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1. Project summary

Problem to be solved:
European decision-makers in government, non-governmental organisations (NGOs), and industry as well as the general public need detailed information on future climate. In this way it becomes possible to evaluate the risks of climate change due to anthropogenic emissions of greenhouse gases. Projections of future climate change already exist, but are deficient both in terms of the characterisation of their uncertainties and in terms of their regional detail. To date, the assessment of potential impacts of climate change has generally relied on projections from simple climate models or coarse resolution Atmospheric-Ocean General Circulation Models (AOGCMs), neither capable of resolving spatial scales of less than ~300km. This coarse resolution precludes the simulation of realistic extreme events and the detailed spatial structure of variables like temperature and precipitation over heterogeneous surfaces e.g. the Alps, the Mediterranean or Scandinavia. Simple models include, at best, a limited physical representation of the climate system.

Scientific objectives and approach:
PRUDENCE is a European-scale investigation with the following objectives:
a) to address and reduce the above-mentioned deficiencies in projections;
b) to quantify our confidence and the uncertainties in predictions of future climate and its impacts, using an array of climate models and impact models and expert judgement on their performance;
c) to interpret these results in relation to European policies for adapting to or mitigating climate change.

Climate change is expected to affect the frequency and magnitude of extreme weather events, due to higher temperatures, an intensified hydrological cycle or more vigorous atmospheric motions. A major limitation in previous studies of extremes has been the lack of: appropriate computational resolution - obscures or precludes analysis of the events; long-term climate model integrations - drastically reduces their statistical significance; co-ordination between modelling groups - limits the ability to compare different studies. These three issues are all thoroughly addressed in PRUDENCE, by using state-of-the-art high resolution climate models, by co-ordinating the project goals to address critical aspects of uncertainty, and by applying impact models and impact assessment methodologies to provide the link between the provision of climate information and its likely application to serve the needs of European society and economy.

Expected impacts:
PRUDENCE will provide a series of high-resolution climate change scenarios for 2071-2100 for Europe, characterising the variability and level of confidence in these scenarios as a function of uncertainties in model formulation, natural/internal climate variability, and alternative scenarios of future atmospheric composition. The project will provide a quantitative assessment of the risks arising from changes in regional weather and climate in different parts of Europe, by estimating future changes in extreme events such as flooding and windstorms and by providing a robust estimation of the likelihood and magnitude of such changes. The project will also examine the uncertainties in potential impacts induced by the range of climate scenarios developed from the climate modelling results. This will provide useful information for climate modellers on the levels of accuracy in climate scenarios required by impact analysts. Furthermore, a better appreciation of the uncertainty range in calculations of future impacts from climate change may offer new insights into the scope for adaptation and mitigation responses to climate change. In order to facilitate this exchange of new information, the PRUDENCE workplan places emphasis on the wide dissemination of results and preparation of a non-technical project summary aimed at policy makers and other interested parties.

2. Scientific/Technical Objectives and Innovation

2.1 Summary

European decision-makers in government, NGOs, and industry as well as the general public need detailed information on future climate. Only this way it becomes possible to quantify the risks brought about by a changing climate reflecting the continuous anthropogenic emission of greenhouse gases. Such quantifications are absolutely necessary to formulate and implement realistic adaptation and mitigation strategies (Arnell, 1996). Projections of future climate change exist but are deficient in terms of regional detail and in terms of the characterisation of uncertainty associated with them. The assessment of potential impacts of climate change has, to date, generally relied on data from simple climate models or coarse resolution Atmospheric-Ocean General Circulation Models (AOGCMs), incapable of resolving spatial scales of less than ~300km (Mearns *et al.*, 2001). The former includes, at best, only a limited physical representation of the atmosphere-ocean-biosphere system, while AOGCM information is insufficient in simulating the spatial structure of temperature and precipitation in areas of complex topography and land use distribution (e.g. the Alps, the Mediterranean, Scandinavia), see also Figure 1. The description of regional and local atmospheric circulations (e.g. narrow jet cores, mesoscale convective systems, sea-breeze type circulations) and the representation of processes at high frequency temporal scales (e.g. precipitation frequency and intensity distributions, surface wind variability) are likewise insufficient to provide accurate information. The main objectives of PRUDENCE will be, on a European scale:

- First, to address and reduce these deficiencies;
- Second, to provide substantial examples of the use of resulting climate change scenarios in climate impacts models;
- Third, to assess implications of the results for future European policies for adapting to or mitigating climate change.

PRUDENCE will provide improved model representation of regional climate information in utilising high-resolution models (at spatial scales of ~50 km, and a few ~20km). PRUDENCE will also attempt to provide more reliable scenarios of changes regarding the scale and frequency of extreme events and impacts on natural resources as well as socio-economic systems.

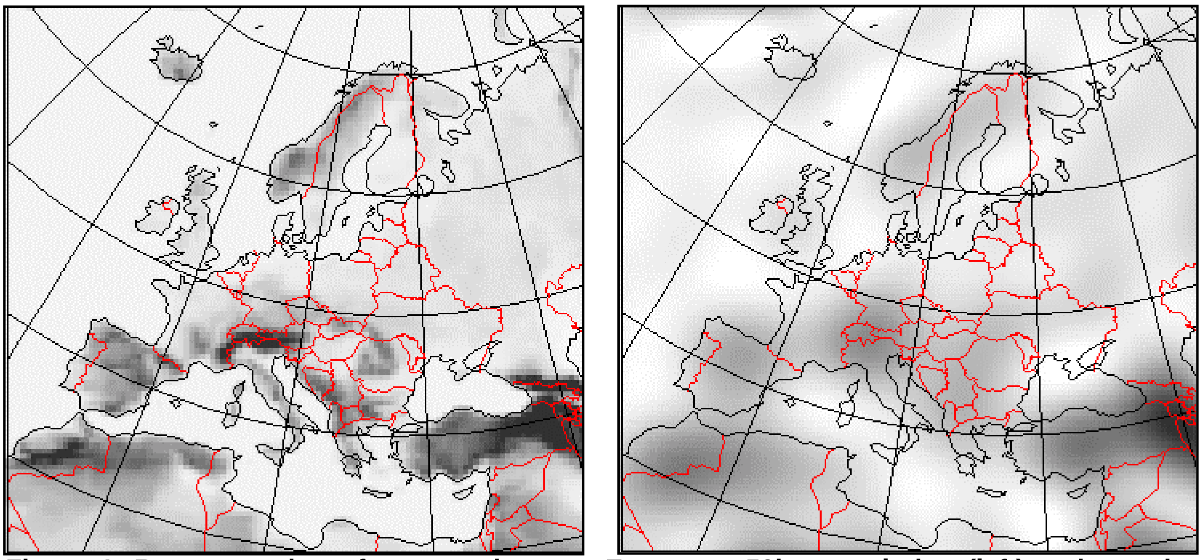

Figure 1. Representation of topography over Europe at 50km resolution (left) and a typical AOGCM at ~300km (right).

The urgent need for improved numerical models and scenarios becomes particularly apparent when considering extreme events. The importance of extreme events for our economy and environment has drastically been demonstrated during the last few years with a number of serious events affecting the European continent: snow-storms and avalanche conditions in France, Switzerland and Austria, disrupting the access to major Alpine valleys for several weeks (February 1999); a series of major flooding events in several catchments of Germany, Austria and Switzerland following heavy precipitation and large snow melt (May 1999); a severe winter storm followed by storm surges affected the United Kingdom, Denmark, Northern Germany and Sweden (December 3-4, 1999); two major storms caused many casualties and tremendous damage to infrastructure and forests in France, Switzerland and Southern Germany (December 26-28, 1999); a major flooding episode to the south of the Alps affecting the Piemonte region in Italy and several valleys in Switzerland (October 15-19, 2000); and finally a series of serious flooding events in the United Kingdom (October/November 2000). Each of these events has caused numerous fatalities and tremendous capital damage. For instance, according to recent re-insurance estimates, the winter storms on December 26-28, 1999, have killed ~125 people, flattened an estimated amount of 120,000 m^3 of timber, damaged or destroyed many homes, and caused power disruption in many regions of France for several weeks. The insured loss throughout Europe resulting from these two storms is estimated to 7 billion € and the uninsured damage to another 8 billion €.

It is anticipated that climate change will affect the frequency and magnitude of extreme events, as driven by an intensified hydrological cycle (Stocker *et al.*, 2001). A major limitation to such studies in the past has been the lack of appropriate computational resolution (which smears out the character of the events), the lack of long-term integrations (which drastically reduces the statistical significance), and the lack of co-ordination between different modelling groups (which led to unresolved differences between different studies). These three issues are all thoroughly addressed in PRUDENCE, using state-of-the-art climate models of various high-resolution, a co-ordinated project layout that also addresses critical aspects of uncertainty, and the application of impact models and impact assessment methodologies that will provide the link to the needs of our society and economy.

In summarising the specific objectives, PRUDENCE will:

1. provide a series of high resolution climate change scenarios for 2071-2100 for Europe;
2. in practical terms characterise the level of confidence in these scenarios and the variability in them related to model formulations and climate natural/internal variability;
3. assess the uncertainty in European regional climate scenarios resulting from model formulation;
4. quantitatively assess the risks rising from changes in regional weather and climate over all of Europe, and estimate future changes in extreme events such as flooding and wind storms, by providing a robust estimation of the likelihood and magnitude of the changes;
5. demonstrate the value of the wide-ranging climate change scenarios by applying them to climate impacts models focusing on effects on adaptation and mitigation strategies;
6. assess socio-economic and policy related decisions for which such improved scenarios could be beneficial;
7. disseminate the results of PRUDENCE widely and provide a project summary aimed at policy makers and non-technical interested parties.

These overall objectives can only be reached at a European level, as they require a community effort to address thoroughly. To really provide practically useful measures of the uncertainty and certainty in climate scenarios, the climate scenario uncertainty space of emission scenarios, model parameterisations, model resolution and natural variability needs to be probed en masse. This requires co-ordinated involvement from as many climate-modelling groups as possible. PRUDENCE proposes to co-ordinate, analyse, and synthesise European high-resolution climate change modelling involving 4 high-resolution Atmospheric General Circulation Models (AGCMs) and 8 European Regional Climate Models (RCMs). Due to the heterogeneity of the possible climate change through Europe and the geographically and sectorially varying impacts this may imply, expertise from both climate and impacts modelling groups as well as experts within social and/or political sciences is required from across Europe to assess the societal risks associated with these changes. Only this way it can be ensured that a comprehensive utilisation of the entire ensemble of high-resolution climate change simulations will take place. Such a comprehensive research effort has never before been carried out. *The co-ordinated efforts within one common European 'end-to-end' project will enable an unprecedented quantification of the uncertainties associated with impacts of future climate changes over Europe*. In demonstrating the feasibility of such a combined effort, PRUDENCE will be setting a new standard for interdisciplinary work throughout Europe, although even this project will not allow for a full geographical nor sectoral coverage.

A consistent set of RCM simulations of climate change for different regions, which can be used as climate change scenarios for impact work, is still not available. In its Third Assessment Report (TAR), the Intergovernmental Panel on Climate Change (IPCC) state that *"The need is there to co-ordinate RCM simulation efforts and to extend studies to more regions so that ensemble simulations with different models and scenarios can be developed to provide useful information for impact assessments. This will need to be achieved under the auspices of international or large national programs. Within this context, an important issue is to provide RCM simulations of increasing length to minimise limitations due to sampling problems"*. PRUDENCE aims not only at providing such comprehensive information for the entire European area, it also <u>promises</u> to demonstrate and carry out impact assessments based upon it, thereby utilising and evaluating the information derived from the RCM simulations.

Numerous model-based studies have been conducted in Europe to investigate the potential impacts of climate change on natural and human systems. Many of these have been summarised in the recent ACACIA report (Parry, 2000) and in successive IPCC reports (Kundzewicz *et al*., 2001). The scenarios used to represent future changes in climate vary widely between impact studies, but only in a few cases are the main sources of scenario uncertainty acknowledged, let alone evaluated (e.g. Hulme and Carter, 2000; Mearns *et al.*, 2001). Furthermore, climate scenarios are not the only sources of uncertainty to consider in evaluating future impacts. Three other important sources are first, uncertainties in the input data used in impact models to represent present-day conditions and/or natural climate variability, second, uncertainties in non-climate scenarios (e.g. of future socio-economic and technological development, other concurrent environmental changes or land use change), and third, uncertainties in the impact models themselves. A recent EU workshop on the topic of uncertainty concluded that "..... *scientists have failed to address uncertainties adequately in the great majority of climate impact assessments conducted to date*." (Carter and Hulme, 1999). PRUDENCE <u>promises</u> to address these uncertainties specifically.

There is a general perception among impact analysts that estimates of impacts at small spatial scales (i.e. sub-GCM-grid scale) should necessarily be based on information about future climate that has been generated at a comparable spatial resolution. There has been a clamour for access to high-resolution projections, either based on statistical downscaling techniques, or generated by RCMs such as those employed in this project. However, it should also be understood that such procedures introduce uncertainties of their own (Giorgi *et al.*, 2001), and the extent to which such high resolution information can provide added value for impact assessments remains unresolved. PRUDENCE promises a thorough assessment of this problem.

In order to ensure that the information produced by the climate and physical impact models is consistent with the information needs of economic and policy modellers, PRUDENCE promises to develop and exploit appropriate outputs of climate and physical impacts for economic and policy modelling. Expertise from integrated assessment of sustainable development policies and climate change strategies is an integrated part of the project.

2.2 Measurable and verifiable expression of the objectives

A number of techniques have been developed with the goal of enhancing the regional information provided by coupled AOGCMs and providing fine scale climate information. The techniques are classified into three categories:

- high resolution and variable resolution "time-slice" AGCM experiments;
- nested limited area or RCM experiments;
- empirical/statistical and statistical/dynamical methods.

Substantial development has been achieved in all these areas of research over the last couple of years (Giorgi *et al.*, 2001). Previous studies have identified important errors in simulations of regional circulation features, such as the tendency for pressure to be too low over Europe and too high north and south of this area (Machenhauer *et al.*, 1998) using older versions of current state-of-the-art climate models. Such errors contribute significantly to local temperature and precipitation biases both in the global climate model and in nested high resolution RCM simulations (Noguer *et al.*, 1998; Machenhauer *et al.*, 1998). Recent efforts have helped to reduce such systematic biases substantially, in GCMs as well as RCMs (e.g. Cubash *et al.*, 2001; Giorgi *et al.*, 2001). Only, such new and improved models will be used within PRUDENCE.

1. Will provide a series of high-resolution climate change scenarios for 2071-2100 for Europe

High-resolution (horizontal grid-spacing up to 150 km) AGCMs are currently in preparation at European climate centres. Atmospheric radiative forcing and matching sea-surface boundary conditions from coarse-resolution AOGCMs will drive them. Simulations with the Hadley Centre HadAM3H have already been conducted and basically determines the time window (e.g. 2071-2100) for the PRUDENCE experiments. Others will be part of the PRUDENCE project (see Table 1). Four distinct sets of experiments will be conducted to form the basis of scenario generation and the uncertainty analysis:

1. One ensemble using on AGCM with driving conditions from each of a three-member AOGCM ensemble;
2. One ensemble using four different AGCMs with driving conditions from the same AOGCM;
3. Two AGCMs will take driving conditions from two AOGCM experiments performed with the same AOGCM but different atmospheric emissions;
4. One AGCM will take driving conditions from two different AOGCMs using the same atmospheric emissions.

Some of these models will provide lateral boundary conditions for the planned RCM simulations.

Eight state-of-the-art European regional climate models will be run using boundary conditions from two of the AGCMs mentioned. Five distinct experiments will be conducted to provide the raw data for scenario generation and to further explore uncertainties:

1. Eight will be driven by boundary conditions from one of the AGCM simulations taken from the three-member ensemble;
2. Two will be driven by boundary conditions from the full AGCM ensemble;
3. Three of these models will also be driven by the same AGCM itself driven by a different emissions scenario;
4. One of these models will be rerun twice with different initial conditions;
5. The two-member AGCM ensemble using the same emissions scenario but a different AGCM than above will drive one model.

In order to carry out a co-ordination of so many RCM simulations, it is essential that the boundary data are readily available for the project from the very beginning and in a timely fashion throughout the project. This explains why some AGCM simulations will be available at the start of the project and why the project involves high-resolution GCMs as well as RCMs.

Table 1 Planned GCM and RCM scenario experiments[1] in PRUDENCE

AGCM / **exp forcing**	HadAM3H	ARPEGE	ECHAM5	CCM3
HadCM3 SRES A2	3 ensemble members 150 km **BDY 1**	2 mem high res.	1 member T106	2 members T80 **BDY4**
HadCM3 SRES B2	1 member 150 km **BDY 2**	1 mem high res.		
ECHAM4/OPYC3 SRES A2			1 member T106 **BDY 3**	
ARPEGE/OPA SRES B2		1 mem high res.		

RCM 50km / **Input**	P5	P9	P1	P10	P6	P2/P12	P8	P7
BDY 1	3 mem		3 mem					
BDY 1		1 mem		1 mem	1 mem	1 mem	1 mem	1 mem
BDY 1 ini cond.							1 mem	
BDY 2	1 mem	1 mem		1 mem				
BDY 3			1 mem					
BDY 4						1 mem		

RCM 20 km / **Input**	P5	P9	P1		P6		P8	
BDY 1	1 mem	1 mem	1 mem		1 mem		1 mem	

[1] The partner identification can be found in Table 3

All models, GCMs as well as RCMs, will also perform one control simulation using sea surface (and lateral) boundary conditions from a long so-called AMIP-type experiment. In the scenario simulations the surface driving conditions (originating from AOGCMs) will always be interpreted as anomalies with respect to the AMIP conditions.

2. In practical terms characterise the level of confidence in these scenarios and the variability in them related to model formulations and climate natural/internal variability

The ensemble simulations will be analysed to estimate the uncertainly due to natural variability in single realisations of a given future climate. Mechanisms underlying the responses in different simulations will then be analysed to indicate whether any agreement represents a robust climate change signal or is due to chance or model formulation.

3. Assess the uncertainty in European regional climate scenarios resulting from model formulation

The eight realisations of European climate change derived from common boundary forcing will be compared to characterise the level of uncertainty in regional climate scenarios related to the model formulation. Mechanisms underlying the model responses will be analysed to assess confidence in any commonality or to try and determine preferred response mechanisms.

4. Quantitatively assess the risk of changes in regional weather and climate over the whole Europe - including robust estimation of the likelihood and magnitude of the changes

The two ensemble regional responses will be analysed in the light of the eight-model analysis to provide a first indication of the level of confidence in scenarios of different variables and statistics (including climate extremes). Analysis of the responses of regional models using different forcing conditions will then determine the degree to which such statements will hold in these cases. From these analyses, and those of the AGCMs, generalised levels of confidence will be provided for all variables/statistics in the scenarios.

5. Demonstrate the value of the wide-ranging climate change scenarios by applying them to climate impacts models focusing on effects on adaptation and mitigation strategies

Models of the large-scale and detailed hydrology of a North European drainage basin, crop production and water use in a South European region, crop production and nitrogen cycling in a North European region, storm surges in Northern Europe, and a larger river catchment in Central Europe will be applied using data from the European climate scenarios developed in the project. All models will be subject to a calibration exercise using data from the model control simulations. The hydrology model for the North European drainage basin will use data from most of the simulations performed in the project to provide a substantial sample of possible impacts. Two crop models for the South European region will be used to evaluate the range of possible impacts and adaptation strategies, especially with respect to crop production, water use and water conservation. Sustainable adaptation measures will be considered for different rain fed and irrigated cropping systems. The soil-plant-atmosphere model applied for the North European region will be used to evaluate the range of possible impacts on crop production and nitrogen cycling for a typical arable crop rotation, including possible adaptation strategies and their effect on nitrate leaching and nitrous oxide emissions. The storm surge model will also take output from several regional climate model scenarios to provide estimates of future extreme storm surge events. The large European river basin hydrology model will take output from models at different resolution to explore the impacts of resolution of climate change scenarios on the predicted changes in river flow and floods. It will also address the role of changes in mean precipitation and snow/rain partition during winter. The Mediterranean Basin already experiences low rainfall and high evaporation rates which, combined with pressure on the available water resource from agriculture and tourism, mean that water shortages in the region are already a risk factor. Research will be undertaken to track the range of future changes in water availability as predicted by the RCMs, and to understand the implications of these changes for the occurrence of hydrological extremes.

Although many new aspects concerning climate model uncertainties are covered in the above model intercomparison exercises, these still do not embrace the full range of uncertainties attributable to the SRES emissions scenarios and climate sensitivities considered by the IPCC (Houghton *et al.*, 2001). This aspect will be addressed using a pattern-scaling method (e.g. Hulme and Carter, 2000) for various regions of Europe.

Table 2. Planned impacts studies in PRUDENCE

Input / Impact model	GCM	RCM 50 km	RCM 20 km
N.E. storm surge	one mem	one from each using BDY1	all members
C.E. river catchment	probed	well probed	all
N.E. drainage area	all	all	all
S.E. agriculture	All (2 for adaptive responses)	all (only 2 for adaptive responses)	Only one from contractor/ partner 10 –UCM- for impact and adaptive responses
N.E. agriculture	all (only 1 for adaptive responses)	all (only 2-3 for adaptive responses)	all (only 2 for adaptive responses)
ecosystems	all	well probed	
simple models and indices	all	all	all
Mediterranean agriculture and hydrology	One parent GCM and associated RCMs at 50km and 20km. Comparisons can be made between (a) different forcings (SRES A2 and B2) (b) different ensemble members (c) different scales. Attention will focus on the range of scenarios.		

6. Assess socio-economic and policy related decisions for which such improved scenarios could be beneficial;

The assessment of potential effects and adaptations for climate change in Europe has so far been drawn from available published material – hence, typically based on GCM scenario simulations. Recently, this has been demonstrated in the European ACACIA project (Parry, 2000). The improved high-resolution scenarios, impacts assessments and the quantification of associated uncertainties within PRUDENCE may have particular impacts on future European policies concerning adaptation and mitigation measures to these changes. Such policy aspect will be assessed by establishment of a soft link between the physical and geographical climate change impact scenarios, and the economic structure and major greenhouse gas (GHG) emission source in Europe. This will include an identification of sectors and areas where climate change significantly will affect the activity, and where adaptation policies would be relevant.

7. Disseminate the results of PRUDENCE widely and provide a project summary aimed at policy makers and non-technical interested parties.

A PRUDENCE Internet site, complete with a large atmospheric model data archive for use in climate impacts models and for driving data for regional models. The site will provide an interface to access the data and all other PRUDENCE documents including the project summary. A final public PRUDENCE workshop that presents the economic, social and policy making aspects of the regional climate change scenarios will be held in order to establish a dialogue and link with other integrated assessment activities across Europe.

2.3 Organisational innovation

PRUDENCE will be the first project to harness the experience and intellectual capital that exists in both climate and impacts modelling across Europe into a focused, co-ordinated task designed to provide the governments, the agricultural sector, forestry, the industry, and the citizens of Europe with the wide range of information required to formulate a scientifically based response to the potential risks and advantages of a changing climate.
The project provide a means of making existing, presently short-term and uncoordinated national regional climate projects into a more effective and collated means of providing recommendations for EU-policies on the climate issue. In the IPCC TAR (Houghton *et al.*, 2001) such efforts are highly recommended in order to be able to provide better regional assessments of climate change and their impacts.

2.4 Scientific innovation

The assessment of potential impacts of climate change has, to date, generally relied on data from simple climate models or coarse resolution AOGCMs. The former includes, at best, only a limited physical representation of the atmosphere-ocean-biosphere system. The latter overcome this limitation, and provide a firm scientific basis for their predictions, at least at the scales they are capable of representing in practice. Previous studies with coarse resolution AOGCMs can only resolve scales of, at best, 300km, which disputes the value of using such data in the vast majority of climate impacts models, as these can require data at as little as 1km resolution. This study will make extensive use of RCMs capable of resolving spatial scales as fine as 50km, and exploit the role and need for even finer resolution approaching scales at 20 km. This high-resolution is essential for resolving climatic features and weather extremes in Europe and so is a necessity for any quantitative impact study.

In recent years, two physically based methods have been applied to bridge this gap. Firstly, limited area models used for weather forecasting or process studies were modified to allow them to be integrated on climate timescales. These RCMs would then use lateral boundary conditions from an AOGCM to provide a high-resolution realisation of the driving AOGCM climate over the domain of the RCM. A second method, which has been applied in only a few cases, is the use of a high resolution AGCM. In this case the AGCM also takes boundary conditions from an AOGCM but in this case at the sea-surface only and hence can provide a somewhat independent realisation of the climate compared to the driving model.

Though RCMs have been applied much more widely than high-resolution AGCMs, even so little systematic evaluation of their responses to climate change has been attempted. In the case of the AGCMs, only a handful of climate change experiments of any sort have been run and no comparison of results has been attempted. PRUDENCE will address both of these issues by running and analysing a series of high resolution AGCM and RCM climate change experiments using common boundary and radiative forcings focusing on European climate change issues. For the first time the RCMs will take their boundary conditions from high-resolution AGCM experiments.

An important issue when considering adaptation and mitigation responses to climate change is the uncertainty in the predictions. In addition to uncertainties derived from the model formulation there are those derived from climate variability and future atmospheric emissions. A single climate simulation realisation is insufficient to provide the information needed for a comprehensive assessment of potential climate change and their impacts. This is already well recognised with many AOGCM experiments involving ensemble integrations to provide a more sufficient sample of possible future climates. In a similar way, the possible future climate forcing can only be estimated and various emissions scenarios have been developed to provide future climate forcing and these are also being used in AOGCM experiments. However, neither of these issues has been addressed to date in the context of high-resolution climate change scenarios. PRUDENCE will provide an initial evaluation of these uncertainties by running two AGCM ensembles and four RCM ensembles and by using two different emissions scenarios to drive its future climate simulations (see also Table 1).

The final groundbreaking area of PRUDENCE is its inclusion of climate impacts models and driving them from its high-resolution climate change scenarios and to involve expertise from the socio-economic sector in assessing the possible role of these results for European policies. Traditionally, the impacts modellers have applied coarse resolution mean changes, with some appropriate post-processing, to models calibrated using observed data (e.g. Hulme *et al.*, 1999). PRUDENCE will demonstrate an alternative approach in two areas. Firstly, it will provide high-resolution data, which implicitly contains much of the level of detail required by the impacts models. Secondly, using also data from the atmospheric control simulations in the verification of the models makes checks. This will give more confidence in the use of the full spectrum of spatial and temporal resolution of the atmospheric anomaly simulations to drive the models for the future climate impacts.

There are other potentially productive outcomes of including atmospheric and impacts models in the project together. Comparing the results of using control simulation data in the impacts models with observations may give useful feedback to the atmospheric modellers about deficiencies still present in their models. By providing data directly to impacts modellers the atmospheric modellers will get a better insight into the use of and requirements for climate change data. Conversely, by receiving data directly from atmospheric modellers, the impacts modellers will get a better idea of the potential and limitations of climate model data.

It has been established that the biophysical response to climate change in sectors such as agriculture, forestry and water management may be very different in Northern and Southern Europe (Parry, 2000). The magnitude, sensitivity and uncertainty of these responses have, however, not been explored with spatially detailed climate scenarios. Also the realistic adaptive responses that will fulfil the requirements of both the individual sectors and the society as a whole has not been analysed. Such analyses will be performed for selected biophysical sectors and regions in Europe within PRUDENCE.

Much is known about the impact of climate change and climatic variability on the primary agricultural productivity. Much less is known about the indirect effects of climate through factors like water conservation, nutrient flows and soil fertility, and cropping systems sustainability (Rosenzweig and Hillel, 1998; Salinger *et al.*, 2000). These indirect effects will have large consequences for crop management and adaptive strategies. The project will analyse the effect on possibilities of increasing water use and maintaining system sustainability in Southern European and on reducing nitrogen losses in Northern European agriculture, as these will include some of the most important effects on agriculture in Europe. Effects on nitrogen cycling will also affect nitrous oxide emissions from agriculture and are thus important to consider in mitigation strategies (Rosenzweig and Hillel, 2000).

It is planned to use also a dynamic vegetation model, which is a new and innovative approach to modelling vegetation dynamics and biogeochemistry. It forms part of a modular approach to vegetation modelling that is being pioneered by a European group of researchers. The modular framework is a new implementation of a dynamic global vegetation model and a generalised ecosystem model (Smith et al, 2001), which takes advantage of new technical insights from a FP4 project on European modelling approaches. The model structure has been successfully used to simulate processes in a variety of ecosystems, e.g. European forests and steppe vegetation producing reliable estimates of vegetation structure and biogeochemical cycling.

An impact study that assesses not only the effect of climate scenario uncertainties, but also scenario application uncertainties and even also impact model uncertainties on impact results will be conducted. This exercise will be illustrative, employing very simple impact models. The idea is to evaluate the relative importance of different sources of uncertainty. A regional, geographically explicit approach will be adopted (e.g. employing gridded data and spatially explicit climate scenarios), focusing on a region or regions for which RCMs are providing comparable information (e.g. Nordic region; the Mediterranean). The uncertainties attached to indices such as these would provide information that is indicative of the uncertainties likely to be encountered in more detailed impact modelling studies in different sectors, which cannot address so many alternatives.

There is a clear need for a systematic evaluation of the current RCMs being applied in Europe, which involves not only an examination of the climate outputs from different models, but also the range of uncertainties propagating through to impacts. From the point of view of policy-relevant impact assessment, it is important to investigate the capability of RCMs in providing:

(a) More reliable estimates than GCMs of future *changes* in climate over the region and at the scale of interest (note that establishing superior performance at simulating present-day climate may not be a sufficient indicator of the performance for future climate);
(b) Additional information on impact-relevant climate variables that GCMs cannot provide (e.g. on the frequency of weather extremes);
(c) Additional information on sub-GCM-grid scale uncertainties in projections.

All of these concerns will be addressed in the PRUDENCE project.

3. Project workplan

3.1 Introduction

PRUDENCE is composed of seven interdependent research work packages.

WP1 European regional climate simulations for 2071-2100 and their analysis: will carry out a series of 30-year simulations of present day and future climate with 4 high-resolution atmospheric general circulation models (AGCMs). These will use observed and model derived sea-surface conditions respectively; the latter from coupled AOGCMs. The atmospheric radiative forcing will be derived from emissions of trace gases and sulphur as specified by the IPCC. Furthermore, WP1 will use AGCM data to drive 8 European regional models. The responses in these experiments will be analysed to determine confidence in differences from the driving models and reliability of fine scale detail.

WP2 Uncertainty assessment of European regional climate model responses to a common forcing: will analyse the responses to climate change in each of the AOGCM experiments, focusing on climate impacts related variables and studying mechanisms to provide guidance on the reliability of the responses. WP2 will also combine the analysis of 8 RCM models, which used identical driving data, to assess the uncertainty in regional model responses due to model formulation. Finally, a range of variables and statistics in which there is confidence in the climate scenarios that can be used to assess changes in rare events (e.g. storms, floods, droughts, heat waves and cold spells), those where scenarios are only indicative and those where confidence is low.

WP3 Impacts on hydrology: will apply data from the climate scenarios from WP1 to hydrological impacts models. WP3 will assess the impacts of a wide range of future climates on river flows, flood risks and water availability in a major North European drainage basin. WP3 will also use 3 regional scenarios at different resolution to assess the effect of resolution on simulating impacts of climate change on river flow and flooding in a major Central European river catchment.

WP4 Impacts on agriculture, forestry, and ecosystems: WP4 will estimate the impacts on crop and biomass production, water use and cropping systems sustainability in a South European region. WP4 will estimate impacts on crop production, nitrogen cycling and forestry in northern Europe and evaluate adaptation options and possible effects on mitigation strategies. WP4 will also predict an envelope of responses to climate change in a number of European forested ecosystems by simulating the vegetation distribution, dynamics and ecosystem processes.

WP5 Risk assessment of European weather and climate extremes in future regional forecast scenarios will quantify objectively the risk of European weather and climate extremes in future regional forecast scenarios. Extremes in wind speed, precipitation, and temperature are a major source of risk to European society and industry. For good adaptation of European policies and industry to the impacts caused by extremes, it is vital that we start to quantify the likely future changes in such risks. New statistical techniques will be developed and applied in order to estimate future risk of extremes as estimated from high-resolution regional climate model integration. Furthermore, a storm surge model will be applied to an ensemble of the RCM scenario simulations.

WP6 Assessment of the role of PRUDENCE on European climate policies will assess the potential effect on European climate policies given economical consequences related to better uncertainty measures and more detailed scenarios of regional climate change obtained within PRUDENCE.

WP7 Management, data, reporting and dissemination is designed to ensure a proper management of PRUDENCE together with the widespread dissemination of PRUDENCE's results, in a usable form, to a wide range of users also outside the project partners. A parallel activity will collate and publish information in forms more suitable to the non-climate specialist and to the general reader.

In order to ensure a comprehensive approach to the publication of its results PRUDENCE devotes work within the same Work Package to Management and Data Dissemination. The adopted philosophy is to make the outputs available in a tiered fashion, with the level of detail in each tier appropriate to the intended audience. At the most detailed level, gridded datasets derived from the global and regional model simulations performed in PRUDENCE will be made freely available to climate scientists, climate impact modellers and other researchers. At the intermediate level a hard copy publication will be produced containing interpreted data that presents PRUDENCE output in forms that are more directly understandable and usable by users who are specialists in their own field but not in climate. PRUDENCE provides within its partners all necessary expertise to provide such detailed information. Top-level summaries will be produced, in the main European languages, for general distribution to the public, industry, and the media. The summaries will be suitable for policy-makers in industry and government but for this audience there will also be prepared a set of PowerPoint™ slides for use in briefings and presentations.

Table 3. List of partners and their role in the PRUDENCE consortium

Partner	Country	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Totals
1. Danish Meteorological Institute, Copenhagen	DK	12	18					24	54
2. CINECA, Bologna	I	18	21						39
3. Météo-France/CNRM, Toulouse	F	16	12						28
4. Deutsches Zentrum für Luft- und Raumfahrt e.V., Weßling	D	7	14,7						21,7
5. Hadley Centre for Climate Prediction and Research, Met Office, Bracknell	UK	26	36				3	3	68
6. Climate Research ETH (Eidgenoessische Technische Hochschule), Zürich	CH	8	12	24					44
7. GKSS Research Center (Institute for Coastal Research), Geesthacht	D	10	18			36			64
8. Max Planck Institut für Meteorologie, Hamburg	D	22,3	15	6				3	46,3
9. Swedish Meteorological and Hydrological Institute, Rossby Centre, Norrköping	S	5	12	24				1	42
10. Universidad Complutense Madrid	E	13	18						31
11. Universidad Politecnica Madrid	E				33			2	35
12. International Centre for Theoretical Physics, Trieste	I	12							12
13. Danish Institute of Agricultural Sciences, Foulum	DK				28			3	31
14. Risø National Laboratory, System Analysis Dept.	DK						14		14
15. University of Fribourg	CH			12		24			36
16. Finnish Environmental Institute, Helsinki	FIN		4		24	7		3	38
17. University of Reading	UK					36			36
18. University of Lund	S				37			2	39
19. Centre International de Reserche sur l'Environment et Developpement,SMASH, Paris	F						30		30
20. Climate Research Unit, University of East Anglia	UK				8	9		1	18
21. Finnish Meteorological Institute, Associated to FEI (No. 16)	FIN		12		6	15		2	35
Total number of person months	---	149,3	192,7	66	136	127	47	44	762

3.2 List of work packages

Work-package No.	Workpackage title	Contractors[2]	Person month	Start month[3]	End month[4]	Deliverable No.
WP1	European regional climate simulations for 2071-2100 and their analysis	1,2,3,4,5,6,7,**8**, 9,10,12		1	36	D1A1-D1A6 D1B1-D1B7
WP2	Uncertainty assessment of European regional climate model responses to common forcing, model formulation, and resolution	1,2,3,4,**5**,6,7,8, 9,10,12,16,21		1	36	D2A1-D2A3 D2B1-D2B3 D2C1-D2C2
WP3	Impacts of future climate scenarios on hydrology	6,8,**9**,15		1	36	D3A1-D3A4 D3B1-D3B5
WP4	Impacts on agriculture, forestry, and ecosy-stems	11,**13**,16,18, 20,21		1	36	D4A1-D4A4 D4B1-D4B4 D4C1-D4C4
WP5	Risk assessment of European weather and climate extremes in future regional forecast scenarios	7,15,16,**17**,20, 21		1	36	D5A1-D5A8 D5B1-D5B2
WP6	Assessment of the role of PRUDENCE on European climate policies	5,**14**,19		1	36	D6A1-D6A4
WP7	Management, data, reporting and dissemination	**1**,5,9,11,13,16, 18,20,21		1	36	D7A1-D7A4

[2] Leading contractor (PI) in bold
[3] From beginning of project
[4] From beginning of project

3.3 List of deliverables

Deliverable No. Contributing partner	Deliverable title	Delivery date (month)	Nature	Dissemination level
D1A1 2,3,5,8,12	WP1: Four high-resolution realisations of global climate for 2071-2100 consistent with the SRES A2 emissions scenario and matching control simulations.	12	Si	RE
D1A2 3,5	WP1: Two high-resolution realisation of global climate for 2071-2100 consistent with the SRES B2 emissions scenario and matching control simulations.	12	Si	RE
D1A3 3	WP1: An additional B2 scenario using sea-surface conditions from a different AOGCM.	18	Si	RE
D1A4 2,5,12	WP1: Three additional control and A2 scenarios using two of the models used for D1A1 forming two and three member ensembles.	12	Si	RE
D1A5 3,4,5,8,12	WP1: A comprehensive analysis of the simulations and assessment of the reliability of the scenarios.	33	Da	PU
D1A6 5,8	WP1: A large set of boundary data for driving regional climate models.	12	Da	PU
D1B1 1,2,5,6,7,8, 9,10,12	WP1: Eight RCM realisations of European climate for 2071-2100 consistent with the SRES A2 emissions scenario and matching control simulations.	24	Si	RE
D1B2 1,5	WP1: Two three-member ensemble European climate scenarios for 2071-2100 consistent with the SRES A2 emissions scenario and matching control simulations.	24	Si	RE
D1B3 5,9,10	WP1: Three RCM realisations of European climate for 2071-2100 consistent with the SRES B2 emissions scenario and matching control simulations.	24	Si	RE
D1B4 5,6,8,9	WP1: Three RCM realisations of European climate for 2071-2100 derived from one AGCM A2 scenario.	24	Si	RE
D1B5 1,2,4,8,12	WP1: A two-member ensemble European climate scenarios for 2071-2100 consistent with the SRES A2 emissions scenario using a different driving AGCM than for D1B2	24	Si	RE
D1B6 1,5,6,8,9	WP1: A four -member ensemble European climate scenario for 2071-2100 consistent with the SRES A2 emissions scenario using on a very high resolution of 20 km.	33	Re	PU
D1B7 1,4,5,6,7,8,10	WP1: A comprehensive analysis of the simulations and assessment of the reliability of the scenarios, including weather-type based interpretation of RCM results.	33	Re	PU

D2A1 3,5,8	WP2: An assessment of the uncertainty in high-resolution global climate scenarios resulting from the model formulation, the driving AOGCM and the emissions scenario.	33	Re	PU
D2A2 2,5,7,8,10,12	WP2: An authoritative A2 emissions-driven high-resolution global climate scenario for 2071-2100.	18	Da	PU
D2A3 16,21	WP2: Upper and lower estimates of regional temperature change across Europe based on pattern scaling methods for the SRES emissions range and the IPCC range of climate sensitivities.	33	Re	PU
D2B1 1,2,4,5,6,7,8, 9,10,12	WP2: An assessment of the quality of simulations of current climate by European RCMs	33	Re	PU
D2B2 1,2,4,5,6,7,8, 9,10,12	WP2: A comprehensive assessment of the regional interpretation by eight European RCMs of an AGCM response to climate change driven by the SRES A2 emissions scenario.	36	Re	PU
D2B3 1,2,4,5,6,7,8, 9,12	WP2: An assessment of the uncertainty in European regional climate scenarios resulting from the model formulation, the driving AGCM, the emissions scenario and internal model variability.	36	Re	PU
D2C1 1,2,5,8,12	WP2: An assessment of the reliability of three ensemble realisations of European regional climate for 2071-2100 consistent with the SRES A2 emissions scenario.	30	Re	PU
D2C2 5,8,9,10	WP2: An assessment of the reliability of three realisations of European regional climate for 2071-2100 consistent with the SRES B2 emissions scenario.	33	Re	PU
D3A1 9	WP3: Hydrological models of a major North European drainage basin interfaced with a range regional and high resolution global climate models.	12	Me	CO
D3A2 8,9	WP3: Hydrological models of a specific North European river basin interfaced with a range regional and high resolution global climate models.	12	Me	CO
D3A3 8,9	WP3: Validation of the hydrological components of control simulations in the climate models used for D2C1 & D2C2	24	Re	PU
D3A4 9	WP3: A comprehensive assessment of the potential impact of future climates on river flows, flooding and water availability in a North European drainage basin.	33	Re	PU
D3B1 6	WP3: A detailed hydrological model of a major Central European catchment interfaced with both standard and high resolution versions of a regional climate model.	33	Me	CO
D3B2 6,8	WP3: An assessment of the potential impact of future climates on river flows and flooding in a Central European catchment.	33	Re	PU

D3B3 6	WP3: An assessment of the impacts of degrading the resolution of the input data on the simulations of a Central European catchment hydrology in current and future climates.	33	Re	PU
D3B4 15	WP3: Impacts on snow amount and glacier mass balance in the Alpine domain.	33	Re	PU
D3B5 6,8,9,15	WP3: Validation of the hydrological components of the climate models used for D2C1 & D2C2	33	Re	PU
D4A1 11	WP4: Crop-climate model verified for response to adaptive options under current climate	16	Me	RE
D4A2 11	WP4: Report on response of crop and biomass production, water use and sustainability indicators for a wide range of climate change scenarios.	30	Re	PU
D4A3 11	WP4: Report on effectiveness of adaptive management options for a restricted range of climate change scenarios.	33	Re	PU
D4A4 11,20	WP4: Report on uncertainty in climate model estimation of soil water balance parameters in the Mediterranean region	33	Re	PU
D4B1 13	WP4: Soil-plant-atmosphere model for the North European region verified for adaptive responses under current climate	16	Me	RE
D4B2 13	WP4: Report on response of crop production and nitrogen cycling for a wide range of climate change scenario	30	Re	PU
D4B3 13	WP4: Report on effectiveness of adaptive management options and effect on mitigation strategies for a restricted range of climate change scenarios	33	Re	PU
D4C1 18	WP4: Simulations of present day forest landscapes and ecosystem processes from selected regions under current climates	12	Si	RE
D4C2 18	WP4: Validation of model output under current climate against forest inventory data at selected sites	18	Re	RE
D4C3 18	WP4: Simulations of ecosystem processes at selected EUROFLUX sites from 1994	18	Si	RE
D4C4 18	WP4: Modelled predictions of both vegetation and ecosystem processes for selected forest regions for the period 2071-2100 using the regional climate model outputs and their various SRES scenarios.	33	Re	PU
D4C5 16,21	WP4: GIS environment for mapping of uncertainties	12	Me	PU
D4C6 16,21	WP5: Analysis, interpretation and presentation of uncertainties in impacts in GIS	33	Re	PU

D5A1 17	WP4: Set of new statistical tools suitable for the proper robust estimation of risk due to weather and climate extremes	12	Me	PU
D5A2 17	WP5: Risk analysis of extremes in observed gridded data sets, AGCM, and RCM model output using the tools developed in D5A1	33	Re	PU
D5A3 15	WP5: Assessment of the frequency and intensity change of wind-storms and maps of damage potential of storms, particularly through wind-gusts	24	Re	PU
D5A4 15,20	WP5: Assessments of the general change in heat waves and cold spells as related to human health, agricultural risk and energy demand	33	Re	PU
D5A5 15	WP5: Sensitivity of hydro-power supply to changing temperature and precipitation patterns	33	Re	PU
D5A6 20	WP5: Assessments of the change in frequency/severity of droughts and high-intensity rainfall events in the Mediterranean.	24	Re	PU
D5A7 16,21	WP5: Maps of present-day and future resource risk for Europe or for sub-regions of Europe, based on gridded or site-based information	33	Re	PU
D5A8 16,21	WP5: Analysis of uncertainties in estimated changes in resource risk	33	Re	PU
D5B1 7	WP5: An assessment of the quality of the surface winds and pressure in the RCM control simulations.	24	Re	PU
D5B2 7	WP5: An assessment of possible changes in North European storm surges in a future climate and of the uncertainty due to the driving model formulation.	33	Re	PU
D6A1 14,19	WP6: A Work report that provides a discussion of the climate and physical impact information that is needed for economic and policy analysis at the national and regional sector level	6	Re	RE
D6A2 5,14,19	WP6: A Work report that provides an overview of the methods and models available for linking climate, physical impact and economic sector models together to estimate the benefits and costs of mitigation and adaptation actions at the national and regional levels in climate sensitive sectors of the economy	24	Re	RE
D6A3 5,14,19	WP6: A Work report that presents methodological framework for using the data generated by this project in conjunction with economic assessments to address the asymmetry between the costs and benefits of climate change actions in the EU	30	Re	PU
D6A4 14,19	WP6: A workshop that presents the economic, social and policy making aspects of the regional climate change scenarios in order to establish a dialogue and link with other integrated assessment activities in Europe	33	O[5]	PU

[5] Public Workshop

D7A1 1,5	WP7: A directly accessible archive of boundary data for AGCM and RCM climate change experiments and of climate scenarios for climate impacts models.	24	Da	PU
D7A2 1,5	WP7: A PRUDENCE web-site incorporating interfaces to the boundary and scenario data, an assessment of the reliability of the scenarios and detailing other project findings.	33	Da,Eq	PU
D7A3 1,5,8,9,16,21	WP7: A presentation summarising the climate scenarios, their uncertainties, the example applications developed in PRUDENCE and other major findings.	36	Re	PU
D7A4 1,5,11,13,16, 18,21	WP7: A presentation particularly summarising the impacts of climate change, their uncertainties, together with economic, social and policy making aspects of the regional climate change scenarios as obtained in PRUDENCE.	36	Re	PU

3.4 Workpackage descriptions

DWP Workpackage description

Workpackage number : 1	**European regional climate simulations for 2071-2100 and their analysis**										
Start date or starting event:	**Start-up meeting, Month 1**										
Participant codes :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**
Person-months per participant:	**12**	**18**	**16**	**7**	**26**	**8**	**10**	**22.3**	**5**	**13**	**12**

1 Objectives;

A: High-resolution AGCM simulations

1. To provide state-of-the-art AGCM global scenarios of climate change for the period 2071-2100 with respect to 1961-1990 at higher resolution (with spatial resolutions of 100-150km over Europe) than is currently available from coupled AOGCMs.
2. To provide some assessment of uncertainty in the climate scenarios due to the different model formulations, three models will be driven by the same radiative forcing and sea-surface forcing.
3. To provide some estimate of uncertainty in the climate scenarios from other sources, each model will be run at least twice with either different atmospheric radiative forcing or sea-surface forcing or initial conditions.
4. To assess the realism of the scenarios, the control (1961-1990) simulations will be compared with observations from this period and the response in the anomaly simulations (2071-2100) will be analysed.
5. To provide lateral boundaries for regional climate models to be run, boundary data from two of the models will be saved.

B: RCM simulations

1. To provide detailed European future climate scenarios including information on changes in extreme events, eight independently developed state-of-the-art European RCMs, with spatial resolutions of ~50km over Europe will be used to simulate climate change for the period 2071-2100 with respect to 1961-1990.
2. To provide very detailed information of scenarios most models will run on a horizontal resolution of about 20 km driven by the same AGCMA2 boundary data
3. To provide some assessment of uncertainty in the scenarios due to the different model formulations all models will be driven by the same boundary forcing and incorporate the same atmospheric radiative forcing.
4. To provide some estimate of uncertainty in the scenarios from other sources, seven of the models will be run at least twice with either different boundary conditions (and matching AGCM radiative forcing) from the same driving model or a different driving model or different initial conditions.
5. To assess the realism of the scenarios, the control simulations will be compared with observations and the response in the anomaly simulations will be analysed.

2 Methodology / work description;

A: High-resolution AGCM simulations

The control simulations will all be driven by the same observed time-series of sea-surface conditions for the period 1961-1990 and the same observed time-series of atmospheric trace gases and sulphate aerosols. The latter will be derived from emissions data provided by the IPCC Special Report on Emissions Scenarios (SRES).

The anomaly simulations will all be driven by changes in sea-surface conditions as predicted by state of the art AOGCMs and changes in the radiative forcing derived from the SRES emissions scenarios for the year 2071-2100.

In a set of simulations, three models will use sea-surface forcing from the same AOGCM simulation and the same atmospheric forcing derived from the SRES B2 scenario.

In a second set of simulations three models will be run as above but using the SRES A2 scenario, the fourth model will be driven by the SRES B2 scenario and sea-surface conditions from a different AOGCM (using SRES B2).

Two models will be run for additional SRES A2 scenarios to form two and three member ensembles. Equivalent simulations of the AOGCM above will provide the sea-surface conditions. Matching additional control simulations with these models will also be run to provide sufficient statistics to fully analyse the ensemble responses.

Some of these models will provide lateral boundary conditions for the planned RCM simulations.

Each partner will assess the quality of its model's control simulation and analyse the responses in the anomaly integrations. The analysis will focus on the mechanisms involved in the responses to help determine their realism.

B: RCM simulations

The simulations will be driven by boundary conditions from some of the AGCMs from WP1A and will incorporate the same radiative forcing due to atmospheric trace gases and sulphate aerosols as in the parallel AGCMs.

	For one set of simulations, eight models will be driven by boundary conditions from one of the AGCM simulations taken from the three-member A2 ensemble. The full three members AGCM A2 ensemble will drive two of these models. Three of these models will also be driven by the same AGCM itself driven by a B2 emissions scenario. One of these models will be rerun twice with different initial conditions. The two members AGCM A2 ensemble (i.e. using a different AGCM than above) will drive an eighth model. Six of these models will also be used in a very high resolution of about 20 km driven by the same AGCM A2 simulation to assess the scale dependent features. Each partner will assess the quality of its model's control simulation and analyse the responses in the anomaly integrations. The analysis will focus on comparing the responses with those of the driving model at both large and small scales. Two partners with access to and expertise in analysing daily surface observations will provide a validation of the distributions and extremes of these variables in the control simulations. One will also analyse the change in return periods of extreme events in the anomaly simulations. The WP co-ordinator will synthesise the results from the partners' analyses and then may request or perform further analyses to help provide a coherent set of findings. For example, establishing a common mechanism involved in similar responses may increase confidence in the response.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** **A: High-resolution AGCM simulations** D1A1 Four high resolutions realisations of global climate for 2071-2100 consistent with the SRES A2 emissions scenario and matching control simulations. D1A2 Two high-resolution realisation of global climate for 2071-2100 consistent with the SRES B2 emissions scenario and matching control simulations. D1A3 An additional B2 scenario using sea-surface conditions from a different AOGCM. D1A4 Three additional control and A2 scenarios using two of the models used for D1A1 forming two and three member ensembles. D1A5 A comprehensive analysis of the simulations and assessment of the reliability of the scenarios. D1A6 A large set of boundary data for driving regional climate models. **B: RCM simulations** D1B1 Eight RCM realisations of European climate for 2071-2100 consistent with the SRES A2 emissions scenario and matching control simulations. D1B2 Two three-member ensemble European climate scenarios for 2071-2100 consistent with the SRES A2 emissions scenario and matching control simulations. D1B3 Three RCM realisations of European climate for 2071-2100 consistent with the SRES B2 emissions scenario and matching control simulations. D1B4 Three RCM realisations of European climate for 2071-2100 derived from another AGCM A2 scenario or different initial conditions. D1B5 A two-member ensemble European climate scenario for 2071-2100 consistent with the SRES A2 emissions scenario using a different driving AGCM than for D1B2. D1B6 A four -member ensemble European climate scenario for 2071-2100 consistent with the SRES A2 emissions scenario using on a very high resolution of 20 km. D1B7 A comprehensive analysis of the simulations and assessment of the reliability of the scenarios with special focus on the confidence in differences of driving models and reliability of fine scale detail, including weather-type based interpretation of RCM results
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project** **A: High-resolution AGCM simulations** M1A1 Month 6 Data from first A2 scenario made available to regional modelling groups. M1A2 Month 12 Simulations with the B2 scenario and the A2 scenario ensemble completed and all relevant data made available to regional modelling groups. M1A3 Month 18 Responses from first scenario simulations analysed and results passed to the WP co-ordinator. M1A4 Month 24 All scenario simulations completed and data passed to impacts modellers as required. M1A5 Month 36 Responses from all scenario simulations analysed, results passed to the co-ordinator and synthesis of results produced. **B: RCM simulations** M1B1 Month 18 Initial A2 scenario simulations completed. M1B2 Month 24 Responses from first scenario simulations analysed and results passed to the WP co-ordinator. M1B3 Month 24 All scenario simulations completed and data passed to impacts modellers as required. M1B4Month 36 Responses from all scenario simulations analysed, results passed to the co-ordinator and synthesis of results produced.

DWP Workpackage description

Workpackage number : 2	**Uncertainty assessment of European regional climate model responses to common forcing, model formulation, and resolution.**											
Start date or starting event:	**Start-up meeting, Month 1**											
Participant codes :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**16**	**21**
Person-months per participant:	**18**	**21**	**12**	**14.7**	**36**	**12**	**18**	**15**	**12**	**18**	**4**	**12**

1 Objectives;

A: Uncertainty caused by forcing and model formulation

1. To provide an analysis of the combined responses in models of WP1A to determine the level of variability derived externally from the forcing and internally from the models.
2. To assess uncertainty in a climate scenario provided by an AGCM by comparing the responses of the two models providing two realisations of an A2 scenario-driven climate.
3. To asses uncertainty in an AGCM climate scenario driven by an AOGCM by comparing the responses of a model providing two realisations of an B2 scenario-driven climate driven by sea-surface conditions from different AOGCMs.
4. To assess uncertainty in a climate scenario driven by an emissions scenario by comparing the responses of the two models providing realisations of A2 and B2 scenario-driven climates.
5. To provide a more authoritative A2 emissions-driven climate scenario by forming ensemble statistics from one model providing three realisations of an A2 scenario-driven climate.
6. To assess the full range of uncertainties in European temperature change attributable to the SRES emission scenarios and climate sensitivities considered by IPCC.

B: Uncertainty in RCM simulations

1. To provide an analysis of the eight different regional interpretations, from WP1B, of the AGCM A2 response to determine the uncertainty in regional simulations due to different model formulations.
2. To assess systematic errors in the control simulations to inform the analysis of the responses and provide this information to partners running impacts models.
3. To assess confidence in responses common between the models and to indicate preferred responses in those, which disagree.

C: Scenario confidence

1. The principle aim is to define a range of variables and statistics in which there is confidence in the climate scenarios, those where scenarios are only indicative and those where confidence is low.
2. To provide robust statistics on similarities and differences in responses in three European RCMs by comparing an ensemble of each driven by the three member AGCM A2 ensemble from WP1A.
3. To provide a good statistical comparison of the responses of two European RCMs to an A2 scenario-driven climate. This compares two RCM-AGCM pairs, each simulating two realisations of an A2 emissions-driven climate.
4. To assess whether the level of consensus obtained in the responses of European RCMs driven by the same AGCM A2 scenario (examined in WP2A) is seen in responses of some of the RCMs when driven by an AGCM B2 scenario.
5. To assess the uncertainty in European RCM simulations due to internal RCM variability.

2 Methodology / work description;

A: Uncertainty caused by forcing and model formulation

Each partner will compare the responses in their anomaly integrations. The analysis will focus on establishing the confidence in common responses and reasons for differences.

The WP co-ordinator will liase closely with the relevant partners to provide the uncertainty estimates and derive ensemble statistics for the authoritative A2 emissions-driven climate scenario. Again the analysis will focus on the mechanisms involved in the responses to provide guidance on the reliability of the resulting climate scenarios.

Use of pattern scaling techniques to compute full uncertainty range of regional climate in Europe.

B: Uncertainty in RCM simulations

Each partner will analyse the mechanisms involved in the responses of their RCMs to provide guidance on their reliability.

The WP co-ordinator will synthesise the results from the partners' analyses of their control simulations focusing on model processes, which are important in their response to climate change. Also, the assessment of the models' simulations of extreme events from WP1 will be incorporated.

The WP co-ordinator will combine the analysis of the response of the driving AGCM from WP1 and the partners' analyses of the RCM responses. The responses, and the mechanisms underlying them, will be compared. Again, further analyses may be undertaken or requested as appropriate.

C: Scenario confidence

	Each partner will analyse the statistics of the responses from any ensemble simulations or compare the responses from RCM simulations driven by AGCMs incorporating different atmospheric forcing scenarios. Those partners analysing extreme events of surface variables will provide additional validation of the ensemble of control simulations and changes in the return periods of extreme events in the future climates. The WP co-ordinator will combine the analyses of the responses of the driving AGCMs (WP2) and the partners' analyses of the RCM responses in four areas. The responses of the three RCM ensembles will be compared with the results of the single realisations analysed to provide further evidence on the level of consensus between models. The dependence of the level of consensus in RCM responses on emissions scenario will be examined by comparing the three B2 RCMs with the responses from the A2 RCMs analysed. Here, analysis of the response mechanisms will help to identify reliable responses. The dependence of regional climate scenarios on the AGCM-RCM pairing will be examined by comparing of the responses, and underlying mechanisms, in the simulations of two different pairings using the same atmospheric forcing. Robustness of extremes and fine-scale detail in RCM responses will be analysed through the statistics of a three-member ensemble just varying the initial conditions.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** **A: Uncertainty caused by forcing and model formulation** D2A1 An assessment of the uncertainty in high-resolution global climate scenarios resulting from the model formulation, the driving AOGCM and the emissions scenario. D2A2 An authoritative A2 emissions-driven high-resolution global climate scenario for 2071-2100. D2A3 Upper and lower estimates of regional temperature change across Europe based on pattern scaling methods for the SRES emissions range and the IPCC range of climate sensitivities. **B: Uncertainty in RCM simulations** D2B1 An assessment of the quality of simulations of current climate by European RCMs. D2B2 A comprehensive assessment of the regional interpretation by eight European RCMs of an AGCM response to climate changes driven by the SRES A2 emissions scenario. D2B3 An assessment of the uncertainty in European regional climate scenarios resulting from the model formulation, the driving AGCM, the emissions scenario and internal model variability. **C: Scenario confidence** D2C1 An assessment of the reliability of three ensemble realisations of European regional climate for 2071-2100 consistent with the SRES A2 emissions scenario. D2C2 An assessment of the reliability of three realisations of European regional climate for 2071-2100 consistent with the SRES B2 emissions scenario.
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** **A: Uncertainty caused by forcing and model formulation** M2A1 Month 24 Preliminary analysis of responses in parallel simulations from each partner made available to the co-ordinator and use of pattern scaling methods. M2A2 Month 36 Reports detailing the uncertainties in high-resolution global climate scenarios and the authoritative A2-emissions driven high resolution global climate scenario for 2071-2100. **B: Uncertainty in RCM simulations** M2B1 Month 18 Report on the quality of simulations of current climate by European RCMs. M2B2 Month 30 Report on the uncertainty in European regional climate scenarios resulting from the formulation of the RCM indicating the level of confidence in any preferred or consensus responses. **C: Scenario confidence** M2C1 Month 24 Preliminary analysis of responses in ensemble and parallel simulations from each partner made available to the co-ordinator. M2C2 Month 36 Reports detailing the uncertainties in European regional climate scenarios and summarising climate scenarios derived from the SRES A2 and B2 emissions scenarios.

DWP Workpackage description

Workpackage number : 3	**Impacts of future climate scenarios on hydrology**
Start date or starting event:	**Start-up meeting, Month 1**

Participant codes :	**6**	**8**	**9**	**15**
Person-months per participant:	**24**	**6**	**24**	**12**

1 Objectives;

A: North European drainage basin

1. To provide a comprehensive assessment of the impact of plausible future climates on the hydrology of a major North European drainage basin.
2. To provide models of the large-scale hydrology of a major North European drainage basin land (and lake) areas to simulate river flows interfaced with a range of high resolution global and regional climate models. Modelling will be on the entire drainage basin scale and for a specific North European river basin.
3. To provide estimates of impacts (and their uncertainties) on river flows, flood risks and water availability in regions of a major North European drainage basin derived from the range of climate scenarios from models of different formulation, varying resolution and different forcing data.
4. To provide an assessment of the realism of the hydrology of the climate models by comparing with that of the large-scale hydrology model.

B: Central European catchment

1. The main aim is to provide an assessment of the feasibility of simulating impacts of climate change on river flow and flooding in the a major Central European river basin using climate scenarios of various resolutions.
2. To provide a hydrological model of a major Central European river basin which can be driven by climate model output at various resolutions, e.g. within a nested grids approach.
3. To provide estimates of uncertainty in scenarios of river flow and flood risk for a major Central European river basin based on uncertainties in runoff related surface climate parameters from the climate scenarios analysed in WPs 1 and 2.
4. To provide an assessment of the realism of the hydrology of the climate models by comparing with that of the large-scale hydrology model.

2 Methodology / work description;

A: North European drainage basin

Investigate techniques for providing the full range of variability in the inputs to the hydrological model derived from the climate models

Use data from up to 20 of the climate scenarios produced in WP1 to provide estimates of changes in: river flows in sub-basins with different pollution loads and different environmental significance; flood risks associated with snow-melt or high rainfall, and water availability. Close communication will be maintained with WPs 1 and on the trustworthiness of the climate change simulations.

Analyse components of the hydrological budget within the hydrology model and the relevant modules of the climate model to demonstrate any deficiencies in the latter.

B: Central European catchment

Investigate techniques for providing the full range of variability in the climate model inputs to the hydrological model.

Use data from climate scenarios of various spatial details and degree of downscaling to provide estimates of changes in river flows in sub-catchments with different environmental significance and in flood risks associated with snowmelt or heavy rainfall. The scenarios will be those produced in WP1 with additional parallel higher resolution RCM integrations, achieved by exercising a hierarchy of nested grids, down to 14 Km grid spacing (in 5-year slices).

Identify surface climate changes critical for hydrological impacts (also including soil moisture and evapotranspiration) and assess the uncertainty of runoff scenarios by reference to uncertainties in surface climate. Advice will be sought from the co-ordinators of the climate model analysis WPs on the reliability of the available scenarios.

Analyse the sensitivity of runoff scenarios with respect to surface climate components of the hydrological budget within the hydrology model and the relevant modules of the climate model to demonstrate any deficiencies in the latter.

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

A: North European drainage basin

D3A1 A hydrological model of a major North European drainage basin interfaced with a wide range of European regional and high-resolution global climate models.

D3A2 A hydrological model of a specific North European river basin interfaced with a wide range of European regional and high-resolution global climate models.

	D3A3 Validation of the hydrological components of the climate models used for D2C1 & D2C2. D3A4 A comprehensive assessment for the potential impact of future climates on river flows, flooding and water availability in a North European drainage basin. **B: Central European catchment** D3B1 A detailed hydrological model of a major Central European river basin interfaced with both standard and high-resolution versions of a regional climate model. D3B2 An assessment of the potential impacts of future climates on river flows and flooding in a Central European river basin. D3B3 An assessment of the impacts of degrading the resolution of the input data on the simulations of a Central European river basin in current and future climates. D3B4 Impacts on snow amount and glacier mass balance in the Alpine domain. D3B5 Validation of the hydrological components of the climate models used for D2C1 & D2C2.
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** **A: North European drainage basin** M3A1 Month 12 Develop the interfacing between the large-scale hydrological model and the climate models. M3A2 Month 24 Report on the performance of the hydrological components of the climate models. M3A3 Month 36 Report detailing the possible changes in river flow, flood frequency and water resources in climates responding to plausible future emissions scenarios for the period 2071-2100. **B: Central European catchment** M3B1 Month 18 Develop the interfacing between the detailed hydrological model and climate models at various resolutions. M3B2 Month 30 Complete the simulations of the detailed hydrological model of Central European river catchment driven by climate scenarios from a regional climate model run at standard and high resolution. M3B3 Month 36 Report detailing the changes in river flow and flood frequency in a Central European river catchment for one realisation of a possible future climate of the period 2071-2100 and their sensitivity to the resolution of the driving model.

DWP Workpackage description

Workpackage number : 4	**Impacts on agriculture, forestry and ecosystems**					
Start date or starting event:	**Start-up meeting, Month 1**					
Participant codes :	**11**	**13**	**16**	**18**	**20**	**21**
Person-months per participant:	**33**	**28**	**24**	**37**	**8**	**6**

1 Objectives;

- Overall to analyse the impacts of a range of detailed climate change scenarios on agriculture, forestry and ecosystems for selected regions in Southern and Northern Europe, and to evaluate adaptation options and possible effects on mitigation strategies.

A. Impacts on agriculture in a South European region

1. To assess the impact on the sustainability of cropping systems in future climate scenarios derived from the different regional climate models using different forcing data.
2. To provide a wide-ranging assessment of the impact of possible future climates on crop yields and water use in a Mediterranean region. To suggest mitigation and adaptation strategies as response to the range of possible impacts.
3. To present trends in biomass production. The compromise between crop residue incorporation into the soil and biomass for biofuel production will be analysed in different cropping systems and climate scenarios.
4. To supply information on trends in water use in rain fed and irrigation systems.
5. To analyse the effect of climate change scenarios on crop production and water use with the crop-climate model linked within a GIS to allow analysis of the spatial response across the region.
6. To analyse the efficiency of adaptations for a restricted range of climate change scenarios that could maintain the sustainability of cropping systems as well as management practices under future climate scenarios based on current and new crop sequences adapted to the enhanced weather variability.
7. To explore future water availability (precipitation minus evapotranspiration) in the Mediterranean region as predicted by climate models. What is the range of predictions in the RCMs? What are the implications of this uncertainty for agricultural impacts and planning?

B. Impacts on agriculture in a North European region

1. To provide an assessment of the effect of a range of detailed future climate change scenarios on crop production and nitrogen cycling for an arable crop rotation in a region in Northern Europe, and to evaluate possible adaptive strategies focusing on nitrogen losses and nitrous oxide emissions.
2. To define the relevant adaptive management options and set up an efficient structure for exploring these options with the soil-plant-atmosphere model, including a verification of the model using climate input from control runs of the climate models.
3. To analyse the effect of climate change scenarios on crop production for a number of soil types and climatic sites within the selected region using the soil-plant-atmosphere model.
4. To analyse the efficiency of the proposed adaptive strategies for a restricted range of climate change scenarios and the effect of these strategies on environmental impact, including nitrate leaching and nitrous oxide emissions.

C. Impacts on forestry, ecosystems, health, transport, energy, etc.

1. To predict an envelope of responses to climate change in a number of European forested landscapes by simulating the distribution, dynamics and biomass of the forest vegetation as well as ecosystem processes.
2. To use a generalised ecosystem model as a means to compare and assess the different regional model climates outputs and their various SRES scenarios.
3. To describe changes in resource potential (using simple impact models or indices) for Europe and for sub-regions in relation to multi-decadal natural climate variability.
4. To assess the relative importance of alternative sources of uncertainty in determining future impacts on resource potential in Europe.

2 Methodology / work description;

A. Impacts on agriculture in a South European region

Two existing crop-climate models will be interfaced with a Geographical Information System to allow efficient analysis of the spatial responses in crop production and water use over the region. The model will be adapted to include plant responses to increased atmospheric CO_2 concentrations. They will be calibrated and validated for winter and summer crops with data from field experiments and scientific literature. Rotation modelling will generate the sustainability indicators of productivity, stability, trends in yield, evapotranspiration, and water use efficiency.

The current management will be defined for selected arable crops, and the model will be adapted to properly simulate a range of possible adaptive options, including changes in crop species, cultivar, sowing dates and irrigation management. The possibility of including alternative soil water management strategies such as minimum tillage and stubble mulching will also be investigated. The performance of the model will be evaluated using climate input from the control runs of the models in WP1. Special emphasis will be given to ensure a realistic response of the adaptive options by comparison with results from field experiments.

The response of crop production and water use over the region to the range of climate change scenarios for 2071-2100 delivered by WP1 and WP2 will be analysed. Emphasis will be given to attributing uncertainty in the various factors affecting uncertainty in the climate change scenarios. The winter and summer crops chosen will allow to study the influence of climatic changes on season length, water availability and water requirements. Impact analysis will be done on the evolution of sustainability indicators of the cropping systems representative of Southern Europe.

Based on the analysis of responses for the wide range of climate change scenarios a smaller number of scenarios (3 to 5) will be selected for detailed analysis of the adaptive options defined above. The effectiveness of the adaptive options will be evaluated in terms of biomass production, crop yields, and water use and irrigation requirements. A compromise between residue management vs. biomass production for biofuel will be sought. Adaptation strategies for sustainability will be sought with current and new crop sequences.

Spatial patterns of water availability will be estimated for the Mediterranean Basin by importing model output on precipitation and evapotranspiration (which may be a model variable, or may be calculated from model variables such as temperature and sunshine) into a GIS. Then, measures such as soil moisture from a simple Thornthwaite-type water balance, and/or the Palmer drought index, will be used to estimate water availability. The study will focus on uncertainty arising from the range of predictions in the climate models.

B. Impacts on agriculture in a North European region

An existing state-of-the-art soil-plant-atmosphere model will be applied to simulate crop production, nitrogen cycling and nitrogen losses from an arable agroecosystem. A typical arable crop rotation consisting of winter and spring cereals, pulses and oil seed crops will be defined, and the model will be set up to allow efficient automatic analysis of response to climate scenarios. Three typical soil types for the region will be incorporated in the system. The ability of the model to simulate plant responses to increased CO_2 will be evaluated by comparison with responses in literature. In addition the model will be adapted to properly simulate a range of possible adaptive management options, including cover crops, winter/spring cereal, sowing date, level of nitrogen fertiliser and irrigation (for sandy soils). The effect on nitrous oxide emissions will be estimated by using the model output to calculate the emissions by applying the IPPC 1997 methodology. The performance of the model will be evaluated using climate input from the control runs of the models in WP1. Special emphasis will be given to ensure a realistic response of the adaptive options by comparison with results from field experiments.

The response of crop production, nitrogen use and nitrogen losses to the range of climate change scenarios for 2071-2100 delivered by WP1 and WP2 will be analysed. Emphasis will be given to attributing uncertainty in the various factors affecting uncertainty in the climate change scenarios. The response will be simulated for three different soil types and a small number of sites over the region.

Based on the analysis of responses for the wide range of climate change scenarios a smaller number of scenarios (3 to 5) will be selected for detailed analysis of the adaptive options defined above. These responses will be analysed separately for three different soil types. The effectiveness of the adaptive options will be evaluated in terms of effects on crop yield, nitrogen use and nitrogen losses. Evaluating the effect on nitrous oxide emissions will assess the effect on mitigation strategies.

C. Impacts on forestry, ecosystems, health, transport, energy, etc.

A state-of-the-art ecosystem model of vegetation dynamics and ecosystem processes will be used. It operates within a modular framework to allow different formulations depending on whether specific sites or regions are to be modelled It will be applied using the various climate model outputs from within the project. The model is driven by time series climate data of monthly mean temperature, precipitation and sunshine. Simple soil texture information for each site or grid cell to be modelled will be used e.g. from the FAO soil database.

Climate for the last 100 years will be used to drive the model using the CRU 1901-2000 gridded time series climate dataset to simulate forest composition, biomass, NPP, carbon storage in a number of natural and semi-natural forested regions.

Modelled results from selected regions in Europe will be compared to available forestry inventory data on biomass etc from selected forested landscapes as a means of validating modelled forest composition and biomass.

Modelled carbon and water fluxes will be compared to the long term measurements of fluxes carried out under the EU funded EUROFLUX project (from 1994) at selected forest sites in Europe as another way of validating the ecosystem model and its processes.

The simulations will be then projected forward to 2071 using the modelled climate data from available GCMs.

Simulations 2071-2100 will be done using the full range of different anomalies produced from the different regional climate scenarios including the various SRES scenarios produced in from WP1.

Simulations will be carried out both at the different forest sites within Europe and in the selected EUROFLUX sites used under the present climate simulations.

Vegetation and fluxes between 2071 and 2100 will be compared with present-day simulations and data.

	Interpretation of the different results obtained by using the range of RCMs and their scenarios at the different forestry and EUROFLUX sites will be done in terms of the strengths and weakness of each RCM and their SRES scenarios. In order to explore multiple sources of uncertainty in estimates of impacts both at European scale and over sub-regions of Europe defined by RCMs, simple impact models or indices will be employed that have been tested and applied in previous assessments. A regional, geographically explicit approach will be adopted (e.g. employing gridded data and spatially explicit climate scenarios), focusing on Europe as a whole, or on a region or regions for which RCMs are providing comparable information (e.g. Baltic region; Mediterranean). Some impact uncertainties will be calculated for sites from which observational data are available. Some impact models/indices describe resource potential, usually requiring monthly mean climate information (e.g. accumulated temperature requirements for crop development, space heating or cooling; wind energy). Use of GIS environment for mapping of present and future resource potential as well as their uncertainties.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** **A. Impacts on agriculture in a South European region** D4A1 Crop-climate model verified for response to adaptive options under current climate D4A2 Report on response of crop and biomass production, water use and sustainability indicators for a wide range of climate change scenarios D4A3 Report on effectiveness of adaptive management options for a restricted range of climate change scenarios D4A4 Report on uncertainty in climate model estimation of soil water balance parameters in the Mediterranean region **B. Impacts on agriculture in a North European region** D4B1 Soil-plant-atmosphere model verified for response to adaptive options under current climate D4B2 Report on response of crop production and nitrogen cycling for a wide range of climate change scenario D4B3 Report on effectiveness of adaptive management options and effect on mitigation strategies for a restricted range of climate change scenarios **C. Impacts on forestry, ecosystems, health, transport, energy, etc.** D4C1 Simulations of present day forest landscapes and ecosystem processes from selected regions under current climates D4C2 Validation of model output under current climate against forest inventory data at selected sites D4C3 Simulations of ecosystem processes at selected EUROFLUX sites from 1994 D4C4 Modelled predictions of both vegetation and ecosystem processes for selected forest regions for the period 2071-2100 using the regional climate model outputs and their various SRES scenarios. D4C5 Analysis, interpretation and presentation of present and future resource potential (simple impact models and indices) in GIS. D4C6 Analysis, interpretation and presentation of uncertainties in D4C5 in GIS
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** **A. Impacts on agriculture in a South European region** M4A1 Month 16 Crop-climate model verified under current climate conditions M4A2 Month 30 Analysis of response of crop and biomass production, water use and cropping systems sustainability for a wide range of climate change scenarios completed M4A3 Month 32 Analysis of uncertainty in model estimation of Mediterranean soil water balance parameters completed M4A4 Month 36 Analysis of effectiveness of adaptive management options completed **B. Impacts on agriculture in a North European region** M4B1 Month 16 Soil-plant-atmosphere model verified for adaptive options under current climate conditions M4B2 Month 30 Analysis of response of crop production and water use for a wide range of climate change scenarios completed M4B3 Month 36 Analysis of effectiveness of adaptive management options and impact on mitigation strategies completed **C. Impacts on forestry, ecosystems, health, transport, energy, etc.** M4C1 Month 16 Simulations from ecosystem model verified under present climate using inventory data and preparation of GIS environment. M4C2 Month 20 Simulations of ecosystem processes verified using EUROFLUX sites M4C3 Month 32 Predictions and analysis of vegetation and ecosystem processes in selected regions using the RCM SRES scenarios and results from impact modelling of resource potential. M4C4 Month 36 Assessment of the different RCM modelled outputs in terms of the impacts on Forest ecosystems and analysis of uncertainties in impact modelling of resource potential.

<table>
<tr><td colspan="2">DWP Workpackage description</td></tr>
<tr><td colspan="2">Workpackage number : 5 — Risk assessment of European weather and climate extremes in future regional forecast scenarios
Start date or starting event: Start-up meeting, Month 1
Participant codes : 7 15 16 17 20 21
Person-months per participant: 36 24 7 36 9 15</td></tr>
</table>

Participant codes	7	15	16	17	20	21
Person-months per participant	36	24	7	36	9	15

1 Objectives;

A. Analysis of extremes

1. To quantify objectively the risk of European weather and climate extremes in future regional forecast scenarios. Extremes in wind speed, precipitation, and temperature are a major source of risk to European society and industry. For good adaptation of European policies and industry to the impacts caused by extremes, it is vital that we start to quantify the likely future changes in such risks.
2. New statistical techniques will be developed and applied in order to estimate future risk of extremes as estimated from high-resolution regional climate model integration.
3. A detailed assessment of the impact of possible future climates on the severity of storm surges.
4. To interface a state of the art storm surge model with a series of regional climate models.
5. To determine the impact of scenarios of future climate on the storm surge climate and to assess the reliability of projected changes in the severity of extreme events.
6. To investigate impacts of climate model predictions on changes in the occurrence of low rainfall and high rainfall episodes for the Mediterranean region
7. To analyse changes in indices of resource risk using daily climate model outputs and to assess uncertainties in estimated changes.

B. Storm surge

1. A detailed assessment of the impact of possible future climates on the severity of storm surges.
2. To interface a state of the art storm surge model with a series of regional climate models.
3. To determine the impact of scenarios of future climate on the storm surge climate and to assess the reliability of projected changes in the severity of extreme events.

2 Methodology / work description;

A. Analysis of extremes

Statistical methodology will be developed and adapted to provide robust estimates of European weather and climate extremes in the regional climate forecasts. Techniques from modern statistics and epidemiology such as spatial risk mapping, incidence modelling, and odds ratios will be adapted for use in quantifying weather and climate risk. In particular, the risk of extreme wind speeds caused by winter storms and the risk of rainfall extremes in summer. Climate extremes such as anomalous seasonal totals of heating degree days (in winter) in northern Europe, and excessively hot days (in summer) in southern Europe, will also be investigated.

These techniques will be then applied to observed, AGCM, and RCM gridded output data and the results compared. Extreme weather events are often due to small-scale processes and are highly sensitive to model resolution. By comparing the RCM results with the AGCM results, it will be possible to judge the improvement obtained by using RCMs.

Aggregate Risk Indices (ARI) will be developed for quantifying and monitoring the increased or decreased risk of extremes over the European region due to global warming. These will avoid problems encountered with local point estimates by taking into account the dependency between extremes in different locations. They will enable proper confidence estimates to be made of future risk in Europe due to extremes.

Modelled daily and monthly rainfall along North-South and West-East transects across the Mediterranean Basin will be extracted for the present and future. Criteria for droughts and high-frequency rainfall events will be defined in terms of absolute and relative (percentile) thresholds. These criteria will be used to assess the range of predictions of changes in the frequency of drought and high rainfall events

Indices of weather extremes, which usually require climate information at a daily time step (e.g. consecutive dry days, related to drought risk; number and timing of frost events, important for transport, agriculture and forestry) will be analysed. Maps of potential risk for the European region constructed. A range climate model outputs will be used to evaluate the uncertainties in estimated changes in risk.

B. Storm surge

Modelled daily and monthly rainfall along North-South and West-East transects across the Mediterranean Basin will be extracted for the present and future. Criteria for droughts and high-frequency rainfall events will be defined in terms of absolute and relative (percentile) thresholds. These criteria will be used to assess the range of predictions of changes in the frequency of drought and high rainfall events.

Drive the storm surge model with wind stress and sea-level pressure data from three European regional climate model 30 year control simulations and compare with the results obtained when using driving data from atmospheric reanalyses and with tide gauge measurements.

	Derive changes in sea level from the AOGCM providing the sea-surface boundary conditions for the AGCM and RCM simulations providing the climate scenarios. Drive the storm surge model, incorporating the sea-level change information, with data from the 30-year anomaly simulations of the three European RCMs. The RCMs will all be driven by the same AGCM to explore uncertainty due to the driving model formulation.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** **A. Analysis of extremes** D5A1 Set of new statistical tools suitable for the proper robust estimation of risk due to weather and climate extremes D5A2 Risk analysis of extremes in observed gridded data sets, AGCM, and RCM model output using the tools developed in D5A1 D5A3 Assessment of the frequency and intensity change of wind-storms and maps of damage potential of storms, particularly through wind-gusts D5A4 Assessments of the general change in heat waves and cold spells as related to human health, agricultural risk and energy demand. D5A5 Sensitivity of hydro-power supply to changing temperature and precipitation patterns D5A6 Assessments of the change in frequency/severity of droughts and high-intensity rainfall events in the Mediterranean. D5A7 Maps of present-day and future resource risk for Europe or for sub-regions of Europe, based on gridded or site-based information. D5A8 Analysis of uncertainties in estimated changes in resource risks. **B. Storm surge** D5B1 An assessment of the quality of the surface winds and pressure in the RCM control simulations. D5B2 An assessment of possible changes in North European storm surges in a future climate and of the uncertainty due to the driving model formulation.
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** **A. Analysis of extremes** M5A1 Month 12 Novel and innovative new methods for quantifying the probability of weather and climate extremes in Europe. Report detailing findings on extremes in observed data over Europe M5A2 Month 24 European extremes simulated by low-resolution AGCM simulations and comparison with observed extremes. Present and future resource risks in gridded format. M5A3 Month 36 Risk of future extremes as forecast by the high resolution regional climate models including estimates of uncertainty **B. Storm surge** M5B1 Month 24 Report on the quality of the driving data from the RCM control simulations M5B2 Month 36 The possible changes in North sea storm surges in a future climate scenario for the period 2071-2100 and the uncertainty in these due to the formulation of the driving model

DWP Workpackage description

Workpackage number : 6	**Assessment of the role of PRUDENCE on European climate policies**
Start date or starting event:	**Start-up meeting, Month 1**
Participant codes :	**5 14 19**
Person-months per participant:	**3 14 30**

1 Objectives;

1. To design climate model and impact assessment model outputs for use in economic and policy assessments.
2. To review existing models and methods for translating changes in climate and the impacts of climate on the physical environment into economic impacts in climate-sensitive sectors of national economies that are useful for policy makers.
3. Development of a burden sharing framework based on information about the costs and benefits of adaptation and mitigation.

2 Methodology / work description;

The main aim of the research in this area is to work with the other partners to ensure that the information produced by the climate and physical impact models is consistent with the information needs of economic and policy modellers. Collaboration in this area will focus on the developing the appropriate outputs of climate and physical impacts for economic and policy modelling. Special concern will be focused on:

- ❑ Identifying the climatic and environmental variables and the parameters of their distributions to which producers, consumers, and factor owners respond in making decisions under risk and uncertainty in different sectors.
- ❑ Identification of the relevant spatial and temporal resolution of these variables and their distributions that most influence production, consumption and investment decisions under risk and uncertainty.

An investigation of methodological frameworks for economic and policy analysis will review existing models and methods for translating changes in climate and the impacts of climate on the physical environment into economic impacts in climate-sensitive sectors of national economies that are useful for policy makers. Because policy makers require detailed information about economic impacts at the sectoral level, the emphasis of this research will be on national and regional economic sector models. Work in this area will focus on methods for coupling climate and physical impact models to economic-sector models to try to project what the possible range of climate effects will be on the important economic decisions that occur in environmentally sensitive sectors. Special concern will focus on:

- ❑ Construction of taxonomy of climate change damages to highlight the relevance of magnitude, pace, variability, vulnerability and uncertainty.
- ❑ Selection of sectors to include in the analysis based on such criteria as their economic importance, susceptibility to climate risk, data availability and other such considerations.
- ❑ Definition of different types of climate risk and uncertainty in climate projections that will affect the decisions of economic agents in the sector and policy makers and a review of alternative approaches for assessing economic decisions in these sectors under risk and uncertainty.
- ❑ Review of economic models and methods for simulating the effects of climate change on climate sensitive sectors, with emphasis on national and regional sector modelling in the study area.
- ❑ Description of how existing climate, physical impact and economic-sector models could be linked to assess the impacts of climate risk and uncertainty in climate projections on economic impacts in the sector, using existing models. This will include the evaluation of how uncertainty can be incorporated in the policy response for example through the use of precautionary principles.

An analytical framework will be developed, that policy makers in the EU can use to distribute the burden of mitigation and adaptation policies based on information about the distribution of both mitigation and adaptation costs and benefits at the national level. Work in this area will focus on reviewing alternative burden sharing frameworks and demonstrating how the information about the national costs and benefits of both mitigation and adaptation can be used by EU policy makers to address the asymmetry between the costs and benefits of climate change actions. Special concern will focus on:

- ❑ Design of an integrated framework for assessing climate change mitigation and adaptation strategies for the European Union. Costs curves will be based on results from a bottom up model giving a detailed projection of the 15 member states economy and energy systems up to 2030 to derive a projection in 2050 in order to develop an estimation (orders of magnitude of mean and distribution) of sectoral and regional costs of climate change hedging strategies. This will facilitate the establishment of a comprehensive and internally consistent picture of baseline scenarios and GHGs emissions reduction costs.
- ❑ A review of alternative burden sharing frameworks and discussion of how appropriate they are to address the asymmetry between the costs and benefits of climate change actions in the EU. It will be considered to what extent regional impact scenarios should be included in the discussion of global and

	regional burden sharing versus a strategy that focuses on more aggregate global representation of impacts ❑ Based on work in Task 2 of this WP, development of a methodological framework for using the data generated by this project in conjunction with economic assessments to address the asymmetry between the costs and benefits of climate change actions in the EU.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** D6A1 A Work report that provides a discussion of the climate and physical impact information that is needed for economic and policy analysis at the national and regional sector level. D6A2 A Work report that provides an overview of the methods and models available for linking climate, physical impact and economic sector models together to estimate the benefits and costs of mitigation and adaptation actions at the national and regional levels in climate sensitive sectors of the economy. D6A3 A Work report that presents methodological framework for using the data generated by this project in conjunction with economic assessments to address the asymmetry between the costs and benefits of climate change actions in the EU. D6A4 A workshop that presents the economic, social and policy making aspects of the regional climate change scenarios in order to establish a dialogue and link with other integrated assessment activities in Europe.
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** M6A1 Month 6 Work report D6A1 submitted to project group M6A2 Month 31 Work report D6A3 submitted to workshop participants M6A3 Month 33 Workshop to present the final project results

DWP Workpackage description

Workpackage number : 7	**Management, data, reporting, and dissemination**									
Start date or starting event:	**Start-up meeting, Month 1**									
Participant codes :	**1**	**5**	**8**	**9**	**11**	**13**	**16**	**18**	**20**	**21**
Person-months per participant:	**24**	**3**	**3**	**1**	**2**	**3**	**3**	**2**	**1**	**2**

1 Objectives;

1. To ensure the effective dissemination of AOGCM and AGCM boundary conditions required for many of the simulations performed in WP1.
2. To make available a range of impact assessments based on the climate scenarios for the period 2071-2100.
3. To make available a large range of documented climate scenarios for the period 2071-2100.
4. To disseminate the results of the impact models.
5. To encourage widespread use of the results from the climate modelling experiments performed by the PRUDENCE consortium.

2 Methodology / work description;

The large amount of boundary data required by the consortium will be held, in an agreed format, on dedicated disks attached to an ftp server allowing direct access by all partners. This archive will then be expanded, as the project continues, to include data defining the climate scenarios that the project will develop, elements of which will be used within the consortium for the impacts modelling WPs. Internet-based interfaces will be provided to allow easy access to and extraction of the data. These will be expanded to incorporate information about the scenario data when it becomes available and examples of its use from the WPs 3-6. The data available will also include evaluation of impacts and adaptations strategies in selected sectors.

The impact assessment studies will be made available as a special report and also made available on a CD-ROM.

All project reports will be made available on the internet and presentation will be developed to summarise the findings of PRUDENCE.

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

D7A1	A directly accessible archive of boundary data for AGCM and RCM climate change experiments and of climate scenarios for climate impacts models.
D7A2	A PRUDENCE web-site incorporating interfaces to the boundary and scenario data, an assessment of the reliability of the scenarios and detailing other project findings.
D7A3	A presentation summarising the climate scenarios, their uncertainties, the example applications developed in PRUDENCE and other major findings.
D7A4	A presentation particularly summarising the impacts of climate change, their uncertainties, together with economic, social and policy making aspects of the regional climate change scenarios as obtained in PRUDENCE.

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

M7A1 Month 3	Specification of model output required for the WPs.
M7A2 Month 6	First complete set of AGCM 30 year control and anomaly data available on the PRUDENCE ftp server.
M7A3 Month 12	First complete set of RCM control and anomaly data available on the PRUDENCE ftp server.
M7A4 Month 12	PRUDENCE web-site developed incorporating an interface to the boundary data.
M7A5 Month 24	Data from all relevant scenario simulations available to the consortium via a prototype internet interface.
M7A6 Month 36	All PRUDENCE reports, including an assessment of the PRUDENCE climate scenarios, available on the PRUDENCE web-site along with an interface to the scenario data.
M7A7 Month 36	Summary presentation of the results of PRUDENCE produced and available from the web-site.

3.5 Time schedule

The project tasks are planned for the following three-month periods of the three years from the start of the project. Shading shows the time during which some of the relevant project partners will be working on that particular task. The number at the top of each column refers to the end month of that quarter. A more detailed project planner is provided in Appendix 1.

Task	3	6	9	12	15	18	21	24	27	30	33	36
D1A1	■	■	■	■								
D1A2	■	■	■	■								
D1A3					■	■						
D1A4	■	■	■	■								
D1A5			■	■	■	■	■	■	■	■	■	■
D1A6	■	■	■	■								
D1B1			■	■	■	■	■	■				
D1B2					■	■	■	■				
D1B3			■	■	■	■	■	■				
D1B4					■	■	■	■				
D1B5					■	■	■	■				
D1B6					■	■	■	■	■	■	■	
D1B7					■	■	■	■	■	■	■	■
D2A1					■	■	■	■	■	■	■	■
D2A2			■	■	■	■						
D2A3			■	■	■	■	■	■	■	■	■	■
D2B1							■	■	■	■	■	
D2B2							■	■	■	■	■	■
D2B3							■	■	■	■	■	■
D2C1					■	■	■	■	■	■		
D2C2					■	■	■	■	■	■	■	■
D3A1	■	■	■	■								
D3A2	■	■	■	■								
D3A3					■	■	■	■				
D3A4					■	■	■	■	■	■	■	■
D3B1	■	■	■	■	■	■	■	■	■	■	■	■
D3B2							■	■	■	■	■	■
D3B3							■	■	■	■	■	■
D3B4									■	■	■	■
D3B5	■	■	■	■	■	■	■	■	■	■	■	■
D4A1	■	■	■	■	■							
D4A2					■	■	■	■	■	■		
D4A3									■	■	■	■
D4A4									■	■	■	■
D4B1	■	■	■	■	■							
D4B2					■	■	■	■	■	■		
D4B3									■	■	■	■
D4C1	■	■	■	■								
D4C2			■	■	■	■						
D4C3					■	■						
D4C4							■	■	■	■	■	■
D4C5	■	■	■	■								
D4C6									■	■	■	■
D5A1	■	■	■	■								
D5A2	■	■	■	■	■	■	■	■	■	■	■	■
D5A3				■	■	■	■	■				
D5A4					■	■	■	■	■	■	■	■
D5A5						■	■	■	■	■	■	■

D5A6												
D5A7												
D5A8												
D5B1												
D5B2												
D6A1												
D6A2												
D6A3												
D6A4												
D7A1												
D7A2												
D7A3												
D7A4												
Task	3	6	9	12	15	18	21	24	27	30	33	36

4. Contribution to programme/key action

PRUDENCE contributes directly to Key Action 2 “Global change, climate and biodiversity”, specifically to the first objective “To understand, detect, assess and predict global change processes” under its heading “Climate change prediction and scenarios” (RTD priority 2.1.3).

One area requiring investigation under RTD priority 2.1.3 is the provision of more reliable scenarios including systematic treatment and quantification of uncertainties of climate change and its impacts over decades to century at European level. PRUDENCE will be the first project to provide a large number of co-ordinated high-resolution climate scenarios for Europe, systematically evaluated to determine the level of reliability and then applied in a series of example climate impacts models. This will assess the sensitivity of biophysical sectors to relevant climate changes and also evaluate the uncertainty in terms of possible responses and adaptation options. Furthermore, PRUDENCE will provide improved model representation of the hydrological cycle due to the high-resolution models, which enables more reliable scenarios of changes regarding the scale and frequency of extreme events and impacts on natural resources, and socio-economic systems.

5. Community added value and contribution to EU policies

5.1 European dimension of the problem

The prospect of human-induced climate change, with potentially serious consequences for the natural environment and human societies, has spurred the world's nations to create a UN Framework on Climate Change, with the ultimate aim of avoiding 'dangerous anthropogenic interference in the climate system'. The European Union has taken the lead among industrialised countries in calling for reductions in greenhouse gas emissions. It is establishing policies to achieve such reductions within its own borders and to increase commitment among European citizens to pursue or accept the application of adaptation and mitigation strategies.

Although the broad response of global climate to increased greenhouse gas concentrations is well established, there remain many unknowns in the regional details of current projections of future climate change. As a result our ability to accurately assess the implications of climate change at the regional level is severely limited. The central internal objectives of PRUDENCE are to improve regional climate scenarios, in quantifying their associated uncertainties; to demonstrate their use in climate impacts models, and further to assess the uncertainties associated with this process. The latter underpin the formulation of adaptation and mitigation policies, which will be further, strengthened by directly involving socio-economical expertise within the project. The general aims of PRUDENCE are to improve Europe's ability to assess the consequences of global climate change for European society, and on this basis to assist to formulate more precise response strategies and more scientifically based negotiating positions.

5.2 European added value for the consortium

Understanding and modelling climate change remains one of the greatest challenges ever faced in science. National climate research programmes within European countries have achieved outstanding success in this field and have resulted in a diversity of modelling approach that is a unique European asset. But advances in understanding the complexities of the climate system increasingly require the pooling of resources, in particular computing power to permit the multiple runs of the coupled and high-resolution climate models necessary to explore the range of possible climate futures. It will not be possible for European climate science to maintain its world-leading status unless it achieves greater co-ordination of its research. PRUDENCE would represent a major step forward in establishing a co-ordinated European approach, exploiting the benefits of the variety of models in Europe while harmonising experimental and analytical methodologies. EU support is essential if Europe wants to keep its influence on the international scene and to influence international decisions taken to reduce climate change, their impacts and the economical costs related to these as well at those associated with mitigation and adaptation strategies.

5.3 Contribution to EU policy

Europe is taking the lead on implementing policies to reduce emissions of greenhouse gases. The present project will provide a community effort that will improve the scientific basis for implementation of this policy. Such an effort will assist in a successful implementation of the FCCC (Framework Convention on Climate Change) and the Kyoto Protocol and for the negotiations in the post Kyoto process. Current evidence shows that Europe is vulnerable to the anticipated climate change in several respects. Much better regional predictions are required to guide long term planning in sectors such as agriculture and energy. It will likewise contribute to define future EU agricultural and energy policies. If emissions policies are to be put in place, then we need to know what reductions are needed to produce required effect, and in the longer term we need confirmation that policies are being effective. As the implementations of such policies become apparent, a cost benefit analysis of emission controls will become necessary, both to carry policies within Europe, and persuading the rest of the world to follow.

6. Contribution to Community social objectives

PRUDENCE recognises that a changing climate may have consequences for the quality of life and health and safety, employment, and the environment. PRUDENCE will provide new tools allowing European decision-makers to quantify the risks brought about by a changing climate reflecting the continuous anthropogenic emission of greenhouse gases.

6.1 Quality of life and health and safety

Climate affects virtually every aspect of human life. Cultures, societies and economies have developed within a climatic 'envelope' that has until recently been assumed constant, but is now believed likely to change at an unprecedented rate. Climate change will affect quality of life and health through a variety of routes including: changes in available water resources, new or altered disease vectors, changes in agricultural productivity, changes in the profile of economic activity affecting livelihoods, changes in circulation patterns affecting air quality, and raised sea levels resulting in loss of land for human habitation. While some changes may ultimately have benefits, the process of change is almost always stressful for the communities and industrial sectors involved. PRUDENCE will provide new tools - in the form of high resolution scenarios of future climate that will be the most complete produced to date - to help anticipate and ameliorate the adverse impacts of climate change on humans both at the individual and at the societal level, and to identify and exploit the positive impacts. It will also provide demonstrations of the use of these tools in important economic, environmental or social sectors where the impacts of climate change are likely to be felt.

6.2 Employment

Development of technology that allows more efficient use of resources and the maintenance of sustainable forms of production and consumption is a growth industry worldwide. But the competitive advantage of one technology over another will depend not only on innovation and efficiency but also on the environmental legislation within which business decisions are taken and which can have the effect of encouraging or discouraging particular technologies. By being at the forefront of climate change prediction Europe can continue to play a leading role in negotiating international environmental policy. This strong science-policy connection represents a substantial opportunity to European manufacturers of 'green' technology, by allowing them to set strategic directions for their development and marketing that will best assure their future competitiveness.

Industries with long lead times for change, such as power generation, forestry and water supply, are in particular need of soundly-based climate change scenarios for strategic planning and to assure their long-term competitiveness. But many other sectors of industry and commerce are also sensitive to the direct or indirect impacts of climate change. Their planning process must increasingly take account of future trends; either in the environment itself or in the legislation designed to protect it. Output from PRUDENCE will help to serve this need.

The post-Kyoto process can have a significant influence on the world economy. A reduction of CO_2 emissions can be achieved by replacing current technology with more energy-efficient technology and by switching to low-carbon fossil fuels. In the longer term, renewable energy sources such as wind, solar, and biomass technologies could meet part of the worlds' energy demand. These and other developments aimed at mitigation and reduction of global change may have stimulating effects and create jobs. In fact, there are hints that emission reductions may have a positive effect on economy and employment.

6.3 Preserving and/or enhancing the environment

Climate change represents a major threat to the European and global environments. Natural ecosystems will become stressed if climatic zones shift at a faster rate than the ecosystems can migrate. Similarly human systems of agriculture, silviculture and fishing may become increasingly ill adapted to their changing climatic surroundings. Changing availability of natural resources such as water supply may adversely affect the sustainability and environmental impact of industrial practices. A more stressed environment will be even more vulnerable to natural hazards, such as severe storms, droughts or flooding event, than is the situation in the present climatic conditions.

The best defence against these possibilities is reliable forecasts of the climatic future to be encountered. PRUDENCE recognises that climate change response strategies require not only central, or 'best-guess' estimates of future changes, but a reliable indication of the plausible *range* of possibilities, so that realistic best and worst case scenarios can be described. Thereby appropriate degrees of flexibility and robustness can be built into future plans. Climate change scenarios to date have generally lacked this extra but essential information.

7. Economic development and scientific and technological prospects

Climate change scenarios are necessary input to downstream models providing information relevant to a wide range of human and natural systems. To give just a few examples that illustrate this diversity, the climate change scenarios from PRUDENCE will allow improved precision in estimating changes in: agricultural productivity; vectors of human and animal diseases; the hydrological balance of major catchments; air quality; the economic competitiveness of weather-sensitive industries such as winter and summer tourism; weather-related risks covered by the insurance industry; viability of species or ecosystems within their current geographical distribution; environmental stresses affecting human and animal health and mortality; coastal protection and risk of flooding of low-lying areas. PRUDENCE will then demonstrate the application of its scenarios for most of these systems.

The community that uses climate change scenarios to address these topics is equally diverse, spanning scientists, economists, and policy-makers in government and industry. Through the IPCC process strong links have already been established between climate science and climate impact modellers and the latter will continue to have a strong appetite for the data that PRUDENCE will provide. The general public also has an interest in knowing the climatic future that might await them and their children.

In order to ensure a comprehensive approach to the publication of its results PRUDENCE devotes a complete Work Package to Data Dissemination. The adopted philosophy is to make the outputs available in a tiered fashion, with the level of detail in each tier appropriate to the intended audience. At the most detailed level, gridded datasets derived from the global and regional model simulations performed in PRUDENCE will be made freely available to climate scientists, climate impact modellers and other researchers. At the intermediate level a hard copy publication will be produced containing interpreted data that presents PRUDENCE output in forms that are more directly understandable and usable by users who are specialists in their own field but not in climate. Top-level summaries will be produced, in the main European languages, for general distribution to the public, industry, and the media. The summaries will be suitable for policy-makers in industry and government but for this audience there will also be prepared a set of PowerPoint™ slides for use in briefings and presentations.

7.1 Exploitation and Dissemination

The data generated within the PRUDENCE project are expected to be widely distributed among universities and research centres in Europe. These data will be made available via web access and to some extent (excluding any full data set from climate models) the PRUDENCE CD-ROM.

The data will be used for impact research and policy studies. The reports and data generated during the project will without doubt influence the next IPCC assessment report.

The project can be seen as a prototype for joint modelling within the European Union. It is therefore paving the way towards new approaches in European climate research, since it de facto creates some type of "virtual climate centre" with modelling and assessment experts decentralised in different research centres while centrally co-ordinated by an executive committee recruited from these research centres.

8. Description of the consortium

The partners of PRUDENCE consist of the major research centres in Europe working on climate and related topics. They are drawn from national meteorological services, universities and government-funded research organisations (Table 3, page 15). Each has a proven record of success in its own right but all have experience of successful collaborative work on multi-lateral projects within international research programmes such as those of the European Community, the World Meteorological Organisation and the International Geosphere-Biosphere Programme. The IPCC process, began in 1988, has sensitised climate scientists to the need for this research to make tangible contributions to the formulation of environmental policy. IPCC has also strengthened the international co-operation fostered by the international research programmes. The PRUDENCE consortium, which includes many scientists who have played leading roles in successive science assessments of IPCC, builds on a strong, existing network of European collaboration. Scientists from these institutes have played a major role as lead and contributing authors in the Science Assessments of the Intergovernmental Panel on Climate Change (IPCC). Collectively the consortium has access to the bulk of the computing resources available within Europe for climate research.

DMI (Partner 1) will coordinate the project. A Project Manager will be assigned to the PRUDENCE project to assist the Project Co-ordinator in maintaining the control on the various phases of the project. The manager will also work on the scientific tasks of the project. At the scientific level, DMI will apply the HIRHAM regional climate model at 50km resolution for several of the PRUDENCE down scaling experiments, all covering the entire European area and for duration of 30 years. An additional ~20km resolution experiment is aimed for (See Table 1, page 7). The HIRHAM model has been extensively tested in many international projects. In the MERCURE project this model has been substantially improved. DMI will contribute to a centralised uncertainty assessment of European regional climate model responses.

Personel	1 Senior scientist	1 Scientist
Expertise	The PRUDENCE coordinator and DMI principale investigator	In charge of computational aspects and project management
Contribution to WPs	WP1, WP2, WP7	WP1, WP2, WP7
Contribution to Milestones and Deliverables	M1B1, M1B2, M1B3, M1B4, M2B1, M2B2, M2C1, M2C2, M7A1-7 D1B1, D1B2, D1B5, D1B6, D1B7, D2B1, D2B2, D2B3, D2C1, D7A1, D7A2, D7A3, D7A4	M1B1, M1B2, M1B3, M1B4, M2B1, M2B2, M2C1, M2C2, M7A1-7 D1B1, D1B2, D1B5, D1B6, D1B7, D2B1, D2B2, D2B3, D2C1, D7A1, D7A2, D7A3, D7A4

The senior scientist as well as the scientists will all be part time financed by EU and part time by DMI.

CINECA (Partner 2) will use a global climate model (the NCAR CCM3) and a regional climate model (the ICTP RegCM) to produce global and regional simulations for present day conditions (1961-1990) and for future conditions (2071-2100). The global model will be run at a spectral truncation of the order of T80 (about 2 degrees) while the regional model will be run at a horizontal grid point spacing of about 50 km for an area encompassing the European region and the Mediterranean Basin. Data necessary to run the regional model will be provided by the global model. The forcing scenario will be the A2 developed by the IPCC. Two realizations with the global model and one with the regional model will be completed. Analysis of the simulations will be carried out.

Personel	1 Researcher	1 Engineer	1 Post-Doc
Expertise	Principale Investigator	In charge of computational aspects	Work on runs and analysis
Contribution to WPs	WP1, WP2	WP1, WP2	WP1, WP2
Contribution to Milestones and Deliverables	D1A1, D1A4, D1B1, D1B5, D2A2, D2B1, D2B2, D2B3, D2C1	D1A1, D1A4, D1B1, D1B5, D2A2, D2B1, D2B2, D2B3, D2C1	D1A1, D1A4, D1B1, D1B5, D2A2, D2B1, D2B2, D2B3, D2C1

Meteo-France/CNRM (Partner 3) developed a numerical model of the atmosphere for short-range operational forecasting and also for climate modelling studies. This model, ARPEGE-IFS, has also been developed by the ECMWF for medium-range forecasting. Among the characteristics of this model, one is particularly suitable for regionalisation of climate impacts. The horizontal grid can be non-uniform over the globe, allowing focusing the computations and the analyses on a region of interest. This technique has been widely tested in operational short-range forecasting, as well as with multidecadal climate simulations. Tests with an adiabatic version as well as with a full parameterisation package in aquaplanet mode indicate that the technique allows to get the results of a high resolution global model on a part of the globe, with the computational cost of a model with a lower horizontal resolution. In the MERCURE project, this model has been validated against the observed climatology over Europe. In the present project, it will be used, together with another version with constant resolution, to simulate the climate response to the anthropogenic scenarios.

Personel	1 Researcher	1 Engineer	1 Post Doc
Expertise	Principale Investigator	In charge of computational aspects	Work on analysis
Contribution to WPs	WP1, WP2	WP1, WP2	WP2
Contribution to Milestones and Deliverables	M1A3, M2A1 D1A1, D1A2, D1A3, D1A5, D2A1	M1A3, M2A1 D1A1, D1A2, D1A3, D1A5, D2A1	M2A1 D2A1

DLR (Partner 4) developed statistical tools to evaluate GCM and RCM output in combination. The diagnostic tools are mainly based on circulation pattern analysis. They were first tested in the previous MERCURE project. In the PRUDENCE project DLR will apply these tools to selected GCM/RCM output of partners in order to ...

- ... count the frequency of weather-types (circulation patterns) in GCM runs,
- ... compare the analyzed weather-type frequencies among different models,
- ... evaluate the change of circulation patterns from present climate to scenario,
- ... quantify the relative contribution of changing circulation patterns to local/regional changes of climate parameters as simulated by RCMs,
- ... quantify the potential of statistical-dynamical downscaling and statistical-dynamical extrapolation from complete 30-year GCM/RCM runs.

The results will help to interpret the causes of disagreements between model output and reality as well as between different models. The results will also help to understand the causes of simulated regional climate changes. To a certain degree it will be possible to discriminate exogenous, allochthonous and autochthonous contributions to a simulated net climate change.

Personnel	1 Researcher	1 Post Doc
Expertise	Principale Investigator	Specialist in data evaluation
Contribution to WPs	WP1, WP2	WP1, WP2
Contribution to Milestones and Deliverables	M1A3, M1B3, M2B1, M2B2 D1A5, D1B7, D2B1, D2B2, D2B3	M1A3, M1B3, M2B1, M2B2 D1A5, D1B7, D2B1, D2B2, D2B3

Hadley Centre (Partner 5) will use the HadAM3H AGCM. HadAM3H is a state of the art high-resolution atmospheric general circulation model. It is based on the atmospheric component of the world-renowned Hadley Centre coupled model HadCM3. It has been updated with substantial changes to the representation of clouds and precipitation, increased horizontal resolution and the introduction of a representation of the sulphur cycle and the direct and indirect effects of sulphate aerosols on radiation. HadAM3H provides a more accurate simulation of regional surface climate elements, especially over Europe, than HadCM3 as well as information at higher spatial and temporal scales. The Hadley Centre will also use HadRM3H. HadRM3H is a regional climate model version of HadAM3H configured to run at both 50 and 25km using boundary conditions from the latter. It provides accurate simulations of the mean climate over Europe and adds considerable skilful detail both spatially and temporally (especially in the context of extreme events) when compared with simulations of its driving model, HadAM3H. It has been designed to reproduce the large-scale patterns of HadAM3H and hence to add useful fine-scale detail to the large-scale patterns of climate and climate change derived from the latter.

Personnel	JL2 scientist	JL3 scientist	JL3 scientist
Expertise	Manager, regional predictions	Management and analysis of Hadley Centre simulations	Analysis of model performance in simulating climate
Contribution to WPs	WP2, WP6, WP7	WP1, WP2, WP7	WP1, WP2
Contribution to Milestones and Deliverables	D2A1, D2A2, D2B1, D2B2, D2B3, D2C1, D2C2, D6A2, D6A3, D7A1, D7A2, D7A3, D7A4	D1A1, D1A2, D1A4, D1A5, D1A6, D1B1, D1B2, D1B3, D1B4, D1B6, D1B7, D2A1, D2A2, D2B1, D2B2, D2B3, D2C1, D2C2, D7A1, D7A2, D7A3, D7A4	D1A1, D1A2, D1A4, D1A5, D1A6, D1B1, D1B2, D1B3, D1B4, D1B6, D1B7, D2A1, D2A2, D2B1, D2B2, D2B3, D2C1, D2C2,

ETH (Partner 6) will use CHRM, a climate version of the meso-scale limited area model HRM, which has been adapted from the German Weather Service's forecasting models suite, as driven by GCM simulations produced by partners in WP1. ETH has undertaken extensive evaluations of CHRM for climate downscaling, was engaged in international model inter-comparison projects, and has examined precipitation processes critical for regional climate predictability and sensitivity to global warming. The same model has been used to study the dynamics of mid-latitude cyclones, mountain flow systems and heavy precipitation in the Alpine region. Simulations will be performed at 50 km for 30 years periods and at 14 km for five year periods (time windows) within WP1, while analysis will be undertaken within WP2, also supplemented by help from additional staff in the context of Alpine precipitation. In the field of runoff modeling ETH has a long tradition in the development and validation of distributed hydrological models for areas of complex topography. Within WP3, the ETH group will perform coupled (to the CHRM, at different resolutions) runoff modeling using the distributed WASIM model and giving special emphasis on flood forecasting systems.

Personnel	1 Researcher	1 Researcher
Expertise	Principal Investigator, in charge of all CHRM simulations.	In charge of fine scale CHRM simulations and hydrological modeling.
Contribution to WPs	WP1, WP2	WP2, WP3
Contribution to Milestones and Deliverables	D1B1, D1B4 D1B7, D2B1, D2B2, D2B3	D1B6 D3B1,D3B2,D3B3, D3B5

GKSS (Partner 7) will apply the "Lokalmodell" of the German Weather Service with changes by the Potsdam Institute for Climate Research. The LM will be run with spectral nudging routines implemented by GKSS. Simulations will be carried out at 50 km resolution covering the entire European area and for duration of 30 years. GKSS will also apply the GKSS storm surge model TRIM to the North Sea. The model is a stream model and will be run with a resolution of 20 km. The model will take wind stress and sea-level pressure from the output of the GCMs and RCMs in this project for the 30 years simulations.

Personel	1 Researcher	1 Researcher	1 PhD student
Expertise	Principale Investigator	In charge of model analysis	Work on analysis
Contribution to WPs	WP1, WP2, WP5	WP2, WP5	WP1, WP2, WP5
Contribution to Milestones and Deliverables	M1B1, M1B2, M1B3, M1B4, M2B1, M2B2, M5B2 D1B1, D1B7, D2A2, D2B1, D2B2, D2B3, D5B1	M2B1, M2B2, M5B1 D5B1, D5B2, D2A2, D2B1, D2B2, D2B3, D5B1	M1B1, M1B2, M1B3, M1B4, M2B1, M2B2, M5B2 D1B1, D1B7, D2A2, D2B1, D2B2, D2B3, D5B1

MPG.IMET (Partner 8) will use the ECHAM5 AGCM, which is the fifth generation in the series of MPI's Climate Model. It is a spectral model with use of a semi-implicit, leap frog time integration scheme and the spectral transform method for treating the dry dynamics. The model uses a terrain-following hybrid vertical co-ordinate and a shape-preserving semi-Lagrangian transport scheme for advecting water vapour, cloud water variables and other tracers. The ECHAM5 incorporates a full radiative transfer package also including atmospheric aerosols and cloud ice, a non-local boundary layer scheme, and a mass flux cumulus parameterisation. MPG.IMET will also use the regional climate model REMO, which is based on the Europamodelle (EM, the former numerical weather prediction model) of the German Weather Service. It is a 3- dimensional hydrostatic model for the atmosphere and solves prognostic equations of surface pressure, horizontal wind components, temperature, and water vapour and cloud water content. In addition to the physical parameterisation schemes of the EM the physical parameterisation package of the global climate model ECHAM4 is implemented as an alternative option. Fields from analysis or global climate models can be used to drive the model at the lateral boundaries. Standard horizontal resolutions are 0.5° and 0.16°. The validation of REMO concentrated on the hydrological components of the water cycle. Simulation results of long runs up to ten years using ECMWF re-analysis data as lateral boundary conditions have been compared successfully with observations. The following regions have been investigated with REMO: Europe, Arctic, Antarctic, Siberia, Indonesia, India, Brazil, Peru, Africa, North America, Baltic Sea, North Sea, North Atlantic, Pacific.

Personnel	1 Researcher	1 PhD student
Expertise	Principale Investigator	Data analyses
Contribution to WPs	WP1, WP2, WP3, WP7	WP1, WP2, WP3
Contribution to Milestones and Deliverables	M1A1, M1A2, M1A3, M1A4,M1B1, M1B2, M1B3, M1B4, M2A1, M2A2, M2B1, M2B2, M5B2, M2C1, M2C2, M3A1, M3A2, M3A3, M3B1, M3B2, M3B3, M7A1 to M7A7 D1A1, D1A5, D1A6, D1B1, D1B4, D1B5, D1B6, D1B7, D2A1, D2A2, D2B1, D2B2, D2B3, D2C1,D2C2, D3A2, D3A3, D3B2, D3B5, D7A3	M1A1, M1A2, M1A3, M1A4,M1B1, M1B2, M1B3, M1B4, M2A1, M2A2, M2B1, M2B2, M5B2, M2C1,M2C2, M3A1, M3A2, M3A3, M3B1, M3B2, M3B3, D1A1, D1A5, D1A6, D3A2, D3A3, D3B2, D3B5,

SMHI (Partner 9) will apply the RCA regional climate model at ~50km resolution in 30-year long downscaling experiments covering Europe. An additional ~20km resolution run is aimed for. The RCA developed in the Swedish regional climate modelling program SWECLIM has been used for GCM-, ERA- and NCEP-downscaling, e.g. in the PIRCS-project. RCA has modules for atmosphere, land-surface, deep lakes and shallow lake systems and the Baltic Sea. RCA derives from the international limited area forecasting project HIRLAM, but with reworked/replaced physical parameterizations (E.g. TKE-turbulence, CAPE-based closure for convection, cloud microphysics, radiation for varying CO_2, evapotranspiration from root zone, precipitation uptake on vegetation, hydrological snow and soil water processes with sub-grid scale inhomogeneity). Furthermore, SMHI will apply the HBV model. It is a widely used semi-distributed conceptual runoff model and a standard tool for hydrological forecasting and design in Sweden, Norway and Finland. It includes routines for snow accumulation and melts, soil moisture, storage routing, runoff response and a choice of equations for evapotranspiration. It has been applied at scales from 1 to several 100 000 km^2, even in large-scale climate modelling applications. SMHI will use HBV to turn a large number of the PRUDENCE climate scenarios into water impacts for the Lule River basin and for the Baltic Sea drainage basin.

Personnel	Researcher	Researcher	Researcher	Researcher	Engineer/ reseacrher
Expertise	Principale Investigator	In charge of RCM activities	Hydrological modeling for Baltic Sea drainage area	Technical management of models and data	Hydrological modelling for Lule älv
Contribution to WPs	WP1, WP2, WP3, WP7	WP1, WP2	WP3, WP7	WP1, WP7	WP3
Contribution to Milestones and Deliverables	D1B1, D1B3, D1B4, D1B6, D2B1, D2B2, D2B3, D2C2, D3A1, D3A2, D3A3, D3A4, D3B5, D7A3; M1B1,M1B2, M1B3,M2B1, M2B2,M2C2, M3A1,M3A2, M3A3,M7A7	D1B1, D1B3, D1B4, D1B6, D2B1, D2B2, D2B3, D2C2 M1B1,M1B2, M1B3,M2B1, M2B2,M2C2	D3A1, D3A3, D3A4, D7A3 M3A1,M3A2,M3A3,M7A1,M7A7	D1B1, D1B3, D1B4, D1B6, D7A3 M1B1,M1B3,M7A3,M7A5	D3A2, D3A3, D3A4 M3A2,M3A3

UCM (Partner 10) will apply the PROMES regional climate model at 50 km resolution for two realisations of European climate (A2 and B2 emission scenarios) for 30-year time-slice. The PROMES model was entirely developed by the UCM modelling group throughout the last 12 years. This model has been nested in both GCM and ERA output for several regional climate experiments and validated in several international research and intercomparison projects (e.g. PIRCS-project). It was also applied for simulating the Iberian Peninsula climate sensitivity to an induced land degradation. The same model has shown a good ability in the simulation of torrential rain events (MCS) in the Western Mediterranean.

Personnel	Researcher	Researcher	Researcher	1 Post-doc
Expertise	Principale Investigator	In charge of RCM activities	RCM activities	Work on runs and analysis
Contribution to WPs	WP1, WP2	WP1, WP2	WP1, WP2	WP1, WP2
Contribution to Milestones and Deliverables	D1B7 D2A2, D2B1, D2B2, D2C2	D1B1, D1B3, D2B1, D2B2, D2C2	D1B1, D1B3, D2B1, D2B2, D2C2	D1B1, D1B3, D1B7, D2A2, D2B1, D2B2, D2C2

UPM (Partner 11) will apply the CERES models within the DSSAT and the cropping systems simulation model, CropSyst, for simulation of biomass production, growth and development, yield, evapotranspiration and irrigation requirements of crops representative of current rain fed and irrigated cropping systems. The models will also be applied to crop rotations for sustainability analysis in long term simulations for a range of soils typical of the main agricultural areas. The models are currently used for water stress and drought impact studies and for sustainability analysis with current observed weather in the semiarid areas of the Iberian Peninsula.

Personnel	1 Senior researcher	1 Researcher	1 Researcher
Expertise	Principal Investigator	In charge of crops modelling and data analysis	In charge of crops modelling and data analysis
Contribution to WPs	WP4,WP7	WP4,WP7	WP4, WP7
Contribution to Milestones and Deliverables	D4A1, D4A2, D4A3, D4A4, D7A4	D4A1, D4A2, D4A3, D4A4, D7A4	D4A1, D4A2, D4A3, D4A4, D7A4

ICTP (Partner 12) will complete one set of 30 year present day (1961-1990) and future climate (2071-2100) experiments with a regional climate model (the ICTP RegCM) driven by fields from a corresponding global climate simulation with the Hadley Centre global atmospheric model (HadAM). The model domain will cover the European region and the Mediterranean Basin at a horizontal grid point spacing of about 50 km. Will compare results with analogous runs completed with different regional models driven by the same global model fields. Will also collaborate in the completion and analysis of the experiments planned by CINECA (Partner 2) and compare results with the ICTP experiment.

Personel	1 Researcher	1 Researcher	1 Post-Doc
Expertise	Principale Investigator	In charge of model analysis	Work on analysis
Contribution to WPs	WP1, WP2	WP1, WP2	WP1, WP2
Contribution to Milestones and Deliverables	D1A1, D1A4, D1A5, D1B1, D1B5, D2A2, D2B1, D2B2, D2B3, D2C1	D1A1, D1A4, D1A5, D1B1, D1B5, D2A2, D2B1, D2B2, D2B3, D2C1	D1A1, D1A4, D1A5, D1B1, D1B5, D2A2, D2B1, D2B2, D2B3, D2C1

DIAS (Partner 13) will apply the DAISY soil-plant-atmosphere model for simulation of crop growth and nitrogen turnover in soil and plants and for estimation of losses from the agricultural system. The DAISY model has been extensively tested international on datasets from long-term field experiments and always ranked amongst the models giving the most realistic performance. The model will be applied to a crop rotation typical for arable farming in Denmark and for a range of typical Danish soil types using regional climate data for Denmark. Two department of DIAS will contribute to the project. Department of Crop Physiology and Soil Science has considerable expertise in development and application of dynamic models of crop production and nutrient turnover and losses from soils and plants. Department of Agricultural Systems have large experience in applying models at various spatial scales. DIAS will lead WP5 and be responsible for the definition of adaptation scenarios, coupling of the crop-soil model to climate change scenarios, implementation of methods for estimating analysis of effect on mitigation strategies, analysis of the model results and dissemination of the results.

Personel	1 Senior scientist	1 Scientist	1 Scientist
Expertise	Principale Investigator	In charge of model activities	Support of modeling
Contribution to WPs	WP4, WP7	WP4, WP7	WP4, WP7
Contribution to Milestones and Deliverables	D4B1, D4B2, D4B3, D7A4	D4B1, D4B2, D4B3, D7A4	D4B1, D4B2, D4B3

Risø National Laboratory, Systems Analysis Department (Partner 14) will participate in PRUDENCE in order to facilitate the establishment of a linkage between the outputs of climate models and physical impact assessment and policy making on social and economic aspects of climate change in Europe. The main focus of this activity is to design climate and impact assessment model output in a way where it can be used in economic and policy assessment, and to consider how improved information about specific European climate change impacts can be used in policy decisions about adaptation and mitigation policies.

Personal	Senior Research Specialist	Scientist
Expertise	Principal researcher	Assistant
Contribution to WP's	WP6	WP6
Contribution to Milestones and Deliverables	D6A1, D6A2, D6A3, D6A4	D6A1, D6A2, D6A3, D6A4

University of Fribourg (Partner 15) is working with the Canadian Regional Climate Model (CRCM-2) and is developing this model in close collaboration with international partners. The main objectives of the research conducted in Fribourg is related to extreme events, in order to assess the sensitivity and vulnerability of the Alpine region to wind-storms, heat waves, heavy precipitation in a future, changing global climate. Current activities include the testing of the CRCM-2 capability in reproducing observed extreme events such as the "Vivian" (1990) and "Lothar" (1999) wind-storms. The modeling activities are conducted in parallel to the development of methods aimed at identifying synoptic situations that are capable of triggering extreme events of one type or another. Furthermore, the spatial and temporal resolution of the RCM results are sufficient to be applied to certain impacts studies climate-impacts studies at the Department of Geosciences. These notably include the impacts of climate extremes on damage to infrastructure and forests and, on longer time scales, to glacier retreat and permafrost degradation. Furthermore, the implications of the work undertaken here have stimulated policy dialog within local, national and international frameworks. The participation in PRUDENCE will involve using GCM outputs in the selected "time-window" of the 21st Century to initialize the RCM for regional investigations of the sensitivity of Alpine climate to European-scale climatic change, and the impacts of this change on the Alpine cryosphere and on a range of extreme events.

Personel	1 Researcher	1 Post Doc
Expertise	Principal Investigator	Work on analysis
Contribution to WPs	WP3, WP5	WP3, WP5
Contribution to Milestones and Deliverables	M5A1, M5A2, M5A3 D3B5, D5A3, D5A4, D5A5	M5A1, M5A2, M5A3 D3B5, D5A3, D5A4, D5A5

FEI (Partner 16) and FMI (Partner 21) will first apply pattern scaling methods to climate model outputs for the SRES emissions range and IPCC range of climate sensitivities to assess the "full" uncertainty range of regional climate change in Europe, for comparison with PRUDENCE climate model outputs. Impact indicators will then be used to explore different sources of uncertainty according to the scheme shown in Table 4. Most impacts and their uncertainty ranges will be presented in map and tabular form. Scale-related issues in comparing grid-based climate model outputs against site-based observations (e.g. for precipitation-based indices) will also be examined.

FEI

Personnel	1 Senior scientist	1 Scientist
Expertise	Principal Investigator	Work on analysis
Contribution to WPs	WP2, WP4, WP5, WP7	WP2, WP4, WP5, WP7
Contribution to Milestones and Deliverables	M2A1, M4C4, M5A2, M7A6, M7A7 D2A3, D4C6, D5A8, D7A3, D7A4	M2A1, M4C1, M4C3, M4C4, M5A2, M7A6, M7A7 D2A3, D4C5, D4C6, D5A7, D5A8, D7A4

FMI associated to FEI

Personnel	1 Senior scientist	1 Senior scientist	1 Scientist
Expertise	Principal Investigator	In charge of model analysis	Work on analysis
Contribution to WPs	WP2, WP4, WP5, WP7	WP2, WP4, WP5	WP4, WP5
Contribution to Milestones and Deliverables	M2A1, M4C1, M4C3, M4C4, M5A2, M7A6, M7A7 D2A3, D4C5, D4C6, D5A7, D5A8, D7A3, D7A4	M2A1, M4C1, M4C3, M4C4, M5A2 D2A3, D4C5, D4C6, D5A7, D5A8	M4C1, M4C3, M4C4, M5A2 D4C5, D4C6, D5A7, D5A8

Table 4: Impact models and indices to be applied in uncertainty analysis

Index	Description (and impact sector)	Resolution of climate data Temporal	Spatial	Source
Resource potential				
Thermal growing season	Temperatures above 5°C (agriculture, natural ecosystems)	Monthly/ daily	Grid	1
Accumulated temperature	Growing degree-day requirements for crops (agriculture)	Monthly	Grid	2
	Heating degree-days (energy)	Monthly	Grid	3
	Cooling degree-days (energy)	Monthly	Grid	3
Potential biomass	Lieth model (ecosystems)	Annual	Grid	4
Potential vegetation	Holdridge life zones (natural vegetation)	Monthly	Grid	5
Wind potential	Wind speed (energy)	Monthly	Grid/site	6
Baltic sea ice	Annual maximum extent of sea ice cover based on temperature (transport, marine life)	Monthly	Grid	7
Resource risk				
HWDI (Heat wave duration index)	Longest period >5 consecutive days with Tmax >5°C above the 1961-90 daily Tmax normal (health)	Daily	Grid/site	8
CDD	Maximum number of consecutive dry days (Rday < 1mm) (agriculture)	Daily	Grid/site	8
R5D	Maximum 5-day precipitation total (water resources)	Daily	Grid site	8
FD (frost days)	Total number of frost days (Tmin<0°C) (ecosystems, transport)	Daily	Grid/site	8
Frost-free season	Dates of first and last frost (ecosystems, transport)	Daily	Grid/site	9
Snow season	Total number of days with snow depth < 20 cm (recreation/tourism)	Daily	Grid/site	10

1 Carter (1998); 2 Carter et al. (1991); 3 UK-CCIRG (1996); 4 Lieth (1972); 5 Holdridge (1947); 6 Tuomenvirta et al. (1999); 7 Tinz (1996); 8 Frich et al. (2001); 9 Carter and Granskog (2000); 10 Beniston (1997)

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Frich, P. *et al*., 2001: Global changes in climatic extremes during 2nd half of the 20th century. *Climate Research* (submitted)

Holdridge, L.R. 1947: Determination of world plant formations from simple climatic data. *Science*, 105, 367-368.

Lieth, H., 1972: Modelling the primary productivity of the world. *Nature and Resources*, 8, 5-10.

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UK-CCIRG, 1996: *Energy*. Chapter 8 in: Review of the potential effects of climate change in the United Kingdom. United Kingdom Climate Change Impacts Review Group Second Report, HMSO, London, pp. 109-120.

Uiversity of Reading (Partner 17) will develop and adapt statistical methods to provide robust estimates of European weather and climate extremes in the regional climate forecasts. Techniques from modern statistics and epidemiology such as spatial risk mapping, incidence modelling, and odds ratios will be adapted for use in quantifying weather and climate risk. In particular, the risk of extreme wind speeds caused by winter storms and the risk of rainfall extremes in summer. Climate extremes such as anomalous seasonal totals of heating degree days will also be investigated. These techniques will be then applied to observed, AGCM, and RCM gridded output data and the results compared. Aggregate Risk Indices (ARI) will be developed for quantifying and monitoring the increased or decreased risk of extremes over the European region due to global warming. These will avoid problems encountered with local point estimates by taking into account the dependency between extremes in different locations. They will enable proper confidence estimates to be made of future risk in Europe due to extremes.

Personnel	1 Researcher	1 Post-Doc
Expertise	Principal Investigator	WIll apply statistical methods
Contribution to WPs	WP5	WP5
Contribution to Milestones and Deliverables	D5A1, D5A2	D5A1, D5A2

University of Lund (Partner 18) will use the LPJ-GUESS ecosystem model of vegetation dynamics and ecosystem processes at specific sites and within specific European regions to simulate forest composition, biomass, NPP and carbon storage. It will be driven by different climate data provided from the WPs within the project. Initial testing and validation of the modelling approach will be done using the CRU 1901-2000 gridded time series climate dataset and results compared to available forestry inventory data. Modelled carbon and water fluxes will be compared at specific EUROFLUX sites as a further validation. Simulations will then be projected forward to 2071 using GCM climate data. Simulations from 2071-2100 will be done at different forests and at the EUROFLUX sites using the full range of RCMs including the available SRES scenarios from WP1.

Personnel	1 Scientist	1 Scientist	1 Scientist
Expertise	Principale Investigator	Overall responsibility for model development	Model development and applications
Contribution to WPs	WP4, WP7	WP4	WP4,WP7
Contribution to Milestones and Deliverables	D4C1, D4C2,D4C3, D4C4, D7A4 M4C1,M4C2,M4C3, M4C4, M7A6		D4C1, D4C2, D4C3, D4C4, D7A4, M4C1,M4C2,M4C3, M4C4, M7A6

SMASH – CIRED (Partner 19) will participate in PRUDENCE effort to ensure consistency between the outputs of climate and physical impacts models and the information needs of economic modellers and policy makers. This collaboration is aimed at building an analytical framework to assess the burden of adaptation and mitigation policies at a national level with respect to risk and uncertainty in climate change damages and benefits and policy options costs.

Personel	Research director	Research fellow
Expertise	Principale investigator	Work on analysis
Contribution to WPs	WP6	WP6
Contribution to Milestones and Deliverables	D6A1, D6A2 D6A3, D6A4	D6A1, D6A2 D6A3, D6A4

UEA (Partner 20) has worked extensively on climate change impacts for the Mediterranean region, developing impacts models to study the implications of changes in water availability and heat stress. In PRUDENCE, the role of UEA will be to pursue this work, using the output from the climate model simulations in Work Packages 1 and 2 as the starting condition for the impacts models. In Work Package 5, UEA will study impacts on water availability, seeking to address questions related to the range of model predictions of precipitation and evapotranspiration, and the implications of this uncertainty for agriculture in the Mediterranean region. In Work Package 6, UEA will explore the implications of model predictions of climate extremes, of drought, flood and heat, again for the Mediterranean.

Personnel	1 Senior Scientist	1 Junior scientist	1 Permanent-staff scientist
Expertise	To lead day-to-day work on the project	Data extraction and manipulation	Principal investigator
Contribution to WPs	WP4, WP5	WP4, WP5, WP7	WP4, WP5, WP7
Contribution to Milestones and Deliverables	M4A3, M5A1, M5A3 D4A4, D5A4, D5A6	M4A3, M5A1, M5A3 D4A4, D5A4, D5A6	M4A3, M5A1, M5A3 D4A4, D5A4, D5A6

9. Project management

PRUDENCE is a complex project. Therefore, appropriate weight has been given to management and quality control. The project co-ordinator will monitor progress across all WPs. The project co-ordinator will appoint a project manager to assist with the overall co-ordination of the entire project, whilst a specific contractor (PI), who will be responsible for the delivery of agreed products to other WPs and the synthesis of PRUDENCE, will lead each WP. The PI's are identified in the *List of work packages* (see page 17). The co-ordinator and project manager maintains an ongoing dialogue with WP leaders in order to assist planning, identify problems and slippages in advance and facilitate solutions, and ensure that the work stays focused on the projects' objectives. The complete management structure envisaged for PRUDENCE is indicated in Figure 2.

The management of PRUDENCE will broadly follow the Project Management methodology of the PRINCE (Projects IN a Controlled Environment) system widely used in government and industry.

A Scientific Steering Group consisting of senior scientists from most of the contracting organisations will fulfil the role of the Project Board. A Project Manager will be assigned to the PRUDENCE project to assist the Project Co-ordinator in maintaining the control on the various phases of the project. The leaders of the seven research Work Packages will fulfil the role of the Project Assurance Team, plus other experts co-opted as required.

An External Advisory Group will be created. This group will include representatives from the user community of the PRUDENCE final products, as well as special interests groups. A total of five externals have indicated their strong interest in the development of PRUDENCE. They have very different expertise in climate change related issues and also represent broadly the European Union geographical extension (Their letters of recommendation are attached as Appendix 2). The Project Board will appoint the members of the External Advisory Group and invite the members to attend part or all of their meetings.

PRUDENCE recognises the existence of other EC RTD projects with related objectives. Therefore PRUDENCE will exchange knowledge and advances with the impacts of climate change project "Modelling the Impact of Climate Extremes (MICE)" and co-ordinate its efforts in analysing extremes from the high-resolution model simulations with similar efforts using statistical down scaling techniques in the project "Statistical and regional dynamical downscaling of extremes for European regions (STARDEX)". This will be strenghtend by including participants from these two projects in External Advisory Group.

Each Work Package will be divided into Stages and outline Stage Plans formulated. A detailed Stage Plan will be constructed only when that particular Stage is about to commence. Reporting of progress to the Project Manager by WP leaders will in general be on an Exception basis, i.e. occurring only when significant departures from the Stage Plan are likely to occur. Reports by the Project Manager to the Project Board will be quarterly highlights and Exception reports. The Board will meet during the full PRUDENCE workshops (see next paragraph) and at other times, either in person or by conference call, as required by circumstances. Through the Project Manager the Board will ensure that the risks surrounding the progress of each Work Package and the timely achievement of the deliverables are kept under review, and that corresponding risk management strategies are in place.

The PRUDENCE consortium will meet in its entirety four times throughout the project. The first workshop will occur at the beginning of the project to ensure that detailed Work

Package plans are fully aligned with overall project objectives, to maximise networking between the different partners and to agree details of the data transfer and dissemination systems fundamental to the project. The following workshops will occur in the beginning of the following two years. These will review progress, prepare the structure for the annual report, revise, if necessary, workpackage plans in the light of events and ensure that future plans remain focused on project objectives. The fourth workshop will take place early in the last half-year of the project, to review and collate results, to agree any further analyses to rectify errors or to fill gaps, and to agree report structures and writing assignments. This workshop will also have a public part, which presents the economic, social, and policy-making aspects of the regional climate change scenarios, in order to establish a dialogue and link with other integrated assessment activities across Europe.

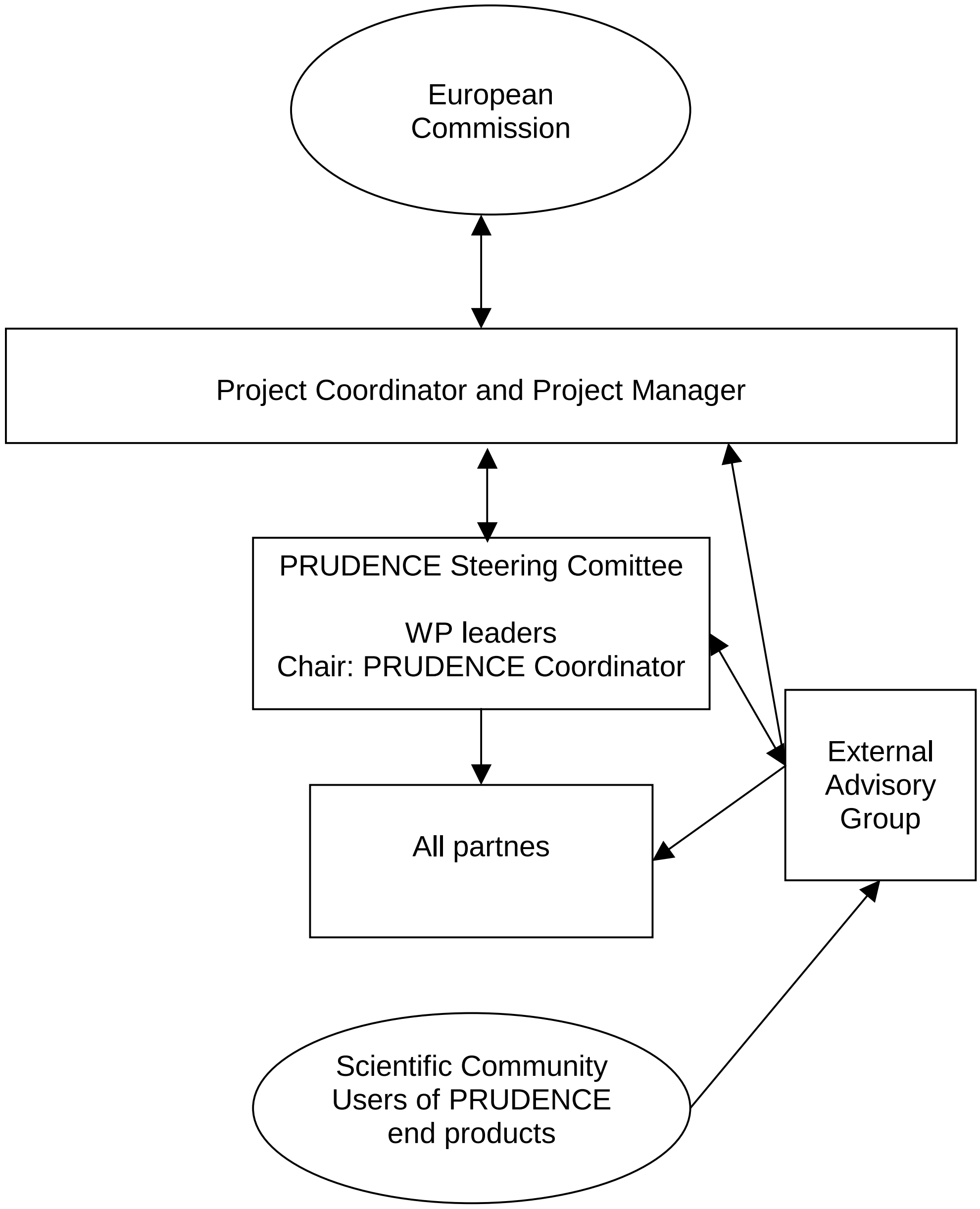

Figure 2. PRUDENCE management structure

Whenever possible the workshops will be organised to coincide with relevant international conferences assuming no negative impact on the project. This will minimise the partners' travel commitments whilst maximising attendance at the workshops. The workshops will always be open to other scientists in the field, either in the capacity as observers or direct participants as time dictates.

10. References

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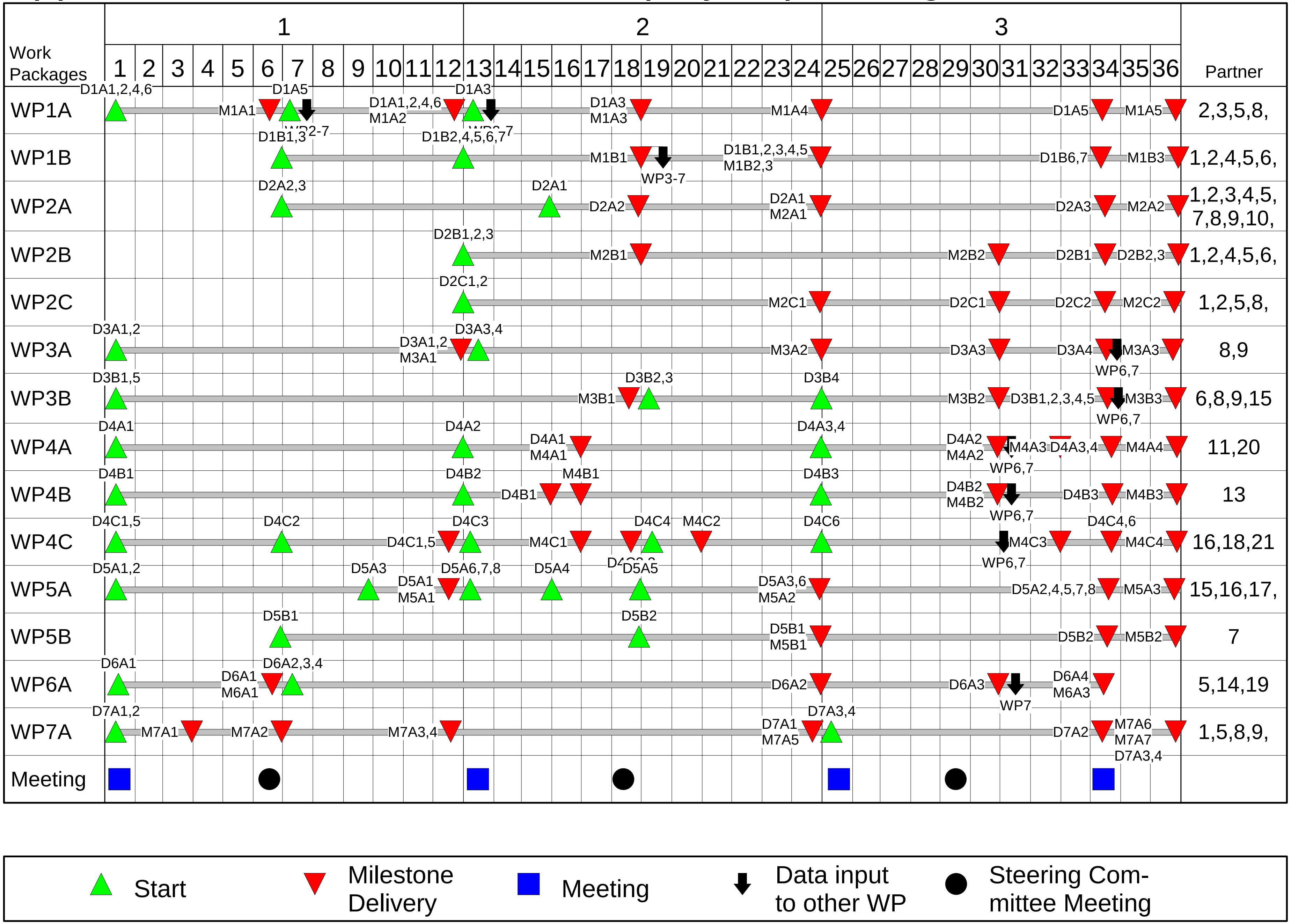
Appendix 1. PRUDENCE project planning



Appendix 2: Letters of recommendation

Swiss Reinsurance Company	2 pp.
Electricité de France	1 p.
Hamburg Institute of International Economics	1 p.
Swedish Electrical Utilities	1 p.
National Observatory of Athens	1 p.