desire to continue this collaboration in order to focus research activities, and to answer specific questions and specific stakeholder needs. This interaction is continuing through the ENSEMBLES project (www.ensembles-eu.org) funded under the EC's 6th Framework Programme. The EC is also responding to the needs of the stakeholder/policy-maker with a focus on mitigation and adaptation strategies in its most recent call for proposals.

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