CONTENTS

WHAT IS THE MICE PROJECT?

Human activities, such as industry, land clearance, agriculture and animal husbandry, are increasing the concentrations of greenhouse gases in the atmosphere. These gases are responsible for maintaining atmospheric temperatures at levels which support life. However, growing atmospheric concentrations throughout the 20th century, and up to the present day, are leading to rising atmospheric temperatures, and related changes in climate. It is likely that these changes are already causing impacts on natural systems and human activities. It is widely believed amongst the scientific community that, in the future, these impacts will become greater, eventually threatening the stability of economic and social systems.

The research project MICE (Modelling the Impacts of Climate Extremes) looked at the future impacts of climate change on human activities in Europe. In particular, it concentrated on the impacts of changing intensities and occurrences of extreme events. Such changes, for example in windstorm, heat waves, drought, and floods, are widely expected to have greater impacts on human activities than a change in the average climate. The structure of the project is outlined in Figure 1.

Figure 1: Structure of the MICE Project

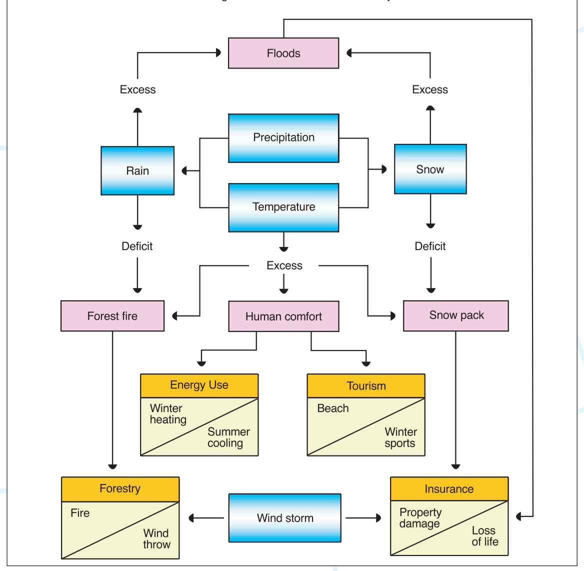


Figure 1: Structure of the MICE Project

The objectives of the MICE project were:

- to identify and catalogue European climate extremes (high rainfall, droughts, windstorm etc.) in observed and modelled climate data;
- to assess future changes in climate extremes in response to global warming;
- to assess the impact of changes in extremes on specified economic sectors;
- to communicate the results to stakeholders.

The impact sectors studied in MICE were:

- Water supply.
- Mediterranean agriculture.
- Forestry.
- Energy demand.
- Property insurance.
- Tourism.

In some of these impact sectors, for example, agriculture and energy use, the relationships between climate and impact are well understood. In others, such as winter sports and Mediterranean beach holidays, the potential implications of climate change are only just beginning to be appreciated.

MICE consisted of eight European partners:

- The UK (University of East Anglia, Norwich),
- Poland (Polish Academy of Sciences, Poznań),
- Sweden (Lund University),
- Germany (University of Köln),
- Portugal (University of Lisbon),
- Switzerland (University of Bern),
- Greece (National Observatory of Athens)
- Italy (Applied Meteorology Foundation, Florence).

The three-year project ran from January 2002 to December 2004. MICE (Contract No EVK2-CT-2001-00118) is part of a cluster of three projects, all related to European climate change and its impacts, funded under the EU Framework 5 Programme. The other projects in the cluster are PRUDENCE (Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects) and STARDEX (Statistical and Regional Dynamical Downscaling of Extremes for European Regions).

The web pages of the three projects can be accessed at:

MICE
http://www.cru.uea.ac.uk/cru/projects/mice/
PRUDENCE
http://prudence.dmi.dk/
STARDEX
http://www.cru.uea.ac.uk/cru/projects/stardex/

A special issue of the journal ***Climate** Research* will appear in late 2005/early 2006, devoted to the results of the MICE project.

CLIMATE MODELS

CLIMATE MODELS

Key Messages:

- **It is difficult to distinguish between natural variability and climate change.**
- **Climate models have limitations and uncertainties.**
- **Climate models are the best tools we have for long-term climate prediction.**
- **Climate models are needed to build regional scenarios of climate change.**
- **These scenarios are the basis for studying the impacts of climate change.**

What are Climate Models?

Climate models use a computer representation of the laws of physics describing the transport of mass and energy in the atmosphere. These equations are solved at predefined time intervals for a number of grid points across the surface of the Earth, into the atmosphere, and down through the oceans. By changing the atmospheric concentrations of the greenhouse gases in the model, we can observe how the climate changes.

Climate models work at different spatial scales. Global Climate Models (GCMs) simulate the climate over the whole Earth. A typical GCM might have the following characteristics:

- Horizontal resolution of grid points in the model atmosphere at 2.5° latitude by 3.75° longitude (equivalent to around 265 km x 300 km over mid-latitudes).
- 19 vertical levels in the model atmosphere.
- 20 vertical levels through the model ocean, with a horizontal resolution of 1.25° latitude by 1.25° longitude.

These figures describe a GCM developed by the UK Hadley Centre. Figure 2 shows the main characteristics of the model. The MICE project used data from this Hadley Centre GCM.

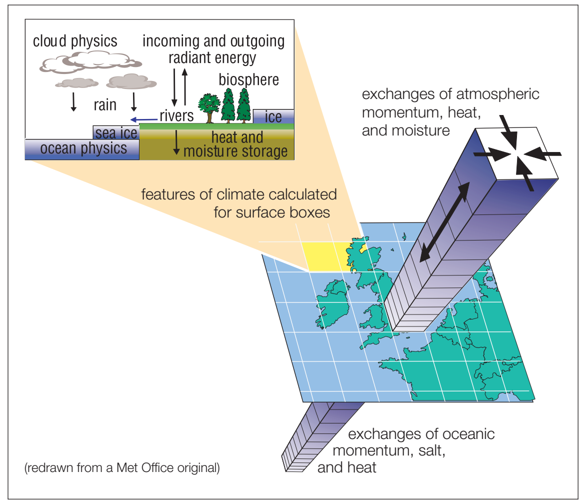


Figure 2: Conceptual structure of HadCM3

One problem with GCMs is their coarse spatial resolution. To overcome this, and hence improve the model simulation of real conditions, Regional Climate Models (RCMs) have been constructed. The UK

CLIMATE MODELS

Hadley Centre RCM, used in MICE, runs at a much higher spatial and temporal resolution than a GCM. Its spatial resolution is 0.44º x 0.44º (approximately 50 km x 50 km over Europe). As a result, the model orography has much finer detail, and it can simulate smaller-scale weather features than is possible with the relatively coarse GCMs.

How do climate models simulate future climates?

In order to simulate future climates, the models have to make some assumptions about how future atmospheric concentrations of greenhouse gases will evolve. In order to make realistic assumptions there has to be a story, or scenario, of how human societies, economies and technologies will evolve into the future.

The IPCC (Inter-governmental Panel on Climate Change) produced the Special Report on Emissions Scenarios (SRES) (Nakicenovic and Swart, 2000), which set out four scenario families. These are taken from storylines describing four possible future worlds:

- The A1 family describes a future world of very rapid economic growth and, in the A1FI scenario, this is based on intensive fossil fuel use. A1FI is a high emissions scenario, with CO_2 concentrations at 810 parts per million (ppm) and global temperatures expected to increase by around 4°C by the 2080s (2070 - 2099).
- The A2 family describes a world of self-reliance and preservation of local identities. This has medium high emissions, with atmospheric CO_2 concentrations reaching 715 ppm and global temperatures expected to increase by around 3.3°C by the 2080s.
- The B2 family emphasises local solutions to economic, social, and environmental sustainability. The accompanying emissions scenario is medium low, with CO_2 concentrations at 562 ppm and global temperatures expected to increase by around 2.3°C by the 2080s.
- The B1 world is one of global solutions, with rapid changes toward a service and information economy, reductions in material intensity, and the introduction of clean and resource-efficient technologies. It has low emissions, with atmospheric CO_2 concentrations at 525 ppm and global temperatures expected to increase by around 2°C by the 2080s.

How did MICE use climate models?

By looking at results from a number of climate model experiments, MICE examined how the occurrence of climate extremes is likely to change in the future. It looked at changes in the frequency and intensity of windstorms, floods, droughts, and heat waves. A particular goal of MICE was to explore the uncertainties associated with using different climate models, at different spatial resolutions and based on different future storylines. The model experiments were selected particularly to examine the effects of:

- Changing the model resolution (by comparing regional and global climate model experiments).
- Using different SRES scenarios, with different atmospheric greenhouse gas concentrations in the models (which in turn reflect different visualizations of economic futures).
- Exploring the relationship between natural variability and climate change.

The climate models used here are the suite of global and regional climate models developed by the Hadley Centre, UK Met Office. They are based on the SRES storylines describing our future, most commonly the A2 scenario, but also the B2 and A1FI.

CLIMATE EXTREMES

INTRODUCTION

The MICE project analysed extremes of temperature (heat waves), precipitation (drought and flood, snow climates of mountain regions) and wind speed (storms). The likely future behaviour of these extremes under climate change was assessed by comparing model predictions of the future with the modelled present, and with observations of the present-day climate.

Annual indices of extremes were constructed using temperature, rainfall and wind data from climate models and observations. Typical indices are, for example:

- The longest period without rain in each year. Calculated by counting the number of continuous dry days, this index is a measure of drought conditions.
- The number of days in each year with rain more than 20 mm. This is a measure of the number of episodes of very intense rainfall, which may lead to flooding.
- The annual number of very hot days. What is considered 'very hot' will vary depending on location, even within Europe. In the Mediterranean, this was taken to be the number of days greater than 32°C, whereas over Northern Europe a much lower threshold required, around 25°C.
- The annual number of days with wind speed above a threshold of 25 m/s. This is a measure of the frequency of high winds.

Using annual indices greatly simplifies the analysis of extremes, and provides useful measures of the nature of extremes for impacts analysis. Special statistical techniques for extremes analysis allow us to explore the behaviour of very rare events, such as the most severe event (drought, rainstorm etc.) to be expected once in 200 years.

TEMPERATURE

Key Messages:

In the warmer climates of 2070-2099 under the A2 scenario:

- **Heat waves will become hotter and last longer over much of Europe.**
- **The cold season will be much shorter.**
- **The number of very cold days, with temperatures below freezing, will decrease by as much as 4 months in Northern Europe.**

Observed globally-averaged temperatures indicate that the six warmest years on record have all occurred since 1997 (in order of severity: 1998, 2002, 2003, 2004, 2001 and 1997). Across Europe the warmest ever summer since 1500 was 2003. Moreover, the 20th century was the warmest 100 year period in the last 1000 years, and had the greatest warming within a century.

The analysis of temperature extremes in MICE suggests that Southern Europe will experience considerable future warming under both the A2 and B2 scenarios, with the greatest warming occurring with A2 emissions.

The number of freezing days in winter (warmest daytime temperatures below 0°C) is likely to decrease across Europe, with the greatest reductions in the north where the freezing season may shorten by up to 120 days per year by 2070-2099 compared to 1961-1990. The number of frost days in winter (lowest night time temperature below 0°C) may decrease across Europe by between 60 and 120 days per year, with the greatest reductions again being found in northern areas. These changes have implications for snow conditions, winter transport,

CLIMATE EXTREMES

pests and diseases, vegetation, slope stability, the length and timing of the growing season, and energy demand.

An analysis of the occurrence of tropical nights during summer (minimum night time temperatures above 20°C) shows that these will occur in regions which have never previously experienced such warm night time conditions. The number of tropical summer nights will increase in regions such as the Mediterranean by up to 60 days per year by 2070-2099. This has implications for human comfort levels, human health, and energy demand increases for space cooling.

The number of consecutive days with high daytime temperatures exceeding 25ºC increases by several weeks across the UK and Scandinavia, with greater increases across the rest of the continent (Figure 3). A possible indication of what is to come was experienced in Paris, France, during the European summer heatwave of 2003. Parisian temperatures on most days in early August exceeded 40°C, and the highest night time temperatures ever recorded were on 11 and 12 August (25.5°C). This led to a sharp increase in the number of deaths in that month. It is estimated that the excess number of deaths, over those normally recorded, was 14,000.

RAINFALL

Key Messages:

- **More intense rainfall has already been observed.**
- **Snowmelt and ice-jam floods have become less common, and this trend is likely to continue in the future.**

In the warmer climate of 2070-2099 (A2 emissions scenario):

- **Southern Europe and the Mediterranean are expected to become generally drier with prolonged droughts commonplace in summer and reduced rainfall in winter.**
- **Northern Europe is expected to become generally wetter in winter but periods of drought are likely to become more frequent in summer.**
- **The number of episodes of heavy rainfall (intense showers) could increase, either absolutely, or as a proportion of the total rainfall. In a wetter Northern Europe, there will be more days of high rainfall. In a drier Southern Europe, a higher proportion of the rainfall will fall on very wet days (although the absolute number of days of high rainfall will decrease).**
- **Increasing winter rain is expected over most of Europe, leading to a greater flood risk.**

Changes in the frequency and intensity of rainfall can have devastating consequences for the built and natural environments. In August 2002 a series of heavy rainfall events resulted in the deaths of 100 people from flooding in Germany, Austria, Russia and the Czech Republic. Floods rapidly spread across Europe causing severe damage to housing and public infrastructure, forcing thousands of people out of their homes. The worst-affected region was the Czech Republic, where Prague and the region of Southern Bohemia saw approximately 200,000 people forced to leave their homes. In addition to the rising water levels, residents faced the spread of disease and the pollution of their water supply and food as sewage treatment plants were forced to close.

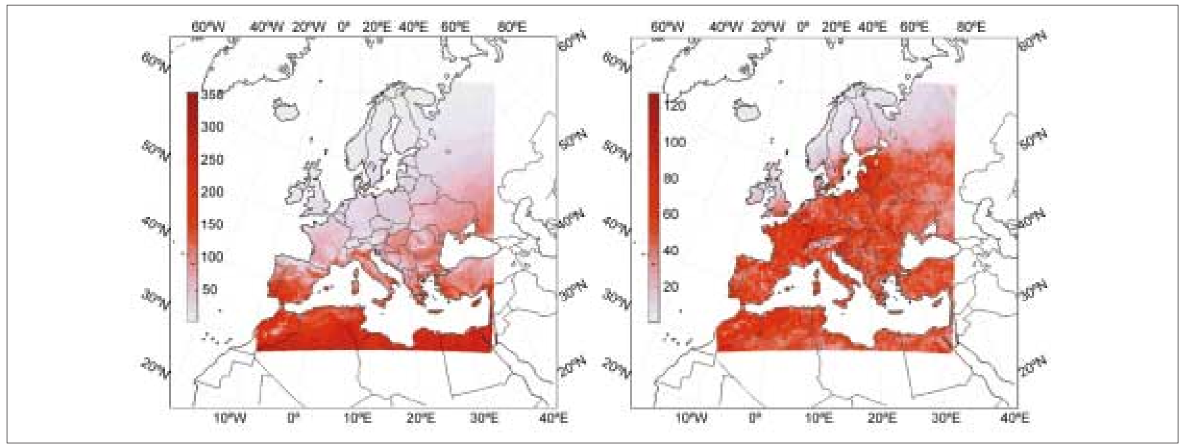


Figure 3: The length of the warm period defined as the number of consecutive summer days with maximum temperature >25°C during the 1961-1990 period (left) and the change by 2070-2099 (right), shown as the difference between 2070-2099 minus 1961-1990, under the A2 scenario.

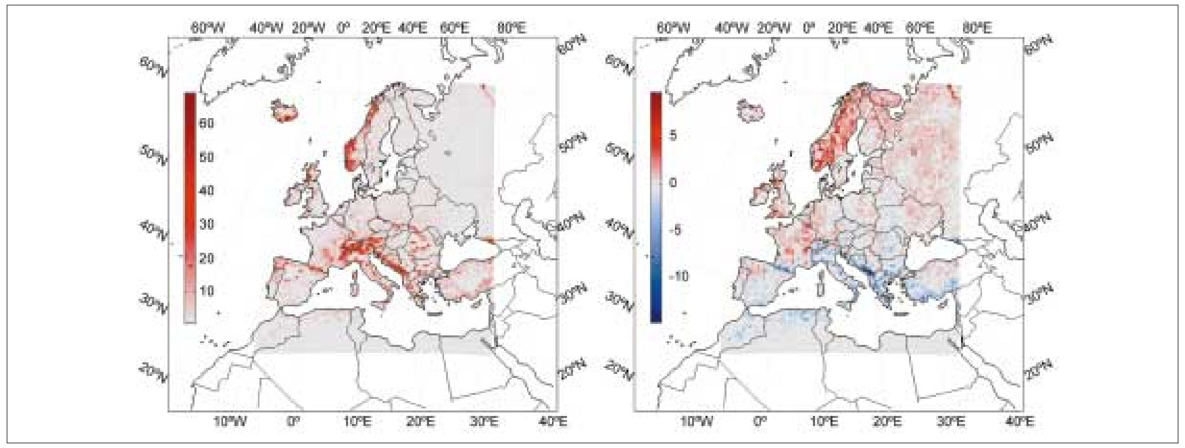


Figure 4: The number of intense rainfall days during 1961-1990 (left) and the change by 2070-2099 (right), shown as the difference between 2070-2099 minus 1961-1990, under the A2 scenario.

An analysis of future changes in rainfall indices in MICE found that, over Northern Europe, rainfall amounts tend to increase during the winter and decrease during the summer. In addition, and as has already been found in the observed record, the frequency of heavy/intense rainfall events will continue to increase in the future, particularly in the winter season. Over Southern Europe, rainfall is expected to decline throughout the year. However, an increased proportion of the rainfall which does occur will be in intense events (Figure 4). These changes in heavy rainfall events have implications for flash flooding, urban drainage, water management, erosion, slope stability and ground water recharge.

Over much of Southern Europe at the present day, little or no rainfall is experienced during the month of August. The MICE project studied the behaviour of the Mediterranean summer drought in the future, in response to climate change. It was found that most of the Mediterranean and southern France can expect several months of summer drought in every year, with much reduced rainfall in winter. In parts of southern/central Spain it is likely that droughts will, on occasion, persist throughout the year. The resulting stress on water resources will probably lead to a shift in the main seasons for both the agriculture and, combined with higher summer temperatures, the tourism sectors.

CLIMATE EXTREMES

WIND

Key Messages:

- **Under both the A2 and B2 scenarios, fewer storms in total are expected in the future (2070-2099).**
- **However, the number of severe winter storms over Western Europe is expected to increase in the future in response to human-induced climate change.**

High wind speeds are associated with large depressions, otherwise known as extra-tropical cyclones, which develop across the North Atlantic and generally tend to track along an axis from south-west to north-east across the ocean into Europe. These systems tend to be relatively short duration hazards but are still capable of causing significant damage and disruption. Many studies have found, during the latter part of the 20th century, an increasing trend in the frequency of damaging windstorms developing across the North Atlantic. However, no consistent trends across 100 years of data have been detected.

Despite the lack of a clear trend in storm activity, the associated damage produced by storm impact has revealed how vulnerable Europe is to windstorms. The storm Lothar which tracked across France on December 26th 1999 killed 87 people and destroyed 5000 km^2 of forest.

Within MICE, cyclones developing across the North Atlantic were identified and tracked from observed and climate model gridded data. For all systems, irrespective of intensity, the analysis found that storm track density in the future, under the A2 and B2 scenarios, is reduced, particularly over Northern Europe (the Norwegian Sea and Scandinavia).

For the more intense/severe systems, the track density is also reduced over Northern Europe but is found to increase south of 60°N over Western Europe. The A2 and B2 scenarios differ mainly with regard to the most extreme systems, with less pronounced changes in the B2 scenario (2070-2099) compared to 1961-1990 (Leckebusch and Ulbrich, 2004).

An analysis of extreme wind speeds from the Hadley Centre climate models showed a future increase in the number of days with very high wind speeds over a latitude band from 45°N to 55°N under the A2 scenario (Figure 5). However, in the B2 scenario no such changes compared to the baseline period could be identified.

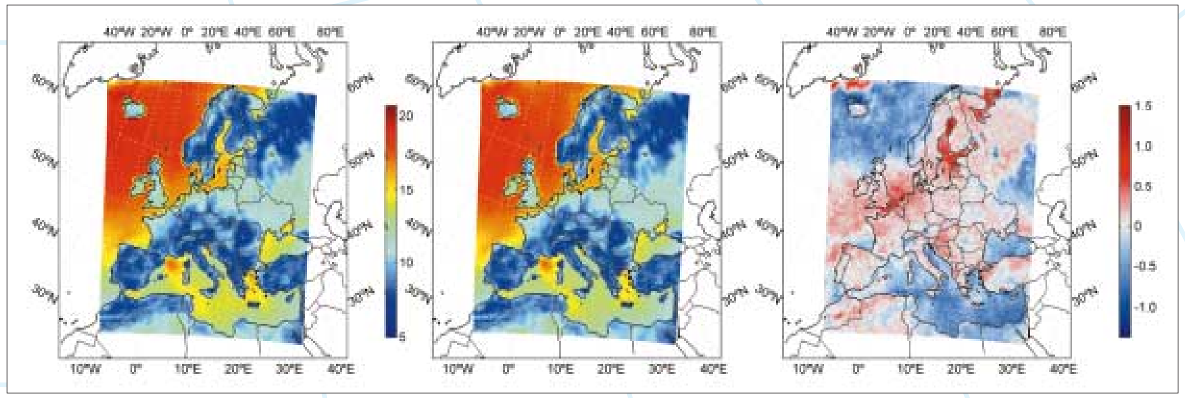


Figure 5: The left hand and centre maps show the wind speed which separates the windiest 5% of days from the remainder, for 1961-1990 (left), and for 2070-2099 (centre) under the A2 scenario. The right hand map shows the difference (2070-2099 minus 1961-1990), i.e. pink indicates that the 95% threshold has become higher, and conditions are windier. Units m/s.

IMPACT SECTORS

INTRODUCTION

Six impact sectors were investigated in the MICE project:

- Water: the effects of intense rainfall events leading to flooding, and droughts.
- Mediterranean agriculture: the effects of heat stress and drought.
- Forestry: the changing risk of forest fire, windstorm damage and bark beetle attack through the influence of windstorm, heat stress, drought and flood.
- Energy: focussing on the relationship between energy demand and temperature,
- Insurance: the effects of windstorm damage on property-related insurance losses, and flooding.
- Tourism: Alpine winter sports holidays focussing on snow production, and Mediterranean summer holidays focussing on heat stress and human comfort levels.

WATER

Key Messages:

- **Floods, droughts and episodes of water pollution are likely to become more severe and more common in the future (2070-2099) under the A2 scenario.**
- **There will be adverse effects on a number of activity sectors including:**
  - **Agriculture.**
  - **Hydroelectricity production.**
  - **Property insurance.**
  - **Health.**

Northern and Central Europe

According to climate model results, average summer rainfall over Central Europe is likely to decrease in the future. However, the same trend is not seen in the highest extreme daily precipitation amounts. The models indicate that the number of days with intense precipitation and the annual maximum daily rainfall is higher in the period 2070-2099 than for the period 1961-1990 over much of Europe, especially in Central and Northern parts. This includes the basins of the Elbe, Odra and Vistula, which suffered destructive flooding in 1997, 2001, and 2002.

In many areas, river flooding risk may increase in the future. There are several mechanisms triggering inundations, which are affected in different ways by climate change. An increase in intense precipitation may increase the risk of summer flooding. In wetter and warmer winters, with increasingly more frequent rain and less frequent snow, the risk of flood may also increase because rainfall is delivered to the river rapidly, whereas snow is stored until the spring melt. On the other hand, ice-jam floods may become less frequent and less severe. Since snowmelt is earlier and less abundant, the risk of spring floods decreases.

Western and Southern Europe and the Mediterranean

The model predictions show that "dry and hot" extremes are likely to become more severe in the future for most of Europe. The duration of the longest dry spell in the period 2070-2099 over Europe is likely to be considerably longer than in 1961-1990. Bivariate analysis of the longest hot and dry spells (with several thresholds of "hot" and "dry") shows considerable changes. Longer dry spells and longer warm-and-dry spells are predicted, particularly in Spain, Portugal, Italy, the north coast of France, the south coast of Britain, and Southern Ireland (Figure 6). The areas already affected by water deficit in the present climate (e.g. Southern Europe) are expected to experience even more severe conditions in the future.

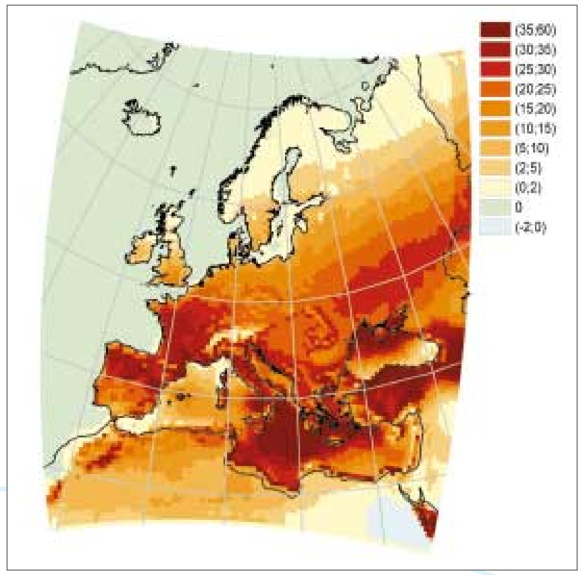


Figure 6: The difference (2070-2099 minus 1961-1990) in the average number of dry and hot days (maximum temperature ≥30°C and precipitation ≤0.1 mm) experienced across Europe under the A2 scenario.

AGRICULTURE

Key Messages:

Mediterranean Agriculture (A2 and B2 scenarios)

- **Reductions in yields are expected in the future (2070-2099), due to:**
  - **Shorter growing season.**
  - **Extreme events during development stages.**
    - **Higher risk of heat stress during the flowering period.**
    - **Higher risk of rainy days during sowing dates.**
    - **Higher rainfall intensity.**
    - **Longer dry spells.**
- **These effects are expected to be greatest over the southern Mediterranean and North Africa.**

European agriculture is sensitive to extremes of climate. As an example, during the summer of 2003, European agriculture was severely affected by the heat wave that began in early June and continued until August. Crop development was accelerated by 10-20 days resulting in earlier ripening and maturity. High temperatures and solar radiation resulted in increased crop water consumption causing acute depletion of soil water and an eventual lowering of crop yields. Cereal production was badly affected across the whole of Europe and yields fell by 23 Mt compared to 2002. As a consequence, the low cereal harvest had to be covered by more than 6 Mt of imports under mandatory quotas and more than 10 Mt from carry-over stocks.

The effect of climate change on the development and yield of typical summer (sunflower) and winter (wheat) Mediterranean agricultural crops was investigated in the MICE project using the CROPSYST model. In addition, the frequencies of climate extreme events (e.g., minimum and maximum temperatures exceeding temperature thresholds, rainy days) during specific crop development stages (e.g., sowing, flowering, maturity) were monitored under present and future climate scenarios.

The increase in temperature in the A2 and B2 scenarios was found to cause the earlier onset of the main phenological stages and a reduction of the length of the growth season in both crop types (wheat and sunflower). In addition, the frequency of extreme climate events during specific crop development stages (e.g., heat stress during the flowering period, rainy days during sowing dates) also increased (Figure 7). All these changes, together with higher rainfall intensities and longer dry spells, determined a potential impact on crop yields that is greatest in the summer crop (sunflower), in the southern areas of Mediterranean countries under the A2 scenario (Figure 8).

IMPACT SECTORS

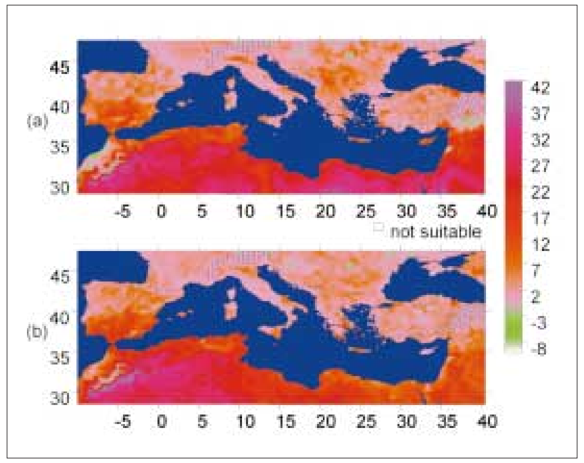


Figure 7: The percentage change in the risk of heat stress during the flowering stages of crop development across the Mediterranean region as a result of climate change. Differences are between the present day (1961-1990) and the future (2070-2099) periods for the (a) A2 and (b) B2 scenarios.

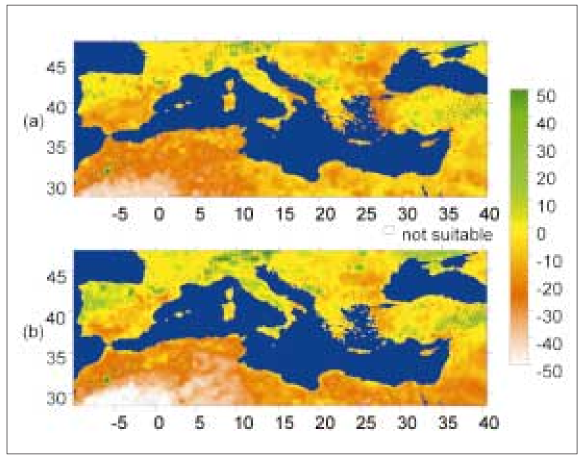


Figure 8: The percentage change in summer crop yield across the Mediterranean region as a result of climate change. Differences are between the present day (1961-1990) and the future (2070-2099) periods for the (a) A2 and (b) B2 scenarios. Green colours indicate that yields are expected to increase, orange colours that they are expected to decrease.

FORESTRY

Key Messages:

Mediterranean Forest Fires

- **In the future (2070-2099) under the A2 and B2 scenarios, an increased risk of forest fire is expected due to:**
  - **A higher number of dry and hot days.**
  - **Longer dry and hot spells.**
  - **A longer season with fire risk.**
- **The increased risk will be greatest in continental and upland areas.**

Boreal (Northern) Forests

- **In the future (2070-2099) under the A2 and B2 scenarios, there will be an increased risk of damage to Boreal forests due to the combined negative effects of increased mean temperature and extreme temperature.**
- **There is an increased risk of tree damage due to:**
  - **Early spring frost.**
  - **Summer droughts.**
- **Spruce, the most economically important tree species in Europe, is facing:**
  - **Increased risk of bark beetle damage.**
  - **Increased wind throw risk outside its natural distribution.**

IMPACT SECTORS

Mediterranean Forest Fires

Every year approximately 45,000 forest fires break out across Europe. The long hot summer of 2003 was a bumper year for forest fires, with more than half a million hectares of woodland destroyed across Mediterranean Europe. According to the European Commission, each hectare of forest lost to fire costs Europe's economy between €1000 and €5000. Fires cause considerable damage in terms of loss of life and in environmental terms through the destruction of fauna and flora. They also have serious economic implications: destruction of habitats, forest damage, costs of fire-fighting, and so on. Most of these fires are caused by people. However, there are many natural factors such as drought, wind speed and topography, which influence the spread of fires and govern their devastating effects.

In a future warmer climate, under both the A2 and B2 scenarios, there may be an increase in the meteoro-logical risk of fire. This increase can be attributed to a higher number of dry and hot days i.e., areas with temperatures greater than 30ºC and relative humidity below 20%, longer hot and dry spells and a longer fire risk season. The areas most at risk are in hilly, continental regions (Figure 9).

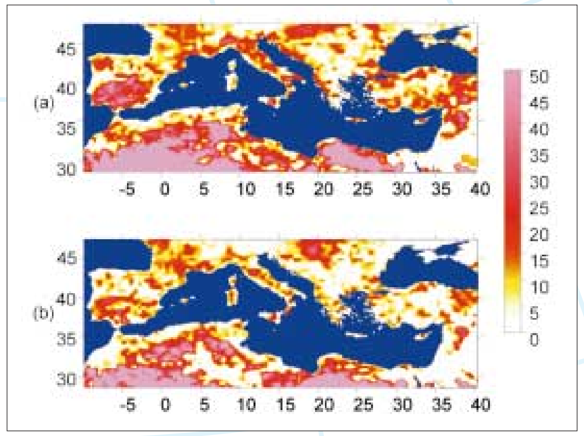


Figure 9: Changes in the length of the fire risk season defined as DSR (Daily Severity Rating) >6 for at least 5 days for the (a) A2 and (b) B2 scenarios for the Mediterranean region. Differences are between the present day (1961-1990) and future risk (2070-2099).

Boreal Forests

Strong winds blow down and break trees resulting in large economic losses in timber and ecosystem productivity. For example, in the UK, the Great Storm of October 1987 felled 15 million trees and the windy winter of 1989/90 blew down 100 million m³ of timber throughout Western and Central Europe. More recently, on the 8th February 2005, a severe storm hit the southern part of Sweden, with inland gusts exceeding 35 m/s. This resulted in devastating forest damages which far exceeded previous records. The Swedish National Forest Board estimated the losses at about 70 million m³ of timber, nearly three times the previous record of 25 million m³ which occurred during one of two large storms in 1969. In fact, the annual total loss for that year was 36 million m³ of timber.

Current discussions about climate change impacts on forests have often focused on the assumed increased growth encouraged by a warmer climate. However, extremes may be of greater importance. The combination of a raised mean temperature and an increase in extreme weather events will have negative effects on boreal forests in several ways.

- Predictions based on regional climate model data point toward an increased risk of frost damage on Norway spruce. In a milder climate, tree dehardening will begin up to two months earlier in southern boreal forests. Large temperature variations may occur earlier in the year, increasing the risk of freezing temperatures below the hardiness level.
- Summer dry spells are likely to increase in Europe, especially in the western and central parts of the boreal forest zone. Trees suffering from drought experience a decrease in vitality and will be more susceptible to frost damage and attacks by pests and disease.
- In southern Scandinavia and Western Europe, the risk of wind throw is projected to increase.
- Currently, the Norway spruce bark beetle (*Ips typographus*) is the pest that causes the greatest economic losses in spruce. Related to warmer temperatures, bark beetle damage is likely to become even worse in the future, since there is increased risk of an additional generation each year (Figure 10).

Forest management would have a large impact on susceptibility to storm damage and bark beetle damage.

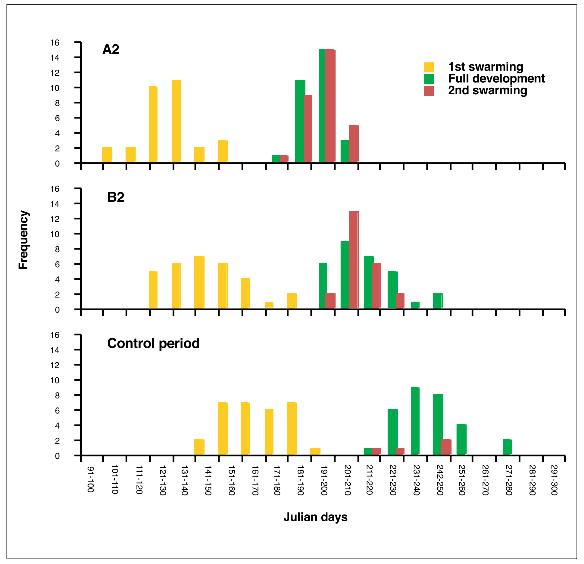


Figure 10: Results from running the bark beetle model for central southern Sweden for the control period (1961-1990) and the A2 and B2 future scenarios (2070-2099). In both future scenarios full development occurs earlier than during the control period, and there is a greater likelihood of a second generation of bark beetle.

ENERGY

Key Messages:

Pan-European Energy Demand

- **Energy production in Europe is sensitive to extremes of temperature. High temperatures can lead to the shut down of power plants due to overheating and the lack of suitable cooling waters extracted from rivers.**
- **Pan-European studies show a decrease in monthly energy consumption during the space heating season in milder winters and an increase in consumption during the space cooling season in hotter summers.**

Energy Demand in Southern Europe

- **There is an increasing trend in energy demand due to economic growth.**
- **Energy demand is lower during spring and autumn and holidays/weekends. There is a peak in demand in December and July.**
- **There is a definable temperature at which energy demand is at a minimum (in Athens, 22°C).**
- **The seasonal cycle of demand will change in response to global warming, with lower demand in winter (space heating) and higher in summer (space cooling).**

Energy consumption is sensitive to changes in temperature. In the UK, this was demonstrated during the relatively mild winter of 1994/5 and the unusually warm summer of 1995. The combination of a mild winter and a warm summer led to savings of £200 million and £74 million for domestic gas

IMPACT SECTORS

consumers, respectively. The additional cost of electricity for space heating meanwhile was £34 million. This leads to an estimate that a 2°C increase in annual temperatures would save domestic consumers around £688 million (at 1995 prices) (Watson and Woods, 1997).

More recently, during the summer of 2003, record high temperatures across Europe resulted in problems with power plant cooling due to water shortages and warm river waters. For example, German nuclear power plants on the Upper Rhine and the Neckar River were forced to reduce their power production by 20% for several days in August due to river (cooling) water temperatures in excess of 26°C. In the case of the Obrigheim plant on the Neckar, this had to be completely turned off due to insufficient cooling water. The potential for Germany to face blackouts was high at this time and several power plants had to obtain special permission from the German water resources management administration to exceed the limits of cooling temperatures to which they are restricted by law.

The modelling of pan-European gas and electricity consumption was carried out in the MICE Project. Two seasons were analysed – the space heating and the space cooling seasons.

During the space heating season, there is evidence of a strong relationship between air temperatures and the consumption of electricity and gas. In both forms of energy, increases in temperature lead to a reduction in demand. As a result, the decreases in energy consumption can be expected to become larger through time as the climate change signal becomes stronger. The size of the reduction is expected to vary across Europe along a northwest-southeast gradient; smallest in maritime regions and largest in the southernmost parts of continental Europe where the greatest degree of warming is expected to occur. Figure 11 shows that, across Italy, the decrease in electricity consumption during the space heating season is expected to be of the order of up to 35% by 2070-2099.

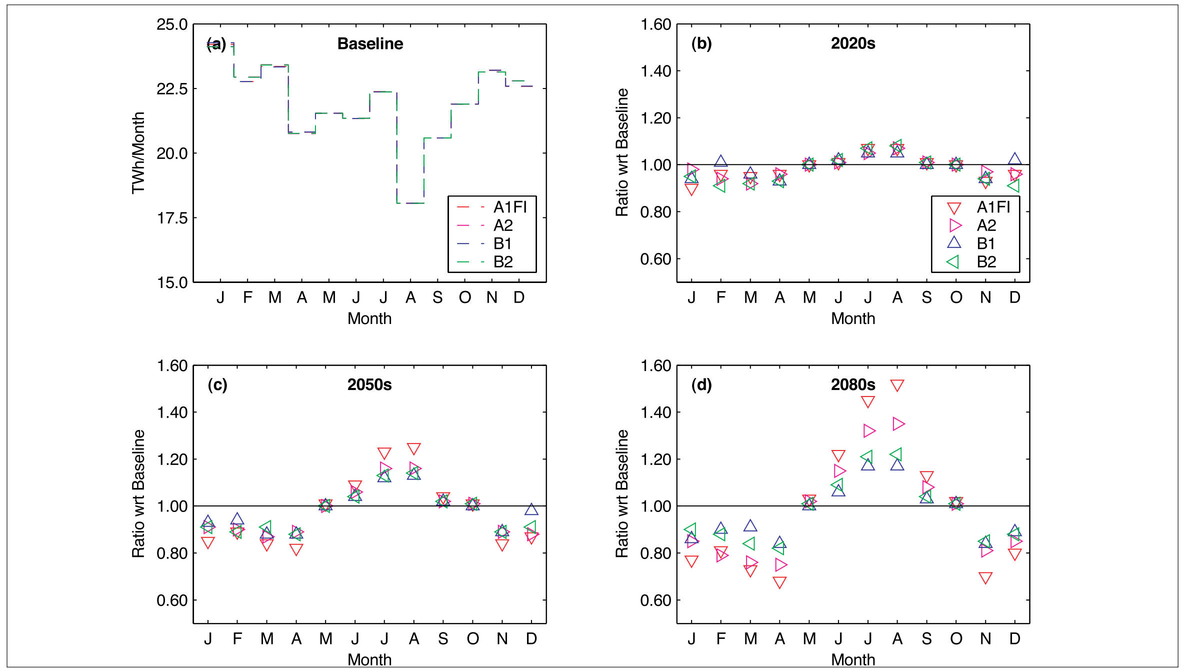


Figure 11: Monthly ratios of future Italian monthly electricity consumption under four SRES scenarios with respect to a baseline period of 1961-1990. The 2020s represent the 30 year period 2010-2039, the 2050s represent 2040-2069 and the 2080s represent 2070-2099.

In contrast, the results from the space cooling season are more mixed. An analysis of electricity consumption during the warmer months of the year suggests a relationship between temperatures and consumption. This relationship varies on a north-south transect across the study area, changing from an inverse linear function in the north to a quadratic function with a breakpoint around 18°C in the south. The behaviour of gas consumption across Europe also indicates the existence of an inverse linear relationship, which remains constant across the entire study area. Figure 11 shows that, across Italy, in the future the expected increase in electricity consumption is of the order of up to 55% during the summer months by 2070-2099.

PROPERTY INSURANCE

Key Messages:

Property Damage from Windstorm for the UK

- **With adaptation, insured property losses due to windstorm are expected to increase by 15% in 2070-2099 under the A2 scenario.**
- **Without adaptation, they are expected to be much higher.**
- **Potential adaptation strategies include increasing the responsibility of the policy holder to ensure properties are well maintained, and the identification of thresholds above which insurance is not available.**

Storm damage is a major component of insurance claims costs and can cause operational problems through the handling of large volumes of claims and the difficulty in obtaining tradesmen and materials to carry out repairs. As an example of the huge losses that can be incurred following large storm events, in 1990 four large windstorms affected Europe resulting in insured losses of €8.8 billion and economic losses of approximately €11.6 billion. More recently, in 1999, a series of three storms produced €8 billion and €16 billion in insured and economic losses, respectively (all losses at 2004 prices).

An estimation of potential future loss due to winter windstorm suggests an increasing loss potential for property damages for wide parts of Western Europe (e.g., England, France, and Germany), up to 15%. This is comparing the 2070-2099 period to the baseline of 1961-1990 for the A2 scenario (Figure 12). No significant future changes compared to 1961-1990 could be identified in the B2 scenario. This estimation already takes adaptation to possible future conditions into account. Without adaptation the increase will be approximately 20%.

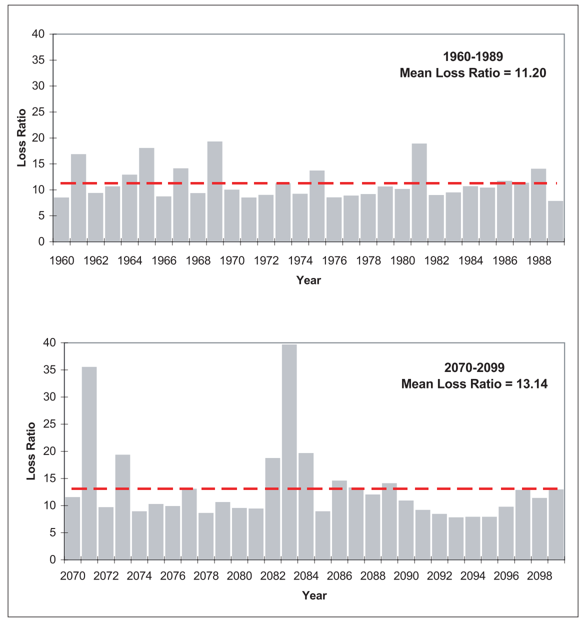


Figure 12: The loss ratio per €100,000 of insured value for England during the baseline period (1960-1989); and the future period (2070-2099) under the A2 scenario. The dashed line represents the mean loss ratio for each 30 year period. The mean loss ratio increases by approximately 15% in the future.

TOURISM

Key Messages:

Winter Sports in the Alps

- **Snow depth is expected to decrease by about 20-30% by 2020 under the A2 scenario.**
- **The most sensitive altitude range is below 1500m.**
- **For every 1°C rise in temperature there will be about 14 fewer skiing days.**

Mediterranean Summer Tourism

- **Warmer Northern European summers encourage an increase in domestic holidays.**
- **In a warmer future, there is an increased likelihood of people from the Mediterranean holidaying in the north.**
- **More frequent and more intense heat waves and drought are likely to discourage Mediterranean summer holidays.**
- **There is likely to be a shift in the Mediterranean holiday season to spring and autumn.**

Winter Sports in the Alps

A range of climate change studies were carried out in the MICE project to construct a set of snow cover scenarios from climate model data. Figure 13 shows that for the 2020s (2010-2039) there is a marked decrease in the depth of snow in the Alps. In general, the decrease is of the order of 20-30%, with the greatest reduction being found at altitudes below 1500 m. These analyses have also found that the number of days with snow cover greater than 30 cm is a function of temperature and that every 1°C

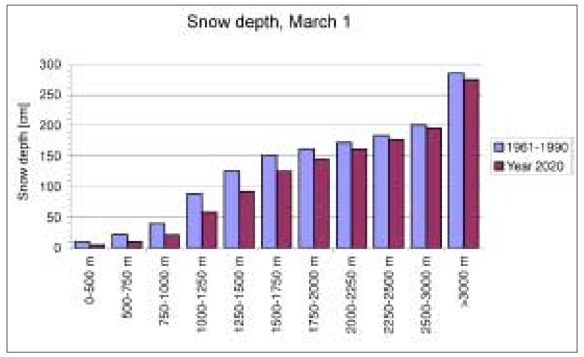


Figure 13: Snow depth at March 1st for the baseline period (1961-1990) and the future period 2010-2039 (the 2020s) at different altitudes in the Alpine region under the A2 scenario.

increase in temperature is associated with a 14 day decrease in the length of the ski season.

In addition to the effect on the amount of snow lying under climate change, increased winter temperatures are likely to lead to an increase in the altitude of the snowline by up to 100 m per decade. Climate models also show that snow fall events at higher elevations could lead to an increase in the risk of avalanche in the future.

Mediterranean Summer Tourism

As some measure of the economic importance of summer tourism to the Mediterranean, 147 million international tourists visited the Mediterranean in 2003 (this is 22% of the international tourism market) and generated €8.8 billion for the region (WTO, 2004a,b). Seventy percent of these tourists visited just two countries, Italy and Spain. It is very difficult to model the response of tourists to climate change. However, through discussions with experts at a MICE regional workshop "Impacts of climate extreme events on Mediterranean tourism and beach holidays", it was possible to identify some of the impacts climate change may have on the tourism industry.

Temperature over the Mediterranean region may rise by 0.3-0.7ºC per decade in the future. This has implications for the number of days with temperatures exceeding 40ºC, which obviously will affect the thermal comfort of tourists and their ability to acclimatise to a region with such high temperatures. Summer rainfall may decrease by approximately 15% in the future, leading in turn to shortages in the public water supply and more widespread desertification, which may affect the aesthetics of the region. In combination, decreased rainfall and increased temperatures may lead to a greater frequency of forest fires. Intense rainfall events in winter may increase, leading to greater erosion rates and a higher risk of flooding.

It is not, however, just the change in climate over the Mediterranean that will impact on the region's tourism. Improvements in the climate of the source regions of the tourists visiting the Mediterranean will also affect the popularity of the area. Warmer, drier and more reliable summers in Northern Europe will encourage tourists to take domestic holidays and will encourage those in the Mediterranean to holiday further north, away from the high temperatures and water deficits likely in the south during the summer. It is also likely that the Mediterranean holiday season will split into two, in the spring and the autumn, when climate conditions should be more comfortable.

WORKSHOPS

Key Messages:

- **The need for near future as opposed to distant future scenarios – 2020s instead of 2080s. The issue of climate change tends to be ignored by decision-makers and policy-makers because of the timescale.**

- **The need for more reliable climate modelling – the message from the end-users is to reduce uncertainty and to provide more accurate and consistent (inter-model) information. Uncertainty is too large to make climate change a manageable issue, and as such it tends to be overlooked in decision making.**

- **The need to make research results more accessible to the lay-person. Stakeholders should be involved in the research, and information should be disseminated at interim stages.**

- **The need to bridge the gap between what scientists can produce and what end-users require.**

The MICE project defined a number of activity sectors where future climate changes can be expected to have large impacts, but where we lack mathematical models to quantify these impacts. These sectors are:

- winter sports in Alpine regions, affected by future changes in snowfall, snow cover and temperature (Schwarb, 2004),
- flooding in Central Europe (Kundzewicz, 2004),
- catastrophic forest damage in Scandinavia (Stjernquist, 2004),
- beach holidays in the Mediterranean Basin (Giannakopoulos, 2004).

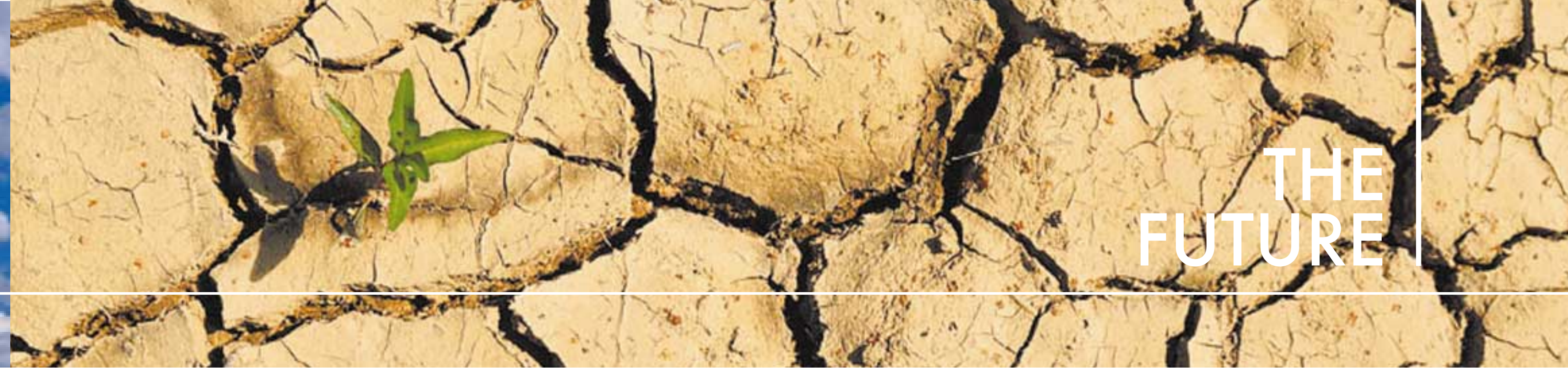
For these sectors, the MICE project took the approach of eliciting expert opinion on the likely impacts.

In order to harness the collective wisdom of stakeholders and end-users, a set of four regional mini-workshops were organized, covering each of the sectors. The workshops served as a platform for communication between scientists and stakeholders, enabling the two-way flow of information – from scientists to stakeholders and from stakeholders to scientists.

End-users of information generated in the MICE project were given the opportunity to react to the scenarios of climate change and to reflect on their perceptions of the likely impacts of projected changes in extremes on relevant activity sectors and the potential to adapt and avert adverse consequences.

The regional workshops served as a vehicle for dissemination of the state-of-the-art of the scientific understanding of climate change, and for the identification of stakeholders' needs from the research community. The audience was drawn from managers and employees in the sector of concern, public administrators at different levels, spatial planners, representatives of the insurance and reinsurance industry, researchers, educators, and the media. In addition to the regional mini-workshops, a large pan-European stakeholder workshop was held in Florence in October 2004, towards the end of the MICE project. End users from the six impact sectors investigated in MICE attended the workshop along with climate scientists and government representatives. In total there were 44 participants with 24 stakeholders, 14 MICE representatives and six additional climate scientists.

The workshops identified several common needs amongst the varied impact sectors. These are shown in the key messages.



THE FUTURE

The partners in the MICE project worked over three years to study the impacts of climate change on a range of human activities and the environment in Europe. A strong component of the project was the involvement of end-users throughout, and especially in the workshops which were a forum for the exchange of knowledge between scientists and stakeholders. This booklet has been produced as part of the stated objective of MICE to deliver the project results to end-users, in a form useful to those involved in the operational management of climate change impacts.

If the booklet goes someway towards fulfilling the need for useful information on climate change amongst policymakers and managers, and towards presenting research results in a relevant, interesting and accessible manner, the project will have succeeded in one of its major goals.

The MICE project is just one of a number of projects funded by the European Commission to study future climate change and its impacts. A new project, ENSEMBLES, an Integrated Project funded under the EU Framework 6 Programme, continues this work. The web page for this project can be accessed at: http://www.ensembles-eu.org/.

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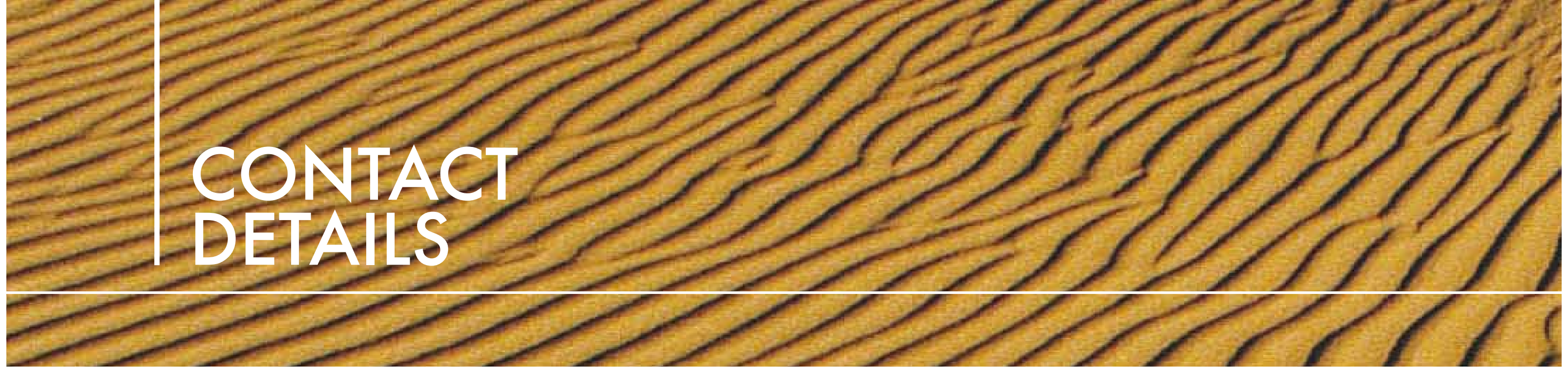

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