Modelling the Impact of Climate Extremes:

An overview of the MICE Project

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Abstract:

This paper provides an overview of the aims, objectives, research activities undertaken, and a selection of results generated in the European Commission-funded project entitled "Modelling the Impact of Climate Extremes" (MICE) - a pan-European end-to-end assessment, from climate model to impact model, of the potential impacts of climate change on a range of economic sectors important to the region. MICE focussed on changes in temperature, precipitation and wind extremes. The research programme had three main themes – the evaluation of climate model performance, an assessment of the potential future changes in the occurrence of extremes, and an examination of the impacts of changes in extremes on six activity sectors using a blend of quantitative modelling and expert judgement techniques. MICE culminated in a large stakeholder-orientated workshop, the aim of which was not only to disseminate project results but also to develop new stakeholder networks, whose expertise can be drawn on in future projects such as ENSEMBLES. MICE is part of a cluster of three projects, all related to European climate change and its impacts. 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).

1 Introduction:

MICE (Modelling the Impact of Climate Extremes) is a European Commission (EC) 5th Framework funded project under the Energy, Environment and Sustainable Development programme (Grant number: EVK2-CT-2001-00118). Co-ordinated by the University of East Anglia, UK, MICE ran for 36 months from January 2002. The eight project partners were drawn from across Europe: Germany, Greece, Italy, Poland, Portugal, Sweden, Switzerland, and the UK, experiencing a range of climates and a large diversity in activity sectors at the regional scale.

The purpose and aims of MICE were to carry out a thorough assessment of the impact of climate change from model output to likely impacts on human and natural environments. This was achieved by (1) identifying potential changes in the frequency and magnitude of rainfall, temperature and windstorm events in Europe due to global warming, and (2) examining the impacts these changes may have on specific sectors – agriculture, commercial and natural forestry, energy use, water resources, tourism and civil protection/insurance.

The MICE research activities were organised into three main stages. Stage One involved taking information about future changes in climate extremes from climate models. These models were first evaluated regarding their ability to simulate the current day occurrence of extremes using observed gridded and station data. Stage Two involved using model output to assess future changes in the occurrence of extremes. In particular, return periods, joint probabilities, sequential events and the spatial patterns of extremes. The third and final stage focussed on the impacts of changes in extremes on six activity sectors using a variety of methods. Where possible, pre-existing quantitative models were used e.g., forest fire and windthrow models. For other sectors, such as energy use, the relationships with climate are well understood, and models exist, but had to be adapted for use in a climate change impact assessment. For categories such as tourism, models exist only for the physical part of the system, e.g., modelling snow depth or human comfort. In order to assess the full impact on the activity sector it was also necessary to conduct an expert-judgement based analysis.

To guarantee the maximum utilitarian value of the MICE research findings, stakeholder/end-user input was encouraged throughout the project. At each six-month project meeting stakeholders local to the region hosting the meetings were able to discuss their concerns and highlight the information they would require to make judgement-based policy decisions regarding their adaptation to climate change. In addition to these local project meetings, a series of activity-specific mini workshops were held, culminating in a final pan-European workshop hosted by the University of Florence, Italy in October 2004 with the aim of disseminating the information produced by MICE and establishing a wider, two-way interface between stakeholders and academics. A broad spectrum of stakeholders/end-users attended the Florence workshop. These included members of government from several countries, forestry representatives from Sweden and Italy, energy specialists from France and the UK, water authorities from Poland and the UK, agricultural specialists from Spain and Italy, tourism representatives from Greece and Switzerland and insurance companies from Switzerland and the UK (Hanson et al., 2006).

The following sections of this paper describe the three main stages of the MICE research plan, illustrated with selected results where appropriate. Section 2 focuses on the definition and extraction of climate extremes indices for analysis from climate model, observed and reanalysis data. Section 3 outlines the model evaluation exercises undertaken by MICE. Section 4 describes the analysis of future climate extremes with respect to their temporal and spatial characteristics. Section 5 focuses on the quantitative modelling of the impacts of changes in climate extremes and includes a description of the four mini-workshops and the final stakeholder workshop held in Florence. Finally, section 6 presents the conclusions of the project.

2 Definition and Extraction of Climate Indices:

MICE focussed on changes in extremes rather than in the mean climate for a number of reasons. First, climate scientists have, for a number of years, thought that 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, it is believed that 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. Second, empirical evidence suggests that the response of the environment and human activities to extreme weather and climate events such as windstorm, floods and droughts is different to the response to that instigated by a change in the mean climate. The response time is shorter, and we would argue that the response tends to be greater. For example, changes in mean rainfall such as those predicted by most GCMs, is likely to lead to slowly-evolving changes in the natural and managed ecosystems, which can be accommodated relatively easily. However, if floods or droughts become more severe and/or more frequent, the impacts will extend to include damage to property and loss of human life. In order to assess changes in extremes and impacts on activity sectors, it was first necessary to identify and appropriately define impacting weather and climate events. From this catalogue, a range of indices were selected, together with their parent climate variable, for analysis (Table 1).

2.1 Definition of Indices of Extremes:

MICE defined three types of extremes based on percentile and fixed thresholds, and absolute amounts for temperature, precipitation and wind speed. These were (1) **diagnostic measures**, e.g., the number of days per year above the 95th percentile of temperature, where the percentile value is calculated from 1961-90 data, (2) **impacts-related measures**, related for example to sectors such as agriculture (e.g. date of the first autumn frost), energy supply/demand (based on degree days) and flood (e.g. greatest 3-day precipitation total per year), and (3) **indices for the calculation of extreme value parameters** based on distributions such as the Generalized Extreme Value distribution, e.g., the highest and lowest temperature values in each year, the highest daily rainfall amount in each year. In total, forty-one indices were identified and defined.

2.2 Extraction of Indices:

Indices were extracted for the MICE study domain (Figure 1) from several datasets. During the first half of the project NCEP reanalysis data (Kalnay et al., 1996; Kistler et al., 2001) for the standard climate normal period 1961-1990 and climate model data, provided by the LINK project (HadCM3, HadAM3H and HadRM3H) were utilised.

NCEP reanalyses were used for the validation exercises, for the period 1961-90, because they are gridded and are hence, more directly comparable with climate model data than are station observations (from point sources). The NCEP data are generated at a resolution of T62 (approximately 1.875° resolution) and have been re-gridded to 2.5°. However, it cannot necessarily be assumed that reanalyses are a true picture of the climate at the local scale. For this reason, for selected case study areas, MICE compared station records with reanalysis grid box output.

Climate change experiments conducted using the UK Hadley Centre's third generation coupled atmosphere-ocean global climate model (AOGCM), HadCM3 (Johns et al., 2003; Gordon et al., 2000; Pope, 2000), span the period 1860 to 2099. While daily data were available, the model has a relatively low spatial resolution of 2.5° latitude by 3.75° longitude, which limits its use at the local scale. As a result, several experiments were utilised from HadAM3H (a high resolution, atmosphere-only GCM (AGCM)) and HadRM3H – an atmospheric regional climate model (RCM) nested within HadAM3H (Hulme et al., 2002). Both are run at the higher spatial resolutions of 1.25° by 1.875° and 0.44° by 0.44°, respectively, which improves their ability to simulate small scale weather phenomenon. However, both suffer from the fact that they are run for two time slices only (1961-90 and 2070-99). Data for all three models were provided for the A2 and B2 SRES scenarios (Nakicenovic and Swart, 2000).

Due to the withdrawal of HadAM3H and HadRM3H in 2003 by the Hadley Centre, the MICE indices were re-extracted for the replacement models HadAM3P and HadRM3P (Jones et al., 2003). Due to the constraints of the two time periods available for both the high resolution AGCMs and the RCMs, MICE analyses were restricted to these two periods. The loss of information from using the 30-year windows, especially with respect to natural decadal-scale variability in extremes occurrence, was evaluated by comparison with the transient climate scenarios generated by the driving AOGCM, in this case HadCM3.

A number of comparisons were conducted between the different climate models: (1) between the different forcing scenarios (A2 and B2), to examine the effect of varying the scenario on the response of extreme event occurrence; (2) between the GCM and RCM experiments to examine the effect of increased spatial resolution and orographic detail; (3) between the GCM/RCM data and the NCEP reanalysis data in order to validate the climate model output; (4) between station data and the NCEP reanalysis and GCM/RCM data for the reference period in a validation exercise of the three data types; and (5) between a subset of indices derived from both (H and P) versions of the climate models in order to identify any significant differences between the two versions.

3 Climate Model Evaluation:

Instead of the widely used validation of the mean, and other measures of the complete distribution, MICE carried out an evaluation of the ability of the climate models to describe the tails of the distribution in the 1961-90climate reference period. To achieve this goal, MICE compared climate model results with NCEP reanalysis data, for the 1961-90 period. In this context, the reanalysis data have the following advantages over point observations: first, they are gridded, and thus both reanalysis and model data share the common characteristics of gridded data which make them clearly comparable; second, they are broadly homogeneous, and certainly free of many of the sources of error that can affect point observations; finally, they are readily available. However, reanalysis data are in themselves partly the product of numerical weather modelling, and as such have their own errors and inconsistencies which, with respect to the MICE variables, will have the greatest effect on rainfall and wind data, whist temperature data can be expected to be reliable. MICE made the assumption that NCEP reanalysis and climate model data can be compared usefully to evaluate climate model performance.

For the spatial domain selected by MICE, 304 HadCM3 grid boxes cover the region. It was not possible to carry out a rigorous analysis of the entire region so instead, comparisons were carried out on a subset of grid boxes. HadCM3 and NCEP use different grids, so to avoid the smoothing associated with interpolation to a common resolution, MICE selected data for common grid boxes. Model evaluation was conducted by comparing frequency distributions using the Anderson-Darling test (very good at the tails of a distribution) and the Cramér-von Mises test (good at all parts of a distribution, particularly the centre). Rigorous testing demonstrated that the interpolation of the results, rather than of the raw data before the analysis, is acceptable, so that we could examine the performance of the model on a geographical basis.

For the RCM validation MICE compared point data (station records) to grid box data from HadRM3 and NCEP. To illustrate, Figure 2 shows an example of the comparison between NCEP, HadRM3 and station observations. This figure shows the number of frost nights (defined as Tmin <0°C) and the maximum observed one day rainfall (mm) in each year at Larissa, Greece (black), compared to HadRM3 (red) and NCEP (blue). In evaluating the comparison, it is important to note that although we would expect the mean and the variance to agree, we would not expect year-to-year variations to be in agreement. From Figure 2 it can be seen that in general there is good agreement between the three data sets when temperature is analysed. NCEP closely reflects the variation in the number of frost nights in Greece during the 1961-1990 period, particularly from the late 1960s to the mid-1980s. HadRM3 also performs well but with an overestimation of the variability of the time series. For precipitation-based indices (Figure 2 bottom plot), HadRM3 performs markedly better than NCEP, which fails to capture the mean or variance of the series.

In general, NCEP did not always compare well with observational data in terms of extremes. For example, NCEP data shows an unrealistic increase in absolute maximum temperatures and extreme events related to high temperatures for 1981-90, which is not found in station data (not shown). NCEP also tends to underestimate the number of tropical nights for continental stations, although it generally performs well in reproducing the patterns of extremes for these stations. In addition, NCEP does not reproduce the observed precipitation patterns related to extremes. In particular, it fails to represent violent and extreme thunderstorm activity or extreme recorded rainfall amounts.

In general, the evaluation of HadRM3 concluded that:

1. For most temperature indices based on daily maximum temperature and daily minimum temperature there are some statistically significant differences between indices calculated from observations and from HadRM3 output. Since the bias is negative for most indices, i.e., the model tends to underestimate temperature extremes, future values may be even higher than indicated by the simulations.

2. For indices based on total precipitation, although results are less clear, the general tendency is for more pronounced extremes from the model, i.e., longer summer droughts and more intense high precipitation events.

3. For daily mean wind indices, preliminary results indicate no statistically significant difference, either between HadRM3 and the observations for the baseline period, or between HadRM3 simulations for present day and future conditions.

4. Generally, duration indices from the models compare better with observations than absolute values. Differences between model extremes and observed extremes appear to be due to localised systematic error in the models, for example, over mountainous regions.

4 Future Climate Extremes:

The aim here was to identify statistically significant changes in extremes in the future. Extremes were identified for two periods (1961-90 and 2070-99) from HadCM3, HadAM3H/P and HadRM3H/P daily data. Results from the two time series were then compared using two methods - Generalized Extreme Values distribution (GEV) and Generalized Pareto Distribution (GDP), respectively obtained from time series of extremes and peak-over threshold values; and indices or measures of extremes, such as percentile thresholds, fixed thresholds and other indices chosen for applications, e.g. the greatest 3-day precipitation total per year.

In addition, MICE undertook an assessment of the change in the temporal and spatial characteristics of extremes in the context of the global model's (HadCM3) long term decadal scale variability. Inter-model comparisons were also carried out. Results from both these exercise are not shown here.

To illustrate the results produced from HadRM3H/P and HadAM3P, changes in the occurrence of extremes of intense precipitation and drought are briefly discussed below. Further information can be found in Kundzewicz, (2003), Kundzewicz et al. (2004a, 2004b) and Kundzewicz et al. (2006), and Ulbrich et al., (2003a, 2003b)

4.1 Precipitation Intensity:

For precipitation intensity MICE found that both HadRM3H and HadRM3P suggest a decrease in small-to-moderately high precipitation, fewer days with intense precipitation and a general reduction in low-to-moderate precipitation classes in the future for the A2a scenario. Figure 3 shows the number of days of intense precipitation defined as those exceeding 10 mm in one day, across Europe for the baseline period, 1961-1990, (left) and the change in the future (2070-2099) on the right. There is clear indication of a decrease in intense rainfall events across Southern Europe, particularly in Mediterranean countries (shown in blue), and an increase in intense rainfall in Northern Europe (shown in red).

4.2 European Summer Drought:

Figure 4 shows the change in the length of the summer drought, based on the HadRM3H A2a simulation. Summer drought is defined as the dry period (all daily rainfall totals below 0.1 mm) spanning Julian day number 180. Over the Mediterranean region of Europe, especially southern Italy and southern Spain, the length of the summer drought is anticipated to increase by more than 30 days. In contrast, parts of Scandinavia witness a reduction in length of the summer drought.

5 Impact Modelling:

The modelling of climate change impacts was divided into two categories. First, where the climate change-impact relationships were well understood, and/or where empirical data were available to derive such relationships MICE utilised pre-existing techniques to develop and/or adapt quantitative models. The impact sectors which MICE was able to model in this manner include energy use, insurance (Klawa and Ulbrich, 2003), forestry (Jönsson et al., 2004; Nilsson et al., 2004; Schlyter et al., 2006) and agriculture in the Mediterranean. For the second category, where the relationships are complex and/or poorly understood, an expert judgement-based approach was taken to study the likely impacts. Examples of this type of analysis include the assessment of the potential impacts of climate change on tourism in the Mediterranean (Giannakopoulos, 2004), winter tourism in the Swiss Alps (Schwarb, 2004; Schwarb and Kundzewicz, 2004), and the ecological damage to forests in Sweden (Stjernquist, 2004; Schlyter et al., 2006). First, the changing behaviour of the primary underlying extremes e.g., temperature (beach tourism), snow lying (winter sports), and precipitation (floods) was examined. Results from these analyses were then presented at local mini-workshops which were held with stakeholders from the relevant activity sectors. This allowed stakeholders the opportunity to examine these results and discuss their views on the likely implications for their sector. In total, four mini-workshops were held during 2003 and 2004. These were:

1. Climate Change and Winter Tourism held in Lucerne, Switzerland on November 4th 2003 (Schwarb, 2004).
2. Climate Change and Flood Hazard held in Poznan, Poland on March 25th 2004 (Kundzewicz, 2004a, 2004b; Szwed et al., 2004).

3. Climate Change and Catastrophic Weather Damage on Forests in Northern Europe held in Helsingborg, Sweden on May 6th 2004 (Stjernquist, 2004).

4. Climate Change Impacts on Mediterranean Beach Tourism held in Crete, Greece, on June 10th 2004 (Giannakopolous, 2004).

Impacts on energy use in Europe, and Mediterranean summer tourism illustrate the application of the two approaches.

5.1 Impacts on Energy Use in Europe:

The contrasts between Mediterranean climates in the south and boreal climates in Northern Europe, and between maritime climates in the west and continental climates in Central Europe, lead to very different patterns of energy consumption, both in terms of the total amount consumed and the seasonal distribution. How these contrasting consumption patterns will be affected by global warming is a matter of great economic interest. For example, to what extent will global warming lead to a substantial uptake of air conditioning in northern countries? How great a decrease in winter energy consumption is to be expected in the different regions of Europe?

Fifteen European countries have been included in this pan-European study of changes in energy use (based on electricity and gas consumption) with climate change. The importance of including information about the magnitude and frequency of future extreme temperature events has been assessed by developing three separate models for each country. The first model is based on the relationship between mean-monthly near-surface air temperatures and monthly energy consumption figures. In contrast, the second model uses monthly climate indices, derived from daily maximum and minimum temperature data, to explain the month-to-month variations in national energy consumption. The final model uses fluctuations in heating and cooling degree days to describe the waxing and waning demand for electricity and gas on a month-to-month basis. The idea is that by comparing and contrasting the results from the three models the importance of including information about extreme events can be identified. For each country four SRES scenarios have been analysed: A1FI, A2, B2 and B1.

Figure 5 presents the evolution of electricity consumption in Italy and Finland over the next 100 years due to climate change according to the model based on the number of heating and cooling degree days and monthly energy consumption. Results are presented as 30-year mean monthly ratios of future electricity consumption relative to a modelled baseline for the 2050s and 2080s. During the 2020s, the change in energy consumption is not significantly different from the baseline period.

Figure 5c and 5d show the change in energy consumption in Italy for the 2050s and 2080s, respectively. Countries in the Mediterranean tend to follow a similar pattern of decreasing electricity consumption during the winter months set against increases during the summer months. As expected the greater magnitude of warming experienced results in larger increases in summertime mean consumption levels over a 30-year period. By the 2050s, average consumption is up by 10-30% during June, July and August. By the 2080s, this increase in consumption has grown further still, exceeding 50% in August, based on the A1FI scenario.

For Finland (Figure 5e and 5f), the degree day model also suggests a reduction in electricity consumption during the space heating season and an approximately 5% increase in mean electricity consumption during the summer by the 2080s. In any given year within this 30 year period, the increase in consumption under the warmest scenarios (A1FI and A2) can exceed 30%. These increases are the result of a dramatic increase in the number of cooling degree days experienced in Finland (not shown).

Overall, the increase in electricity consumption during the summer in the 2020s in both Italy and Finland is offset by the reduction in energy consumption in the wintertime. During the 2080s, this characteristic continues for Finland, but the 20% decrease in electricity consumption in the winter does not offset the 20-60% increase in energy use in summer in Italy.

Relating these changes to the current baseline absolute electricity usage for these two countries (Figure 5a for Italy and Figure 5b for Finland) it can be seen that both countries exhibit a seasonal cycle in energy consumption, although the cycle for Finland is more pronounced than that of Italy. Both show higher demand during the space heating season and lower demand during the space cooling season. The results discussed above suggest that under the A1FI scenario, by the 2080s, during the summer months in Italy, the average electricity consumption of 21 TWh/month could increase by up to 50% to approximately 30 TWh/month. For Finland the increase is in the region of 9% resulting in a change from 5 to 5.5 TWh/month in the summer. During the winter months Italy could see a decrease in electricity demand of around 20% from 23 to 18 TWh/month. Finland could see a decrease in demand of around

5% from 7 to 6.5 TWh/month. As a result the seasonal cycle of electricity demand could alter markedly in Italy, with peak demand shifting to the summer season in the future compared to the present-day situation where peak consumption occurs in winter. Finland could experience a different situation with a flattening out of the cycle of electricity consumption in the future to produce more uniform consumption patterns throughout the year.

5.2 Impacts on 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, generating 113bn US$ for the region. Seventy percent of these tourists visited just two countries, Italy and Spain (WTO, 2004a; 2004b). The important questions with respect to climate change are:

- Will tourists avoid the Mediterranean region completely because of excessive heat?
- Will tourism spread into the cooler spring and autumn seasons to avoid the summer heat?
- Will people from Northern Europe be more likely to stay at home if their summer climate 'improves'?

To assist in answering these questions, MICE held a mini-workshop in Crete, Greece in June 2004 (Giannakpoulos, 2004). The aim was to elicit expert advice on the likely impacts of climate change on the Mediterranean tourist industry. MICE provided information to the workshop participants on the potential climate changes for the region and globally.

The Mediterranean tourism experts identified the likely impacts of predicted changes in extremes on tourism and beach holidays in the Mediterranean. These included:

- increased drought and fire risk
- increased water shortages
- increased heat stress
- beach degradation and habitat loss due to sea level rise
- increased vulnerability to tropical diseases e.g., malaria
- more flash floods
- poor air quality in cities

The resultant consequences of these impacts was a decrease in Mediterranean summer holidays due to improvements in North European summers encouraging domestic holidays in Northern Europe. In fact, even the domestic market in the Mediterranean is likely to holiday away from the region. Mediterranean summer holidays could decrease in popularity due to high temperatures and the negative characteristics listed above. Instead, the shoulder seasons, spring and autumn, will possibly become more attractive, offsetting the losses produced due to the perceived improvement in the Northern European summer climate and the “worsening” of the Mediterranean summer climate.

MICE was only able to make a preliminary analysis of the effects of climate change on Southern European tourism. In addition, we looked at winter sports in the Alps, and this is reported by Schwarb (2004). There remains much to be done in this exciting research area. This includes, for example, understanding the impact of sea level rise of coastal resorts, of flooding, and the computation of changes in quantitative measures such as human comfort indices.

6 Summary and Conclusions:

This paper has provided an overview and a selection of results generated of the MICE (Modelling the Impact of Climate Extremes) EC 5th Framework project. MICE carried out an assessment of the likely influence of changes in climate extremes (temperature, precipitation and wind) on economic sectors important in Europe. The research programme was based around three broad objectives - climate model evaluation, assessment of future changes in the occurrence of extremes, and the assessment of impacts of changes in extremes on six activity sectors - agriculture, commercial and natural forestry, energy use, water resources, tourism and civil protection/insurance.

Focussing on two examples, changes in precipitation intensity and the length of the summer drought in Europe, this paper highlights the future behaviour of different weather and climate extremes. The regional climate model shows a coherent spatial pattern of future change in precipitation intensity with increases in the number of intense rainfall events across Northern Europe and decreases across Southern Europe. An examination of the length of the European summer drought season confirms this behaviour indicating that the number of dry days may increase in the future, particularly in the Mediterranean region.

On the impacts side, this paper has highlighted the results produced from the modelling of energy consumption in the Mediterranean and in Finland and the expert-judgement approach applied to summer tourism in the Mediterranean. In the future it is expected that energy consumption in the Mediterranean will increase by between 15-55% in August in Italy in the 2080s relative to the baseline period. Electricity consumption in Finland follows a similar cycle of decreasing wintertime and increasing summertime energy consumption but in this case the changes are not as marked as in Italy. Changes in the pattern of electricity consumption suggest a shift in the timing of peak consumption from winter to summer in Italy and a flattening of the annual cycle of consumption in Finland, where consumption patterns become more or less uniform throughout the year by the 2080s. Mediterranean tourism is expected to expand during the shoulder seasons of spring and autumn with a decline in summertime activities.

MICE placed strong emphasis on the involvement of stakeholders throughout the duration of the project in order to ensure that the outputs from MICE were of practical use to the wider user community. A large pan-European workshop was held in Florence in October 2004. In total there were 44 participants with 24 stakeholders, 14 MICE partners and six additional climate scientists. The workshop was very well received and proved to be a valuable tool in promoting a two-way dialogue between stakeholders and scientists, which is vital when carrying out applied impact studies.

More in depth results can be found in the MICE Special Issue of Climate Research published in summer 2006.

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Impact category	**Climate extreme**	**Parent variable**
Forestry: Wind throw Forest fire Ecological damage	 Wind storm Heat stress, drought Flood, drought, heat stress	 Storm tracking Temperature, rainfall
Mediterranean agriculture	Heat stress, drought	Temperature, rainfall
Energy use	Summer heat waves	Temperature
Tourism Beach Winter sports	 Heat stress & human comfort Deficit or excess of snow	 Temperature Precipitation, temperature
Insurance & civil protection Property damage Loss of life	 Wind storm Floods	 Storm tracking Rainfall, snow
Water	Floods & drought	Precipitation

Table 1: The five impact sectors studied in MICE and the associated climate extreme and parent variable of interest.

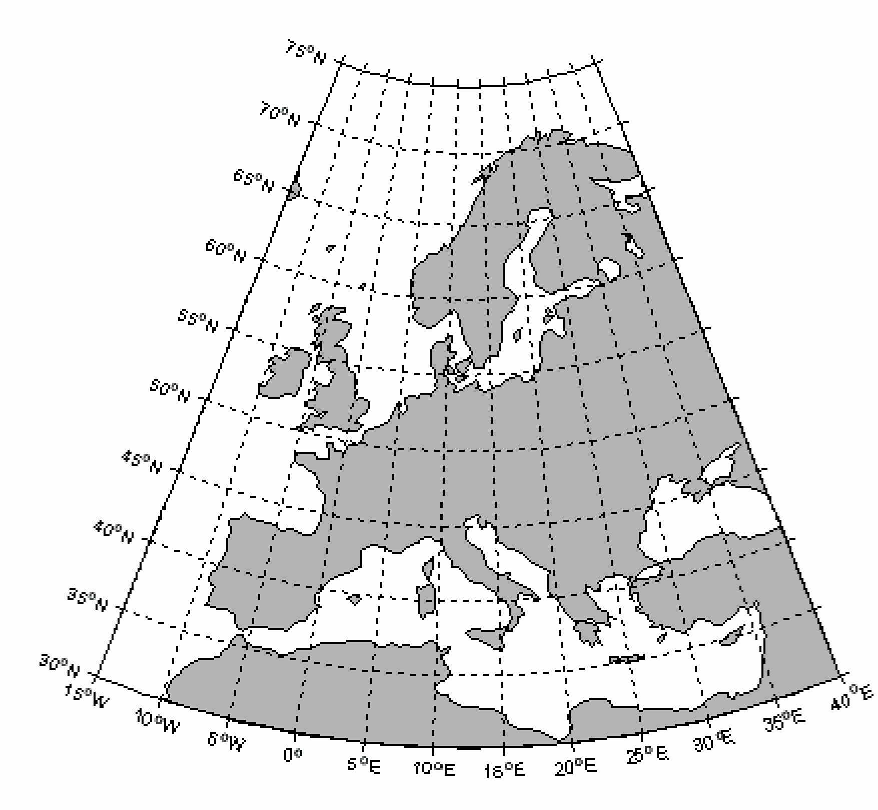
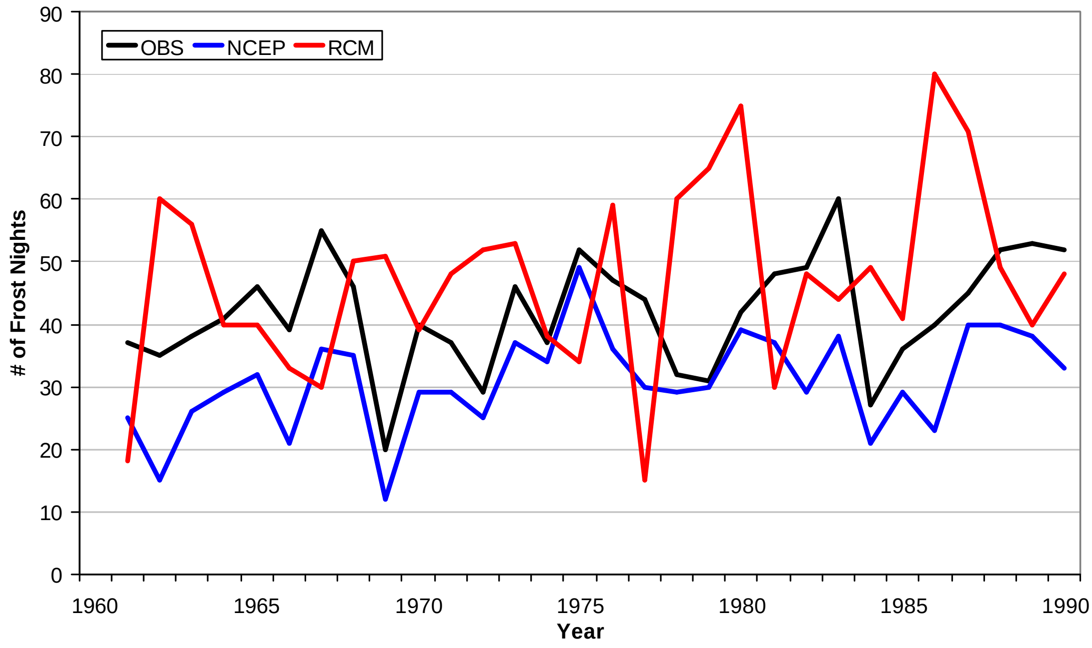


Figure 1: The MICE study domain



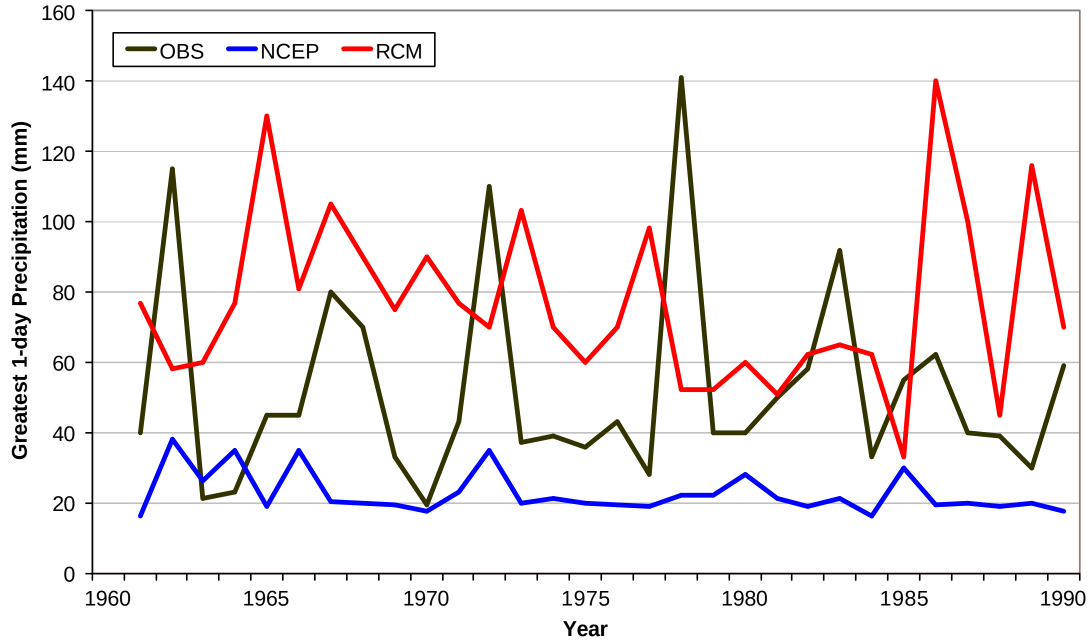


Figure 2: Comparison of annual number of frost nights with Tmin <0°C (top) and the annual maximum one-day rainfall (bottom) at Larissa with station data (black), NCEP (blue) and HadRM3 data (red).

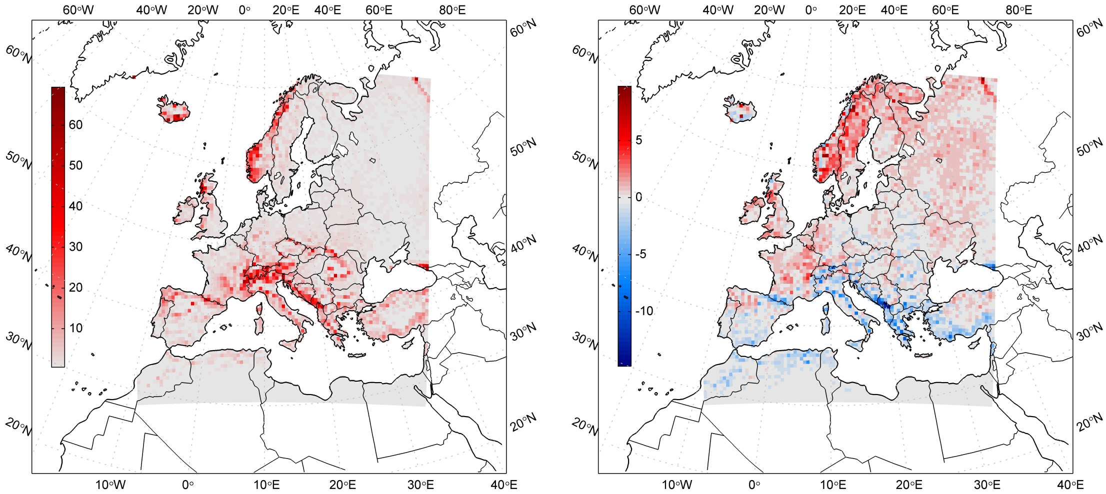


Figure 3: The number of intense rainfall days (>10 mm) during 1961-1990 (left) and the change by 2070-2099 (right), shown as the difference between the future (2070-2099) minus the baseline (1961-1990) periods, under the A2 scenario

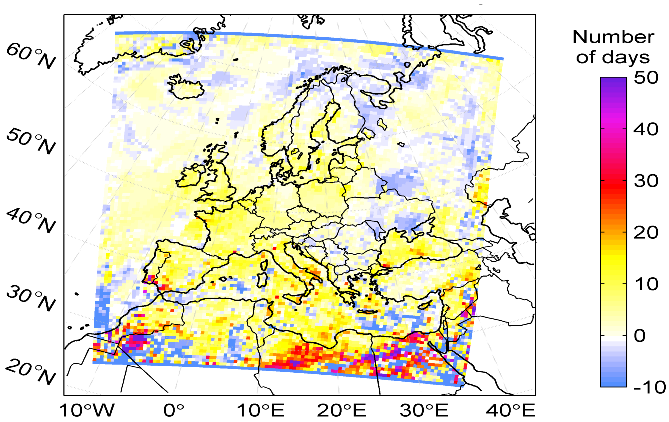


Figure 4: The difference (future minus baseline) in the length of the summer drought as simulated by HadRM3H for the baseline (1961-1990) and the future (2070-2099) periods, for SRES scenario A2a.

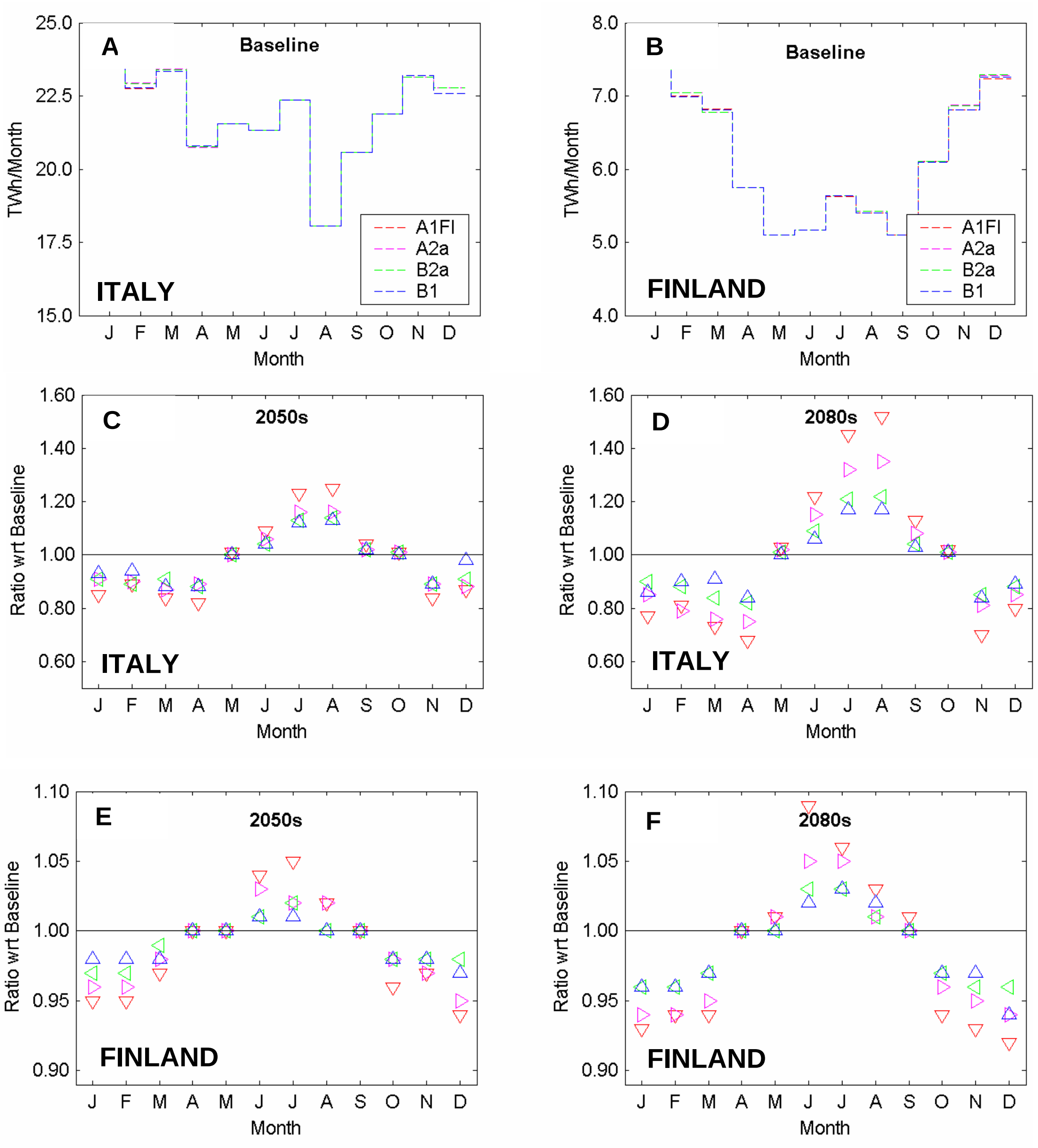


Figure 5: Monthly electricity consumption for Italy and Finland for the period 1961-1990 (A and B). Monthly ratios of future Italian (C and D) and Finnish (E and F) monthly electricity consumption under four SRES scenarios with respect to baseline computed using the model based on the number of heating and cooling degree days for the 2050s (left) and 2080s (right). ▽ represents the A1FI scenario, ▷ represents the A2 scenario, △ represents the B1 scenario and ◁ represents the B2 scenario.