Modelling the Impact of Climate Extremes

MICE

Description of Work

Part of the work programme addressed:

Energy, environment and sustainable development

Key action 2:
“Global change, climate and biodiversity”

RTD Priority: 2.1.3:
“Climate change prediction and scenarios”

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1. Project summary

Problems to be solved

It is widely accepted that climate change due to global warming will have substantial impacts on the natural environment, and on human activities. Furthermore, it is increasingly recognized that changes in the severity and frequency of extreme events, such as windstorm and flood, are likely to be more important than changes in the average climate. MICE seeks to identify the likely changes in the occurrence of extremes of rainfall, temperature and windstorm in Europe due to global warming, using information from climate models as a basis, and to study the impacts of these changes for selected impact categories: agriculture (Mediterranean drought), commercial forestry and natural forest ecosystems (windstorm, flood and fire), energy use (temperature extremes), tourism (heat stress in the Mediterranean, changes in the snow pack) and civil protection/insurance (windstorm and flood). Throughout the project, a continuing dialogue with stakeholders and end-users will be maintained.

Scientific objectives and approach

The information on future changes in extreme events will be taken from climate models. The first objective is therefore to evaluate the ability of such models to successfully reproduce the occurrence of extremes at the required spatial and temporal scales. This will be done by comparison with observations (station and gridded). Second, the model output will be analysed with respect to future changes in the occurrence of extremes. Statistical analyses will determine changes in (a) the return periods of extremes, (b) the joint probability of extremes (combinations of damaging events such as windstorm followed by heavy rain), (c) the sequential behaviour of extremes (whether events are well-separated or clustered) and (d) the spatial patterns of extreme event occurrence across Europe. The range of uncertainty in model predictions will be explored by analysing changes in model experiments with different spatial resolutions and forcing scenarios. The third objective is to determine the impacts of the predicted changes in extremes occurrence on selected activity sectors. For some activities, good quantitative impacts models already exist and will be utilized (e.g., forest fire and windthrow models). For others, such as energy use and agriculture, the relationships with climate are well understood, and models exist, but may have to be adapted for the particular case of extremes. For categories such as tourism, models exist only for the physical part of the system, e.g., modelling snow depth, such that in addition an expert-judgement-based approach will be adopted.

Expected impacts

MICE will develop techniques to analyse changes in the occurrence of extreme events in climate models due to global warming, taking into account the uncertainties inherent in model predictions. These changes will be used, together with a suite of impacts models to be developed during the project, to study the implications for impacts categories ranging from natural forest ecosystems through to tourism. End-users will provide advice throughout the duration of MICE, and will be informed of the results through a number of impact-specific and general workshops to be held in the final year, and through a summary of the final report dedicated specifically to their needs. MICE will provide end-users with a suite of techniques with which to study changes in climate extremes, and the potential impacts of these changes. These tools can be used to explore sensitivities and vulnerabilities to such changes in sectors as diverse as forestry and tourism.

2. Scientific/technical objectives and innovation

Objectives

Increasing concentrations of greenhouse gases in the atmosphere are expected to cause changes in climate at all spatial scales, from global to local. To evaluate these changes, experiments are performed with three-dimensional numerical climate models. Where these are global scale, they are known as general circulation models, or GCMs. Regional climate models or RCMs can provide more detailed information which, at the local scale, may be more accurate. The output from these models may be used to explore potential impacts of climate change on the human environment and activities. The **impacts of climate change are likely to be more severe due to changes in the occurrence of extreme events** than due to a change in the mean climate. Possible reasons are:

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 (1). 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.

2. **The response of the environment and human activities to climate**. The response to extremes such as wind storm, floods and droughts is different from the response to a change in the mean climate. The response time is shorter, and we would argue that the response is greater. As an example, a change in mean rainfall of a place, on the scale which is predicted by most GCMs, is likely to lead to slowly-evolving changes in the natural environment and agriculture, which can be relatively easily managed. 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.

This project will study changes in extreme event occurrence as predicted by climate models for Europe, and will evaluate the impacts of the predicted changes on selected categories of the human environment and activities. The impact categories are shown below, together with the climate extremes of importance for these categories, and which MICE will investigate, and their parent climate variables.

Impact category	Climate extreme	Parent variable
a. Forestry i. Wind throw ii. Forest fire iii. Ecological damage	 Windstorm Heat stress, drought Flood, drought, heat stress	 Storm tracking Temperature, Rainfall
b. Mediterranean agriculture	Heat stress, drought	Temperature, rainfall
c. Energy use	Summer heat waves	Temperature
d. Tourism	Heat stress & human comfort Deficit or excess of snow	Temperature Precipitation, temperature
e. Insurance & civil protection i. Property damage) ii. Loss of life)	 Wind storm Floods	 Storm tracking Rainfall, snow

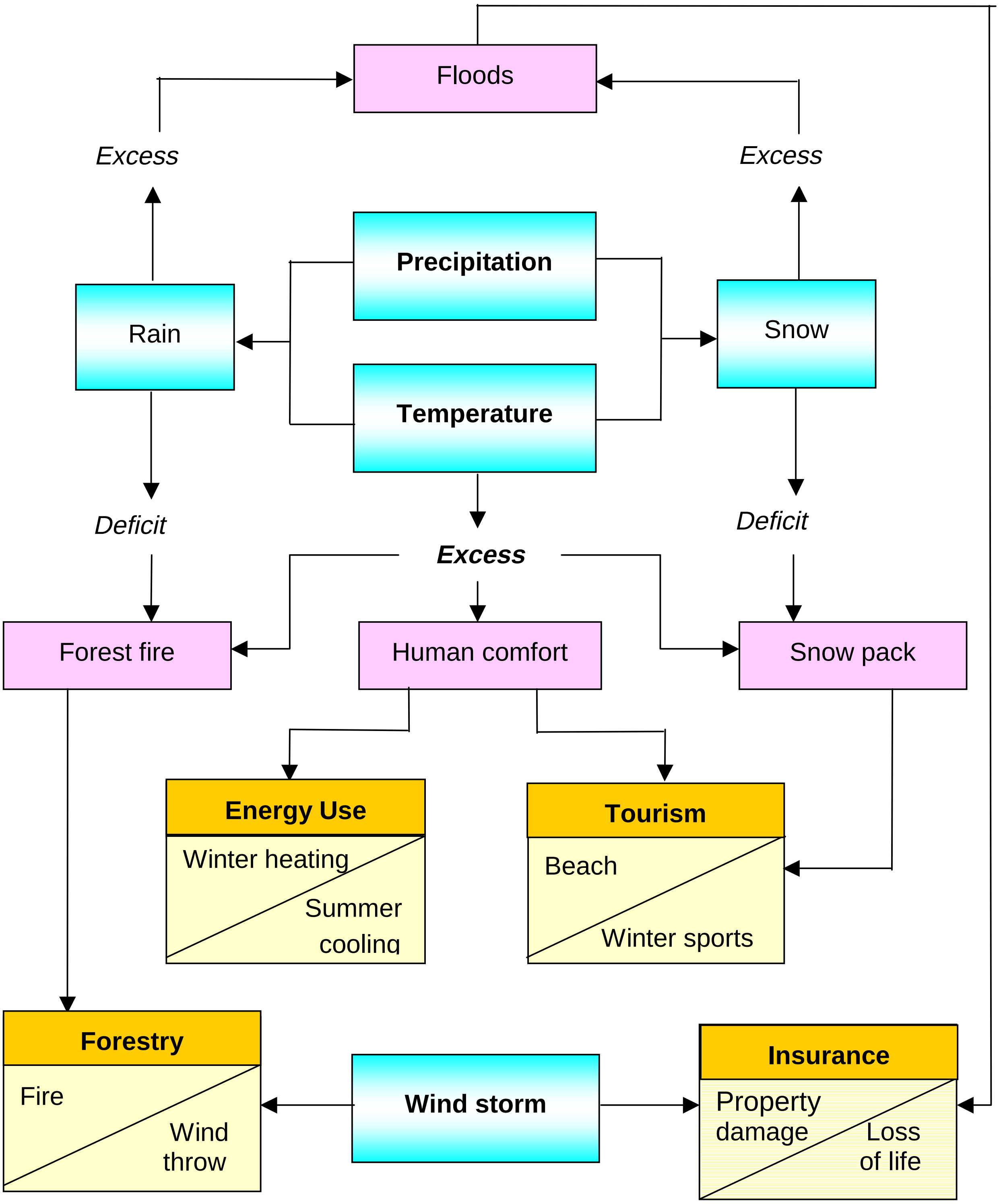
These impacts categories are chosen to provide examples of activity through from primary (forestry and agriculture) to tertiary (tourism, insurance). Whereas the impact of climate change on primary activities such as forestry and agriculture is well recognized and has been intensively studied, we provide examples here of activities where the impacts of climate change are less well recognized and documented. We seek to determine the extent to which

substantial impacts from climate change can be expected in these sectors, especially with respect to changes in the occurrence of extremes.
The general structure of the MICE research is shown in Figure 1. The specific goals are:

1. **Set-up**. (a) develop a catalogue of extremes of importance in the European context. These are likely to be based on temperature, rainfall, and windstorm; (b) define these extremes in terms of thresholds and measures which have relevance to the selected impacts sectors; (c) identify the climate models which will be analysed in the project.
   Measurable target: Specification of the context of the project in terms of quantitative definitions of climate extremes and choice of climate models to be studied.
2. **Analysis of extremes**. Output from climate models, both GCMs and RCMs, will be analysed with respect to changes in the occurrence of extreme events. Validation will be performed against present-day gridded (reanalysis) data sets. The following analyses will be performed on the model output:
   a. **Extreme value analysis** (based on the Generalized Extreme Value distribution, the Generalized Pareto Distribution and simulation modelling) will be used to explore future changes in the occurrence of extremes.
   b. **Joint probabilities of extremes** will be analysed in order to look at combinations of climate variables that might cause more damage when they occur together than when they occur singly. Examples include heavy rain followed by windstorm. The rain reduces soil strength and root anchorage, thus lowering the critical wind speed for damage.
   c. To examine changes in the sequential behaviour of extremes in the future, by building **models based on Poisson cluster processes** and perturbing their parameters based on the results from the analyses of climate model output.
   d. Analysis of changes in the spatial patterns of extremes using techniques such as principal components analysis. Relationship between the predicted changes and atmospheric indices such as the North Atlantic Oscillation.

   Measurable targets: Results from statistical analyses in a form appropriate for impacts analyses.
3. **Evaluation of uncertainty**. By analysing changes in extremes in model ensembles with different spatial resolutions and forcing scenarios, it will be possible to evaluate the range of uncertainty in the model predictions.
4. **Impacts of extremes**. The results from the analyses described above will be studied with respect to impacts. For some impacts categories, models already exist which will permit the translation of changes in extreme event occurrence into impacts. To take the example of forestry, fire and windthrow models have been widely developed. For other impacts categories, such as energy use and agriculture, the relationships with climate are well understood, and models exist, but may have to be modified for the particular case of climate extremes. Finally, for categories such as tourism, models exist only for the physical part of the system, e.g., modelling snow depth, such that in addition an expert judgement-based approach will be taken.
   Measurable target. Quantitative and expert judgement-based estimates of the impact of changes in climate extremes on the specified impact categories.
5. **Communication to stakeholders**. It is planned that stakeholders representing the impacts categories will be involved throughout the project in an advisory capacity. Also, a European stakeholder workshop will be held in the final months of the project to disseminate results.
   Measurable target: Attendance of selected stakeholders at progress meetings; organization of workshop.

Figure 1: Structure of research to be performed in MICE



Innovation

The overall concept of the project is to carry out an **end-to-end integrated assessment** of the impacts of climate change, starting from the output of climate models, then carrying out analyses of extremes and their changes in a high-CO_2 world, and finally using the results to look at the likely impacts on human activities and the natural environment. This end-to-end assessment will be carried out in the context of dialogue with stakeholders and end-users from the very beginning, in order to ensure that the project results are useful to this community. A final project workshop for stakeholders will be held to evaluate the implications of the results.

This integrated approach to impact evaluation offers a number of advantages, of which perhaps the most important is the involvement of stakeholders and end-users to ensure the usefulness of the work. It is increasingly the preferred methodology. The MICE proposal is perhaps unique in that it focuses especially on **climate extremes in a high-CO_2 world**.

The application of the output from climate model experiments to the study of climate change impacts is a very widely used technique. Scientists have used raw model data from general circulation models (2) and downscaled results obtained either by the development of statistical transfer functions (e.g., (3, 4)) or by dynamical techniques (nested regional climate models, e.g., (5)). With respect to the application of model data, MICE is innovative in three ways:

1. It will concentrate on **climate extremes, and their impacts**. This will require the development of novel techniques:
   a. to determine **appropriate measures of extremes**. For example, how is it possible to define conditions likely to lead to flooding, in terms of the output available from climate models? A number of possible answers to this question exist, and will be explored. For example, we might use an absolute measure, such as the number of days in a month with rainfall greater than 5, 10 or 15 mm/day, or we might use a relative measure, based on percentiles of the rainfall distribution.
   b. To **validate** the climate model output against observations. Instead of the widely-used validation of the mean, and other measures of the complete distribution, here the validation will focus on the extremes. Techniques, such as those described below, must be developed for this.

2. It will use **analysis techniques** which have not been widely used in climate change scenario construction, and which must be selected on the basis of their suitability for analysis of extreme events. Analysis techniques will be required for application to the data sets of extremes in both the spatial and temporal domains. In the temporal domain we will apply standard extreme value analysis techniques based on the Generalized Extreme Value distribution and the Generalized Pareto Distribution. Use of more flexible approaches based on the percentiles of the parent distribution and simulation modelling will also be explored. In the spatial domain, Principal Components Analysis (6) and Canonical Correlation Analysis (7) will be appropriate. Although the techniques in themselves are not innovative, their application in the context of climate change scenarios of extremes is new, and many issues will have to be explored as a result.

3. It will characterize uncertainty by comparing:
   a. the predicted changes in extremes in climate models with different starting conditions, forcing scenarios and spatial resolutions.

b. the changes in extremes throughout a GCM simulation (present day to 2100) with the observed changes in the shorter (often 30-year) windows available for RCMs.
c. the changes in extremes throughout a forced GCM simulation with the natural variability seen in control simulations.

Having carried out the analysis of extremes, the next step will be to examine their impacts on a number of activity sectors, and the natural environment. To a great extent, this involves applying tried and tested techniques and known relationships in a novel context, i.e. to study climate change impacts. Whereas no single section of the methodology is innovative, the linkage between changes in the occurrence of extremes and the evaluation of the economic/ecosystem impact is new. The intention is, wherever possible, to extract a quantitative figure for the size of the impact. In order to permit comparison between sectors, this should wherever possible be expressed as a monetary figure, and techniques exist for this (8). The climate change/impacts linkages to be explored are:

1. **Storm track analyses** will be used to examine the impacts on the **insurance** industry (property damage) and on natural and managed **forest** ecosystems. Storm track analyses have been carried out on climate model output, and (9) noted that a remarkable common signal was an increase of storm track activity over the East Atlantic and Europe. Here, we will apply the results from storm track analyses of GCMs and RCMs to models of property damage (known in the insurance industry as catastrophe models) and forest damage (10).

2. **Thermal heat stress** will affect **tourism** and **energy use** in Europe. Hot extremes in summer are likely to become more common due to global warming, and cold extremes less common. The size of the perturbation will be evaluated from climate model data. Tourism impacts will arise through increased summer heat stress (11) which has been extensively studied. **The link between heat stress and tourism will be entirely novel**, although an emerging literature is developing (12). Energy use/temperature relationships are linear for the appropriate climate variable (degree days), are well understood and can be used to evaluate the effect of climate change on energy consumption across Europe, as the requirement for air conditioning increases, and the need for space heating becomes less common.

3. **Forest fire** occurrence is affected by **excessive heat and/or aridity**. Research and forestry groups throughout the Mediterranean have developed fire models, e.g., (13, 14), and there have been EC-funded projects, e.g., LUCIFER, DELFI. Two fire models will be available to the group and can be adapted to explore the effects of climate change on fire occurrence in the region.

4. Changes in extremes of precipitation will affect **flood occurrence** and (depending on changes in temperatures) **snowpack conditions.** Flooding in particular has implications for the insurance industry (15). We will develop measures of extreme conditions likely to lead to flooding, and use these to study changes in high-intensity rainfall in GCMs and RCMs. Changes in snowpack will have implications for winter sports (16). Snow depth is available as a variable in climate models, or can be simulated based on daily temperature and precipitation inputs (17) and will be used to study changes in a high-CO_2 world.

Successful communication with stakeholders and end users is a fundamental pillar of the project. The final stage will be to host a workshop for dissemination purposes. We also intend to produce selected excerpts from the final report in a professionally-designed and accessible form, and a budget item is included for this purpose.

3. Project workplan

The project workplan may be summarized as follows:

> An **end-to-end integrated assessment** of the impacts of climate change, starting from the output of climate models, then carrying out analyses of extremes and their changes in a high-CO_2 world, and finally using the results to look at the likely impacts on human activities and the natural environment. This end-to-end assessment will be carried out in the context of a continuing dialogue with stakeholders and end-users.

3.1 Definitions of extremes

The first step is to define extreme events in terms relevant for impacts on European human activities and the natural environment. Some examples of suitable measures of extremes are given in Table 1. These are appropriate for analysis within a climate modelling framework, i.e., they can be used to look at the change in occurrence between snapshot periods (see Section a.2), and between different model experiments.

Table 1 Suitable measures of extremes

Variable	*Measure*	*Impact*
Temperature	Number of degree days >35°C	**Tourism**: Heat stress measure for tourists from northern Europe travelling to the Mediterranean
Temperature	Number of degree days above spatially variable thresholds	**Energy** use throughout Europe
Temperature + rainfall	Spring + summer rainfall < 50 mm; summer temperature above 25°C	Forest **fire**
Rainfall	Number of days with rainfall > 20 mm	Small-catchment and flash **flooding**
Rainfall	Number of days with rainfall > 30 mm	Small-catchment and flash **flooding**
Rainfall	Longest spell of wet days Longest spell of dry days	**Flood** occurrence **Drought** occurrence in Mediterranean agriculture
Snow	Number of days in main skiing season with snow depth > 20, 30 and 40 cm	Winter **tourism**
Wind storm	Events with wind speeds > 17 m/s	**Insurance**: Property damage
Wind storm + flood	Events with wind speeds > 17 m/s and rainfall > 20 mm	**Insurance**: Property damage

3.2 Climate data for analysis

3.2.1 Climate model output

The project will be based on the publicly–available output from climate models. We will look at output from both global GCMs, and from Regional Climate Models (RCMs). GCMs have the advantage that they are integrated over a long and continuous period of time, for example, for the UK Hadley Centre model HadCM3 for 1869 to 2099, but have a relatively low spatial resolution which can affect the accuracy of the output. RCMs have a much higher spatial resolution which may improve accuracy. Amongst the disadvantages is the fact that they are generally only run for snapshot periods, for example the Hadley Centre RCM output is for two thirty-year periods: 1961-90 and 2070-99.

In defining which model data to use, two considerations related to the purpose of MICE must be taken into account:

i. The purpose of MICE is to study the evolution of climate extremes in response to anthropogenic climate change, and as such the emphasis will lie on daily data. In order to properly study the changes in extremes both monthly and daily data will be required (see Table 1). Because extremes are, by definition, rare, in order to have a sufficiently large sample for analysis, windows of twenty years (at least) are required at each time step. Where two or more climate variables are to be analysed (here, temperature, rainfall and windstorm), the volumes of data to be analysed become very large.
ii. MICE will not initiate any modelling work, but will be based on the acquisition and analysis of existing modelling experiments. An important part of the project is the comparison of modelling experiments, with respect to their simulation of extreme events. A number of comparisons will be undertaken:
   a. between present-day model results and re-analysis data (NCEP or ECMWF) for the purposes of validation.
   b. between different ensemble members of a particular GCM simulation, to understand the uncertainty introduced by changing the starting condition.
   c. between experiments performed with the same GCM, but with different forcing emissions scenarios.
   d. between GCM and RCM experiments, to evaluate (a) the 'value added' by dynamical downscaling and (b) the loss of information, especially regarding long-term variability in modes of circulation such as the North Atlantic Oscillation, due to only having narrow (typically 30 year) windows available for the RCM.

The project will be based on publicly-available model output. Climate model output will be available at the required daily scale from at least one generic climate model: HadCM and its associated regional climate model HadRM. The details are as follows:

i. HadCM2 and HadCM3 are two versions of a global model with a relatively low spatial resolution (2.5^o latitude by 3.75^o longitude). HadCM2 has been used to perform an ensemble of climate change simulation from 1860 through to 2099, using observed forcing in the historical period and a close approximation to IS92a (1% per annum compound increase in greenhouse gas concentrations) in the future. The results from control, greenhouse gas-only and all anthropogenic gas simulations are available.

   For HadCM3, we will have access to output from two ensembles of simulations, forced respectively with the A2 (high, expected global mean temperature increase by 2055, 2.64^{o}C) and B2 (mid, global mean temperature increase by 2055, 1.58^{o}C) emissions scenarios of IPCC. Simulations have been performed (and are available) for the greenhouse gases alone, and for all anthropogenic gases (including sulphate aerosols), as well as control experiments. The period of simulation is 1859 to 2100.

   Associated with HadCM3, we will have access to the Regional Climate Model HadRM3, which has a domain encompassing Europe and North Africa with a spatial resolution 0.44^o. HadRM3 output at the necessary daily scale is expected to become available at the beginning of 2002 for two 30-year periods: the present day (1961-90) and 2070-99.

Clearly it is not possible to make all possible comparisons of extreme events in all climate models, ensemble members and forcing scenarios. Comparisons are likely to include:

- Between different forcing scenarios, to examine the effect of varying the forcing scenario on the response of extreme event occurrence: HadCM3 A2 and B3 forcing scenarios.
- Between GCM and RCM experiments: HadCM3 and HadRM3
- Between GCM/RCM and re-analysis data (validation): comparison of HadCM3 and HadRM3 simulation of extremes for the present day and ECMWF (European Centre for Medium-range Weather Forecasting) or NCEP re-analysis data.

3.2.2 Re-analysis data

The advantages of using re-analysis information for validation is that it is gridded, and hence is more directly comparable with climate model data than are station observations (from point sources). The ECMWF re-analysis data, for example, is generated at a resolution of T106 (approx. 1^{o} resolution) and has been re-gridded to 2.5^{o} resolution by BADC (British Atmospheric Data Centre) for distribution to the science community.

The impacts of climate change on some activity sectors can be well represented by gridded data. For example, flooding in large catchments must be caused by excessive rainfall over a very wide area, which should be represented by gridded data. This is of particular interest for the river basins of central Europe, such as the Rhine, the Danube and the Oder. There is evidence for an increase in heavy precipitation events in eastern Europe since the mid-1930s (18). There are long-standing model results to indicate increased precipitation intensity in response to climate change (1).

However, the re-analysis information cannot be assumed to be necessarily a true picture of the climate at the local scale. Being based on the output of a numerical model of the global atmosphere into which observations have been assimilated, in regions of poor observational cover the model takes over to a greater extent to infill with consistent values. The balance between observational and model constraints also varies with the type of data: the atmospheric circulation and temperature away from the surface are considered to be the most reliable, with surface air temperature somewhat less so and precipitation least reliable. Wind strength is likely to be reliable in comparison with area-averaged data. We can only ascertain accuracy of the re-analysis data by comparison with observations, building on existing studies (19). This will be done for a number of case study areas, selecting 5-6 station records from each, and comparing their time series with re-analysis grid-box output.

3.3 Analysis methods for extremes

Data sets will be extracted for a European window, for the extremes as identified above. It is likely that two time periods will be used: for 1961-90 and for 2070-99, because these periods should be available for all the model data sets. The loss of information from using 30-year windows, especially with respect to natural decadal-scale variability in extremes occurrence, will be evaluated by comparison with the full simulation by the parent GCM. For 1961-90, data sets will be extracted both from climate models and from re-analyses, for validation purposes.

The data sets will be analysed in the spatial and temporal domains.

3.3.1 Temporal domain

For each grid square in the European domain, for all climate model data there will be two 30-year time series available for each climate variable, and for the re-analyses we will extract matching 1961-90 data sets. In addition, for the parent GCM, data sets will be extracted for the complete time series from 1961 to 2099 for the control and forced simulations.

For a typical GCM with a resolution of 2.5° by 3.75°, a spatial domain selected to include the 15 EU countries will consist of around 10 grid boxes in the west-east dimension, and 15 from north to south. If comprehensive analyses are to be carried out on the extracted data sets of extremes, it will not be possible to analyse all 150 grid squares. Instead, we will select representative subsets of grid squares, likely to be as follows:

- Two north-south transects through western and central Europe respectively
- Two west-east transects at ~50°N and through the Mediterranean Basin respectively
- A subset chosen to respect the altitudinal range found in Europe

Around 25-30 grid squares are likely to be analysed. This approach will be used both for GCMs and the RCM experiments.

Time series of extremes, as shown in Table 1, will be extracted. These form the basis for comparison between time periods, between forcing scenarios, and for validation.

It is important that comprehensive and rigorous techniques are applied in the validation stage, and this is an aspect which is often neglected in modelling studies. We will use cross-validation and bootstrapping, in order to maximise synthetically the data available for validation. Rigorous performance tests will be employed, which will include not only the widely-used root mean square error and explained variance, but also skill scores which compare climate model performance against reference models of climatology and persistence (20).

MICE will exploit the range of methods available for the analysis of extremes (20). We propose the use of the following:

(i) The Generalized Extreme Value distribution (GEV). If a sample of *n* cases is chosen from a parent distribution, and the maximum (or minimum) of each sample is selected, then the distribution of maxima (or minima) can be modelled by the GEV distribution. For application to MICE, appropriate data sets would include:

- the maximum daily rainfall in each year
- the highest recorded maximum temperature in each summer
- the lowest recorded minimum temperature in each winter

The parameters of the fitted distribution can be used to estimate the *T*-year quantile value, X_T, of an extreme, as follows:

$$X_T = \xi + \frac{\alpha}{\kappa}\left[1 - \{-\ln(F)\}^{\kappa}\right] \qquad \ldots 1$$

where F is the cumulative probability, given in terms of the return period *T* by $F = (T\text{-}1)/T$, and ξ, α, κ are the position, scale and shape parameters respectively of the GEV distribution. The quantile value *X*, with a return period *T* = 10, 20 or 50 years, is an excellent comparative measure of the change in the occurrence of extremes between the present day and the future in climate models, as well as a tool for validation.

Related to the GEV distribution, the *Generalized Pareto Distribution (GPD)* is used with Peak-over-threshold (POT) samples. This method extends the size of the sample of extremes by taking all values above a threshold, and fitting the GPD. Care must be taken to ensure (a) that the selected extremes are independent, i.e., that they arise according to a Poisson process, usually by imposing a minimum separation distance and (b) that the threshold is chosen to optimise the size of the extremes sample (21, 22). We have identified sources of publicly – available GEV distribution and GPD fitting software.

(ii) Simulation Modelling. This is a method to extend records of short duration by generating series of synthetic data based on the statistics of the distribution. It is important to ensure that the distributions from which the samples are drawn are correct, i.e., adequately capturing the autocorrelation structure and any trend in the data. Generalized Linear Models (GLMs) fulfil these criteria (23, 24), and software to fit these models exists. Stochastic weather generators can also be used for this purpose, and GIUB (Partner 6) will contribute software that allows the simulation of daily and hourly weather data for all variables considered within MICE. Finally, the synthetic time series can then be analysed by using the GEV and POT extreme value techniques described above (25).

(iii) Joint probabilities. To explore the **joint probability** of extremes which together may have a greater potential for damage than each would alone. For example, intense rainfall associated with high wind speeds can, for insurance, lead to additional losses to building contents and, in forests, reduce soil strength and root anchorage, lowering the critical wind speed for damage. The methods used will be based on standard extensions of univariate Extreme Value theory, as described by (26).

(iv) Poisson process-based models to analyse the sequential behaviour of extremes now and in the future. These models aim to represent the structure of event sequences realistically, using a small number of interpretable parameters such as mean event arrival rate and mean duration (27). Again taking the example of wind storm, we will build and perturb Poisson process-based models based on the results from the storm climatologies. If it is found that sequential events are likely to become more common in future, reinsurers would have to consider the possibility of modifying their definition of an ‘event’ (a fixed number of hours during which damage can be claimed for) in order to make a better recovery. In forestry, sequences of storms may lead to enhanced damage due to fatigue effects on root anchorage. The damage to the French forest at the end of 1999 arose from such a sequence, including Lothar and Martin. Rainfall events may also be analysed with respect to the Poisson distribution in order to better understand changes that will affect flood occurrence. Sources of publicly-available software have been identified.

These four analyses are progressively more innovative. It is proposed that the most effort is devoted to (i) and (ii), where the techniques are well understood. (iii) and (iv) will be undertaken primarily at the level of a feasibility study, concentrating on evaluating methods and likely benefits. In the application of all these techniques, uncertainty is an important consideration, and fitting of confidence intervals is seen as intrinsic.

3.3.2 Spatial domain and teleconnections

Seasonal and interannual climate variability is organised into characteristic patterns, or modes, of the climate system. To take the example of the North Atlantic Oscillation (or NAO), year-to-year changes are characterised by an alternation between a "high-index" state, consisting of an intense Iceland Low with a strong Azores High to its south – hence strong mid latitude westerlies – and a "low-index" state with weakened Low and High centres giving weak mid latitude westerlies. We will explore the relationship between the NAO and the MICE datasets of extreme events, i.e., teleconnections, with respect to two research issues:

- There is a considerable literature on the ability of climate models to simulate indices such as the NAO (28). If climate models can simulate these large-scale atmospheric variations better than they can simulate the climate variables studied here with respect to extremes (29), and if we can show relationships between extreme event occurrence and the phase of these oscillations, then this provides an alternative route for the exploration of the changes in extreme events in response to climate change.
- The relationship between the occurrence of the NAO and the occurrence of extreme event occurrence across Europe will not necessarily remain stable in a future, warmer, world. MICE will explore these relationships in the scenarios for 2070-99 compared to those for 1961-90. In addition the evolution of the relationship in the complete GCM simulation (1961-2099) will be evaluated for comparison.

The NAO and the processes it influences are of particular relevance to some of the impacts sectors considered in MICE, through its relationship to wind storm occurrence (30), decadal-scale variability in wind speeds (31), precipitation, runoff and the length of the growing season over Europe (32), and snow depth and duration over the Alps (33).

We will identify these influences by analysing the data sets of extremes constructed in MICE together with indices of the strength/phase of the NAO. The preferred statistical tools for performing these analyses are multivariate techniques: principal components analysis (PCA) followed by principal components regression, and canonical correlation analysis (CCA). PCA identifies patterns describing the internal variability within a single data set. The eigenvectors, which in MICE might for example be calculated from a matrix of grid-point maximum wind speeds through time, may be regressed against potential explanatory variables such as the North Atlantic Oscillation. CCA maximises the interrelationship between two data sets and thus may be used with the example of the maximum wind speed matrix to look at the relationship with the sea level pressure field (20). Investigation of the PCA scores with respect to time series variations in the eigenvectors will be carried out.

3.4 Variables for analysis

3.4.1 Temperature

This is the most straightforward variable for analysis, because its simulation by climate models is, first, reasonably accurate and, second, on a day-to-day basis comparable with time series from observations (point data). Summer maximum temperature extremes will be analysed with respect to heat stress (human comfort, tourism) and energy use (air conditioning). Winter minimum temperatures will be analysed with respect to energy use (space heating) and snow melt (winter sports, tourism). Suitable measures include:

i. Number of degree days above (below) the 95^{th} (5^{th}) percentile of the re-analysis series (the baseline). This will be a suitable baseline for validation, and to explore changes between the scenarios for 1961-90 and 2070-99.
ii. Changes in the return period of baseline extreme values selected from the re-analysis data. High and low extremes might be the 97^{th} (3^{rd}), 98^{th} (2^{nd}) and 99^{th} (1^{st}) percentile values in the reanalyses – how do these change in the 1961-90 climate model data (validation) and in the 2070-99 output (climate change).

3.4.2 Precipitation

Precipitation is expected to be the most poorly-modelled climate variable to be used in MICE, and care will have to be taken to validate both the GCM/RCM precipitation extremes against the re-analyses, and the re-analyses against station data. Inevitably, the station data will have greater variability and larger extremes, whilst extremes in the gridded data will be truncated. An important question to be answered is the extent to which using a RCM improves the modelling of precipitation extremes.

Both high and low rainfall extremes will be analysed, and their impacts on floods and on agriculture and forestry respectively. High extremes will be evaluated from daily data (short intense storms) but also from monthly data (slowly developing regionally-extensive floods in large catchments). Low extremes can be evaluated from monthly rainfall, and by looking at the duration of rain-free periods (appropriate in the Mediterranean situation). Wherever possible, MICE will work with monthly rainfall, since in general monthly rainfall totals are much better simulated than daily values.

The state of the snow pack will be evaluated from the snow-lying data that should be available for all the model experiments considered here, and for the re-analysis data. However, the improved definition of altitude in RCMs is of particular interest. Observational data sets are available for validation. For example, there are data for 18 stations in the western Italian Alps (565 – 2720 m elevation) on monthly snowfall and snow cover duration, with the longest record including data from 1877 to 1996, and the average station record duration being 61 years. Further, data sets of daily water equivalent and snow depth for several decades are available for selected representative locations in Switzerland. The analyses of changes to the snow pack under conditions of global warming will be evaluated with respect to the impacts on tourism (winter sports).

3.4.3 Windstorm

There is no coherent signal in the historical record that would lead us to believe anthropogenic climate change is already affecting storm occurrence over Europe (34). However, a consensus is emerging from experiments performed by European modelling groups that the storm track over Europe will intensify in the future in response to increasing greenhouse gas concentrations (35). This signal is found in the LMD gridpoint model, with the ECHAM spectral model at different resolutions (T21, T42), and with the Hadley Centre model (36). However, exceptions exist. Work with the CGCM has suggested a reduction of storm activity over Europe (37), and little change in extra-tropical storm activity in the North Atlantic in response to a doubling of atmospheric CO_2 concentrations (38). (39) find reduced synoptic activity (around 20% for the storm track over Europe) in a $2xCO_2$ equilibrium experiment with the NCAR CCM1.

In the face of this uncertainty, a major goal of MICE will be to compare the predictions of windstorm occurrence from different climate models, especially between different forcing scenarios (e.g., a comparison of SRES A2 and B2 forcings which will be available for the Hadley Centre models) and between GCMs and RCMs (HadCM3 and HadRM3). Variables for analysis will include:

- **Cyclone frequency and intensity**, calculated from 1000 hPa geopotential height data. Core pressures are calculated from the height values of the minima using the barometric height equation.
- **Stormtracks** computed by 2.5 to 8 day bandpass filtering the standard deviation of the 500 hPa geopotential height.
- **Mean and extreme wind speeds** at 10m.

Extreme wind information will be used to investigate impacts on forestry and property damage, as described in Section 3.5

3.5 Modelling the impacts

Modelling will be of two types. First, where the climate change – impact relationships are simple and well understood, and/or where empirical data are available to derive such relationships, we will use a transfer function-based approach to model the impacts of extremes on activity sectors. We will work in a GIS environment to generate regional maps of the perturbation due to global warming. The impact sectors which we expect to able to model in this manner are:

- Energy use (summer air conditioning and winter space heating)
- Insurance losses -- property damage from windstorm
- Forestry – damage through windthrow
- Forestry –damage through forest fire in the Mediterranean
- Mediterranean agriculture – drought and heat stress

Second, where the relationships are complex and/or poorly understood, an expert judgement-based approach will be taken to study the likely impacts:

- Tourism – impacts on Mediterranean tourism from more frequent/intense heat waves
- Tourism – impacts on winter sports of changes in snow-lying characteristics (depth, duration)
- Civil protection and insurance losses – property damage and loss of life from changes in flood characteristics
- Forestry – ecological damage in Sweden from complex extremes such as spring floods (high rainfall and high temperatures leading to rapid snow melt) and winter storm damage (high snowfall in relatively warm conditions leading to wet and heavy snow on the boughs).

In this second category, the approach will be as follows. First, we will model the primary underlying extremes: temperature (beach tourism), snow lying (winter sports), and precipitation (floods). Second, the results of this modelling exercise will be presented in an accessible format. Then, small workshops will be held with stakeholders in the tourism and flood protection industries, to examine these results and discuss their views on the likely implications. The outcome of the discussions from these four workshops will form the basis of short reports, in colour and written for stakeholders and policy makers. A budget item is included to disseminate these reports within Europe, and in addition they will be available for download from the Web. They will form briefing documents for the final European stakeholder workshop.

3.5.1 Impacts on energy use

The energy sector should be the most straightforward to study, and it should be possible to carry out the impacts modelling at the pan-European scale. Data are widely available, and energy use depends linearly on temperature, which is reasonably well-modelled by GCMs/RCMs. 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? Data on energy consumption in Europe is readily available from EUROSTAT. Close relationships exists between energy consumption and the number of heating degree days in winter and cooling degree days in summer (40). These close relationships should make the development of transfer functions to relate energy use to changes in extreme temperatures under climate change relatively straightforward. By building these transfer functions into a GIS, along with the scenarios of the change in temperature at the extremes of the distribution, it will be possible to study contrasts in energy use response to climate change across Europe.

3.5.2 Impacts on insured property losses from windstorm

GIS-based damage models are available (41) which use the physical characteristics of a storm (wind speed, central pressure, track orientation) to predict, on a two-digit postal code level, insured losses. It is proposed to generalize such a model, and use it to explore the impact of the predicted future changes in storm climatology on insured losses. The storm track climatologies from the climate models will be input directly to the damage model to explore changes in losses. These losses will be (a) calculated on an “as-if” basis, and (b) normalized following the procedure described by (42).

The empirical models referred to above are based on windstorm – insured losses relationships for the UK and Netherlands. (43) found very little difference between the two models. However, it is likely that differences will exist across Europe. Insurance companies will be approached to discuss whether our data base of information on property damage can be extended. These approaches will be made in the early months of the project, since negotiations are likely to be protracted.

3.5.3 Impacts on forests

Wind throw in trees. Existing models of wind throw (e.g., (10)) are essentially stand-level mechanistic models (incorporating the influence of soil type, water balance and tree height and geometry), applied across landscapes using representations of windiness based on digital terrain models (and associated geographic predictors based on orography) or boundary layer wind flow models such as WA^{s}P (44). They can only be integrated over relatively small areas, for example a single forest, and provide a classification of risk, rather than a model of losses. We propose the development of a GIS-based analogue wind throw model, which will allow evaluation of the impact of any change in windstorm frequency/severity across case study areas of Europe. An appropriate model as a starting point is ForestGALES. Such a model will be used to develop generalized profiles of risk, and presence of forests within the topography. Thus data bases of forest distribution will be required, for example the UK using the new National Inventory of Woodlands, which includes all woodlands over 2ha. These variables will form layers within the GIS. A rule base will be developed to consider changes to forest structure and extent over the prediction period. When the storm track climatologies for 1961-90 and 2070-99 are input to the GIS, the effects of changing climate on risks within the forestry sector can be evaluated.

Ecological damage. Ecological damage to trees by climate extremes may have large economic implications in the extensive boreal forests of Scandinavia. Relevant extremes include: drought spells, storm damage especially in combination with heavy snow loads, springtime floods (high rainfall and high temperatures leading to rapid snowmelt) One or more case study sites will be identified in southern Sweden. Impacts models will be developed from evidence of historical damage. Using GIS, the results will be extrapolated to a larger area of northern Europe. The model results will be applied to analyse future scenarios.

Forest fire. Fire occurrence is a function of high temperature extremes and low rainfall extremes. There is also a strong human dimension – for example, distance from the road is a strong predictor of the number of fires, and management issues are important. We will have access (through FMA and ICAT) to two fire models developed for Mediterranean countries, both developed to operate in a GIS environment. These will be used in conjunction with the scenarios of change in temperature and rainfall to look at the implications of climate change for fire occurrence: both the number of outbreaks and the extent of the burnt area.

3.5.4 Impacts on tourism

Mediterranean summer holidays. As some measure of the economic importance of summer tourism, 175 million international tourists visited the Mediterranean in 1996, with 75% of these tourists visiting one of just four EU countries (45). The important questions with respect to climate change are:

- Will tourists avoid the Mediterranean region completely because of excessive heat? This would be a negative result.
- Will tourism spread into the cooler spring and autumn seasons to avoid the summer heat? This would be a positive result.
- Will people from northern Europe be more likely to stay at home if their summer climate ‘improves’? Again, this is a negative result.

Answers can only be provided by expert judgement and, as already explained, small workshops are planned at which these questions will be addressed. However, MICE will provide information to the workshop participants on:

- The changes in heat wave occurrence as predicted by the suite of climate models to be used in the project. This can be done on a pan-European basis so that the change in both push factors in northern Europe, and pull factors in southern Europe, can be evaluated.
- Some idea of the physiological impact of these predicted changes can be established by inspection of the literature on heat stress and the increase in human mortality (e.g., (11)).

Winter sports. Snow lying is a direct output of climate models (and reanalyses), but can also be simulated based on daily temperature and precipitation data. Following a top-down approach a first estimate of changes can be evaluated by studying monthly or even seasonal information. Quality of the snow is also important for winter sports. Some information on the likely change in quality can be obtained from modelled temperature and precipitation, especially from the RCM with its improved orography. GIS-based scenarios of the change in the persistence of snow lying, and snow quality as it is related to temperature, will be generated and made available to the participants in the workshop on this topic. In order to assess the quality of the information in the GIS data base, a comparison with local measurements and output from local snow modelling exercises will be carried out at representative case study locations.

3.5.5 Insured losses and floods

Flash floods result from extremely intense rainfall over a short period – a few hours to a day. Potential changes due to global warming can be evaluated by studying daily rainfall. Flooding in large catchments is a product of persistent heavy rainfall over weeks or even months, and the impacts of climate change should be clear in data at a resolution of weeks-months. As background material for the stakeholder workshop on the topic of floods, scenarios will be produced for changes in extreme daily, weekly and monthly rainfall. The workshop will concentrate on both types of flood, taking as the case study regions: central Europe for large basin floods; the Mediterranean for flash floods.

3.6 Structure of work

On the following pages, the component parts of MICE are presented which will guide the work on a day-by-day basis. These components are:

a. Project planning timetable, setting out the time lines for each work package and the associated deliverables.
b. Analysis of the project critical path
c. Summary workpackage list, setting out the responsible partner, start and end months, and associated deliverables.
d. Descriptions of work packages 1 to 6.
e. List of deliverables, setting out the responsible partner and expected deliverable date. These deliverables are designed to be explicitly quantified and verifiable.
f. List of milestones, setting out the responsible partner and the associated deliverable.

3.6.1 Risks of failure

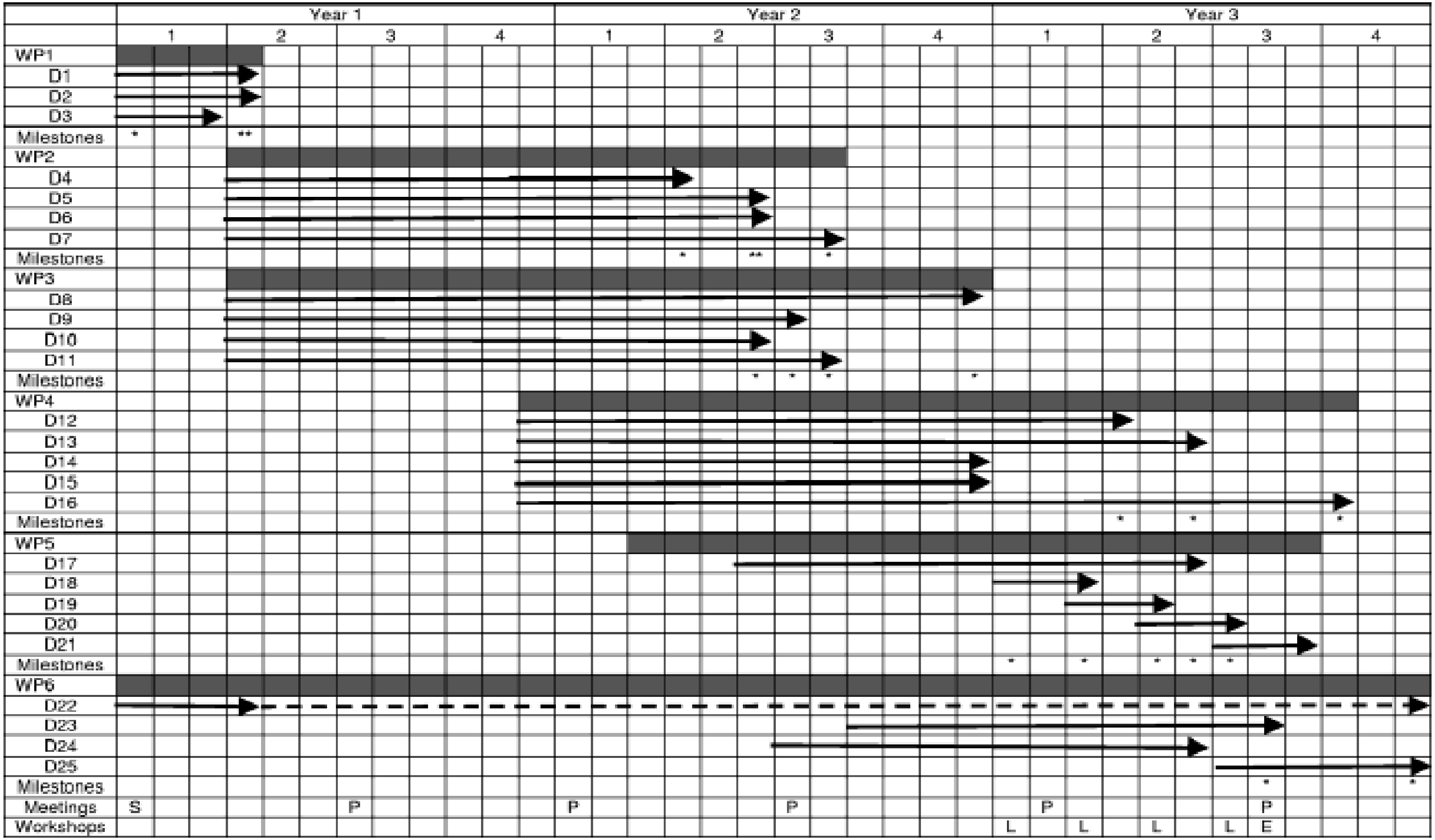
The following points at which failure may occur have been identified:

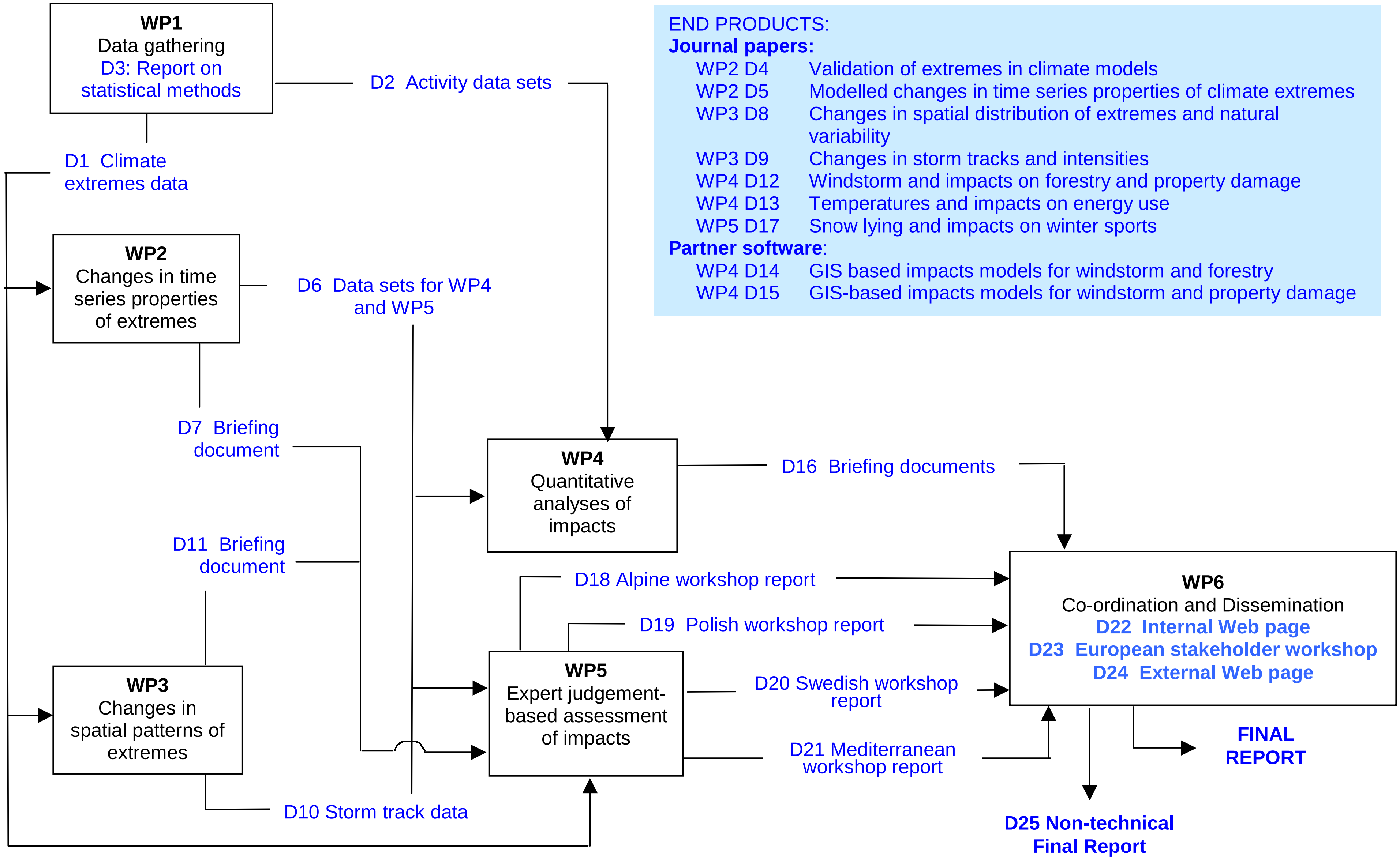
Climate model data. The project is built principally around model data from the UK Hadley Centre. These will be obtained through the LINK project at UEA, which for many years has successfully operated as a dissemination point for the Hadley Centre. The HadCM2, HadRM2 and HadCM3 experiments are already available, and at least two MICE participants (UEA and ICAT) have experience of working with them. All the HadRM3 experiments described in the proposal are promised to be available by early next year. If for some reason (which we judge to be highly unlikely) this proves not to be the case, we would fall back upon more extensive use of HadRM2, and comparison of model results from HadCM2 (Coarse resolution) and HadRM2 (fine resolution).

Economic data for impacts modelling. This will be obtained from national bureaux of statistics, and from EUROSTAT. Two potential problems are foreseen:
(a) lack of availability at better than the seasonal/annual scale. In preference, the project will use daily climate information on extremes to build monthly predictors: for example, degree-day totals, numbers of days above/below critical thresholds. This will allow construction of impacts models using monthly predictand information. But we recognize that in some cases it will be necessary to resort to seasonal/annual information.
(b) lack of comparable predictand series between the different EU nations. The predictands described here are deliberately selected for simplicity, in the expectation that this will increase the potential for comparability.
In order to evaluate the risk of failure at this point, collection of predictand data sets takes place very early in the project, in WP1 (Months 1-4).

Impacts modelling. The impacts models to be used in MICE range from the relatively simple and well-developed (e.g. in agriculture and energy use), where we see little risk of failure, to much more sophisticated attempts to model impacts in, for example, tourism. In the latter case, the existing body of work is much smaller, and the associated risk of failure in MICE is much higher. We have deliberately sought to manage this risk by emphasising quantitative impact evaluation in the well-studied activity sectors, and proposing more speculative, qualitative evaluations of impacts for the less intensively studied sectors.

3.6.a Project planning timetable Meetings: S= Start-up; P = Project management; Workshops: L = local; E = European





3.6.b. MICE critical path analysis

3.6.c. Summary workpackage list

Work-package No[1]	Workpackage title	Lead Participant No[2]	Person-months[3]	Start month[4]	End month[5]	Deliverable No[6]
1	Extraction of climate extremes for analysis	UEA	23	0	4	D1 D2 D3
2	Time series characteristics of extremes under climate change	ICAT	68	4	20	D4 D5 D6 D7
3	Spatial patterns of extremes under climate change	UKOELN	43	4	20	D8 D9 D10 D11
4	Quantitatively modelling impacts of changes in climate extremes on activity sectors	FMA	78	12	32	D12 D13 D14 D15 D16
5	Expert-judgement based approach to understanding impacts of changes in climate extremes on activity sectors	PAS	53	15	32	D17 D18 D19 D20 D21
6	Co-ordination and dissemination	UEA	20	0	36	D22 D23 D24 D25
	TOTAL		285			

[1] Workpackage number: WP 1 – WP n.
[2] Number of the contractor leading the work in this workpackage.
[3] The total number of person-months allocated to each workpackage.
[4] Relative start date of the work in the specific workpackage, month 0 marking the start of the project, and all other start dates being relative to this start date.
[5] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.
[6] Deliverable number: Number for the deliverable(s)/result(s) mentioned in the workpackage: D1 - Dn.

3.6.d.1 Workpackage description

Workpackage number : 1 — **Extraction of climate extremes for analysis**

Start date or starting event: — **Start-up meeting, Month 0**

Participant codes :	UEA	ICAT	NOA	UKOELN	FMA	GIUB	PAS	LU
Person-months per participant:	2.3	2	2	4	2	1.5	5	3

1 Objectives;

1. To select the climate models and re-analyses to be used in MICE
2. To identify appropriate observational records of climate for validation
3. To define the climate extremes to be addressed in the project, in quantitative terms which will permit the extraction of appropriate data sets from climate model/re-analysis sources
4. To identify data sets representative of the impacts categories, for construction of transfer functions to translate the changes in climate extremes into quantifiable impacts (WP4)
5. To extract these data sets

2 Methodology / work description;

Start-up meeting. The major goals of the start-up meeting will be to address the first three objectives listed above: to select the models and re-analyses; to identify the observational records; to quantitatively define the extremes for analysis. Two experts on the statistics of extreme meteorological events will be asked to give presentations.

Selection of climate models. Models will be selected to permit the following questions to be addressed:

- What improvement in simulation of extremes is obtained by using a high-resolution RCM rather than a coarse-resolution GCM?
- What is the effect on the climatology of extremes of changing from a moderate emissions scenario to a high emissions scenario?
- What is the range of change in the simulation of extremes (now and in the future) found in different GCM experiments (different ensemble members, and different model generations)?

Re-analysis data will be taken either from ECMWF or NCEP. The criteria for selection will include that the required variables are available for the time period of concern for validation, 1961-90. All other considerations being equal, we are likely to opt for the higher spatial resolution of ECMWF.

Observations. Each group will be responsible for providing 5-6 daily temperature and rainfall records for the period 1961-90, and in addition 5-6 daily wind speed records for northern Europe will be assembled. These will be used for comparison with the reanalysis and model data. To validate gridded data against point observations is unrealistic – rather the data will be used to understand the effect of moving from gridded to point scales.

Definition of climate extremes. Gridded data sets of extreme temperature, precipitation (rainfall and snow lying) and wind speed will be extracted for a European window for the periods 1961-90 and 2070-99. In addition, for HadCM3, data sets for the complete experiment will be extracted for selected grid points to assess the representativeness of the 30-year windows available for HadRM3. Extremes will be defined with respect to thresholds in both absolute (e.g., number of days with temperatures above 35^{o}C) and relative (e.g. 95th 99th percentile) terms, as well as extracting data sets appropriate for extreme value analysis (e.g., annual maxima series). Definitions for each climatic variable must be established at the start-up meeting.

Data sets representative of activity sectors. Transfer functions can be developed in the areas of agriculture, forestry, energy use and insured losses. Considering data sets for climate extremes and for the economic activity sectors at the same time should ensure that appropriate predictor and predictand variables are chosen for use in the transfer functions.

Extraction of data sets. Responsibilities for data set extraction will be allocated at the start-up meeting.

3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** D1: Data sets of climatic extremes for temperature, precipitation and wind in observations, re-analyses and climate models (present-day and future scenarios). D2: Data sets of economic/ecosystem activity sectors, to be predictor variables in transfer functions of WP4. D3: Specification of types of statistical analyses to be undertaken on extreme event series.
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project** M-1-1 Month 1: Start-up meeting M-1-2 Month 4: Delivery of activity sector data sets M-1-3 Month 4 Delivery of climate extreme data sets

3.6.d.2 Workpackage description

Workpackage number : 2	**Time series characteristics of extremes under climate change**					
Start date or starting event:	**Month 4, delivery of climate extreme data sets**					
Participants:	**ICAT**	**UEA**	**NOA**	**GIUB**	**PAS**	**LU**
Person-months per participant:	**15**	**12**	**13**	**3**	**15**	**9**

1 Objectives;

To analyse climate extremes with respect to their time series characteristics in the climate model/re-analysis and observation data sets. The goals are to evaluate (i) the impact of anthropogenic climate change on the occurrence of climate extremes in Europe using various model experiments and, hence (ii) the reliability of the greenhouse gas signal. These will be achieved by:

1. Validating the climate model time series against re-analyses
2. Studying the effect of using gridded rather than point data by comparison of climate model and re-analysis time series with observed series of extremes
3. Studying the effect of changing model characteristics with respect to (a) the forcing emissions scenarios (comparing mid- and high-severity scenarios), (b) the spatial resolution (comparing GCM output with RCM output.
4. Comparing, for the selected GCMs and RCM, the occurrence of extremes in 1961-90 and 2070-99.
5. Evaluating the modelling of extremes in the GCM simulation of 2070-99 in the longer-term context of modelled decadal variability.

2 Methodology / work description;

Time series of extremes will be extracted for selected grid points chosen to be representative of gradients across Europe north-south and west-east, and also altitudinal gradients. For all the data sets (GCM, RCM, re-analyses, observations), these selected time series will be analysed using the following techniques:

1. *Extreme value methods* -- the GEV distribution and peak-over-threshold series with the GPD.
2. *Simulation modelling*, to lengthen data sets and allow more robust estimation of extreme event probabilities.
3. *Joint probabilities of damaging extremes*. Examples are (i) rapid spring warming in high latitudes/elevations melting the snow pack, together with high rainfall, will cause severe floods and (ii) windstorm exacerbated by snow-laden trees will intensify wind throw of trees.
4. *Arrival times* of extremes. Changes in arrival times due to anthropogenic climate change (more or less frequent events of the same magnitude as at present) will have severe impacts. They will be modelled by a Poisson process.

Whereas Techniques 1 and 2 have a large supporting literature in climatology, considerable innovation and development will be required to apply Techniques 3 and 4 in this field. The probability of failure is low, since these techniques are widely used in the statistical literature. It is the transfer to the field of climatology which is innovative.

The results will be used in WP4 as a basis for development of the transfer functions, and in WP5 as briefing information for the expert-judgement workshops.

3 Deliverables including cost of deliverable as percentage of total cost of the proposed project

D4: Journal paper comparing the modelling of present-day extreme events in GCMs and RCMs with re-analyses and observations

D5: Journal paper on modelled changes in extreme event occurrence due to anthropogenic climate change

D6: Data sets of present-day and future climate extremes occurrence in a form suitable for transfer function development in WP4

D7: Briefing document on future changes in time series properties of extremes for WP5 Local Workshops

4 Milestones including cost of the Milestone as percentage of total cost of the proposed project

M-2-1 Month 14: Completion of journal article on modelling present-day extremes

M-2-2 Month 18: Completion of journal article on climate change and extreme event occurrence.

M-2-3 Month 18: Delivery of input data on extremes for transfer function development to WP4

M-2-4 Month 20: Delivery of briefing document for WP5 Local Workshops

3.6.d.3 Workpackage description

Workpackage number 3	**Spatial patterns of extremes under climate change**				
Start date or starting event:	**Month 4, delivery of climate extreme data sets**				
Participant codes :	**UKOELN**	**UEA**	**ICAT**	**GIUB**	
Person-months per participant:	**20**	**8**	**10**	**4.5**	

1 Objectives;

To analyse the variation in climate extreme occurrence in the spatial domain, in order to address the question: Do modelled spatial patterns of extreme event occurrence change in response to anthropogenic climate change?

The analysis will be carried out with respect to temperature, precipitation (rainfall and snow lying), wind speeds and storm tracks.

2 Methodology / work description;

Temperature, precipitation, wind speeds

Under WP1, simple measures of the absolute and relative variation in extreme occurrence will be extracted, which can be analysed at all points in the spatial domain for the re-analysis models and the GCM/RCM data. The analyses in this WP will concentrate on the GCM data, because we wish to emphasise variability throughout the simulation. Example measures include:

- For temperature, number of degree-days above and below specified thresholds (e.g., above 35^{o}C, below 0^{o}C).
- For rainfall, number of days above the 95th percentile
- For wind speed, number of days of gale-force wind

These will be validated by comparing the re-analysis and GCM information for 1961-90.

Then, we will examine changes in the spatial occurrence of extremes with time using three techniques:

- Mapping techniques. For example by plotting extreme event occurrence for overlapping ten-year periods in a GIS environment, we can trace changes in the spatial pattern of occurrence with time.
- Using Principal Components Analysis (Empirical Orthogonal Function analysis) to extract the major modes of variation in the occurrence of extremes. The eigenvectors of the significant principal components will be plotted to explore spatial variations. The scores, or amplitudes, of these significant components will be plotted to understand variation in time.

  The relationship between the retained principal components and indices of the large-scale behaviour of the atmospheric circulation (the North Atlantic Oscillation and the Artic Oscillation) will be explored using regression analysis.
- Using canonical correlation analysis to understand the relationship between the spatial pattern of extremes occurrence and the fields of potential explanatory variables such as sea level pressure and 500hPa height.

Storm tracks

Storm track analyses will be carried out on CGCMII, HadCM3 and HadRM3 experiments using cyclone tracking routines developed by UKOELN and based on determining cyclone core pressures from 1000 hPa geopotential height (which can be calculated from sea level pressure, a widely-available model output, using the hydrostatic balance equation). The emphasis will be on the two 30-year periods available for the RCM (1961-90 and 2070-99) but also to look at these periods in the context of the longer-term variability present in the GCM simulation. The goals will be to discover:

- if there is a systematic difference between cyclone developments in the RCM and GCM;
- if there is a systematic difference in the typical cyclone-storm relationships; and'
- if we can identify physical causes producing such differences.

Which overall will provide information on the reliability of the greenhouse gas signal in climate models.

The storm tracking results will be provided as input to WP4, to study the potential impact of changes in storm tracks due to anthropogenic climate change on the impacts categories of property damage (and insurance) and forestry (windthrow).

3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project**
	D8: Journal paper on changes in the spatial distribution of extremes (temperature and precipitation) with time, and the relationship with anthropogenic climate change and natural decadal-scale variability. D9: Journal paper on the changes in storm intensities and track positions in climate models with time, the reliability of model predictions, and the relationships with anthropogenic climate change and natural variability. D10: Storm track results in a form suitable for impacts analysis in WP4. D11: Briefing documents on spatial variability in extremes occurrence for WP5 Local Workshops.
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project**
	M-3-1 Month 15 Completion of journal article on spatial distribution of extremes (D8) M-3-2 Month 18 Delivery of storm track data to WP4 for input to GIS modelling impacts (D10) M-3-3 Month 19 Completion of journal article on storm intensities and track positions. (D9) M-3-4 Month 20 Delivery of briefing documents on spatial variability in extremes occurrence to WP5 (D11)

3.6.d.4 Workpackage description

Workpackage number 4: **Quantitatively modelling impacts of changes in climate extremes on activity sectors**

Start date or starting event: **Month 12**

Participant codes :	**FMA**	**UEA**	**ICAT**	**NOA**	**UKOELN**	**LU**
Person-months per participant:	**30**	**5**	**7**	**6**	**5**	**13**

1 Objectives;

a. To develop transfer function-based models to predict the perturbation in an activity sector generated by the occurrence of extremes. The activity sectors to be considered in this Work Package are:

- Energy use (summer air conditioning and winter space heating)
- Insurance losses -- property damage from windstorm. Such models are known in the insurance industry as "catastrophe models" (to be developed for northern Europe only)
- Forestry – damage through windthrow (northern Europe only)
- Forestry –damage through forest fire (Mediterranean region only)

b. To initialise these models with information on the change in extremes occurrence from WP2 and WP3 in order to obtain quantitative information on the implications for impacts, especially changes in the spatial distribution of risk.

2 Methodology / work description;

The participants in MICE have access to models of windstorm property damage, windthrow damage in forests and wildfire damage in forests. These models will need to be adapted for the purposes of MICE in order to study the impacts of changes in extremes occurrence.

Windstorm-related property damage. Models link property damage (expressed in terms of total claim by postal area, average size of claim, and number of policies claiming) to storm characteristics – central pressure, speed of passage, distance to storm centre etc. These relationships are handled in a GIS environment at the level of two-digit post codes, which allows input of additional layers of information on wind speed (for individual storms), altitude, population density and distance to sea. MICE participants have access to models for the UK and Netherlands, and will seek loss information for France, Germany and Denmark, which would allow generalization along the major European storm track. The catastrophe model will then be used in association with storm track information from climate models to calculate the change in "as-if" losses (i.e., based on present-day values) resulting from (a) a change in the frequency of storms, (b) a change in intensity (c) a change in the position of the European storm track.

2

Windthrow damage in forests. Layers in the GIS will be built up on altitude, aspect and distance to sea, which will allow generalization of risk from windstorm. Then, information on forest cover will be sought, for example, the National Inventory of Woodlands for the UK. A rule-based system will be developed to consider changes to forest structure and extent over the prediction period. Storm track information from the climate models can then be input to evaluate the impacts on the forestry sector.

Forest fire. Forest fire occurrence is closely linked to occurrence of high temperatures and low rainfall. A similar GIS-based approach will be taken. In this case, however, layers will be included on human settlements and roads, proximity to which is a predictor of fire occurrence, as well as on vegetation type. A rule-based system will be used to incorporate changes in settlement patterns between the two periods. Temperature and rainfall extremes for the two periods 1961-90 and 2070-99 will be input to the fire prediction model in order to understand the impacts of changing climate.

For *energy use*, a different approach is proposed. First, data from EUROSTAT on energy consumption will be obtained for winter (gas and electricity for space heating) and summer (electricity for air conditioning). These data will be compared with degree-day information from the ECMWF re-analyses, calculated using variable thresholds depending on location, to develop predictive transfer functions. These will be initialised with information on the change in degree-day occurrence from WP3.

3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** D12: Journal article on the quantitative impacts of changes in windstorm on forest and property damage D13: Journal article on the quantitative impacts of changes in temperature extremes on energy use in Europe D14: GIS-based models of changes in impacts due to changes in windstorm and fire occurrence for damage in forests D15: GIS-based model of changes in impacts due to changes in windstorm occurrence for insured property damage D16: Briefing documents on quantitative impacts for stakeholder/end-user workshop
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project** M-4-1 Month 28: Completion of journal article (D12) M-4-2 Month 30: Completion of journal article (D13) M-4-3 Month 34: Delivery of briefing documents for stakeholder/end user workshop (D17)

3.6.d.5 Workpackage description

Workpackage number : 5	**Expert-judgement based approach to understanding impacts of changes in climate extremes on activity sectors**					
Start date or starting event:	**Month 18**					
Participant codes :	**PAS**	**NOA**	**FMA**	**GIUB**	**LU**	
Person-months per participant:	**25**	**9**	**2**	**4**	**6**	

1 Objectives;

1. To generate useful information on the following extremes:
   i. Snow lying in Alpine regions
   ii. Precipitation in central Europe
   iii. Weather extremes in Scandinavia
   iv. Temperatures in the Mediterranean Basin
2. To interact with stakeholders/end-users for the purpose of understanding and interpreting the implications of this information for the impacts on:
   i. Winter sports
   ii. Flood potential
   iii. Catastrophic weather events and forest damage
   iv. Beach holidays

2 Methodology / work description;

<u>Relevant measures of extremes</u>

The emphasis will be on two activity sectors for which full quantification of the impact is beyond the scope of the project, but for which useful results will be generated from the MICE study of extremes. These are:

- flood and windstorm damage and the implications for insurers, foresters, hydraulic engineers; and,
- tourism (winter sports and Mediterranean beach holidays).

Flood and windstorm damage

The following results from the extremes analyses are examples of the information generated in WP2 and WP3 which should be collated for the regions of interest:

- changes in the return periods of extreme rainfall at a range of timescales from days to months at selected grid points relevant to the specified regions of interest
- evaluation of spatial changes in precipitation over the catchment
- changes in rainfall regime at critical times such as spring, when the joint probability of high rainfall and high temperature (causing snowmelt in the upper catchment) enhances the probability of flood damage in high-latitude forests.

Winter sports

Examples results of interest from WP2 and WP3 are:

- evaluation of spatial changes in snow lying
- evaluation of changes in frequency of winters with conditions favourable for skiing (at selected locations)

Mediterranean tourism

Emphasis will be on changes in the occurrence of extreme temperatures in the Mediterranean region.

<u>Stakeholder/end-user interaction</u>

The analyses of extremes described above will be collated individually into information packs. These will be the background for a series of 4 small workshops held for the purposes of interaction with stakeholders/end-users, one per region and held by the MICE partner from that region. Five-six interested end-users will be invited to each. Presentations will be made on the perturbation in the relevant extremes in the region. The goals of the workshops will be:

- To explore the likely impacts of the predicted changes in extremes
- To consider the policy implications of the impacts in terms of adaptation strategies

Short reports in non-scientific language will be produced by each workshop. These will be made available on the project web page.

3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** D17: Journal paper on changes in snow lying due to anthropogenic warming, and the implications for winter sports D18: Report from Local Workshop 1: The impact of snow lying in Alpine regions on winter sports D19: Report from Local Workshop 2: The impact of excess precipitation in central Europe on floods D20: Report from Local Workshop 3: Weather extremes and catastrophic forest damage in Scandinavia D21: Report from Local Workshop 4: The impact of excess temperatures in the Mediterranean region on summer tourism
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project** M-5-1 Month 25: Local Workshop 1: The impact of snow lying in Alpine regions on winter sports M-5-2 Month 27: Local Workshop 2: The impact of excess precipitation in central Europe on floods M-5-3 Month 29: Local Workshop 3: The impact of weather extremes on catastrophic forest damage in Scandinavia M-5-4 Month 30: Completion of journal article on changes in snow lying and impacts on winter sports (D17) M-5-5 Month 31: Local Workshop 4: The impact of excess temperatures in the Mediterranean region on summer tourism

3.6.d.6 Workpackage description

Workpackage number : 6 **Co-ordination and dissemination**
Start date or starting event: **Month 0**

Participant codes :	UEA	ICAT	NOA	UKOELN	FMA	GIUB	PAS	LU
Person-months per participant:	4	2	2	3	2	1	3	2

1 **Objectives;**

1. To co-ordinate MICE
2. To ensure the scientific merit of MICE through on-going peer review
3. To ensure that the research in MICE is directed towards the needs of the user community (business, local government etc.)
4. To disseminate the results from MICE
   1. to the scientific community
   2. to the community of stakeholders, end-users and policy makers

2 **Methodology / work description;**

Co-ordination will be carried out through a schedule of partner meetings beginning with a start-up meeting in the first month of the project, to be followed by regular six-monthly meetings.

E-mail links will be used between meetings to maintain contact.

Internal and external web pages will be set up where project documentation will be available for download.

Scientific peer review will be achieved through expert advisors. One-two advisors will be invited to each of the project meetings. They will be asked to supply evaluation reports on the progress of the project to date, and on the work planned for the next work period. These evaluation reports will form part of the project documentation, and will be available to the Project Officer from the Commission. Different individuals will be selected for each meetings. As the project progresses their expertise is likely to evolve through the stages:

statisticians → climate modellers → impacts modellers → economists

Needs of the user community

Each partner in MICE has been asked to identify representatives from the regional user community (utilities, insurance companies, local government etc.). A budget item is included to allow meetings to take place with end users and stakeholders, who should be chosen not simply from the partner countries in MICE, but from the wider European community. It is planned that these representatives will be involved from the very beginning of MICE, to ensure that the research framework is constructed in such a way that useful results will be generated. Two representatives of the stakeholder community will attend the start-up meeting.

Dissemination

Dissemination to the scientific community will be achieved primarily through journal articles, and these form a major deliverable item in WP2-4. In addition, presentations will be made at conferences such as the European Geophysical Society (EGS) annual meeting.

Dissemination to the European-wide stakeholder/end-user community will involve:

i. A major workshop in the final months of MICE to which representatives of this community, with special interest in the impacts sectors identified here, will be invited. Presentations will be made on the results from MICE. Feedback will be sought on the relevance of the research for the development of coping and adaptation strategies. The proceedings from this workshop will form part of the Final Report of MICE.

ii. Selected excerpts from the MICE final report will be edited and presented in a professionally-designed and accessible form. This will be mailed out to workshop participants, and other representatives of the user community identified by the partners in MICE. The external web address will be included in this report where further information can be accessed and downloaded.

3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** D22: Internal web page for project management and dissemination of information and documents between partners. D23: European stakeholder/end-user workshop D24: External web page for further dissemination of project information and documents to the user community D25: Non-technical version of Final Report
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project** M-6-1 Month 32: European stakeholder/end-user workshop M-6-2 Month 36: Release of non-technical version of Final Report

3.6.e Deliverable list

Deliverable No[7]	Deliverable title	Principal responsible partner	Delivery date[8]	Nature[9]	Dissemination level[10]
1	Data sets of climatic extremes for temperature, precipitation and wind in observations, re-analyses and climate models (present-day and future scenarios).	UEA	4	Da	RE
2	Data sets of economic/ecosystem activity sectors, to be predictor variables in transfer functions of WP4.	FMA	4	Da	RE
3	Specification of types of statistical analyses to be undertaken on extreme event series.	UEA	3	Re	PU
4	Journal paper comparing the modelling of present-day extreme events in GCMs and RCMs with re-analyses and observations	UEA	14	O*	PU
5	Journal paper on modelled changes in extreme event occurrence due to anthropogenic climate change	ICAT	18	O*	PU
6	Data sets of present-day and future climate extremes occurrence in a form suitable for transfer function development in WP4	ICAT	18	Da	CO
7	Briefing document on future changes in time series properties of extremes for WP5 Local Workshops	PAS	20	Re	RE
8	Journal paper on changes in the spatial distribution of extremes (temperature and precipitation) with time, and the relationship with anthropogenic climate change and natural variability.	ICAT	15	O*	PU
9	Journal paper on the changes in storm intensities and track positions in climate models with time, the reliability of model predictions, and the relationships with anthropogenic climate change and natural variability.	UKOELN	19	O*	PU
10	Storm track results in a form suitable for impacts analysis in WP4.	UKOELN	18	Da	CO
11	Briefing documents on spatial variability in extremes occurrence for WP5 Local Workshops	PAS	20	Re	RE

[7] Deliverable numbers in order of delivery dates: D1 – Dn
[8] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.
[9] Please indicate the nature of the deliverable using one of the following codes:
Re = Report; **Da** = Data set; **Eq** = Equipment; **Pr** = Prototype; **Si** = Simulation;
Th = Theory; **De** = Demonstrator; **Me** = Methodology; **O** = other (describe in annnex)
[10] Please indicate the dissemination level using one of the following codes:
PU = Public
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

O* = Dissemination via journal papers, Web pages, workshops

Deliverable list (cont.)

Deliverable No [11]	Deliverable title	Responsible partner	Delivery date [12]	Nature [13]	Dissemination level [14]
12	Journal article on climate change and the implications for catastrophic weather damage to forests and property	LU	28	O*	PU
13	Journal article on the quantitative impacts of changes in temperature extremes on energy use and Mediterranean tourism in Europe	NOA	30	O*	PU
14	GIS-based models of changes in impacts due to changes in windstorm and fire occurrence for damage in forests	FMA	24	De	CO
15	GIS-based model of changes in impacts due to changes in windstorm occurrence for insured property damage	UKOELN	24	De	CO
16	Briefing documents on quantitative impacts modelling for stakeholder/end-user workshop	FMA	34	Re	RE
17	Journal paper on changes in snow lying due to anthropogenic warming, and the implications for winter sports	GIUB	30	O*	PU
18	Report from Local Workshop 1: The impact of snow lying in Alpine regions on winter sports	GIUB	27	Re	PU
19	Report from Local Workshop 2: The impact of excess precipitation in central Europe on floods	PAS	29	Re	PU
20	Report from Local Workshop 3: The implications of climate change for catastrophic weather damage to forests in northern Europe	LU	31	Re	PU
21	Report from Local Workshop 4: The impact of excess temperatures in the Mediterranean region on summer tourism	NOA	33	Re	PU
22	Internal web page for project management and dissemination of information and documents between partners.	UEA	4	O*	CO

[11] Deliverable numbers in order of delivery dates: D1 – Dn
[12] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.
[13] Please indicate the nature of the deliverable using one of the following codes:
Re = Report; **Da** = Data set; **Eq** = Equipment; **Pr** = Prototype; **Si** = Simulation;
Th = Theory; **De** = Demonstrator; **Me** = Methodology; **O** = other (describe in annnex)
[14] Please indicate the dissemination level using one of the following codes:
PU = Public
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O* = Dissemination via journal papers, Web pages, workshops

Deliverable list (cont.)

Deliverable No[15]	Deliverable title	Responsible partner	Delivery date[16]	Nature[17]	Dissemination level[18]
23	European stakeholder/end-user workshop	**UEA**	**32**	**O***	**RE**
24	External web page for further dissemination of project information and documents to the user community	**UEA**	**30**	**O***	**PU**
25	Non-technical version of Final Report	**UEA**	**36**	**Re**	**PU**

[15] Deliverable numbers in order of delivery dates: D1 – Dn
[16] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.
[17] Please indicate the nature of the deliverable using one of the following codes:
Re = Report; **Da** = Data set; **Eq** = Equipment; **Pr** = Prototype; **Si** = Simulation;
Th = Theory; **De** = Demonstrator; **Me** = Methodology; **O** = other (describe in annnex)
[18] Please indicate the dissemination level using one of the following codes:
PU = Public
RE = Restricted to a group specified by the consortium (including the Commission Services).
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O* = Dissemination via journal papers, Web pages, workshops

3.6.f Milestone list

Milestone Number	Milestone	Principal responsible partner	Due date	Associated deliverable
M-1-1	Start-up meeting	**UEA**	Month 1	
M-1-2	Delivery of activity sector data sets	**FMA**	Month 4:	D2
M-1-3	Delivery of climate extreme data sets	**UEA**	Month 4	D1
M-2-1	Completion of journal article on modelling present-day extremes	**UEA**	Month 16	D4
M-2-2	Completion of journal article on climate change and extreme event occurrence.	**ICAT**	Month 18	D5
M-2-3	Delivery of input data on extremes for transfer function development to WP4	**ICAT**	Month 18	D6
M-2-4	Delivery of briefing document for WP5 Local Workshops	**PAS**	Month 20	D7
M-3-1	Completion of journal article on spatial distribution of extremes	**ICAT**	Month 24	D8
M-3-2	Delivery of storm track data to WP4 for input to GIS modelling impacts	**UKOELN**	Month 18	D10
M-3-3	Completion of journal article on storm intensities and track positions.	**UKOELN**	Month 19	D9
M-3-4	Delivery of briefing documents on spatial variability in extremes occurrence to WP5	**PAS**	Month 20	D11
M-4-1	Completion of journal article on climate change and the implications for catastrophic weather damage to forests and property	**LU**	Month 28	D12
M-4-2	Completion of journal article on impacts of temperature extreme changes for energy use	**NOA**	Month 30	D13
M-4-3	Delivery of briefing documents for stakeholder/end user workshop	**FMA**	Month 34	D16

Milestone list (cont.)

Milestone Number	Milestone	Principal responsible partner	Due date	Associated deliverable
M-5-1	Local Workshop 1: The impact of snow lying in Alpine regions on winter sports	**GIUB**	Month 25	D18
M-5-2	Local Workshop 2: The impact of excess precipitation in central Europe on floods	**PAS**	Month 27	D19
M-5-3	Local Workshop 3: The implications of climate change for catastrophic weather damage to forests in northern Europe	**LU**	Month 29	D20
M-5-4	Completion of journal article on changes in snow lying and impacts on winter sports	**GIUB**	Month 30	D17
M-5-5	Local Workshop 4: The impact of excess temperatures in the Mediterranean region on summer tourism	**NOA**	Month 31	D21
M-6-1	European stakeholder/end-user workshop	**UEA**	Month 32	D23
M-6-2	Release of non-technical version of Final Report	**UEA**	Month 36	D25

4. Contribution to objectives of programme/call

MICE is a project under Key Action 2 '**Global Change, Climate and Biodiversity**' of the Environment and Sustainable Development Programme to the RTD priority 2.1.3 '**Climate change prediction and scenarios'**.

Under 2.1.3, the Work Programme states as a target:

> '**to improve regional climate change predictions and assess impacts'**

Also under 2.1.3, the Work Programme states as a priority:

> **'scenarios of changes regarding the scale and frequency of extreme events (e.g. storms, floods and droughts) and impacts on natural resources, socio-economic systems and human health'**

The project MICE addresses this target and this priority.

MICE will use the output from climate models together with statistical procedures to construct scenarios of changes in the frequency and severity of climate extremes as a result of climate change due to anthropogenic warming. These scenarios will be judged in terms of their accuracy with respect to extreme event occurrence. By looking at different GCM and RCM experiments, the effect of changing the emissions forcing scenario, the starting condition and the spatial resolution can be evaluated.

The extremes selected for study are related to wind, temperature and precipitation, and include windstorm, flood, drought and heat stress. The implications of the changes will be analysed for selected impacts categories. These are agriculture, commercial forestry and natural forest ecosystems, energy use, tourism and insurance. As such, MICE focuses principally on impacts on socio-economic systems. There are two exceptions. First, the study of impacts on natural forest ecosystems lies within the area of natural resources. Second, impacts on tourism will be explored partly through analysis of heat stress on human beings, which could equally be considered to lie within the area of human health.

MICE also contributes towards the objectives of the Activity of a Generic Nature 7.1 'The Fight Against Major Natural and Technological Hazards'. Within this Generic Activity, MICE will undertake activities relevant to Area 1.2 'Floods and Hydrogeological Risks', and to Area 1.4 'Forest Fires'. This Generic Activity emphasises the need for 'end-user/stakeholder-driven, problem-solving and policy-relevant research' which are fundamental aspects of MICE. However, MICE goes beyond the scope of the 'Natural Hazards' Generic Activity in its emphasis on the development and analysis of scenarios of the change in the occurrence of climate extremes under global warming, and in its emphasis on impacts modelling. As such, it is primarily focussed on the objectives of RTD priority 2.1.3.

5. Community added value and contribution to EU policies

a. European dimension of the problem

MICE will address issues related to the impacts of global warming at the European scale, in particular the occurrence of extreme climatic events such as windstorm and floods.

The climate changes that are expected to occur as a result of anthropogenic warming will vary on a regional basis. For Europe, the latest experiments based on the Hadley Centre GCM suggest that rainfall will increase across most countries of the European Union in winter as a result of global warming. The exceptions lie on the Mediterranean fringe, with reduced rainfall in southern Spain, Italy and Greece. In summer, however, rainfall will be reduced almost everywhere, with the exceptions lying in the far North – Finland and northern Sweden. This example demonstrates that climate change and the associated impacts are of concern to the whole community of European nations.

Contrasts exist in the likely future experience of climate change, both internationally and within Europe. These contrasts, when combined with the distinctive character of European societies, cultures and economies, mean that a European-wide programme of action, specific to European needs, is required to deal with the impacts of climate change. The EU Framework IV research programme recognized this and funded the Concerted Action ACACIA (A Concerted Action towards a comprehensive Climate Impacts and Adaptations assessment for the European Union). The MICE project will build upon the expert-judgement based approach of ACACIA by:

1. Bringing quantitative techniques to the analysis of climate model output with respect to the impacts on selected activities within Europe.
2. Concentrating on the study of extreme climate events and their impacts (the most severe impacts are expected from changes in the occurrence of extreme events).

b. European added value for the consortium

MICE brings together statisticians, climatologists and impacts analysts from a diverse range of activity sectors. It deliberately seeks to explore impacts within the context of the geographical diversity of Europe. Thus, with respect to impacts on forestry, for example, it looks at changes in the frequency of forest fires (and associated changes in drought and high temperature occurrence) in the Mediterranean region, changes in the incidence of windstorm damage in western and northern Europe, and snow-related damage in northern and Alpine regions. In order to pursue these separate (in terms of impact) yet related (in terms of causal mechanism) research strands, it is necessary to bring together researchers from across Europe – no single country could offer the required level of expertise.

MICE will explore the range of impacts which may be expected across Europe as a result of anthropogenic change, and will create a dialogue with stake-holders, end-users and policy makers to ensure that the project results (a) are useful to this community and (b) are properly disseminated. In thinking about this user community, the MICE participants wish to access not only representatives from the European Commission, but government and business interests at the national and regional scale. First, this will be achieved by involving stakeholders within the project from the very beginning, by inviting selected stakeholder participants to the start-up meeting. Second, a major stakeholder workshop will be held in the closing months of the project. We wish to bring together groups of end-users from the geographical diversity of Europe, not only to discuss the results from MICE, but also to share their experiences regarding current and future planning for climate change, and to seek their views on research needs. This can only be achieved by building a multi-national consortium of researchers and stakeholders.

c. Contribution to EU policies

MICE will look at future impacts of climate change, especially related to extreme events. It will concentrate on four ecosystem/activity sectors: forestry (commercial and recreational) and agriculture, energy supply, tourism, and insurance (windstorm and flood damage).

Forestry. Forests are currently vulnerable to damage by windstorm and fire. It is estimated that 10% of the French forest was lost during the windstorms at the end of 1999. Each year, 350,000-500,000 ha are lost to fire. It is therefore very important to understand the likely changes in vulnerability due to global warming. Through the principal of subsidiarity, forest policy is not handled explicitly by Europe, but is devolved to the national scale. However, forestry issues are considered at the European level by legislation related to rural development policy, and through the contribution to income and employment and its ecological and social value. European policies related to forestry include the EU Biodiversity Strategy, Natura 20000 and the implementation of the Climate Change Convention. (See Com(1998) 649, *Communication from the Commission to the Council and the European Parliament on a Forestry Strategy for the European Union*)

Agriculture. Ongoing reform of the Common Agricultural Policy (CAP) presents major opportunities to make key areas of European policy more sustainable. The European Consultative Forum on the Environment and Sustainable Development has identified five conclusions about kinds of policies needed for successful reform of CAP. These include the need to ‘protect and perpetuate local diversity and environmental quality’. MICE will concentrate on climate impacts in Mediterranean regions. Reforms of agricultural production to achieve sustainability can only be successful when the potential for climate change is understood, especially in the agricultural systems of the Mediterranean, already under stress from drought and excessive heat.

Energy policy. European energy policy recognizes that the Union has to balance forecast increases in energy dependence against responsibilities for environmental protection under mechanisms such as the Kyoto Protocol. Policy is therefore focussed on three objectives: overall competitiveness, security of supply and environmental protection (see COM(95)682 *An Energy Policy for the European Union*). In the implementation of future policies, it is necessary to understand not only changes in the social and economic context of energy supply and demand, but also changes in climate. Seasonal cycles of energy use in northern Europe are already beginning to change as the winter heating requirement reduces and the need for air conditioning in summer increases. In southern Europe the seasonal cycle is likely to intensify as air conditioning becomes near-universal. These regional contrasts, and especially the effect of extremes such as severe heatwaves, will be explored in MICE.

Tourism. The EU recognizes the economic importance of tourism, and provides support, through the Tourism Unit of DG Enterprise. Article 3u of the Amsterdam Treaty included ‘measures in the sphere of tourism’ in the list of Community activities foreseen in support of the Community’s overall objectives. It is estimated that between 1994 and 1999, the EU contributed around 7.3 billion ECU to tourism projects through Structural Funds. Given the obvious importance of tourism at the European scale, and the sensitivity of this sector to weather, it is important to understand the possible impacts of climate change on Mediterranean beach holidays and winter sports.

Floods and windstorm – insurance and civil protection. MICE will study the impacts of changes in flood and windstorm occurrence, and relate these to the insurance industry. However, policy implications at the European level exist with respect to civil protection. Community action is administered by the Civil Protection and Environmental Emergencies Unit of DG Environment. The roles of this Unit include (a) enhancement of cooperation between Member States, (b) support and supplementation of national efforts with regard to disaster prevention and preparedness, and (c) enhancement of public awareness. Information on the regional potential for change in flood and windstorm frequency resulting from climate change, planned as deliverables from MICE, will contribute greatly to this role.

6. Contribution to community social objectives

MICE will address Community social issues through its explicit contribution towards the quality of life, health, and safety. At a secondary level, the project will also contribute towards improved employment and to the quality of the environment and the availability of natural resources. MICE will look at future impacts of climate change, especially related to extreme events. It will concentrate on four ecosystem/activity sectors: forestry (commercial and recreational), energy supply, tourism, and insurance (windstorm and flood damage).

a. Quality of life and health and safety

MICE will address issues related to civil protection. Windstorm and flood are two hazards to be addressed in MICE. A single storm will normally affect a number of countries along its track. Large river basin floods, such as those in central Europe in 1997, will also affect a number of countries. The ability of these events to affect very large, transnational, regions means that disaster management may usefully be coordinated at the European scale. Information on changes in the occurrence of these hazards due to anthropogenic warming will be deliverables of MICE.

A secure and economic energy supply is a vital building block for the maintenance and improvement of quality of life. Energy demand will be affected by climate change, and by energy saving activities designed to achieve the European commitments under the Kyoto Protocol. Patterns of demand will shift both in time and geographically. MICE will analyse these changes, particularly with respect to the future occurrence of climate extremes such as heat waves. This information will inform decision-making on the future of energy supply in the Community.

b. Improving employment prospects.

A number of the activity sectors considered by MICE are important employers in the EU. For example, tourism is estimated to employ 9 million people in the EU (6% of total employment), and contributes around 5.5% GDP. Even tourist activities that are not obviously large employers at the national scale can be important contributors to the local economy. For example, the Scottish skiing industry, although it only employs around 1000 people, does so at a time of year when other employment opportunities are very scarce, and hence it is an important contributor to the economic well-being of the Scottish Highlands. MICE will look at the impact of changes in climate extremes on both beach holidays and winter sports.

c. Preserving and/or enhancing the environment

MICE will contribute towards the sustainability of the forestry resource in the EU, through the information it yields on future changes in fires, windstorm and flood; all damaging to forests.

This sustainability is important for a number of reasons:

- *Environmental*. The preservation of the natural environment is an important goal in its own right. Moreover, forests are a vital carbon sink that can contribute to the fulfilment of the European commitment to the Kyoto Protocol.

- *Recreational*. Forests have an important recreational role to play throughout Europe.
- *Economic*. The EU has 130 million ha of forest, around 36% of the land area. The EU is the world's second largest paper and sawnwood producer, and the third largest exporter of forest products. Directly and indirectly, therefore, forestry is an important employer.

d. The European Research Area

The European Research Area project offers a new horizon for scientific and technological activity, and for research policy in Europe. It is the successor to the Framework Programmes. It represents a new and exciting philosophy of scientific research, and its role in the Community. Successful implementation should bring Europe to the forefront of international research activity.

MICE is a project of Framework Programme V. However, in its conception and structure, it will impact upon issues that are seen as central to the European Research Area, particularly:

i. Central to MICE is the dialogue between researchers and policy-makers. Through sub-contracts and workshops, this dialogue will be set up in the opening months of the project, and will be instrumental in affecting the way in which the MICE research programme is implemented, and in ensuring proper dissemination of the results. MICE will take great account of the needs of the end-user community, a principal that is central to the European Research Area.

ii. The MICE consortium is selected to be broad based and representative of the entire community of European scientists. It includes not only scientific institutions from within the present EU, but also from Associated (Poland and Switzerland) States. No country has more than one scientific institution in the consortium. As such, MICE has many of the characteristics of a network as envisaged by the European Research Area.

7. Economic development and scientific and technological prospects

a. Dissemination of the results

Successful dissemination to the academic community and the stakeholder community are key goals of MICE.

Dissemination to the **academic community** will be via traditional routes: conference presentations and papers in the refereed literature. As deliverables, we have specified seven journal papers, as follows:

D4: comparing the modelling of present-day extreme events in GCMs, RCMs, re-analyses and observations;
D5: the changes in extreme event occurrence due to anthropogenic climate change;
D8: the changes in the spatial distribution of extremes (temperature and precipitation) with time, and the relationship with anthropogenic climate change and natural variability;
D9: the changes in storm intensities and track positions in climate models with time, the reliability of model predictions, and the relationships with anthropogenic climate change and natural variability;
D12: the quantitative impacts of changes in windstorm on forest and property damage;
D13: the quantitative impacts of changes in temperature extremes on energy use in Europe; and
D17: changes in snow lying due to anthropogenic warming, and the implications for winter sports.

Although these are unlikely to appear as refereed papers within the proposed three-year duration of MICE, they are planned to be submitted within the project time frame. In addition, presentations will be made at conferences such as the European Geophysical Society (EGS) annual meeting.

The **stakeholder/end-user community** audience for the MICE results is primarily management within the civic, public and industrial sectors. Example target audiences are management responsible for day-to-day operations and longer-term strategic planning within sectors such as:

- regional and national government planning authorities;
- authorities responsible for civic protection and flood protection;
- energy supply industries;
- tourism industries – both publicly-funded agencies seeking to promote national/regional tourism and private operators; and,
- planners in agriculture and forestry.

These groups require answers to questions such as:

What likely future changes are to be expected in the occurrence of climate extremes?
What are the uncertainties associated with these predictions?
How can we plan for future climate change in the context of these uncertainties?

MICE will advance the understanding necessary for providing these groups with answers to their questions regarding climate change and the future occurrence of climate extremes.

Dissemination to the user community will be by Web Page, Workshop (and associated Briefing Documents), and Report.

Web Page. It is planned to set up an external Web Page in the final months of the project (Deliverable 23). We have set aside resources in the project for web page development, and we see this as a potentially valuable resource for a very wide community of users. The pages will carry the project deliverables (briefing documents, reports and papers) in an attractive and accessible format. Download facilities for project documents will be available.

Workshops. We plan two separate categories of workshops over the duration of the contract. The first set is related to Work Package 5. This work package deals with impacts in sectors where the relationship between climate extremes and the selected activity is imperfectly understood, or where we believe the interpretation of the results from MICE is better carried out within the stakeholder community. We therefore propose to apply an expert-judgement based approach to enhancing understanding of these relationships, and hence the potential impacts of changes in extremes on these activity sectors. Four local workshops will be held as part of this Work Package, as follows:

Sector	*Activity*	*Country where workshop will be held*	*Responsible partner*
Tourism:	Winter sports	Switzerland	GIUB
	Mediterranean beach holidays	Greece	NOA
Flooding	Large catchments	Poland	PAS
	Forest damage, related to joint catastrophic extremes	Sweden	LU

Briefing documents will be prepared as part of WPs 2, 3 and 4, which will form the preliminary background documents for the local workshops. These are:

Deliverable 7: Briefing on Changes in Time Series Properties of Climate Extremes,
Deliverable 11: Briefing on Spatial Variability in Extremes Occurrence.

In addition, these local workshops will generate their own documentation, which will form input to the final stakeholder/end-user workshop (see below):

Deliverable 17: Report from Local Workshop 1: The impact of snow lying in Alpine regions on winter sports
Deliverable 18: Report from Local Workshop 2: The impact of excess precipitation in central Europe on floods
Deliverable 19: Report from Local Workshop 3: The implications of climate change for catastrophic weather damage to forests in northern Europe
Deliverable 20: Report from Local Workshop 4: The impact of excess temperatures in the Mediterranean region on summer tourism

In addition to forming background documentation for the workshops, these deliverables will be made available on the external project web site.

The goals of this first set of workshops will be to:

- communicate information from WPs 2 and 3 on predicted future changes in extreme event occurrence and the associated uncertainties; and,

- explore, within a dialogue between project participants and stakeholders, the likely impacts of the predicted changes in extremes.
- Produce short reports in non-scientific language. These will be made available on the project web page.

The second category of workshop is the final dissemination workshop, which will be a much larger event, and is Deliverable 22 for WP6. We plan to invite around 30-35 representatives of the user community from the countries represented in MICE to this workshop, which will be held in a central location. Presentations will be made on the results from MICE. It is intended that the workshops will all be managed as a two-way operation. That is, the flows of information must be from MICE participants to the user community, and *vice versa*. The workshops must be organized to optimize the potential for these two-way flows. We envisage that a focus group/think tank approach will be most appropriate for our needs. Feedback will be sought on the relevance of the research for the development of coping and adaptation strategies. The proceedings from this workshop will form part of the Final Report of MICE, and will appear on the project Web page.

Final Report. The final report will appear in two versions. Selected excerpts from the MICE final report will be edited and presented in a professionally-designed and accessible form. This ‘flyer’, which we envisage will be 8-12 pages in length, will be mailed out to workshop participants, and other representatives of the user community identified by the partners in MICE. A budget is allowed in the project costs for this purpose. The external web address will be included in this report, where further information can be accessed.

b. Use and exploitation of the results

The principal strengths of MICE are that it:

i. concentrates on changes in climate extremes in response to global warming;
ii. emphasises the need to understand uncertainty in the predictions of future changes in extremes;
iii. focusses on establishing a two-way dialogue with stakeholders/end users in order to enhance understanding of the impacts of these changes

The MICE partners are all currently involved in the study of climate change and related impacts, from the viewpoint of geophysicists, climatologists and geographers. The emphasis within MICE on extremes will be a new avenue of research for most participants, and as such the results will greatly enlarge understanding of the implications of climate change in Europe. It is expected that the research methods developed in MICE, and the results, will form a platform from which new research projects will develop for many of the participants.

For the stakeholder community, the results from MICE should focus their attention on the importance of extreme events, sectoral sensitivities to changes in the occurrence of extremes, and the range of probable future changes in extremes. Too often in the past, attention has focussed on changes in the mean climate in response to anthropogenic warming, so that some level of complacency has developed with respect to the ability of European institutions to deal with these changes. However, it is highly likely that the impacts from changes in extremes will be much more severe, and MICE will provide the opportunity for stakeholders to start to address the associated risks.

8. The consortium

The project participants (see Table 2) are selected for their:

- understanding of climate change and of the tools available for predicting future climates;
- expertise in the statistical analysis of climate data; and,
- knowledge of the impacts likely to arise from the predicted changes.

In addition, the participants reflect a geographical range and diversity across Europe that will allow MICE to explore impacts in many different geographical contexts: maritime, continental, high-altitude, high-latitude and Mediterranean.

Deliberately, the participants are not primarily climate modellers. The goal of MICE is to use existing model simulations, and to use the output from these simulations to look at changes in climate extremes. Partners are therefore selected rather for their expertise in statistical manipulation, and in the understanding of impacts. Steps have been taken during the preparation of the MICE proposal to ensure that model data will be available. Specifically, data will be accessible from the UK Hadley Centre, through the LINK project at UEA. Other sources of model data may be sought once the project begins. The co-ordinator of MICE, UEA, is a partner in PRUDENCE, which will further facilitate access to model results during the project.

Table 2: Partners in MICE

Contractor No.	Short name	Full name of the Institution	Key Persons
1	UEA	University of East Anglia, Norwich, UK Climatic Research Unit	Dr J.P. Palutikof Dr T. Holt
2	ICAT	Universidade Lisboa, Lisbon, Portugal Instituto de Ciência Aplicada e Tecnologia, Faculdade de Ciências	Prof. João Corte-Real Dr Ricardo Trigo
3	NOA	National Observatory of Athens, Athens, Greece Institute for Environmental Research and Sustainable Development	Prof. D.P. Lalas Dr C. Giannakopoulos
4	UKOELN	Universität zu Köln Institut für Geophysik und Meteorologie	Priv.-Doz. Dr. Uwe Ulbrich
5	FMA	Fondazione per la Meteorologia Applicata, Florence, Italy	Prof. G. Maracchi Dr. M. Bindi
6	GIUB	University of Bern, Bern/Switzerland Institute of Geography	Dr. D. Gyalistras / Prof. Dr. H. Wanner
7	PAS	Research Centre for Agricultural and Forest Environment, Polish Academy of Sciences, Poznan, Poland	Prof. Z. W. Kundzewicz
8	LU	Lunds universitet Naturgeografiska institutionen	Dr L. Barring Dr I. Stjernquist Dr P. Schlyter

The involvement of stakeholders is central to MICE. Participant No. 5 (FMA) has included budget to allow the participation of the Regional Government of Tuscany as a stakeholder in sectors such as forests (fire risk) and agriculture. Other partners have not named their impacts collaborators formally at this stage. A list is provided below (Table 3) of representative links which the partners have into the stakeholder community, and which can be drawn upon during MICE.

Table 3: Links into the stakeholder community

Institute	Named individual	Country	Activity sector
Electricité de France	Jean-Yves Caneill	France	Energy supply
PowerGen	David Farrar	UK	Energy supply
Greek Public Power Corporation	V. Tsadari	Greece	Energy Supply
Rede Eletrica Nacional (REN)	Rui Pestana	Portugal	Energy supply (hydroelectric production) and flooding (national hydrological planning)
Forestry Commission	Chris Quine	UK	Forests (windstorm damage)
Regional Government of Tuscany Dept. of Forestry, Agriculture and Environmental Protection (see letter in support, page	Simone Sorbi	Italy	Forestry, agriculture, civil protection
Cologne Re	Thomas Grollman	Germany	Re-insurance
CGNU Group	Nicholas MIchaelides	UK	Insurance
General Secretariat of Civil Protection	D. Papanikolau	Greece	Civil protection
Instituto Nacional da Agua (INAG)	Aderito Mendes	Portugal	Flooding, civil protection
Federal Institute of Hydrology of Germany	Heinz Engel	Germany	Flooding, civil protection
Regional agency for agricultural development (ARSIA)		Italy	Agriculture

The roles of the eight partners in MICE are as follows:

UEA (Partner 1) is the MICE Project Co-ordinator. To facilitate this role, UEA is the Work Package co-ordinator for WP6, under which the responsibilities for co-ordination and dissemination are undertaken. UEA has extensive experience of co-ordination of EU projects. The Climatic Research Unit at UEA co-ordinated WISE, ADVICE, ACCORD and ADVANCE-10K amongst others. The responsible scientist at UEA was the co-ordinator of WISE. Research activities at UEA will be directed primarily towards statistical analyses of climate model data in order to understand future changes in climate extremes and the surrounding uncertainties. The co-ordinator has published in the field of extreme event analysis, and in the analysis of climate model output. MICE will bring these two strands of expertise together in order to understand extreme events in climate models, and their impacts. UEA is also responsible for WP1, in which the data sets for the project will be compiled. Successful management of this WP is essential for the ultimate success of MICE.

Personnel	1 senior scientist	1 permanent staff
Expertise	Data extraction and impacts analyses	Project co-ordinator and principal investigator; extreme event analyses
Contribution to WPs	WP1, WP2, WP3, WP4, WP6	WP2, WP3, WP6
Responsibility for milestones and deliverables	D1, D22, D24 M-1-3	D3, D4, D23, D25 M-1-1, M-2-1, M-6-1, M-6-2

ICAT (Partner 2) has a long experience in diagnostic studies of the atmosphere, via dynamical and statistical methods, including validation of GCM outputs. ICAT will use that expertise by Co-ordinating WP 2. Several different techniques will be used to characterise time series of extremes for different data sets, including observations, re-analysis, GCM and RCM outputs. The main purpose of this analysis will be to evaluate the impact of anthropogenic climate change on the occurrence of climate extremes in Europe. In this respect we will focus our attention on the effect of changing model characteristics such as a) different forcing scenarios, b) the spatial resolution and c) the generic model type.

ICAT will contribute to WP 3 by analysing the variation of climate extremes occurrence in the spatial domain. For this purpose, different techniques will be employed to analyse potential changes in the spatial occurrence of extremes of temperature, precipitation, wind speeds and storm tracks. These techniques include: Principal Component Analysis (PCA), Canonical Correlation Analysis (CCA) and suitable mapping techniques using Geographical Information Systems (GIS).

Finally, the ICAT group will contribute, under WP 4 to model the impacts of changes in climate extremes on different activity sectors, such as Mediterranean summer forest fires.

Personnel	1 Scientist	1 Technical staff	1 Permanent staff
Expertise	GCM and re-analysis data handling	Technical support	Principal investigator
Contribution to WPs	WP1, WP2, WP3, WP4, WP6	WP1, WP2, WP3, WP4, WP6	WP2, WP3, WP4
Responsibility for milestones and deliverables	D5, D6, D8 M-2-2, M-2-3, M 3-1	D5, D6, D8 M-2-2, M-2-3, M 3-1	D5, D6, D8 M-2-2, M-2-3, M 3-1

NOA (Partner 3) will carry out research on the impacts due to changes in climate extremes in the Mediterranean areas. NOA will mainly concentrate on the sectors of tourism, energy use and wildfire but will also contribute significantly to the analysis of time series characteristics of extremes under climate change. Hence the main focus of work will be on WP2, WP4 and WP5.

NOA will compare extremes from different GCM/RCM experiments groups and will also examine the effects of altering forcing emission scenarios on the model output. We will experiment with low-medium and high set of scenarios and explore the differences they have in the appearance of climate extremes.

NOA will contribute to the development of transfer functions to model impacts of climate extremes on different sectors of the economy. In particular, the impacts on energy use and Mediterranean forest fires will be investigated. Moreover, the impacts on Mediterranean beach holidays and tourism will also be examined due to changes in the occurrence of extreme temperatures. Where possible we will use and improve existing impact models. Where transfer functions for some sectors of the economy do not exist (e.g. tourism) or cannot be devised, an expert-based approach will be taken.

As part of the project dissemination, NOA will organize and host the mini-workshop on Mediterranean tourism and will invite stakeholders and end-users from the Greek Community. More specifically, we will invite the Greek Civil Protection Agency (for the impacts of extremes on forest fires and floods), the Greek Public Power Corporation (for the energy use impacts) and the Greek National Tourism Organization (for the effects on Mediterranean tourism). NOA will author or co-author several of the journal papers and reports connected to the work packages of its participation within the program.

Personnel	1 Research Scientist (D level- junior)
Expertise	Principal investigator
Contribution to WPs	WP1, WP2, WP4, WP5, WP6
Responsibility for milestones and deliverables	D13, D21 M-4-2, M-5-5
Contribution to other milestones and deliverables	D7 M-2-4

N.B NOA is a full-cost contractor and is not asked to specify permanent staff effort

UKOELN (Partner 4) will be the Work Package Co-ordinator for WP 3. UKOELN has researched intensively on the analysis of storm tracks in climate models, and their changes under a perturbed climate. This group will continue this work under MICE, emphasising the effects of changing the spatial resolution between GCM and RCM simulations. Storm track analyses will be carried out on HadCM3 and HadRM3 experiments using cyclone tracking routines developed by UKOELN and based on determining cyclone core pressures from 1000 hPa geopotential height (which can be calculated from sea level pressure, a widely-available model output, using the hydrostatic balance equation). The emphasis will be on the two 30-year periods available for the RCM (1961-90 and 2070-99) but also to look at these periods in the context of the longer-term variability present in the GCM simulation. The goals will be to understand future changes in storm tracks in the context of the effects of changing the underlying characteristics of the models, such as the spatial resolution. UKOELN will work with end-users primarily in the insurance sector to explore the opportunities for application of the storm track analyses.

Personnel	1 Scientist	1 Technical staff	1 Permanent staff
Expertise	In charge of model analyses	Technical support	Principal investigator
Contribution to WPs	WP1, WP3, WP4, WP6	WP3	WP1, WP3, WP6
Responsibility for milestones and deliverables	D9, D10, D15 M-3-1, M-3-2	D10, D15 M-3-2	D9, D10, D15 M-3-1, M-3-2

FMA (Partner 5) FMA will be the Work Package Co-ordinator for WP 4. FMA has researched intensively on the impact of climate change on forest fires and agriculture in previous EU funded projects. This group will continue this work under MICE, emphasising the effects of changing in extreme events on these sectors. The impact on forest fires and agriculture will be carried out on the basis of the climate model output provided by other partners The analysis will be undertaken on the two 30-year periods available for the RCM (1961-90 and 2070-99) but also to look at these periods in the context of the longer-term variability present in the GCM simulation. The goals will be to define the impact of future changes in extreme events and to define appropriated sector mitigation or adaptation strategies to overcome these changes. FMA brings to MICE expertise in establishing and maintaining dialogue with stakeholders. FMA will work with end-users primarily in connection with the Research & Innovation Policies Department of the Tuscany Regional to evaluate the regional impact of climate change on natural and agricultural ecosystems.

Personnel	1 Scientist	1 Permanent staff
Expertise	In charge of quantitative modelling impacts	Principal investigator
Contribution to WPs	WP1, WP4	WP1, WP4, WP5, WP6
Responsibility for milestones and deliverables	D2, D14, D16 M-1-2, M-4-3	D2, D14, D16 M-1-2, M-4-3

GIUB (Partner 6) will conduct the research on climate change impacts on Alpine snow cover and winter tourism, with the main contributions being in Work Packages 2, 3 and 5. GIUB has extensive experience with synoptic-climatological analyses of observed and simulated climates, as well as with the generation and application of regional climate change scenarios for the European Alps. Based on already established collaborations with hydrologists/snow modelers from ETH Zurich, the company Meteodat, and tourism experts from the University of Zurich, GIUB will (1) assess the present-day temporal and spatial characteristics of extreme snow cover conditions in the Alps and their dependence on large-scale climate variability, (2) investigate the sensitivity of future snow cover as simulated by GCMs, RegCMs and local snow models under a range of key assumptions (such as the choice of global radiative forcing scenario, climate model and regionalization procedure), and (3) confront stakeholders with selected, representative scenarios of changes in snow cover in order to assess likely impacts of climate change on the winter tourism industry.

Personnel	1 Scientist	1 Technical staff	1 Permanent staff (Senior Scientist)
Expertise	Statistical analysis, snow modelling	Data acquisition and preparation	Principal investigator
Contribution to WPs	WP1, WP2, WP3, WP5	WP1, WP3	WP1, WP2, WP3, WP5, WP6
Responsibility for milestones and deliverables	D17, D18 M-5-1, M-5-4	D17, D18 M-5-1, M-5-4	D17, D18 M-5-1, M-5-4
Contribution to other milestones and deliverables	D1, D11 M1-3, M-3-4	D1, D11 M1-3, M-3-4	D11, D23, D25 M-3-4, M-6-1, M 6-2

PAS (Partner 7, the Research Centre of Agricultural and Forest Environment, Polish Academy of Sciences) will be the Work Package Co-ordinator for WP 5, responsible for the flood component. PAS has been involved in comprehensive and inter-disciplinary studies of different flood issues (onset, development, preparedness, flood frequency, flood impacts). Having dealt with floods in the global context, PAS has also considerable expertise related to events in Central and Eastern Europe, including the Great Flood of the river Odra in the summer of 1997. A comparison of recent floods and those hypothetical ones, resulting from future precipitation events, according to climatic scenarios is planned in the present project. A holistic perspective on floods will be achieved by studying flood impacts on multiple sectors, such as: agriculture, housing, infrastructure, insurance, transport, health, water supply, tourism. PAS has also gathered considerable experience in detecting change / trend in time series and in mathematical modelling in hydrology, which will be necessary in the present project (e. g., for tracking differences between the precipitation obtained by re-analysis and by climate models). An advantage of PAS is its interface with stakeholders and end users; authorities at different levels, spanning the range from local, through regional, to national, also NGOs and hydrometeorological services.

Personnel (part time)	2 Professors, 1 Associate Professor, 2 Research Scientists
Expertise	Detection of change / trend in time series, Spatial studies of flood hazard, Comprehensive assessment of flood impacts
Contribution to WPs	WP1, WP2, WP5, WP6
Responsibility for milestones and deliverables	D7, D11, D19 M-2-4, M-3-4, M-5-2
Contribution to other milestones and deliverables	D3, D5, D8 M-2-2, M-3-1

LU (Partner 8) LU will focus its contribution to modelling and assessment of direct/catastrophic impacts of extreme weather events on boreal forests WP4/WP5 and to obtain necessary input variables for this work from model output (WP3). The LU partnership has extensive experience from analysing synoptic pressure patterns and impact of extreme weather events and also from analysing various damages to boreal forests (e.g. from storms, frost, false spring starts, acid rain). The group will continue this work under MICE, emphasising the links between weather/climate and forest damages. Existing models of forest ecosystems processes developed in Lund will be used and adjusted to make use of relevant climate/weather parameters. The goal will be to provide a better understanding of the interaction between weather extremes and forest production in present-day climate and under selected climate-change scenarios. LU will work in close collaboration with end users that have the expertise to assess the practical implications of different model results.

Personnel	1 Scientist	1 PhD student	1 Permanent staff
Expertise	In charge of analyses of climate datasets and ecological modelling		Principal investigator
Contribution to WPs	WP2, WP4, WP5, WP6	WP1, WP2, WP4	WP1, WP2, WP6
Responsibility for milestones and deliverables	D12, D20 M-4-1, M-5-3	D12	D12, D20 M-4-1, M-5-3
Contribution to other milestones and deliverables	D4, D5, D6, D7, D16 M-2-1, M-2-2, M-2-3, M-4-3	D4, D5	D4, D5 M-2-1, M-2-2

9. Project management

a. The role of the project co-ordinator

Responsibility for overall management of the project will fall on the Project Co-ordinator, the University of East Anglia (UEA). UEA has wide experience in the co-ordination of Framework Programme research projects for DG Research. Within the Climatic Research Unit (CRU), which is the research unit at UEA responsible for co-ordination of MICE, a number of EU-funded research projects have been co-ordinated. These include work on climate change scenarios, socio-economic impacts of weather extremes, palaeoclimates, ice sheet modelling and climate reconstruction based on historical records. The CRU has an administrator whose sole responsibility is to manage research projects.

Six person-months of effort have been set aside for Project Co-ordination at UEA, out of a total of 31.3 person-months. This is not shown explicitly in Table 4 below, but will come mainly from the allocation of time (four months) to Work Package 6 (Synthesis).

b. The role of work packages

The contribution of each participant to each Work Package is shown in Table 4. This shows scientific and technical effort supported by the Commission (Table 4a) and the effort by scientific and technical permanent staff, funded by the MICE partner institutions. UEA, the Project Co-ordinator holds final responsibility for all work in MICE, and hence is the WP co-ordinator for WP6 (Co-ordination and Dissemination).

At the commencement of work for each WP, it is proposed that at the preceding project management meeting a strategy is drawn up for undertaking and completing the required work, taking into account the specified Deliverables and Milestones. This Strategy Document will have the following elements:

- The research required to fulfil the WP objectives will be specified as a series of modules.
- The interlinkages between the modules will be constructed, such that a logical order of work can be designed.
- Responsibilities will be assigned for the completion of each module (overall responsibility lying with the WP Co-ordinator).
- The points within the modules at which Deliverables and Milestones will be achieved will be specified.

This Strategy Document then becomes the template for the WP, against which progress can be evaluated, and goals checked off.

c. The role of project management meetings

Six project management meetings are planned over the duration of MICE. There will be a start-up meeting in Month 1 of the project followed by six-monthly management meetings. These will have two main purposes. First, it will be an opportunity to review work carried out in the preceding months. Second, the work programme for the following months will be reviewed and a plan drawn up with deadlines.

Table 4a: Number of EU-supported scientific person-months contributed by participants to each Work Package (figures in bold indicate WP co-ordinator)

	WP1 Extraction of extremes	**WP2** Time series character-istics of extremes	**WP3** Spatial patterns of extremes	**WP4** Quantitative modelling of impacts	**WP5** Expert judgement of impacts	**WP6** Co-ordination & dissemin-ation	**Total**
1. UEA							
Project-specific	**2.3**	12	8	5		**4**	31.3
Permanent	**1**	4	1	1		**6**	13
Total	3.3	**16**	9	6		10	44.3
2. ICAT							
Project-specific	2	**15**	10	7		2	36
Permanent		**1**	1	1			3
Total	2	**16**	11	8		2	39
3. NOA*	**2**	**13**		**6**	**9**	**2**	**32**
4. UKOELN							
Project-specific	4		**20**	5		3	32
Permanent	1		**1**			1	3
Total	5		21	5		4	35
5. FMA							
Project-specific	2			**30**	2	2	36
Permanent	1			**14**	2	1	18
Total	3			44	4	3	54
6. GIUB							
Project-specific	1.5	3	4.5		4	1	14
Permanent	1	3	4		1	1	10
Total	2.5	**6**	8.5		5	2	24
7. PAS							
Project-specific	5	15			**25**	3	48
Permanent							
Total	5	15			**25**	3	48
8. LU							
Project-specific	3	9		13	6	2	33
Permanent	1	2		3	2	1	9
Total	4	11		16	**8**	3	42
MICE TOTAL							
Project-specific	21.8	67	42.5	66	46	19	262.3
Permanent	5	10	7	19	**5**	10	56
TOTAL	26.8	77	49.5	85	**51**	29	318.3

* Full-cost partner

The methodologies to be employed in the analyses to be carried out in the following period must be agreed at each project meeting. None of the proposed meetings are in any way redundant. All are essential to the long-term success of the project. A full 2-3 days of effort at each is therefore planned. In order to ensure that the project is maintaining high standards in terms of both the science and of the utility of the results, external reviewers will be invited to all project meetings, drawn from the academic community and the user community. In this way, the project goals will be constantly under review. The Programme Manager from DG Research will be invited to each management meeting.

d. Reporting

Reporting will be carried out on a six-monthly basis, as follows:

Month 7: Six-monthly report (minor)
Month 13: First annual report
Month 19: Mid-term report. This will cover not only work in the previous 6 months, but will also review overall progress in the project, and evaluate the prospects for the remaining months. It will, if required, form the baseline document for the Mid-term Assessment.
Month 25: Second annual report
Month 31: Six-monthly report (minor)
Month 36+ Abbreviated glossy version of final report for stakeholders and end-users
Month 36+ Final Report to the Commission

e. Day-to-day procedures

Project communication on a day-by-day basis will be principally and in the first instance by e-mail. Once research is underway, it is planned to set up a Web Site for the project. This will be a central repository for reports, schedules and deliverables. Designed initially to facilitate communication between partners, this private site will eventually evolve into the public Web Site for the project during the third year.

ISO 9000 forms the basis of quality assurance within the lead institutions, CRU. Quality assurance must be tailored to the specific requirements of a project and, for this project, we stress particularly the need for systematic and orderly documentation, for procedures to ensure that data are fit-for-purpose, and for procedures to verify and validate software. Wherever possible, statistical analyses should be carried out using commercial packages.

References

1) Meehl, G.A., T. Karl, D.R. Esterling, S. Changnon, R. Pielke Jr., D. Changnon, J. Evans, P.Y. Groisman, T.R. Knutson, K.E. Kunkel, L.O. Mearns, C. Parmesan, R. Pulwarty, T. Root, R.T. Sylves, P. Whetton, and F. Zwiers, 2000: An introduction to trends in extreme weather and climate events: observations, socio-economic impacts, terrestrial ecological impacts and model projections. *Bull. Amer. Meteor. Soc.*, **81**, 413-416.

2) Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G. and Livermore, M., 1999: Climate change and world food security: a new assessment. *Global Environmental Change – Human and Policy Dimensions*, **9**, S51-S67, Suppl. S.

3) Hewitson, B.C. and Crane, R.G., 1996: Climate downscaling: techniques and application. *Clim. Res.*, **7**, 85-95.

4) Wilby, R.L., Hassan, H. and Hanaki, K. 1998: Statistical downscaling of hydrometeorological variables using general circulation model output. *J. Hydrol.*, **205**, 1-19.

5) Giorgi, F. and Francisco, R., 2000: Uncertainties in regional climate change prediction: a regional analysis of ensemble simulations with the HADCM2 coupled AOGCM. *Climate Dynamics*, **16**, 169-182.

6) Corte-Real., J., Zhang, X. and Wang, X., 1995: Downscaling GCM information to regional scales: a non-parametric multivariate approach. *Climate Dynamics*, **11**, 413-424.

7) Von Storch, H., Zorita, E. and Cubasch, U., 1993: Downscaling of global climate-change estimates to regional scales – an application to Iberian rainfall in wintertime. *J. Climate*, **6**, 1161-1171.

8) Subak, S., Palutikof, J.P., Agnew, M. and others, 2000: The impact of the anomalous weather of 1995 on the UK economy. *Climatic Change*, **44(1/2)**, 1-26.

9) Ulbrich U. and Christoph, M., 1999: A shift of the NAO and increasing storm track activity over Europe due to anthropogenic greenhouse gas forcing *Climate Dynamics*, **15**, 551-559.

10) Ruel, J.C., Quine, C.P., Meunier, S. and Suarez, J., 2000: Estimating windthrow risk in balsam fir stands with the ForestGales model. *Forestry Chronicle*, **76**, 329-337.

11) Keatinge, W.R., Donaldson, C., Cordioli, E. and others, 2000: Heat related mortality in warm and cold regions of Europe: observational study. *British Medical Journal*, **321**, 670-673.

12) Agnew, M.D., and Viner, D., 2001: Potential impacts of climate change on international tourism. Accepted for publication in *International Journal of Tourism and Hospitality Research*.

13) Maracchi, G. and Costantini, R., 1998: Un Modello Meteorologico pr la Previsione del Rischio d'Incendio Boschivo in Toscana. Proc. III International Conference on Forest Fire Research, Coimbra, 16-20 November 1998.

14) Millán, M. M., Estrela, M. J., and Badenas, C., 1997: Situaciones sinópticas asociadas a la dinámica de incendios forestales en la Comunidad Valenciana. *Ecologia*, **11**, 3-29.

15) Kundzewicz, Z.W., Szamalek, K. and Kowalczak, P., 1999: The great flood of 1997 in Poland. *Hydrological Sciences Journal*, **44**, 855-870.

16) Abegg, B. and Elsasser, H., 1996: Klimaänderung und Wintertourismus in den Schweizer Alpen. In: *Geographische Rundschau*.

17) Rohrer M. B: and L. N. Braun, 1994: Long term records of snowcover water equivalent in the Swiss Alps- 2. Simulation, Nord. Hydrol., 25, 65-78.

18) Easterling, D.R., Evans, J.L., P. Ya. Groisman, T.R. Karl, K.E. Kunkel, and P. Ambenje, 2000: Observed variability and trends in extreme climate events, a brief review. *Bulletin of the American Meteorological Society*, **81(3)** 417-425.

19) Widmann M. and Bretherton C.S., 2000: Validation of mesoscale precipitation in the NCEP reanalysis using a new gridpoint dataset for the northwestern US. *J. Climate*, **13**, 1936-1950.

20) Wilks, D.S., 1995: *Statistical Methods in the Atmospheric Sciences.* Academic Press, San Diego.

21) Davison, A.C. and Smith, R.L., 1990: Models for exceedances over high thresholds. *J. R. Stat. Soc. B.*, **52**, 393-442.

22) Smith, R.L., J.A. Tawn and S.G. Coles, 1997: Markov chain models for threshold exceedances. *Biometrika*, **84**, 249-268.

23) Coe, R. and R. Stern, 1982: Fitting models to daily rainfall. *J. Appl. Meteorol*., **21**, 1024-1031.

24) Stern, R., and R. Coe, 1984: A model fitting analysis of daily rainfall data (with discussion). *J. Roy. Statist. Soc*. **A147,** 1-34.

25) Cheng, E.D.H., 1991: Wind data generator: a knowledge-based expert system. *J. Wind. Eng. Ind. Aerodyn*., **38**, 101-108.

26) Coles, S.G., 1999: Extreme value theory and applications. Lecture notes, with software, University of Bristol. http://www.stats.bris.ac.uk/~masgc/.

27) Onof C, Chandler RE, Kakou A, Northrop P, Wheater HS, Isham V., 2000: Rainfall modelling using Poisson-cluster processes: a review of developments. *Stochastic Environmental Research and Risk Assessment*, **14**, 384-411.

28) Osborn, T.J., Briffa, K.R., Tett, S.F.B., Jones, P.D., and Trigo, R.M., 1998: Evaluation of the North Atlantic Oscillation as simulated by a climate model. *Climate Dynamics*, **15**, 685-702.

29) Christoph, M.; Ulbrich, U., Oberhuber, J.M., Roeckner, E., 2000: The role of ocean dynamics for low-frequency fluctuations of the NAO in a coupled Ocean-Atmosphere GCM. *J. Climate*, **13**, 2536 - 2549

30) Kushnir Y., Cardone V.J., Greenwood J.G. and Cane M., 1997: On the recent increase in North Atlantic wave heights. *J. Climate* **10**, 2107-2113.

31) WASA Group, 1998, "Changing waves and storms in the north-east Atlantic?", *Bulletin of the American Meteorological Society*, 79, 741-760.

32) Hurrell J.W. (1995) Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. *Science* **269**, 676-679.

33) Beniston, M. and Rebetez, M., 1996: Regional behaviour of minimum temperatures in Switzerland for the period 1979-1993. *Theoretical and Applied Climatology*, **53**, 231-243.

34) Trigo, I. Davies, T.D., et al., 2000, "Decline in Mediterranean rainfall caused by weakening of Mediterranean cyclones", *Geoph. Res. Lett*., 27, 2913-2916.

35) Cubasch U. (ed), Caneill J-Y., Filiberti M.A. et al., 1997, "Anthropogenic climate change", Project EV5V-CT92-0123 final report. Office for Official Publications of the European Commission EUR 17466EN Luxembourg, 73pp.

36) Carnell R.E., Senior C.A., & Mitchell J.F.B., 1996, "An assessment of measures of storminess, simulated changes in Northern Hemisphere winter due to increasing CO_2", *Climate Dynamics*, 12, 467-476.

37) Lambert S.J., 1995, "The effect of enhanced greenhouse warming on winter cyclone frequencies and strengths", *Journal of Climate*, 8, 1447-1452.

38) Beersma J.J., Rider K.M., et. al., 1997, "An analysis of extra-tropical storms in the North Atlantic region as simulated in a control and $2xCO_2$ time-slice experiment with a high-resolution atmospheric model", *Tellus A*, 49, 347-361.

39) Zhang Y., & Wang W-C., 1997, "Model-simulated northern winter cyclone and anticyclone activity under greenhouse warming scenario", *Journal of Climate*, 10, 1616-1634.

40) Watson, S.J. and Woods, J.C., 1997: Energy. Chapter 7 in *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995*. Report prepared for the UK Department of the Environment.

41) Dorland, K., 2000: Storm damage analysis in Germany, the UK and the Netherland. Section 5.3 in *Final Report of the WISE (Weather Impacts on natural, Social and Economic systems) Project*, EU ENV4-CT97-0448.

42) Pielke, R. Jr. and C. W. Landsea, 1998: Normalized Hurricane Damages in the United States:, 1925-95. *Weather and Forecasting* **13**, p. 622

43) Dorland, K., Tol, R.S.J. and Palutikof, J.P., 1999: Vulnerability of the Netherlands and NW Europe to storm damage under climate change. *Climatic Change*, **43**, 513-535.

44) Troen, I. and Petersen, E.L., 1989: *European Wind Atlas*. Risø National Laboratory, Roskilde.

45) Perry, A., 2000: Tourism and recreation. Chapter 12 in *Assessment of Potential Effects and Adaptations for Climate Change in Europe* (The Europe ACACIA Project), EU ENV4-CT97-0531.