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Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection

Proposal acronym:

COMBINE

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4	CMCC	Centro Euro-Mediterraneo per i Cambiamenti Climatici	IT
5	MF-CNRM	Météo-France - Centre National de Recherches Météorologiques	FR
6	KNMI	Het Koninklijk Nederlands Meteorologisch Instituut	NL
7	UiB	University of Bergen	NO
8	DMI	Danish Meteorological Institute	DK
9	ECMWF	European Centre for Medium-Range Weather Forecast	UK
10	ETHZ	Eidgenössische Technische Hochschule Zürich	CH
11	FMI	Finnish Meteorological Institute	FI
12	MNP	Netherlands Environmental Assessment Agency	NL
13	SMHI	Swedish Meteorological and Hydrological Institute	SE
14	WU	Wageningen University & Research Centre	NL
15	UHEL	University of Helsinki	FI
16	CERFACS	European Centre for Research and Advanced Training in Scientific Computation	FR
17	UCL	Université Catholique de Louvain	BE
18	UNIVBRIS	University of Bristol	UK
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Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection (COMBINE)

Abstract

The European integrating project COMBINE brings together research groups to advance Earth system models (ESMs) for more accurate climate projections and for reduced uncertainty in the prediction of climate and climate change in the next decades. COMBINE will contribute to better assessments of changes in the physical climate system and of their impacts in the societal and economic system. The proposed work will strengthen the scientific base for environmental policies of the EU for the post-2012 climate negotiations.

COMBINE proposes to improve ESMs by including key physical and biogeochemical processes to model more accurately the forcing mechanisms and the feedbacks determining the magnitude of climate change in the 21st century. For this purpose the project will incorporate carbon and nitrogen cycle, aerosols coupled to cloud microphysics and chemistry, proper stratospheric dynamics and increased resolution, ice sheets and permafrost in current Earth system models. COMBINE also proposes to improve initialisation techniques to make the best possible use of observation based analyses of ocean and ice to benefit from the predictability of the climate system in predictions of the climate of the next few decades. Combining more realistic models and skilful initialisation is expected to reduce the uncertainty in climate projections.

Resulting effects will be investigated in the physical climate system and in impacts on water availability and agriculture, globally and in 3 regions under the influence of different climate feedback mechanisms. Results from the comprehensive ESMs will be used in an integrated assessment model to test the underlying assumptions in the scenarios, and hence to contribute to improved scenarios. COMBINE will make use of the experimental design and of the scenarios proposed for IPCC AR5. Therefore the project will be able to contribute to the AR5, by its relevant research and by the contribution of experiments to the IPCC data archives.

1. Scientific and/or technical quality, relevant to the topics addressed by the call

Over the last few decades the understanding of the circulation of the atmosphere and the ocean, of the role of biogeochemical processes and of the role of humankind in climate evolution has made great advances, based on observations, laboratory work, theory and numerical modelling. Comprehensive models of the climate system have become major tools for the investigation of climate dynamics and climate change since the beginning of industrialization (IPCC, 2007) and consequently for the development of policies that mitigate climate change or adapt societies to inevitable changes.

In this context, a critical review of the quality of models used for climate projections is essential (IPCC AR4, WG1, chapter 8). Though many improvements have been achieved in climate modelling, or in Earth system modelling, it is clear that the current models need to be improved further in many aspects. Critical to this endeavour are:

- Knowledge on the processes acting in the climate system, on the dynamics of the coupled climate system and on feedback mechanism regulating the magnitude of climate fluctuation and climate change on timescales from days to centuries.
- Knowledge on the modelling of the coupled system, including parameterizations of processes and the discretisation in time and space of the full system.
- Observation to quantify the state of the system and its dynamics, as reference for model testing and for challenging the current understanding
- Experienced personnel, whose collective expertise grows with the complexity of the Earth system models
- Powerful computing resources to allow practically increased model resolutions, the incorporation of further processes, and the use of refined experimental designs.

In view of these challenges, a major goal of the research community is to improve existing models to reduce the uncertainty in climate projections (1) by representing the Earth system more realistically, in its processes and in the dynamics, and (2) by exploiting the existing predictability of the climate system from weeks up to at least a decade. If future models have a higher reliability, and if the state of the system is known sufficiently well, predictive skill will become useful for impact predictions. This will provide a strong scientific base for environmental policies of the EU or other governing bodies. Hence, the science that will allow such seamless predictions must be fostered in the different areas of observations, theory, modelling and computing.

The COMBINE proposal presented here will make a strong European effort towards more comprehensive Earth system models (ESMs) applicable to climate prediction and climate projections, and thus contribute to the longer term goals of the scientific community in Earth system research, as outlined above.

COMBINE will improve ESMs with focus on 5 topics: (1) the carbon and nitrogen cycles, (2) aerosols including their microphysical coupling to clouds and chemistry, (3) the stratosphere, (4) inland ice and sea-ice, and (5) the initialisation technique for decadal climate forecasts. COMBINE will systematically investigate systematically the effects of selected improvements on the predicted and projected climate change, based on coordinated experiments and scenarios proposed for the 5th Assessment Report of IPCC. The effects will be quantified in the physical climate system and in socio-economic impacts, with focus on water availability and agriculture. Last but not least, COMBINE will feed back results of ESMs to integrated assessment models to challenge the assumptions behind climate change scenarios and hence contribute to new scenarios, making an important step forward towards the construction of fully integrated climate change scenarios.

It is expected that COMBINE will increase the knowledge on the roles of (1) a more comprehensive representation of Earth system processes in ESMs for the overall climate change projected in the 21st century, (2) the relative contribution of these processes, resolution and initialisation techniques for climate prediction over a few decades, (3) the suitable strategy for initialisation of decadal forecasts, (4) feedback mechanisms in three regions where different feedback mechanisms prevail, (5) the consistency of scenarios proposed for IPCC AR5. COMBINE will directly contribute to IPCC AR5 through (a) the relevance of the research in COMBINE to climate change studies and (b) by using the experimental design proposed for the internationally coordinated experiments for the scientific work in this project. Hence, climate predictions and projections carried out in COMBINE will add to the data archives of IPCC for climate change research beyond the scope of this project.

1.1 Concept and objectives

The concept of the project, aiming at the main objectives given below, is based on (1) a specific experimental design to quantify effects of individual and combined new components for Earth system modelling, (2) protocols for IPCC AR5 for the definition of the simulations carried out within the general experimental design and (3) the ues of an ensemble of ESMs to assess modelling uncertainty.

1.1.1 Objectives and Expectations

The COMBINE project has the following major objectives:

- To improve Earth system models by incorporating additional processes and representing more Earth system parameters. The processes selected for this project represent: C- and N-cycle; aerosols coupled with clouds and chemistry; stratospheric dynamics and increased resolution, and ice sheets, sea ice and permafrost for the cryosphere.
- To improve initialisation and error correction schemes for decadal climate predictions;
- To use the Earth system models for decadal climate prediction and climate projection experiments following the protocols of the Coupled Model Intercomparison Project for IPCC AR5 simulations.
- To understand and quantify how single or combined new process components influence different climate feedbacks and the magnitude of projected climate change in the 21st century;
- To understand how the initialisation by itself or initialisation combined with improved process components or improved resolution can reduce the uncertainty in decadal climate prediction.
- To analyze projected climate change in three different climate regions: the Arctic, the Eastern Mediterranean and the Amazon basin; where different feedbacks are important. To analyse effects of selected new components in each region. To test if high spatial resolution has significant influence on strength of feedbacks.
- Quantify the impacts in two sectors: water availability and agriculture, globally and within the regions, and analyze the effect of selected new components on these impacts.
- Use Earth system models to find CO2 emissions that are compatible with representative concentration scenarios specified for IPCC AR5 climate projections, and use an integrated assessment model to revise the scenarios accordingly.
- Contribute to IPCC AR5 by relevant research and by disseminating climate prediction and projection data to IPCC data archives.

1.1.2 New Components

COMBINE will focus its work on 5 new components (Table 1.1.2), which have been selected because it is recognized that their incorporation or improvement is important for the fidelity of the simulated climate and the predictive skill of models. Improved ESMs allow more accurate estimates of physical climate change and impacts, and consequently will provide a better scientific base for policy making.

Table 1.1.2 New components for processes (C1-C4) and model initialisation (C5)

New components
(C1) Carbon an nitrogen cycle
(C2) Aerosols, clouds and chemistry
(C3) Stratosphere
(C4) Cryosphere
(C5) Initialisation

Carbon and nitrogen cycle: It is widely accepted that the Carbon cycle will have a significant impact on future climate evolution through a positive feedback of climate change on natural ecosystem functioning and carbon storage (Cox et al, 2000; Friedlingstein et al, 2006; Denman et al (IPCC AR4 Chapter 7), 2007). Further, the carbon cycle is a crucial policy relevant aspect of the earth system as it bridges the gap from human activity to climate change by linking emissions of CO2 to atmospheric concentration (Jones et al, 2006; Denman et al (IPCC AR4, Chapter 10), 2007). However, large uncertainties exist (Friedlingstein et al, 2006) and many key carbon cycle or ecosystem components are still neglected such as the nitrogen cycle (Magnani et al, 2007; Thornton et al, 2007) or the response of melting permafrost (Zimov et al., 2006). Carbon and nitrogen related climate feedbacks will be important to understand climate change in the Amazon basin and similar other tropical climate regions.

Aerosols, clouds and chemistry: The evolution of aerosol emissions, their modification by chemistry and their effect on clouds constitutes a large uncertainty for climate prediction on decadal timescale, with strong regional differences. A strong aerosol cooling in the past and present would imply that future global warming may proceed at or even above the upper extreme of the range projected by the IPCC (Andreae et al., 2005). In addition, cloud feedbacks have been confirmed as a primary source of differences between climate model estimates of the equilibrium climate sensitivity for a CO_2 doubling (IPCC, 2007). The sub grid-scale nature of clouds is a major issue precluding accurate representation of cloud processes in general circulation models, which hampers to some degree our accurate prediction of future chemistry-aerosol-cloud-interactions. Feedbacks between aerosols, clouds and precipitation will be important for the hydrological cycle globally and regionally, for example in the Eastern Mediterranean.

Stratosphere: There is a growing body of evidence that variability in the stratosphere has a significant impact on modes of variability of the tropospheric and surface climate (Baldwin and Dunkerton, 2001). In addition, the impact of climate change on the mass circulation in the stratosphere is a topic of current research (Butchart and Scaife, 2001, Butchart et al., 2006) and its feedback on stratospheric composition and surface climate is in large part unknown.

Cryosphere: The largest climate change in the 21st century will happen in the high latitude. A better representation of sea ice, permafrost and ice sheets is therefore necessary to reduce the uncertainty in high latitude climate change projections, especially in the Arctic region where albedo changes and the possible release of CH_4 and CO_2 from melting soil cause positive climate change feedbacks. Introducing ice sheet models into ESMs will allow for estimates of the polar ice sheet contribution to global sea level change consistent with the predicted climate evolution. The estimation of these fresh water fluxes are also capital for predicting deep water formation evolution near both polar ice-sheets (Swingedouw et al 2006). Hence a better representation of the cryosphere is crucial for predicting not only high latitude earth system evolution, but also the global ocean circulation and the many climatic features related to it. This will represent a significant improvement from the ESMs used in IPCC AR4.

Initialisation: Substantial improvements to decadal climate forecasts have recently been achieved by initializing the ocean in order to predict internal variability in addition to anthropogenic changes (Smith et al., 2007, Keenlyside et al., 2008). Predictions of climate to 2030 should therefore be initialized with the observed state of the climate system in order to take advantage of the predictability of internal variability. This will reduce the uncertainties in medium-term climate predictions relative to the IPCC AR4 projections, which did not attempt to predict internal variability.

1.1.3 Experimental Design and Simulations

The project will rely on an experimental design that allows quantifying effects of single or combined new components (Table 1.1.3.1). It includes reference simulations of different degrees of complexity (E1), (2) specific experiments incorporating single new components (E2), simulations using new ESMs excluding single new components (E3), and new ESMs including combined new components (E4). This particular design is selected because of the expected non-linearity in the effects of combined components. Non-linearity can be investigated by comparison of single component differences D_A and D_Ω and the combined differences D_Σ from the comparison of the new ESMs and the ESMs present in the beginning of the project. This methodology will be applied to for selected new components, depending on time scale and ESM.

Table 1.1.3.1 Experimental design of COMBINE

ESM combinations	*Differences*
(E1) ESM	$D_A(C(i))$ = (E2) – (E1)
(E2) ESM + C(i)	$D_\Omega(C(i))$ = (E4) – (E3)
(E3) newESM – C(i)	$D_\Sigma(\Sigma_j C(j))$ = (E4) – (E1)
(E4) newESM	

This experimental design will be applied to simulations, which will follow the specifications of the protocol for IPCC AR5 simulations. Such a protocol is prepared by the Working Group for Coupled Modelling (WGCM), based on experiments proposed in Meehl and Hibbard (2007). COMBINE will make use of these specifications for decadal and centennial simulations (Table 1.1.3.2). Centennial simulations will include pre-industrial control simulations, transient simulations for the 20th and 21st century, and idealized coupled simulations. Decadal simulations will include predictions for 2005 – 2035 and decadal hindcasts in the late 20th century. The choice of

the scenarios will be made on the basis of the protocol for IPCC AR5 simulations. Simulations for feedback studies in WP7 will make use of a high scenario, possibly of the Representative Concentration Scenario RCP8.5 (Moss et al., 2008). The RCP3 scenario could be selected as a low mitigation case.
Regional models will be used for case studies to downscale selected ESM simulations into 3 regions, the Arctic, the Amazon region and the Eastern Mediterranean, focusing on specific feedback mechanisms. Impact models for water availability and agriculture will be used globally and within the region to find how processes and feedbacks related to the new components influence these impacts. The IMAGE integrated assessment model will be used to propose revised scenarios based on CO_2 emissions from the Representative Concentration Pathway (RCP) driven ESM simulations, as proposed in Meehl and Hibbard (2007).

Table 1.1.3.2 CMIP simulations for centennial and decadal simulations

Centennial Simulation	*Decadal Simulation*
(CS1) Pre-industrial control	(DS1) Climate prediction (2005-2035)
(CS2) 20th century	(DS2) Climate hindcasts
(CS3) 21st century scenario (Representative Concentration Pathway scen.)	
(CS4) +1% CO_2 / year to 4xCO_2	

1.1.4 Earth System Model Ensemble

It is recognized that ESMs have their specific characteristics, and that a multi model ensemble is generally more realistic and robust than any single model, e.g. in comparison with analyses of the 20t century. The inter-model differences also allow for an assessment of the uncertainty of the model results, in terms of regions, seasons and processes. The COMBINE consortium therefore includes different ESMs (Table 1.1.4), and generally makes use of 3 or more models in each task or work package. This built-in multi-model ensemble approach will be indicative of the uncertainty and robustness of the findings with respect to single model features.

Table 1.1.4: ESMs and main developers

ESMs	*Main developer*
(M1) COSMOS	MPG
(M2) HadCM, HadGEM	METO
(M3) IPSL-ESM	CNRS
(M4) CMCC	CMCC
(M5) CNRM-CM	MF-CNRM
(M6) EC-EARTH	ECMWF, EC-Earth consortium
(M7) NORCLIM	UiB

1.1.5 Structure of the project

The project is organized in a total of 8 scientific work packages (WPs): WP1 to WP8 (Table 1.1.5). WP1 to WP5 incorporate and test new “components” in ESMs that are available at the beginning of the project.WP1 to WP5 cooperate in the construction of a new set of ESMs that incorporates combined new components. WP6 and WP7 use the experimental specifications of the CMIP protocol for IPCC AR5 simulations to investigate systematically the effects of single or combined new components on the decadal climate predictions (WP6) and the centennial climate projections and feedbacks (WP7). WP8 uses the WP6 and WP7 simulations to assess impacts at the global and regional scale, to analyze the scale dependency of the feedbacks in the selected regions, and to produce revised scenarios.

Table 1.1.5 Work package structure of COMBINE

New components	*CMIP/AR5 + Evaluation*
(WP1) C and N cycle	(WP6) Decadal climate prediction
(WP2) Aerosols, clouds and chemistry	(WP7) Climate projections and feedbacks
(WP3) Stratosphere	(WP8) Impacts and Scenarios
(WP4) Cryosphere	
(WP5) Initialisation	

1.2 Progress beyond the state-of-the-art

This project is an integrating effort that will bring progress beyond the current state-of-the-art in several aspects. (1) It will generate new knowledge on the role of the selected new components (Table 1.1.2) in the Earth system, specifically for their contribution to the skill of climate predictions and their effect on the feedback mechanism that are important for the magnitude of global and regional climate change. (2) The project will bring progress in Earth system modelling by the incorporation and careful testing of these new processes and procedures. These ESMs will represent more Earth system parameters. A major overall effort is dedicated to the incorporation and improvement of processes in the atmosphere, in the ocean and on land, which determine the spatially resolved abundance of the key radiative agents, including CO_2, aerosols and clouds, and allow representing feedback mechanisms more completely. It is expected that this brings major progress for climate projections on the centennial timescale. As ESMs are made more comprehensive in the representation of the Earth system, the combination of such ESMs with initialisation techniques opens a perspective for climate prediction over a few decades, thus making substantial progress in the quality of climate projections over such timescales. (3) The project will confer the progress in the understanding and modelling of the climate system, represented in the ESMs, to the assessment of impacts in 2 specific sectors - water availability and agriculture – at the global scale and in 3 regions – the Arctic, the Mediterranean and the Amazon region – with their different climate types and climate feedback mechanisms. (4) As the new ESMs will directly represent many aspects that are incorporated with less detail in integrated assessment models (IAMs), the climate projections of this project will allow testing the compatibility of the underlying assumptions of climate change scenarios resulting from IAMs. The combined use of ESM and IAMs is novel and represents an important progress towards the goal of a fully integrated construction of scenarios. (5) Taking the different aspects together, COMBINE is important to make progress towards more accurate climate projections, impact assessment and scenarios, which will be relevant for the European contribution to the 5th Assessment Report of IPCC and environmental policies of the European Union. This progress will be achieved through advances in specific areas, as described below.

1.2.1 Carbon and nitrogen cycle (WP1)

In this work package we will better and more fully represent the carbon cycle in the ESMs and add representation of the nitrogen cycle which has been shown to be important but is not yet widely included in ESMs. Starting from existing state of the art ESMs climate-carbon cycle models, this WP will integrate key carbon and nitrogen cycle related processes that could strongly control the climate-carbon cycle feedback and emissions of other greenhouse gases. These are:

- Coupled carbon-nitrogen cycle both on land and in the ocean, including consideration of nutrient input to coastal ocean regions. We will consider the nitrogen cycle both in its capacity to moderate the carbon cycle (through limitation of vegetation growth and re-mineralization of nutrient under decomposition) and its role in emissions of nitrous oxide (N2O), a greenhouse gas in its own right.
- Land use change. We will develop the ability to drive the ESMs with land cover changes (such as induced by deforestation) rather than prescribed carbon emissions. This will allow a consistency between the land cover scenarios and the CO2 emissions scenarios which has to date been lacking.
- Processes responsible for methane emissions including feedbacks from melting of permafrost or changes in wetlands. We will also develop representation of wild fire in the ESMs and its impact on greenhouse gas and aerosol emissions and disturbance of vegetation.

The work package will also deliver model simulations to evaluate the performance and assess the impact of the new components. Emphasis will be placed on simulations of present day in order to aid the evaluation with observations. Future scenario simulations will be performed under WP7. The new components will have been evaluated off-line prior to implementation in ESMs. Simulations carried out here will focus on evaluation of the new components in a coupled ESM context and assess the impact of the new components on the ESM climate and vice-versa. This activity will also analyse emergent interactions between the new components themselves using experience and expertise gained from leading previous earth-system modelling inter-comparisons.

The work package will also make extensive use of observational datasets to evaluate and constrain the model performance with the new components. Datasets such as a global FLUXNET or NPP-database will enable us to establish general patterns of the carbon and nitrogen cycle and its components, along with CH4 data from GAW and CMDL networks. We will employ innovative techniques to spatialise the data using pattern recognition techniques so that gridded versions of the data can be compared directly to the models. Expertise and experience from all the groups will be combined to bring the maximum benefit from a diverse range of observational and experimental data.

1.2.2 Aerosols, clouds and chemistry (WP2)

Cloud-aerosol interactions are a large uncertainty for climate prediction on decadal timescale. Aerosols affect radiative fluxes by scattering and absorbing solar radiation (direct effect). They also interact with clouds and the hydrological cycle by acting as cloud condensation nuclei (CCN) and ice nuclei (IN). In addition, cloud feedbacks have been confirmed as a primary source of differences between climate model estimates of the equilibrium climate sensitivity for a CO2 doubling (IPCC, 2007). At present, no transient climate simulation accounts for all aerosol-cloud interactions, so that the net aerosol effect on clouds, precipitation and the radiative balance deduced from climate models is not conclusive (Denman et al., 2007; Meehl et al, 2007). Thus additional work is needed to incorporate aerosol-cloud processes that appear to be missing in current general circulation models (GCMs). Different aerosol interactions with mixed-phase and ice clouds have been suggested (glaciation indirect effect in mixed-phase clouds, an inverse cloud albedo effect in cirrus clouds) that could partly offset the aerosol effect on warm clouds (Lohmann, 2002; Abbatt et al., 2006). These pathways will be explored in several ESMs used in this proposal to estimate their climatic effect. In addition changes in circulation regimes will be evaluated in terms of the contribution from the greenhouse gas versus aerosol forcing. The sub grid-scale nature of clouds is a major issue precluding accurate representation of cloud processes in GCMs. Climate models that were used in the AR4 accounted for the sub grid-scale effects, at best, with ad hoc tuning. These will be improved in several ESMs used in this proposal by using the stochastic generation of cloudy subcolumns within GCM columns (Räisänen et al. 2004).

In the ESM used in this proposal, additional interactions between the vegetation, carbon and nitrogen cycles and aerosols will be taken into account. Considering that globally increasing temperatures and CO_2 fertilization are likely to lead to increased photosynthesis and forest growth, an increase in forest biomass would increase emissions of non-methane biogenic volatile organic compounds (NMVOC) and thereby enhance organic aerosol production which would tend to partially offset the warming due to CO_2 (Kulmala et al., 2004). Biological NMVOC emissions themselves depend on CO_2 concentrations showing a several-fold increase of leaf emissions (emissions per leaf area) from plants grown at sub-ambient CO_2 concentrations and a decline above ambient CO_2 concentrations (Arneth et al, 2007). In addition, changes in the partitioning of solar radiation into diffuse versus direct due to cloud-aerosol interactions has important consequences for the net primary production, for the uptake of CO_2 and deposition and emissions of reactive compounds like ozone and VOC.

VOCs also affect the formation of ozone, which damages plants, affects their ability to soak up CO_2 from the atmosphere and accelerates global warming (Sitch et al., 2007). Increasing temperatures and enhanced biomass production could cause higher N_2O emissions and more NO_x and NH_3, which are involved in the formation of N containing aerosols (ammonium sulphate and -nitrate). In addition, increased temperatures will decrease the total particulate matter loading and will shorten the lifetime of nitrogen in the atmosphere (e.g. Morino et al., 2006; Dawson et al., 2007). The actual release of the reactive nitrogen compounds into the atmosphere, and consequently ozone and aerosol production, depends on the role of canopy interactions between emissions, deposition, chemistry and mixing (Ganzeveld et al., 2002). The relevance of considering the nitrogen exchange and cycling for aerosols (and cloud physics) in ESMs has been demonstrated in various studies. Due to increases in NO_x and NH_3 emissions, the role of nitrate aerosols in future climate is expected to become more important (e.g., Bauer et al., 2007). Increased temperature will also change chemical reaction rates in the atmosphere. Moreover, the efficiency of some nucleation mechanisms as for instance observed in boreal forests (Kulmala et al., 2001), coastal (O'Dowd et al., 2002), and urban (Stanier et al., 2004) environments are highly temperature dependent. These pathways will be included in several ESMs used in this proposal.

1.2.3 Stratosphere (WP3)

The overall goal of WP3 is to reduce uncertainties in the representation of climate variability on seasonal to multi-decadal timescales and to improve the representation of the upper troposphere, by including dynamical stratospheric processes in Earth System Models, for better climate prediction and projections.

There is a growing body of evidence that variability in the stratosphere has a significant impact on modes of variability of the tropospheric and surface climate (Baldwin and Dunkerton, 2001, Thompson et al., 2002, Norton, 2003, Charlton et al., 2004, Scaife et al., 2005, Manzini et al., 2006). Focusing on European winter prediction, possible improvements include a better representation of blocking and cold air outbreaks over Europe in winter, due to the representation of realistic stratospheric sudden warmings in the stratosphere resolving models. In addition, the impact of climate change on the mass circulation in the stratosphere is a topic of current research (Butchart and Scaife, 2001, Butchart et al., 2006) and its feedback on stratospheric composition and surface climate is in large part unknown. The emerging role of modelling the stratosphere in coupled atmosphere-ocean models is now recognized internationally (Kushner et al., 2007).

Current climate models (coupled global atmosphere, ocean and sea ice models) and their more comprehensive extensions, the Earth system models, include only limited aspects of the representation of the stratosphere. They usually avoid the explicit simulation of stratospheric variability by additional damping in the upper layers of the model domain, in the lower stratosphere. This technique may provide reasonable results for the modelled mean climate, but it reduces the modelled stratospheric variability and therefore its downward influence. This situation is the state-of-the-art for the climate models used for AR4 (Chapter 8, Randall et al., IPCC 2007). Its quantitative implications for tropospheric and surface variability for seasonal to decadal and longer time scale are still unknown.

In order to go beyond these limitations due to model design, it is necessarily to use the experience matured in the last decades on modelling of the stratosphere and apply it to incorporate the stratosphere resolving models in the current Earth System Models. In addition to provide a model design that will allow the representation of the stratosphere – troposphere dynamical coupling, the implied increase in vertical resolution because of the incorporation of the stratosphere will have other beneficial effects. Namely, it will provide better consistency with the general increase in horizontal resolution (Roeckner et al., 2006) and improved and more detailed representation of the upper tropospheric meteorology to the benefit of clouds feedbacks aerosol processes. The quantification of the role of higher vertical resolution and the Quasi-Biennial Oscillation to radiative-clouds feedbacks (Giorgetta et al., 1999) and consequently to the variability of the tropical troposphere stratosphere system is still to be determined.

1.2.4 Cryosphere (WP4)

The aim of WP4 is to significantly improve the representation of the cryosphere in ESMs, by including ice sheet and permafrost models, by improving the existing modules for sea-ice and snow and by developing conservative coupling methods at the interface between the cryosphere and the rest of the climate system.

These components are intricately linked to the surface energy budget, the water cycle, sea level changes and the surface gas exchange, which are strongly related to climate variability and climate change. The feedbacks associated with the cryosphere, such as between snow and ice albedo and surface temperature, between meridional overturning circulation and SST, between sea- and land-ice melting and oceanic convection, and between permafrost melting and methane emissions, significantly contribute to climate sensitivity. In contrast to its importance in the climate system, the cryosphere is poorly represented in ESMs. The slow cryosphere components are either ignored (e.g. permafrost) or imposed as boundary conditions (e.g. the ice-sheets) in the models. The feedbacks due to these components are therefore presently not contributing to the modelled response to anthropogenic forcing, although they could become particularly important in the coming centuries, with temperature rising in the polar regions faster than elsewhere. WP4 will work on ice-sheets, permafrost and sea-ice, and on the coupling between these components, the atmosphere and the ocean, with special attention paid to energy and water conservation within the model system. This is essential to avoid long term model drifts, misinterpretations of the response to anthropogenic forcing and of the feedbacks of the cryosphere within the Earth System. These feedbacks will be further analysed in WP6 in the case of sea-ice, whose evolution is of special importance in the next decade, and in WP7 for all cryosphere components.

Ice sheet models for Antarctica and Greenland will be coupled to AOGCMs. Until now, only a few AOGCMs include a Greenland ice-sheet model (e.g. Fichefet et al, 2003, Ridley et al., 2005) and even fewer include models for both polar ice sheets (Driesschaert et al., 2007, Mikolajewicz et al., 2007). The current coupling methods do not ensure a strict conservation of water and heat throughout the model system. We will therefore develop new coupling methods upon compulsion of these criteria. The implementation of ice-sheet models in ESMs will allow a study of the feedbacks associated with this new component (cf. WP7) as well as an evaluation of the contribution from the main polar ice-sheets to global sea-level change.

Sea ice modelling is another pressing issue in ESMs. Stroeve et al. (2007) recently showed that most AOGCMs used in the last IPCC report are not able to reproduce the sharp decline in minimum Arctic sea-ice extent observed in recent decades. Most sea-ice models currently used in ESMs lack adequate representations of several processes which could impair their sensitivity to a warming, e.g. fragile ice categories, surface snow behaviour, and occurrence of melting ponds at the surface. All these are important for the surface radiative budget and therefore in the sea-ice feedback on the climate system. More complete sea-ice modules exist as stand-alone models and will be implemented in ESMs in WP4. Furthermore, the coupling methodology will be improved, particularly in terms of the treatment of snow at the ice surface and in terms of energy conservation at the atmosphere – sea-ice and ocean – sea-ice interfaces.

The development of a representation of permafrost in ESMs is also crucial since the melting of permafrost can affect both the surface hydrology and the carbon cycle (cf. WP1). In WP4, several research groups will implement a module in their ESM that computes the evolution of permafrost, i.e. formation and melting. Particular attention will be paid to the upper layer of the permafrost, which melts in summer, creating wetlands and peatlands that strongly influence the soil energy budget and hydrology. The development of such a module, like the development of coupling methods for sea-ice and ice-sheets, therefore requires a careful treatment of the energy and water budgets, a common theme to the three major developments proposed in WP4.

1.2.5 Initialisation (WP5)

The primary aim of this work package is to improve climate forecasts out to 2030 by predicting natural internal variability in addition to anthropogenic changes. This will be a significant advance over IPCC AR4 projections, which did not attempt to predict internal variability. A secondary aim is to investigate the possibility of providing a climate prediction methodology that avoids the need for expensive spin-up and transient simulations, thereby enabling higher resolution decadal forecasts to be made.

On decadal timescales, climate is significantly influenced both by anthropogenic forcing and by natural internal variability. Substantial improvements to decadal climate forecasts have recently been achieved by initializing the ocean in order to predict internal variability in addition to anthropogenic changes (Smith et al., 2007, Keenleyside et al., 2008). Furthermore, ocean initial conditions have a significant impact on regional climate forecasts for the coming 30 years (Smith et al., 2008). Predictions of climate to 2030 should therefore be initialized with the observed state of the climate system in order to take advantage of the predictability of internal variability. This will reduce the uncertainties in medium-term climate predictions relative to the IPCC AR4 projections, which did not attempt to predict internal variability.

This work package will implement different techniques for initializing climate models by exploiting the information provided by the existing observing system and atmospheric reanalyses. The impact of initialisation will be assessed on decadal forecasts with several climate models. The strategies for initialisation of decadal forecasts are so far quite different from the initialisation strategies used in seasonal and weather forecasts. The work will explore different initialisation strategies and their suitability for decadal predictions. Of particular importance will be the implementation of an initialisation strategy that avoids the need for expensive spin-up and transient simulations. If successful, this will be a major advance, opening the door for higher resolution decadal forecasts (including higher vertical resolution to be implemented in WP3).

1.2.6 Decadal climate prediction (WP6)

The overall goal of this work package is the assessment of the impact of the new components developed in WP1-4 and the new initialisation procedures developed in WP5 for decadal predictions.

It is anticipated that the model quality is now sufficient to provide some regional guidance as to the effects of climate change out to 2030. Important issues concerning climate change are regional changes in water availability (soil moisture), affected by changes in precipitation, evaporation and melting of the snow pack. Also important are local daily and seasonal temperature changes. For the society most relevant are the changes in the extremes: floods, droughts, extended heat waves, intense extra-tropical storms and hurricanes.

Due to its chaotic character the climate is on short timescales, in the order of less than one year, dominated by its internal variability. On long time scales, in the order of 100 year, the climate is dominated by the change in external forcings. For the coming century this is the anthropogenic change in greenhouse gas concentrations. On decadal time scales anthropogenic change in greenhouse gas concentrations and internal variability of the climate system both affect the climate signal. Due to its large heat capacity the ocean is strongly affecting the decadal variability. For reliable decadal forecasts therefore the initial state of the ocean and the ocean dynamics as well as its coupling with the atmosphere should be simulated adequately. Dominant modes of variability that affect the ocean variability on decadal times are the Merdional Overturning Ciculation (MOC) and the Pacific

Decadal Oscillation (PDO). Decadal fluctuations in other external forcings such as aerosols and internal variability in the cryosphere will also affect the decadal variability of the climate.

In recent years progress has been made in decadal predictions. This is due to substantial developments in coupled ocean-atmosphere models, and in ocean observing systems. New data assimilation systems haven been developed (Zhang et al. 2007) and seasonal forecasts are being made with state-of-the-art coupled models. These developments provide the scientific basis to perform decadal predictions. Recent studies have demonstrated the potential predictability at decadal time scales (Griffies and Bryan 1997) and decadal prediction experiments have recently been started at several climate centres around the world (Smith et al. 2007, Keenlyside ate al. 2007) .

An important issue of these decadal predictions is to untangle the impact of the change in radiative forcing during the integrations and the effect of the slow manifold of the climate attractor. This issue will be studied by performing ensemble integrations starting from different initial conditions of the atmosphere and ocean. Due to its large heat capacity the ocean plays a key role for the long time scales in the climate system. Other components that can potentially affect the slow manifold are soil moisture, sea-ice and snow.

The prediction runs are designed to test the impact of the new initialisation procedures and new model components that are implemented in COMBINE. It is expected that these new components will improve the quality of the decadal predictions. The results will also be used for impact studies in WP8. As such it will also contribute to future policy actions of adaptation at European and international level.

The acquainted knowledge by performing and analyzing these runs will enlarge the scientific knowledge within the European community.

1.2.7 Climate projections and feedbacks (WP7)

Large positive feedbacks in the climate system are known to amplify the global temperature increase. However, even for the identified radiative feedbacks impacting on the Earth's energy budget, in particular for the cloud-climate feedback, climate models exhibit a very large spread (e.g., Randall et al., 2007; Bony et al., 2006; Soden and Held, 2006).

There are further clear indications for quantitatively important feedback processes in the climate system, which have not yet been included properly in future climate projections through an integrated Earth system modelling approach (see for example IPCC AR4, 2007, chapters 2, 4, 7, 8 and 10). For the carbon cycle feedback, a model inter-comparison was carried out by Friedlingstein et al. (2006, C4MIP) pointing out the significance and considerable uncertainty of the associated processes if they are included in coupled climate models. Feedback processes can add up through small annual increments on climate sensitivity to a sizable feedback after several decades or centuries.

In this work package we will "harvest" on the new knowledge created in the project through newly developed Earth system model components (WP1 – WP4). The climate feedbacks at the centennial timescale and the influence of new components on the climate sensitivity are quantified.

We are here interested in the overall expected feedback strength of the new components added to the climate prediction systems on these time scales. We want to establish whether a certain key feedback suggests the need for a revision of mitigation measures such as emission reductions of greenhouse gases, or points out the possibility for "unpleasant surprises" such as strong positive feedbacks to climatic forcing.

We will confront the results of scenarios including the new feedback components with previous results which do not include those. We will thus establish what we gain through inclusion of the new model components with respect to (a) overall sensitivity of the climate system, (b) importance of single feedback processes contributing to climate change, and (c) improved (= more realistic) uncertainty quantification.

The feedbacks to physical climatically relevant state variables of importance to the Earth's energy budget – the Planck temperature response, water vapour, lapse rate, surface albedo, and cloud feedbacks – will be calculated consistently in the various model simulations for all contributing GCMs using the "partial radiative perturbation" method (e.g., Soden and Held, 2006). This coherent method in all GCMs will improve the understanding of the real model spread (at least for the European sample). The quantification of the individual feedback processes allows understanding in detail the impact the model improvements by WP1-4 have on climate sensitivity. This is particularly important for the influence of WP2 on the cloud feedback and of WP4 on the surface albedo feedback.

As for the carbon cycle feedback, time series of standing carbon stocks on the different carbon pools of the Earth system in the various model systems as well as the carbon fluxes between the subsystems will be analysed for quantification.

1.2.8 Impacts and scenarios (WP8)

Work packages 1-7 dealt with incorporation of new components into ESMs and produced scenarios both without and with these new components, at both centennial and decadal time scales. Work package 8 feeds this information and data to the integrated assessment and impact models of selected, important sectors (climate policy, hydrology/water resources, primary production/agricultural production), with the aim to understand and quantify additional impact characteristics which may result from incorporating the new components into ESMs. The scenario analysis will focus on the consequences of feedbacks for assumptions underlying the original scenarios – and more specifically, assess the consequences of feedbacks for post-2012 climate policy (8.1). The analysis of impacts will be performed at the global scale (8.2) and for a few selected regions, Arctic, Mediterranean and Amazon (8.3), where additional regional feedbacks may be active. Important linkages exist between impact assessments and scenarios. In most cases, physical climate change is only one of the factors that determines impacts and vulnerability of local communities.

All studies summarized in IPCC AR4, have been performed on the basis of one or two IPCC scenarios, which were used to drive off-line impact models. Only in exceptional cases were multiple ensembles of GCM runs used, giving some insight into the variance of the impacts due to differences between models and their initial conditions. COMBINE will attempt to attribute an incremental difference and variance of selected impact variables due to new components and feedbacks incorporated into ESMs. This will provide an important new insight into the robustness of global and regional climate impact assessments. Another inconsistency in IPCC reports is the fact many, if not all, quantitative impact studies summarized in Working Group 2 reports are based on previous generation (TAR) of climate scenarios and not on IPCC AR4 scenarios. This is due to the time lag between the climate scenario production and the time needed to execute and publish climate impact studies. In this study, we will perform a fully consistent impact assessment, using both the official IPCC AR5 runs by the ESMs/GCMs which are involved in COMBINE project, as well as with "additional runs" with the new models after additional components and feedbacks have been incorporated. A third drawback of the IPCC analysis is the inconsistencies between socio-economic scenarios used to generate the emission scenarios (SRES) and the scenarios which are used to drive the impact models. An important aspect of this is to feedback information from the ESM/GCM runs back into the integrated assessment models that have created the scenarios – to evaluate the impact of the new information for climate scenarios and policy making. COMBINE will make an attempt to use a fully consistent set of drivers and climate scenarios to drive impact models. We will build on recent approaches (see Hibbard, 2007, Moss, in preparation) where ESM models are run on the basis of detailed output of Integrated Assessment Models (IAM) models, while in turn ESM output is forwarded to the IAM models. By feeding back the information of the new generation ESM into IAMs (e.g. IMAGE, Bouwman et al, 2007; van Vuuren et al. 2007) it is possible to assess what new climate and earth system feedbacks may imply for climate policy targets.

Finally, we hypothesize that some of the regional feedbacks in the Earth system, which are not resolved or parameterized in global models (Kabat et al 2004), can modulate the global climate change signal in certain regions. We will quantify some of these feedbacks in three regions with contrasting climate conditions (the Arctic, the Mediterranean, and the Amazon).

1.3 S/T methodology and associated work plan

The overall methodology follows the concept explained in section 1.1. ESMs existing at the beginning of the project will be used as a base for the incorporation of new components (cf. Table 1.1.2) The ESMs including the single new components will be validated against analyses and observational data. These tasks are organized in WP1 to WP5. ESMs existing at the beginning and new ESMs including single and combined new components will be constructed, tested and used in WP6 and WP7 for decadal climate predictions and centennial climate projections, respectively. WP6 and WP7 analyse the effect of the new components on the modelled predictability and the feedback mechanisms, respectively. The initial reference simulations will be submitted to the IPCC AR5 data archives (while later simulations will end after the deadline for the submission of data). WP8 will use data of decadal climate predictions and centennial climate projections of WP6 and WP7 for impact analyses, at the global and regional scale, and for studying feedbacks in 3 different regions. Further WP8 will combine the ESM data and integrated assessment modelling to find revised scenarios. This workflow is depicted in the Pert diagram (section 13 iv). The methodologies of the 8 scientific work packages are explained below.

1.3.1 Carbon and nitrogen cycle (WP1)

In this work package new components for the C and N cycle are incorporated in Earth System Models (ESMs) and their performance analysed and evaluated. The work will be split into 3 phases: incorporation of individual new components into the ESM, coupling together of all new components in the ESM, analysis and evaluation of the model including the new components. In the first phase, the following new components will be implemented in the ESMs, as detailed for the individual models in Table 1.3.1:

1. **Inclusion of land-use change**. ESMs should be driven by human induced land cover changes (eg. deforestation). ESMs will quantify the biophysical and biogeochemical implications of these surface changes (METO, CNRS, MPG, KNMI, MF-CNRM, UiB).
2. **Prognostic land and ocean nitrogen cycle**. Nitrogen is a key control on both land and ocean carbon cycle. Mineralization processes also induce emissions of N2O, a greenhouse gases with a century-long life time (METO, CNRS, MPG, UiB). Coastal zones are poorly represented in ESMs, they are the key transfer region between the land and the open ocean. Biogeochemistry of marginal seas, including nitrogen cycle will be implemented in ESMs (UiB)
3. **Permafrost and methane emissions**. Potential melting of the permafrost and large release of CH4 could be an important positive feedback that we need to quantify. It has the potential to be as high as the existing climate-carbon cycle feedback (METO, CNRS).
4. **Wetlands and methane emissions**. Wetlands are the largest present day natural source of methane. Their extent and rate of emission are directly controlled by climatic conditions (METO, CNRS, KNMI).
5. **Biomass fires** Natural and human-induced fires play a key role in CO2, CH4, trace gases and aerosols emissions but also on vegetation dynamics. Climate change is likely to affect the extent and frequency of fires (METO, CNRS).

Table 1.3.1 ESMs developed to incorporate new components (Y=yes, N=no)

Partner	*Land use*	*Nitrogen cycle*	*Permafrost*	*Wetlands*	*Fire*
HadGEM	Y	Land+Ocean	Y	Y	Y
IPSL-ESM	Y	Land+Ocean	Y	Y	Y
COSMOS	Y	Land+Ocean	N	N	N
EC-EARTH	Y	N	Y	Y	N
CNRM-CM	Y	N	N	N	N
NOCLIM	Y	Ocean	N	N	N

In the second phase of the work package, each ESM will be set up to couple together and run all of the new sub-components implemented in the first phase. Interactions between sub-components may be just as important to resolve properly as interactions between each component and the climate system.

In the third phase, short idealised experiments will be utilised to assess the impact of each new component on the carbon cycle and the climate. An extensive array of observational data will be used to critically evaluate and constrain each model component and therefore reduce uncertainty in the interactions and feedbacks. Model evaluation will be a responsibility of each group, but coordination of the activity will be lead by MPI-BGC.

Permafrost soil processes are incorporated together with WP4. The development on permafrost hydrology will be performed in WP4. WP1 will develop the carbon and methane sources models for permafrost soils.

Centennial climate change simulations in order to evaluate the implications of these new components will be performed in WP7.

1.3.2 Aerosols, clouds and chemistry (WP2)

By using several ESMs coupled to a complex aerosol-chemistry module we seek to understand possible changes to robust regional and global signals, such as:

- Are shifts in the circulation regimes a consequence of the aerosol forcing across different ESMs?
- What is the effect of the large regional surface forcing by aerosols and associated changes in the hydrological cycle on vegetation, biogenic sources and sinks?
- Can we assemble enough knowledge on different feedbacks between biosphere, climate, and atmospheric aerosols and gases to identify major positive or negative feedbacks in relation to IPCC scenarios?

Specific objectives:
In order to address these questions, it is proposed to develop and include chemistry, cloud and aerosol modules for ESM's that:

1. Provide an improved description of sub grid-scale aerosol-cloud interactions
2. Couple tropospheric chemistry with aerosols and clouds
3. Include feedbacks with vegetation considering the role of carbon- and nitrogen cycle:

To address item 1, the EC-EARTH, IPSL-ESM and the COSMOS model system will be used. The current treatment of sub grid-scale cloud effects in the COSMOS-ESM (ad hoc tuning of cloud optical thickness) will be replaced by cloud variability derived from model prognostic variables. A sectional aerosol module for large-scale applications to COSMOS-ESM will be implemented to account for aerosol micro-physical processes, which allows to describe the aerosol activation in warm clouds, ice-clouds, and to link the aerosol dynamics with the cloud properties. We will also implement a double-moment cloud microphysics scheme with prognostic cloud droplet and ice crystal number concentrations, which is nothing that any AOGCM contributing to chapter 10 of the IPCC AR4 report had. By accounting for heterogeneous freezing processes, we will investigate the influence of aerosols on mixed-phase/cirrus clouds with impacts on the radiative forcing of aerosols and on the hydrological cycle.
To address item 2, heterogeneous processes on aerosol surfaces and on cloud droplets for major species involved in the O3 cycle will be implemented. This entails the coupling of aerosol-chemistry and cloud interactions within the ESM. The impact on the radiative forcing and for cloud feedbacks will be investigated. Also, the formation of ammonium nitrate in the INCA model and the evaluation of deposition and concentration of the gaseous and aerosol nitrogen species will be parameterized. Adequate parameterisation of the nitrogen fluxes at the interfaces of atmosphere and biosphere need to be developed and implemented into the coupled ESM model. This enables studying the impact of modifications in the radiative forcing and cloud feedbacks from the heterogeneous processes on aerosols and cloud droplets. It also evaluates the effect of coupling of the globally relevant nitrogen component fluxes being exchanged between atmosphere and vegetation/ocean.
To address item 3, a canopy exchanges model to explicitly simulate the net atmosphere-biosphere exchanges of aerosols and reactive trace gases, including oxidized and reduced nitrogen in addition to volatile organic carbon aerosol precursors, is consistently coupled to the COSMOS and EC-Earth's representation of exchanges of momentum, energy, moisture and CO2. This implementation will allow assessing the net gaseous and aerosol exchange flux of reactive N and C between ecosystems and the atmosphere and to consider the atmospheric- and biogeochemistry interactions through the role of nitrogen and ozone deposition to ecosystems. It will also allow studying the feedback loop including biogenic aerosol loading of the boundary layer effecting radiation, cloud formation and precipitation, in turn affecting atmosphere-biosphere exchanges through changes in stomatal exchange (photo-synthesis, dry deposition, and biogenic emissions), boundary layer mixing and wet deposition.
The ESMs including these improved modules will be used in the decadal predictions described in WP7. They will be validated with data from field campaigns in specific locations and satellite products.

1.3.3 Stratosphere (WP3)

The starting point is given by the availability of atmosphere general circulation models with the capability to resolve stratospheric dynamical processes and including physically based parameterization of the momentum flux deposition from sub-grid scale (gravity) waves. WP3 will contribute to the COMBINE objective of advancing climate models by focusing on improving the modelling of the processes associated with increased vertical resolution and on the inclusion of a dynamical stratosphere.

Specific objectives:

- Improve the understanding and the modelling of the stratosphere - troposphere dynamical feedback. Evaluate the implication of the stratosphere troposphere feedback for surface climate predictability on seasonal to decadal timescales.
- Reduce uncertainties in the exchange of water vapour and other gases between the troposphere and the stratosphere. Reduce uncertainties in the distribution of water vapour in the upper troposphere.

The focus of WP3 is on the representation of the stratosphere - troposphere dynamical feedback in a model system without fixed surface boundary condition, e.g. with an atmospheric model (resolving the stratosphere) coupled to a dynamical ocean model. The availability of a small pool of such new ESMs will allow for the first time an estimate of the uncertainties introduced by the coupling to the ocean model on the stratosphere - troposphere system and the determination the aspects of the stratosphere-troposphere feedback that are robust across the available models.

Atmospheric general circulation model resolving the dynamical stratosphere are defined to be models with top above the stratopause. In addition, it is required to incorporate physically based parameterizations of the momentum flux deposition from sub-grid scale (gravity) waves.

The dynamical stratosphere will be incorporated into the ESMs (CMCC, COSMOS, EC-EARTH, IPSL-ESM and METO) and the climate stability of the new model systems will be demonstrated in control simulations.
A 20th Century hindcast simulation will be carried out to investigate the role of the stratosphere troposphere dynamical coupling (against the state of the art modelling, e.g. IPCC AR4) for the historical period, for which we have observations. This will give the background expertise for the interpretation of the results of the runs in WP6 and WP7 into the future.

Prototype versions (including a stratosphere not necessarily at fine vertical resolution) of the new systems will be used in the phase 1 runs of WP6 and/or WP7 (CMCC, COSMOS, and EC-EARTH). The modelling systems that will participate to the second phase runs of WP6 and/or WP7 (EC-EARTH, CMCC, COSMOS, METO and IPSL-ESM) will include an improved stratosphere at fine vertical resolution and/or one or more additional new components from WP1 (carbon cycle), WP2 (aerosol and chemistry) and WP4 (sea-ice and permafrost) and/or initialisation techniques from WP5.

Within WP3, the analysis of the simulations from the new model systems will be targeted to assess the modelled stratosphere troposphere feedbacks and the role of the improved vertical resolution near and above the tropopause, as well as their robustness across models. It is expected that the outcome of this assessment will be a better understanding of the role of the stratosphere in climate and in climate variability and change. The assessment will cover (1) the Artic and Europe regions in winter for evaluating the role of the dynamical coupling on surface climate predictability on seasonal to decadal time scales. This part will make use of analysis of surface climate and variability from WP6; and (2) the troposphere stratosphere system in the tropics for evaluating the influence of the quasi-biennial oscillation (QBO) and the improved vertical resolution on vertical exchanges, water vapour distribution, radiative–clouds feedbacks (in collaboration with WP7) and their implication for tropical tropospheric variability.

1.3.4 Cryosphere (WP4)

The aim of this WP is to incorporate three main components of the cryosphere into ESMs: polar ice-sheets, sea-ice and permafrost. The WP will take advantage of existing models of these components, which have been used in a stand-alone mode but either have not been introduced into ESMs or in a rather simple manner. Therefore the focus of this WP will be to develop coupling methods of the new cryosphere components with the atmosphere, the land surface and the ocean, and to assess the improvements by validation against observations and regional model output.

Specific objectives:
1. Coupling of Greenland and Antarctic ice sheet models to ESMs.
2. Development of new components in sea ice models and improvement of sea ice coupling in ESMs.
3. Introduction of models representing the thermal and hydrological aspects of permafrost (the carbon cycle aspects of permafrost will be implemented in WP1).

To address item 1, existing ice-sheet models will be used. The focus will be on developing water and energy conserving methods to couple these ice sheet models to ESMs. One challenge is to accommodate for the different spatial and temporal scales involved. The downscaling of the ESM outputs will therefore be developed with the guidance of regional climate models. We will redesign or modify existing coupling methods so that they satisfy the criteria of water and energy conservation. In addition, special attention will be paid to ice sheet ocean interaction around Antarctica. Parameterisations for the ice shelf – ocean coupling will be developed based on existing ones and validated by comparing with a regional atmosphere-ice-shelf-ocean model from CNRS-LGGE.

To address item 2, work along two main directions will be performed: (1) Incorporating processes within sea ice models to better represent those categories of ice that are the most fragile, e.g. interactions between waves and newly formed ice, (2) Accounting for processes at the ice – atmosphere interface, e.g. melting ponds at the surface and snow processes. This will lead to a more realistic representation of the sea ice surface characteristics such as its albedo, which is extremely important for surface energy balance. The above developments will be guided by comparisons with in-situ and satellite observations and special consideration will be given to the use of flux-conserving algorithms and adequate tiled coupling techniques, so that the energy and water budgets are ensured and that no drift results from the inclusion of these new processes. The sea-ice model developments in WP4 will be made in close collaboration with the sea-ice initialisation effort in WP5 to ensure maximum coherence in the parallel developments.

The development of permafrost modules (item 3) will be carried out in collaboration with WP1. WP4 will implement representations of the thermodynamical and hydrological processes related to permafrost. This implies the computation of temperature and humidity profiles in the ground, much deeper than in the current land surface models. The depth of the seasonally melted upper permafrost will be diagnosed from this model, allowing the assessment of its impacts on surface hydrology (run off, wetlands). Again, special care will be dedicated to the water and energy conservation of the newly implemented schemes.

The expected outcome of WP4 is not only the improvement of sea-ice models and the implementation of ice sheet and permafrost in EMS, but also a new coupling method between these cryosphere components and the ESMs that is consistent, efficient and mass and energy conserving. The coupled model systems will contribute to an improved climate prediction for the next decades (WP6, in which the role of sea-ice will be assessed) for the next century taking all cryosphere feedbacks into account (WP7). Improvements will include reassessment of sea-ice evolution, ice shelf-ocean interaction, altitude-albedo feedback, freshwater flux to the ocean (contribution of ice-sheets to sea-level rise) and methane emissions from permafrost (with WP1 partners).

1.3.5 Initialisation (WP5)

The work developed in this work package is necessary to take advantage of the predictability of natural internal variability on decadal time scales and of the valuable information given by the existing global observing systems. It aims to initialize the ocean and sea ice components, which are the main contributors to the decadal internal variability of the climate system, by combining observations with model estimates, in a attempt that the information provided by the initial conditions is optimally projected into the future. This work package will provide initial conditions for the decadal forecasts in WP6, as well as an assessment of the most suitable initialisation methodology for decadal time scales. The activities carried out in this work package fall into two main categories: ocean initialisation and sea ice initialisation. In addition, there will be an assessment of different initialisation strategies.

Specific objectives

- Implement and assess initialisation of sea ice
- Implement and assess initialisation of ocean with different techniques
- Implement and assess initialisation strategies for dealing with model errors
- Initialise the decadal forecasts to be carried out in WP6

Ocean initialisation

Initialisation strategies must deal with model errors, which cause forecasts to drift away from the observed state towards the imperfect model climate. Three possible strategies are:

1. Offline empirical hindcast correction. The model is initialised with actual observations, and the forecast bias is removed by an *a posteriori* empirical correction computed from a series of hindcasts. This is the approach adopted for seasonal forecasts (Stockdale et al 1998), where it has been demonstrated that

assimilating ocean observations improves the skill of the predictions (Alves et al 2004, Balmaseda et al 2007).

2. Anomaly initialisation/model attractor. The model is initialised with observed anomalies added to the model climatology, typically obtained from transient simulations. This is the approach adopted for previous decadal forecasts (Smith et al., 2007, Keenleyside et al., 2008).
3. Integrated empirical forecast correction/Real world attractor. The model is initialised with actual observations as in (1), but empirical corrections are applied during the forecast phase to prevent model drift. These corrections are diagnosed from the assimilation phase. This strategy potentially offers the highly desirable advantage of avoiding expensive spin-up and transient integrations, thereby enabling higher resolution forecasts to be made, and allowing initialisation to be easily combined with other new components (WP1-4).

This task will implement the initialisation of the ocean component in several coupled models using one or more of the above strategies: EC-EARTH (strategies 1, 2, and 3), HadCM3 (strategies 1, 2 and 3), HadGEM (strategy 2), COSMOS (strategy 2) and CMCC (strategy 1). This task will provide the initial conditions for integrations to be carried out in WP6. These will also take advantage of existing ocean reanalyses conducted under previous EU projects (ENACT, ENSEMBLES) to sample the uncertainty in ocean initial conditions. The initialisation will make use of the forcing fluxes provided by ERA-40 and ERA-interim atmospheric reanalysis, and the existing ocean observing system.

Sea ice initialisation

Sea ice is an important component of the climate system. In addition to high latitude impacts, sea ice influences climate sensitivity through the ice-albedo feedback and the meridional ocean circulation. However, there are significant errors in the rate of sea ice decline predicted by current climate models (Stroeve et al., 2007). The representation of sea ice in climate models will therefore be improved in WP4, and detailed impacts studies (WP8) will include the Arctic region. To gain maximum benefit from these improvements and assessments it is important that forecasts start from realistic sea ice distributions. Previous decadal forecasts, however, have not explicitly initialized sea ice. This work package will therefore implement and assess the initialisation of sea ice for decadal forecasts. Three sea ice models will be used, namely LIM, GELATO and HadCM3.

The challenge for sea ice initialisation is the very limited data base and to make use of existing data in the most efficient way. Special attention will be paid to deriving relationships between the ice concentration (observed) and ice thickness (not sufficiently observed, but main contributor to the memory of the sea-ice system). The impact of sea ice initialisation will be assessed in a set of test cases chosen from the period after 1978, where there are reliable observations of sea-ice concentration and SST.

Assessment of initialisation strategies

The initialisation strategies implemented for the ocean will be objectively assessed by comparing their performance in a comprehensive set of hindcasts, probably of limited length Since the short verification record is a serious limitation to measure the skill of decadal forecasts, the impact of the initialisation will also be assessed by choosing specific case studies where the internal climate variability is thought to play an important role. The choice of case studies will be guided by results from the EU ENSEMBLES Stream 2 integrations and the focus of the impact studies in WP8. The assessment will be carried out by ECMWF using EC-EARTH model.

1.3.6 Climate prediction (WP6)

In this work package, ensemble simulations will be made with state-of-the-art ESMs to explore the effects of new model components on climate predictions. To this aim, two types of simulations will be performed.

Decadal Prediction simulations

In year 1 at the start of COMBINE project, decadal predictions for the period 2005-2035 will be made. These integrations will serve principally as a benchmark to evaluate the impact on the decadal predictions of the new initialisation schemes and new model components that will be implemented in COMBINE. These runs will follow the WCRP/CMIP5 protocol so that they will also contribute to the AR5 of IPCC. The models used in the first set of runs will already include new components with respect to the AR4 models (Table 1.3.6.1).
In year 3 of COMBINE, decadal predictions will be made following the same protocol as in year 1 but now including the new initialisation schemes and new model components that are implemented in WP1-5. The year 3

simulations will be tested against the year 1 and IPCC AR4 runs in order to evaluate the impact of the new model components and new initialisation procedures on decadal predictions

<u>Potential Predictability simulations</u>
To separately test the potential impact of the new initialisation procedures and the different new model components, Potential Predictability runs are made. The aim of these runs is to investigate the potential impact of these components on the predictability. These integrations are done at lower resolution than the Decadal Prediction runs in order to have the possibility of extensive testing. The Potential Predictability runs will also be done in two streams: in year 1, control simulations and contribution to AR5; year 3 simulations performed with the inclusion of new model components and/or implementation of new initialisation schemes.

Both for the Decadal Prediction and the Potential Predictability experiments, the new components that will be used are: Land-use change and wetlands (WP1); Aerosols, cloud and chemistry (WP2); Stratosphere (WP3); Sea-Ice and permafrost (WP4); and Initialisation (WP5). The major and substantial differences between the Decadal Prediction runs and the Potential Predictability runs are that the former are performed at high resolution and with initial conditions obtained from the observations; the latter are carried out at lower resolution and the initialisation can be obtained either from observations or model simulations of the 20th century.

Table 1.3.6.1: Model set-up for Decadal Prediction runs in stream 1 (year 1) and stream 2 (year 3)

Partner	Models	Initialisation		New Model Components	
		Stream 1	Stream 2	Stream 1	Stream 2
CMCC	**CMCC**	Ocean and Sea-ice from existing analysis	Ocean and Sea-ice from WP5		
MPG	**COSMOS**	Ocean and Sea-ice from existing analysis	Ocean and Sea-ice from WP5	Stratosphere, Carbon cycle (diagnostic)	Stratosphere, carbon cycle (diagnostic), interactive aerosols & chemistry
EC-Earth: KNMI, DMI SMHI	**EC-Earth**	Initialisation from existing analysis	Ocean (ECMWF) Sea-Ice (SMHI and UCL)	Land-use and wetlands	Stratosphere (DMI) Sea-ice (SMHI, UCL) Land-use and wetlands (KNMI)
METO (only stream2)	**HadGEM**		Ocean and sea-ice from WP5		Stratosphere
CERFACS	**CNRM-CM**	Ocean from existing analysis	NEMOVAR analysis from WP5	New coupled model	Same as stream 1

Table 1.3.6.2: Model set-up for Potential Predictability runs in stream 1 (year 1) and stream 2 (year 3)

Partner	Models	Initialisation		New Model Components	
		Stream 1	Stream 2	Stream 1	Stream 2
CMCC	**CMCC**	Ocean and Sea-ice from a spin-up state	Ocean and Sea-ice from WP5	Stratosphere	Stratosphere
MPG	**COSMOS**	Ocean and Sea-ice from a spin-up state	Ocean and Sea-ice from WP5	Stratosphere, Carbon cycle (diagnostic), interactive aerosols	Stratosphere, Carbon cycle (diagnostic), interactive aerosols
EC-Earth: KNMI,DMI, SMHI, UCL	**EC-Earth**	SMHI, UCL sea-ice	SMHI & UCL sea-ice	Stratosphere (DMI) Sea-ice (SMHI, UCL) Land surface (KNMI)	Stratosphere (DMI) Sea-ice (SMHI, UCL) land-use and wetlands (KNMI)
METO	**HadGEM**	Ocean from spin-up state	Ocean and sea-ice from WP5		Stratosphere
MF-CNRM	**CNRM-CM**	Sea-ice from ERA40 analysis and Satellite obs.	ocean and sea-ice from WP5	Sea-ice	Sea-ice

1.3.7 Climate projections and feedbacks (WP7)

In this work package, long climate change simulations are carried out and analysed. The studies are split into two phases. In phase I, simulations done at the climate modelling centres for contribution to the CMIP5 are evaluated and analysed. A focus here is on the quantification of climate feedbacks in the various ESMs in a consistent way.

In phase II, simulations with a set-up consistent with the ones of phase I will be carried out and analysed. The goal of theses analyses is to quantify changes in climate sensitivity and individual climate feedbacks due to the inclusion of new important climate processes by the developments in WP 1 – WP 4.

Phase I

Among the various simulation experiments proposed for CMIP5, we select three for analyses within the scope of this project:

(a) Control simulation (anthropogenic forcings fixed to AD 1850 conditions; 100 year simulation)
(b) +1% CO_2 / year simulation (increase of the global atmospheric CO_2 concentration by 1% per year until a level of doubling is reached - approx. 70 years (until quadruppling of CO_2 plus 100 years of stabilisation – 240 years – when cryospheric feedbacks are considered); aerosol concentrations fixed at AD 1850 conditions; the carbon cycle model is used to quantify fluxes between the carbon pools consistent with the atmospheric CO_2 increase for analysis of the carbon cycle feedbacks)
(c) RCP8.5 simulation: a simulation with transient variation of atmospheric CO_2 and anthropogenic emissions of aerosols and aerosol precursor gases (as observed for 1850 – present, following the "high forcing" scenario RCP8.5 for present – 2100. For the exact set-up we will follow the recommendations for CMIP5 which remain to be detailed. The carbon cycle model is used to quantify carbon fluxes consistent with the prescribed atmospheric CO_2 levels).

The ESMs of all partners contributing to this work packages (Table 1.3.7.1) are already improved over the models used for the simulations in CMIP3, which were made for IPCC AR4. In phase I, besides a contribution to the quality control and timely accomplishment of the simulations for inclusion in the IPCC AR5 database, feedback analyses for each of the ESM simulations shall be done. A novel method for consistent diagnostics of the radiative feedbacks (water vapour, lapse rate, surface albedo, and cloud feedbacks) shall be implemented and evaluated for all of the participating ESMs. The "partial radiative perturbation" (PRP) method (Soden and Held, 2006) computes radiative forcings by greenhouse gases and anthropogenic aerosols as well as the perturbation in radiation fluxes by modifications in the respective physical quantity (e.g., water vapour distributions). With the additional information about the change in this quantity due to the anthropogenic perturbation (e.g., change in water vapour distributions at pre-industrial and doubled-CO_2 conditions), the radiative feedback can be quantified. By implementing this analysis consistently for all ESMs, an important technical source of uncertainty for the feedback processes can be suppressed (e.g., Colman, 2003; Soden and Held, 2006). This task necessitates the implementation of off-line radiation codes for each ESM and their application for the forcing and radiative perturbation computations. Also, high-frequency three-dimensional model simulation output needs to be stored and analysed for two periods of several years at the beginning and end of the simulations.

Table 1.3.7.1 Set-up of ESMs contributing to WP7 phase I

Model	*Carbon/nitrogen (C/N) cycle*	*Aerosols+chemistry*	*Stratosphere*	*Cryosphere*
CMCC	carbon			
COSMOS	carbon	aerosols	yes	
EC-Earth			yes	
HadGEM2-ES	carbon (incl. simplif..land-use change)	both		yes
IPSL-ESM	carbon	aerosols		yes (Greenland)
CNRM-CM	carbon		yes	yes
NORCLIM	carbon			

For the carbon cycle feedback we plan to build on the approach of Friedlingstein et al. (2003) and Friedlingsetin et al. (2006) separating the feedback of climate change to the carbon fluxes (γ factors for land and ocean) and the feedback of atmospheric CO_2 itself on the carbon fluxes (ß factors for land and ocean). For the new model components including more advanced representations of the nitrogen cycle, we will lump the effects of C and N cycle changes together. For the ocean, it will be necessary to separate the effects in changes of biological cycling (change in export fluxes of organic carbon and calcium carbonate, fate of particulate matter, change in oxygenation of the water column in marginal seas and respective changes in N_2O fluxes) and inorganic buffering in relation to changes in the large scale overturning and deep water production. For land carbon cycling, a key variable to follow will be soil organic carbon content in relation to temperature changes as well as the fertilisation effect at different levels of atmospheric CO2. We will also focus effort on diagnosis of the response of vegetation productivity to both elevated CO2 and changes in climate.

Besides the quantification of the global mean feedbacks in terms of feedback parameters ($W/m^2/K$), changes in the climate system response between the CMIP3 and CMIP5 simulations shall be examined in an explorative way focusing on distributions of carbon stocks, cloud fields, and snow and ice distributions (corresponding to the subsequent developments in WP1, 2, and 4).

Phase II

The second phase is further divided into two parts. The first one consists of the establishment of improved versions of the participating ESMs (Table 1.3.7.2) including the new model components developed by WP1 – WP4 and their use for new climate change simulations set-up consistently with the one of phase I. This task includes the testing of the ESM including all new components. In the three simulations analogous to phase I, the change in climate sensitivity (quantified here as the transient global-mean surface temperature increase at the time to the doubling of the atmospheric CO2 concentration in the +1%CO2/year simulations) due to the inclusion of the new components will be examined. It will be assessed how the individual radiative feedbacks change due to the inclusion of the new components (in particular, a change of the surface albedo feedback due to improved cyrosphere processes and of the cloud feedback due to improved aerosol processes are expected).

In the second part, the impact of the improvements due to the individual work packages will be investigated. For each new component, additional control and +1%CO2/year simulations will be carried out with the same set-up as in the first part of phase II, except for one component kept as in phase I. Assuming a linear combination of the changes in climate sensitivity due to each of the components, the individual contributions to modifications in sensitivity and feedback strengths can be quantified. As for the analysis of the carbon cycle feedback, additional sensitivity experiments will be carried out, where the C cycle would not see the increase in CO2 in the atmosphere. With this, the climatic (γ factor) changes in the C cycle can be separated from the ones induced by CO2 increase in the atmosphere (ß factor changes).

Explorative studies of the changes in the response of climate system characteristics to the anthropogenic forcings between simulations in phase I and phase II will contribute to further insights in the feedback processes.

The modelling centres will provide the results of these new simulations to the publicly accessible CMIP5 data base.

Table 1.3.7.2 Expected set-up of ESMs contributing to WP7 phase II

Model	*Carbon/nitrogen (C/N) cycle*	*Aerosols+ chemistry*	*Stratosphere*	*Cryosphere*
COSMOS	both (incl. dyn. veg.)	both	yes (as in phase I)	Greenland
EC-Earth			yes (as in phase I)	ice sheets improved sea-ice
HadGEM2-ES	C (incl. permafrost, wet-lands, improved land use), N (land and ocean)	both	yes	yes (as in phase I)
IPSL-ESM	C (incl. permafrost, wet-lands, improved land use), N (land and ocean)	both	yes	ice sheets and improved sea-ice
CNRM-CM	C (more detailed)	aerosols + sulfur chemistry	yes (as in phase I)	ice sheets new snow scheme
NORCLIM	ocean (N cycle, marginal seas), land C (permafrost), riverine N delivery to ocean			

Scenario information for use for the phase II ESM integrations will be developed, in particular for the highest scenario proposed for IPCC assessment (Moss et al., in preparation) (i.e. a baseline to 8.5 W/m^2 in 2100). In addition information will also be prepared for the lowest scenario (i.e. peaking near 2050, then declining to ~3 W/m^2). Information available from the integrated assessment model IMAGE model will be provided to ESM models include factor such as land cover and land use maps (0.5° x 0.5°); information on crop and livestock distribution (0.5° x 0.5° maps); fertilizer and manure application (0.5° x 0.5° maps); emissions of greenhouse gases and air pollutants (globally, regionally or 0.5° x 0.5°; per sector and annual patterns); concentration of greenhouse gases and air pollutants; and population and economic detail (primary driving forces). Further scenario development will depend on specific data needs by the newly developed ESM components – and also made consistent with scenario development in phase 1 of the work of the Integrated Assessment Modelling Consortium for IPCC.

Table 1.3.7.3 Sensitivity experiments for particular new components done in part 2 of phase II

Component	*Model*
Carbon/nitrogen cycle	COSMOS, HadGEM2-ES, IPSL-ESM, CNRM-CM, NORCLIM
Cryosphere	COSMOS, EC-EARTH, IPSL-ESM, CNRM- CM

1.3.8 Impacts and scenarios (WP8)

Implication of new components of ESM models for existing climate policy scenarios
The new findings of ESM modelling as part of the current proposals could have important consequences for post-2012 climate policy. In most cases the policy implications of new ESM model findings cannot be interpreted directly. Therefore in this WP the integrated assessment model IMAGE, including a detailed description of driving forces of global change, will be applied. After comparison and interpretation of the ESMs results to those provided by the IAM community, this task will take up the information of the ESM model experiments and interpret this in terms of 1) implications of stabilization and concentration peak scenarios and; 2) implication for achieving temperature targets (in particular the EU objective of limiting global mean temperature change to 2^oC). In taking account of different implication of feedbacks, not only the consequences for the CO_2 concentration levels, but also that of N_2O, CH_4 or impacts that occur via different mechanisms (e.g. albedo) will be investigated. Implications will be reported in terms of required changes in the energy and land use in order to meet climate targets (vis-à-vis the changes required without taking into account new information) and the costs of achieving these targets – as far as possible for individual feedbacks.

Impact assessment on global and regional scales
ESM/GCM models involved in COMBINE project will produce a number of climate scenario runs both without and with the new components incorporated. For both, multi-variant statistical and attribution analysis (Trenbeth et al, 2007; Zolina et al, 2004), for precipitation and temperature fields will be performed, looking into statistics of the mean and extreme values. Following the approach by Dai et al. (2004) and Shefield (2008), we will calculate global and regional drought indices for both sets of ECMs scenarios (with and without new components), using a VIC-GLDAS global hydrological model (Haddeland et al, 2006) and analyze explicitly the change in drought indices which may result from new-components scenarios. In addition, one task aims first at evaluating vulnerability of water resources for the AR5 scenario's (without new components) and then projecting additional vulnerabilities as an effect of new ESM components, using the existing global hydrological/water resources models available at Wageningen and in Kassel: Water-LPJ (Biemans et al, 2008); VIC (Haddeland et al., 2006) and WaterGap (Alcamo et al., 2007), all of these extensively used in several parallel studies into global hydrology and water resources (WATCH), and for pan-European water scenarios (SCENES). Second, with water availability quantified, we will investigate impacts on NPP, nature and agriculture sector. We start with an "off-line" analysis using an improved LPJ-ML, which will focus on the additional effects due to new ESM components. Third, we will employ an integrated global assessment model IMAGE to investigate feedbacks with agriculture and other global economic policies. Fourth, the impacts of the AR5 climate scenarios on the terrestrial environment and hydrosphere will be investigated by inputting the AR5 scenarios to the CESR coupled system of models "LandSHIFT" (global land use-biosphere with human dimensions) & "WaterGAP" (hydrosphere with human dimensions). Using this coupled system of models enables a consistent analysis of AR5 climate impacts on changes in land and water resources. This coupled analysis will be a step towards the construction of true earth systems models –i.e. models representing the climate system, terrestrial environment, hydrosphere, as well as humans as agents of change. Finally, we will assess the uncertainties in all these water and NPP estimates, and identify regions where changes, due either to climate, land use or population growth, are likely to lead to additional (=due to new ESM components) serious water shortages or water related risks (Kabat et al, 2008).

Additional regional feedbacks and their influence on regional impacts
It is expected that in some regions of the world regional feedbacks are so strong that a modulation of the global climate change signal can occur. In COMBINE regional dynamical downscaling tools (RCM) with additional feedbacks will be applied to systematically investigate regional feedbacks in the Arctic, the eastern

Mediterranean and the Amazon. GCMs runs from WP6, both with and without the new ESM components, on decadal time scales will be used as boundary conditions for the RCMs used in all these regional impact assessments.

The Arctic case: The response of permafrost to Arctic warming is a key concern, with the potential for strong feedbacks through accelerated emissions of CH4 and CO2. Likewise, large feedbacks involving snow/sea-ice may impact strongly on the Arctic climate. A suite of dynamical downscaling runs, forced by present and improved ESMs from WP6 of COMBINE, will be performed with the Rossby Centre coupled Regional Climate Model (RCAO, Döscher et al., 2006)) and its component models over the Arctic region. This will generate an ensemble of high-resolution Arctic climate scenarios for the coming decades for use by the Arctic climate impacts community. In particular, improvements related to the initialisation and treatment of sea-ice within the ESMs will be assessed by running the RCA atmosphere-only model forced by lateral and surface boundary conditions over the Arctic derived directly from the original and improved ESMs. In this manner the impact of improved ESM sea-ice representation can be isolated within the Arctic, and the subsequent impact on simulated, high-resolution Arctic climate information can be assessed. A similar exercise will also be performed in relation to improved ESM representation of Arctic clouds and aerosols and their impact on the surface radiation budget. In this case the regional ocean model RCO will be forced by original and improved surface energy budgets derived from the WP6 ESMs. The impact on the Arctic ocean, in particular details of sea-ice, will be carefully analyzed. To address permafrost related issues specifically in the Arctic region, an interactive treatment of permafrost will be implemented within RCAO. Local feedbacks involving permafrost changes and their impact on the Arctic atmosphere chemical composition and surface structural state will be assessed and results communicated to interested Arctic stakeholders. For the main downscaling step with RCAO, an ensemble approach will be employed, this will aid in defining the reliability of simulated Arctic climate change, placing some level of probability on a given simulated change actually occurring. The ensemble approach will also be applied with the new ESM boundary conditions to aid in identifying benefits of improved process treatment with respect to key Arctic climate variables.

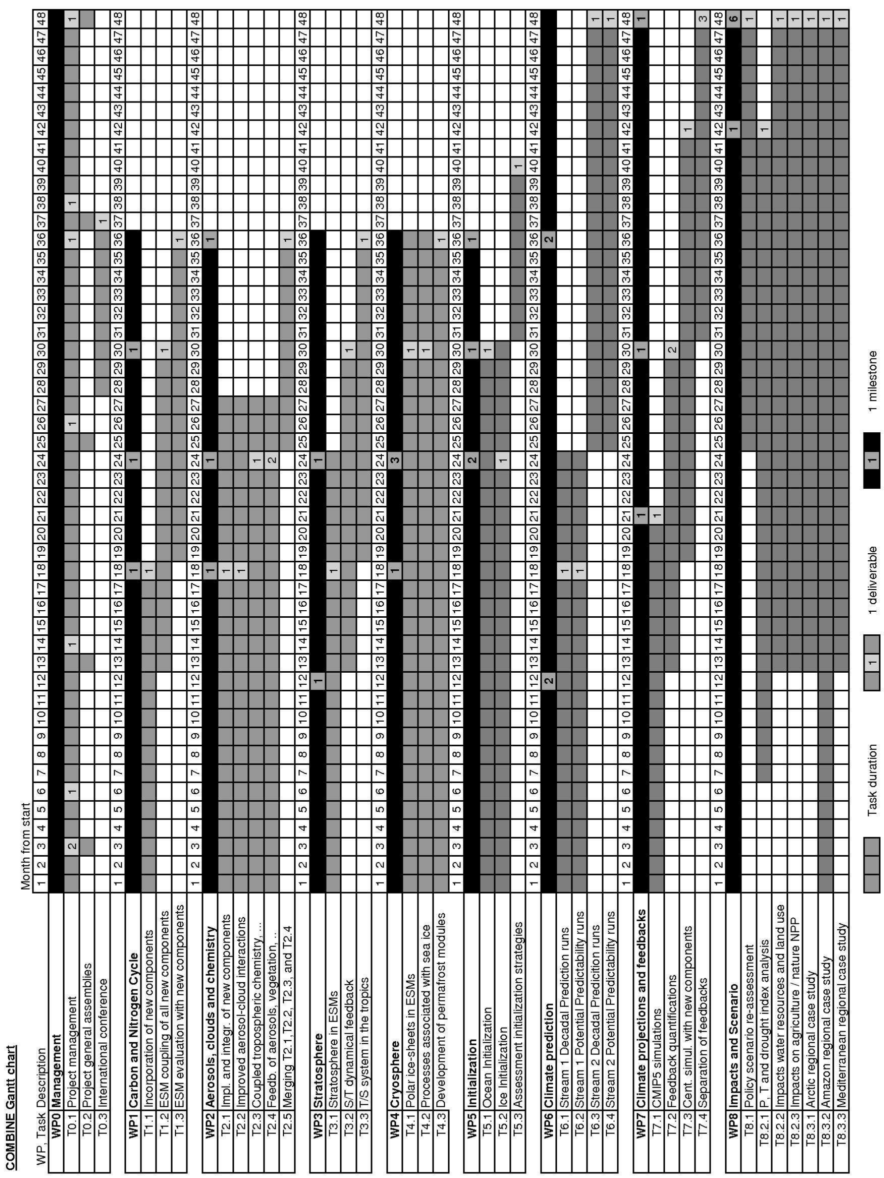
The Amazon case: The Amazon basin has been repeatedly reported as one of the “hot spots” of regional earth system feedbacks with potential consequences for the global climate system (Andreae et al., 2002). One particular focus of the Amazonia impact analysis will be to assess to what extent previous climate change scenario studies predicting a future Amazonia “dieback” (Cox et al., 2000; Friedlingstein et al 2006) need to be revisited considering more explicit dependencies between the C- and N-cycle processes in ESMs as being addressed within WP1 (and WP2). ESM components in need of improvement are C-N interactions both above and below ground, soil respiration as controlled by soil temperature and moisture, the role of fires and fire susceptibility in the system. The analysis will rely on the use of a selection of the DGVMs (e.g., LPJ, ORCHIDEE) extended with modified N-cycle modules accountings explicitly for the role of: N-limitation and N_2-fixation on NPP of these tropical ecosystems, and of N limitation in the stability of soil carbon. Also (improved) dynamic fire modules will be built into these DGVM. These novel parameterizations will build directly on knowledge and data gained in the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA).

The Mediterranean Case: The Mediterranean has been identified as a region with a particularly pronounced response to climate change (IPCC 2007). This may be due to local feedbacks, or to changes in circulation patterns and modes of natural variability (Giorgi 2006, Lionello et al. 2006). More recently, a high sensitivity of precipitation to air pollution has also become evident. Collectively, both phenomena may result in the loss of summer storms and to increased desertification and drought. Regional water resources are already under severe pressure, and the effects of climate change could pose serious threats to regional sustainability, including food security and wildfires. The simulation of the Mediterranean climate requires at least high resolution models on scales of 50km (Li et al 2006). Building on CIRCE, dynamical downscaling simulations of decadal high resolutions runs from WP6 are planned using the newest version REMO, including the aerosol model HAM. We will focus on the simulation of regional feedbacks between aerosols, clouds and precipitation. The local scales will be addresses for Greece (Thessaly and Crete) and Cyprus by applying further downscaling (double nesting with REMO-NH), hydrological modelling and agricultural assessments. Climate scenarios at high spatial resolution for Crete and Cyprus will enable (i) better planning of storage facilities (e.g., dams) based on expected spatial and temporary rainfall patterns, (ii) better founded understanding of aquifer recharge, and (iii) the distribution/cultivation of more appropriate agricultural products.

1.3 i) Overall strategy of the work plan

The overall strategy chosen here includes two phases. The 1st phase makes use of existing ESMs to produce simulations based on CMIP protocols for IPCC AR5 and to incorporate new model components and to test the resulting new ESM. The ESMs ready at the beginning of the project will be used for decadal and centennial climate change simulations, and data of these simulations will be analyzed and submitted to the CMIP5 data archives before the deadline set by IPCC for AR5. These standardised simulations will be used as a reference for the 2nd phase simulations using the new ESMs built in the 1st phase of the project. Data of the 1st and 2nd phase will be compared to isolate the single and combined effects of the new components on decadal climate predictability and on climate feedback mechanisms. The data will be analysed for the physical climate change and socio economic impacts on the global and regional scale. Revised scenarios will result from the combined use of ESM climate projections and integrated assessment modelling. This strategy allows COMBINE to make progress in the understanding of the functioning of the Earth system and in Earth system modelling, and at the same time COMBINE will be able to contribute significantly to the 5th assessment report for IPCC and to support scientifically the EC and other governing bodies for future climate protection policies. This workflow is depicted in the Pert diagram (section 13 iv), while the timing of the work packages is shown in the Gantt chart (section 1.3 ii). The management of the project is organizsed in WP0.

1.3 ii) Timing of the different WPs and their components (Gantt chart)



1.3 iii) Detailed work description broken down into work packages

Table 1.3 a: Work package list

Work package No[1]	Work package title	Type of activity [2]	Lead partici-pant No[3]	Lead partici-pant short name	Person-months[4]	Start month [5]	End month[5]
WP0	Management	MGT	1	MPG	18	1	48
WP1	Carbon and nitrogen cycle	RTD	3/2	CNRS/METO	122	1	36
WP2	Aerosols, clouds and chemistry	RTD	10/11	ETHZ/FMI	110	1	36
WP3	Stratosphere	RTD	4/2	CMCC/METO	102	1	36
WP4	Cryosphere	RTD	8/3	DMI/CNRS	108	1	40
WP5	Initialisation	RTD	9/2	ECMWF/METO	111	1	36
WP6	Climate prediction	RTD	6/4	KNMI/CMCC	166	1	48
WP7	Climate projection and feedbacks	RTD	1/7	MPG/UiB	213	1	48
WP8	Impacts and Scenarios	RTD	14/1/12	WU/MPG/MNP	145	7	48
				TOTAL	1095		

1 Work package number: WP 1 – WP n.

2 Please indicate one activity per work package:

RTD = Research and technological development (; DEM = Demonstration; MGT = Management of the consortium; OTHER = Other specific activities, if applicable in this call including any activities to prepare for the dissemination and/or exploitation of project results, and coordination activities) According to the description of the funding scheme given previously.

3 Number of the participant leading the work in this work package.

4 The total number of person-months allocated to each work package.

5 Measured in months from the project start date (month 1).

Table 1.3 b: Deliverables List

Del. no. [1]	Deliverable name	WP no.	Nature[2]	Dissemination level [3]	Delivery date[4]
D0.1	Project Flyer	0	O	PU	3
D0.2	Internal web site	0	O	RE	3
D0.3	Public web site	0	O	PU	6
D0.4	Year 1 report	0	R	RE	14
D0.5	Year 2 report	0	R	RE	26
D0.6	Year 3 report	0	R	RE	38
D0.7	Brochure	0	R	PU	36
D0.8	Conference	0	O	PU	40
D0.9	Final report	0	R	RE	48
D1.1	Summary report on incorporation and test of new components in the relevant ESM.	1	R	PU	18
D1.2	Each ESM run with multiple new components fully coupled, and performance in control state evaluated.	1	R	PU	30
D1.3	Present day simulation with each ESM using common protocol. Evaluation and, where possible, constraint of new components using available observations	1	R	PU	36
D2.1	Incorporation of stochastic clouds and radiative transfer	2	R	PU	18
D2.2	Incorporation of improved aerosol-cloud interaction in ESMs	2	R	PU	18
D2.3	Report on heteroge-	2	R	PU	24

1 Deliverable numbers in order of delivery dates. Please use the numbering convention <WP number>.<number of deliverable within that WP>. For example, deliverable 4.2 would be the second deliverable from work package 4.

2 Please indicate the nature of the deliverable using one of the following codes:
R = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other

3 Please indicate the dissemination level using one of the following codes:
PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

4 Measured in months from the project start date (month 1).

	neous processes on aerosol and cloud droplet surfaces				
D2.4	Report on the role of chemistry-aerosol-cloud interactions for the radiative forcing at 2xCO2	2	R	PU	24
D2.5	Report on vegetation-C+N-aerosol-cloud coupling	2	R	PU	24
D2.6	Report on aerosol-cloud-chemistry coupled to vegetation and C+N cycles	2	R	PU	36
D3.1	Incorporation of the stratosphere in ESMs	3	R	PU	18
D3.2	Stratosphere troposphere dynamical feedback	3	R	PU	30
D3.3	Troposphere-stratosphere system in the tropics	3	R	PU	36
D4.1	Preliminary validation of AOGCMs including new sea-ice representation	4	R	PU	30
D4.2	Validation of permafrost modules implemented in AOGCMs	4	R	PU	30
D4.3	Assessment of performance of AOGCMs coupled to Greenland and Antarctic models	4, 1	R	PU	36
D5.1	Ocean initialisation	5	R	PU	30
D5.2	Sea-ice initialisation	5	R	PU	24
D5.3	Assessment of initialisation strategies	5	R	PP	40
D6.1	Report Stream 1 decadal prediction experiments. Data stored in CMIP5 archive	6	R	PU	18
D6.2	Report on stream 1 potential predictability experiments. Data stored and available for analysis.	6	R	PU	18
D6.3	Report on stream 2 decadal prediction experiments. Data	6	R	PU	48

	stored in CMIP5 archive.				
D6.4	Report on Stream 2 Potential predictability experiments.	6	R	PU	48
D7.1	CMIP5 simulations including quality control, delivery of results to CMIP5 database	7	R	PU	21
D7.2	Radiative forcing/feedback analysis quantification CMIP5	7	R	PP	30
D7.3	Carbon cycle feedback analysis CMIP5	7	R	PP	30
D7.4	Phase II climate projection experiments including quality control, delivery of results to database	7	R	PP	42
D7.5	Radiative forcing/feedback analysis in phase II projections, comparison to CMIP5 results	7	R	PP	48
D7.6	Feedbacks of individual new components: Carbon/nitrogen cycle	7	R	PP	48
D7.7	Feedbacks of individual new components: Cryosphere	7	R	PP	48
D8.1	Implication of new generation ESMs for existing climate policy scenarios	8	R	PU	48
D8.2	Effects on precipitation and temperature fields and on global and regional drought indices due to new feedbacks in ESMs	8	R	PU	42
D8.3	Impacts of new component ESM scenarios on global water cycle and water resources	8	R	PU	48
D8.4	Impacts of new component ESM scenarios on biomass productivity and agriculture	8,1	R	PU	48

D8.5	Assessment of additional regional feedbacks and their regional impacts in the Arctic	8	R	PU	48
D8.6	Assessment of additional regional feedbacks and their regional impacts in the Amazon	8,1,2	R	PU	48
D8.7	Assessment of additional regional feedbacks and their regional impacts in the Mediterranean	8	R	PU	48

Table 1.3 c: List of milestones

Milestone number	Milestone name	Work package(s) involved	Expected date [1]	Means of verification[2]
M1.1	Prototype of carbon and nitrogen included in biogeochemistry models	1	18	Prototype model
M1.2	Prototype of methane emission models in biogeochemistry models	1	24	Prototype model
M1.3	Complete coupled system of ESM with carbon nitrogen and methane models	1	30	Model data, report
M2.1	Prototype of improved aerosol-cloud-radiation interactions included in ESMs	2	18	Prototype model
M2.2	Prototype of vegetation-chemistry-interactions included in ESMs	2	24	Prototype model
M2.3	ESM with coupled aerosol-cloud-chemistry to vegetation, carbon and nitrogen cycles	2	36	Model data, report
M3.1	Stratosphere implemented in ESMs	3	12	Validated software
M3.2	Multi-model ensemble of hindcasts from stratospheric resolving ESMs	3	24	Model data
M4.1	Prototype of coupling Greenland ice sheet models to ESMs using new coupling method	4	18	Prototype model
M4.2	Complete coupled system of ESMs and ice sheet models of both Greenland and Antarctic ice sheets	4	24	Prototype model
M4.3	Permafrost module implemented in ESMs	1,4	24	Prototype model
M4.4	ESMs including new sea-ice representation and coupling methods	4	24	Prototype model
M5.1	Sea Ice initialisation completed	5	24	Report
M5.2	Strategy 1 for ocean initialisation completed	5	24	Report
M5.3	Strategy 2 for ocean initialisation completed	5	30	Report
M5.4	Strategy 3 for ocean initialisation completed	5	36	Report
M6.1	Decadal prediction experiments Stream 1	6	12	Data sets, report
M6.2	Potential predictability experiments Stream 1	6	12	Data sets, report
M6.3	Decadal prediction experiments Stream 2	6	36	Data sets, report
M6.4	Potential predictability experiments Stream 2	6	36	Data sets, report
M7.1	CMIP5 simulations accomplished	7	21	Data sets, report
M7.2	Radiative forcing and feedback analysis for CMIP5 simulations achieved	7	30	Report

[1] Measured in months from the project start date (month 1).
[2] Show how you will confirm that the milestone has been attained. Refer to indicators if appropriate. For example: a laboratory prototype completed and running flawlessly; software released and validated by a user group; field survey complete and data quality validated.

M7.3	Analysis of phase II runs including impact of new components finished	7	48	Report
M8.1	IMAGE run with updated climate sensitivies and assessment of implications existing climate policy scenarios	8	48	Model datasets, Report
M8.2	Statistical analysis of means and extremes in precipitation and temperature fields completed; global and regional drought indices due to new feedbacks in ESMs	8	42	Model datasets, Report
M8.3	Offline water model runs with new forcings completed	8	48	Model datasets, Report
M8.4	Offline NPP model (agriculture and nature) runs with new forcings completed	8	48	Model datasets, Report
M8.5	Downscaling runs with RCAO including new permafrost submodel completed	8	48	Model datasets, Report
M8.6	Improved DGVMs for Amazon land cover classes operational; impact assessment completed	8	48	Model datasets, Report
M8.7	Downscaling runs with REMO including new cloud aerosol submodel completed; impact assessment completed	8	48	Model datasets, Report

Table 1.3 d: Work package description

Detailed descriptions for each work package are specified below in tabular form. The tables include information on the participants, the invested person months, the objectives, the description of work and the related deliverables.

Work package number	WP0	Start date or starting event:		1		
Work package title	Management					
Activity Type[1]	MGT					
Participant number	1					
Participant short name	MPG					
Person-months per participant:	18					

Objectives

- Manage efficiently the project
- Provide the communication tools for the project: Newsletter and public and internal web sites
- Organize annual general assemblies, with international guest speakers
- Organize international conference on "Comprehensive Modelling of the Earth System for Climate Prediction and Projection" in the end of the 3rd year/beginning of the 4th year
- Prepare and submit in time the annual report to the commission

Description of work

Concise description of the work in this WP and how it contributes to the objectives of the project

T0.1: Management
The coordinator supported by the Project Officer and the administrative staff are in regular contact with the Scientific Steering and Executive Committee (SSEC) of COMBINE and the Scientific Officer of the European Commission. The project office will prepare the necessary scientific and financial reports for the EC. The project office will communicate all necessary information from the EC to the participants for the preparation of the due reports and for the financial aspects. The project office will set up and maintain a public and an internal project website. A quarterly project newsletter will be produced.

T0.2: Annual general assemblies
The project office prepares the general assemblies. Together with the SSEC, the project office produces the programme of the meeting and invites international guest speakers. It plans the formal meeting for the GB, the SSECs and the panels. Together with a local organizer, the project office prepares the information for the participants: registration, local information, etc. The project office handles the financial transactions related to the general assemblies.

T0.3: International conference
The project office organises an international conference at the end of the 3rd year or the beginning of the 4th year To present and discuss the achievements of the project in a wider scientific audience. The project office will produce a flyer and a brochure.

[1] Please indicate one activity per work package:
RTD = Research and technological development; DEM = Demonstration; MGT = Management of the consortium; OTHER = Other specific activities, if applicable (including any activities to prepare for the dissemination and/or exploitation of project results, and coordination activities).

Deliverables (brief description and month of delivery)

D0.1 Kick-off meeting [MPG, 3]
D0.2 Internal web site [MPG, 3]
D0.3 Public web site [MPG, 6]
D0.4 Year 1 report [MPG, 14]
D0.5 Year 2 report [MPG, 26]
D0.6 Year 3 report [MPG, 36]
D0.7 Glossy brochure on the results from the climate change predictions and projections of the COMBINE project [MPG, 38]
D0.8 International Conference on Comprehensive Earth System Modelling for Climate Prediction and Projections [MPG, 40]
D0.9 Final report [MPG, 48]

Work package number	WP1	**Start date or starting event:**				Month 1	
Work package title	Carbon and nitrogen cycle						
Activity Type[1]	RTD						
Participant number	1	2	3	5	6	7	22
Participant short name	MPG	METO	CNRS	MF-CNRM	KNMI	UiB	UNIVBRIS
Person-months per participant:	18	22	29	6	18	22	7

Objectives

- To deliver new carbon and nitrogen cycle components in existing state-of-the-art ESMs
- To include terrestrial emissions of methane in order to evaluate their with feedback with climate change
- To assess and evaluate the new components and hence constrain interactions and feedbacks

Description of work

T1.1: Incorporate new Earth System components into ESMs

In the first phases, the following new components will be implemented in the ESMs: Inclusion of land-use change, prognostic land and ocean nitrogen cycle, permafrost and methane emissions, wetlands and methane emissions, biomass fires and marginal seas

MPG: (MPI-MET):
(1) Include the simulation of the marine nitrogen cycle in the HAMOCC5 model as component of the MPI-M Earth System Model.
(2) Include the simulation of the terrestrial nitrogen cycle into the JSBACH model as component of the MPI-M Earth System Model. Account for agricultural land use (non-natural vegetation, fertilizer application) and landuse change.
(3) Coupling of the JSBACH and HAMOCC Nitrogen components by atmospheric and riverine nutrient transport.
[6 months altogether]

METO: Development of Nitrogen model in TRIFFID and HadOCC, the land and ocean biogeochemical cycle models of HadGEM2. Development of permafrost, wetlands, and fire processes and emissions in HadGEM2 along with continued development of treatment of land-use change [14 months]

CNRS: Development of Nitrogen model in ORCHIDEE and PISCES, the land and ocean biogeochemical cycle models of IPSL-ESM. Development of methane emission models (permafrosts , wetlands, and fire) in ORCHIDEE [14 months]

MF-CNRM: set up coupling between CNRM-CM and IMAGE to be able to study the impact of land-use change on carbon fluxes [6 months].

KNMI: Inclusion of land use maps, wetland representation (including CH4 emissions from it) and terrestrial carbon cycles in EC-EARTH [9 months]

UiB: Refine the simulation of the marine nitrogen cycle in the ocean model in MICOM-HAMOCC

1 Please indicate <u>one</u> activity per work package:
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placing emphasis on anoxia-N_2O relations in sediment and water column, introduce continental inputs of nutrients and carbon from rivers, accounting for the effect of shelf seas on global scale. Introducing land use change in the terrestrial biosphere model [10 months]

T1.2: In the second phase of WP1, each ESM will be set up to couple together and run all of the new sub-components implemented in the first phase. Interactions between sub-components may be just as important to resolve properly as interactions between each component and the climate system. Comparison of results between different groups.

MPG (MPI-MET): Perform coupled control run and contribute to inter-comparison of nitrogen-cycle related fields (N2O, NO3, N2, and NH3 in water and air) [3 months]

METO: Control pre-industrial simulations of new components in an offline mode first, such as within JULES. Same, but within HadGEM2. Evaluation and correction of eventual bias and drift in the ESM [6 months].

CNRS: Control pre-industrial simulations of new components in an offline mode first. Same, but within the IPSL-ESM. Evaluation and correction of eventual bias and drift in the ESM [6 months].

UiB: Revised carbon cycle modules for land and ocean will be coupled to the Bergen Climate Model. Spin-up of a new control run and quality check of results against observations [5 months]

T1.3 In the third phase, present-day experiments will be utilised to assess the impact of each new component on the simulated carbon and nitrogen cycle and the climate. An extensive array of observational data will be used to critically evaluate and constrain each model component and therefore reduce uncertainty in the interactions and feedbacks

MPG (MPI-BGC): derivation of general patterns from in situ and remote sensing carbon cycle related observations (e.g., FLUXNET, NPP database, fAPAR data); organizing model evaluation against contemporary carbon cycle datasets. [9 months]

MPG (MPI-MET): Estimate the importance of the nitrogen cycle for the carbon cycle (e.g. marine biological pump, terrestrial CO2 fertilization and soil respiration). Estimate N2O flux-changes from ocean and land to atmosphere from climate change scenarios and their potential for climate feedback. [3 months]

METO: present day simulations of HadGEM2 using a common protocol accounting for observed changes in land cover changes, fossil fuel emissions and Nitrogen deposition [6 months].

CNRS: present day simulations of IPSL-ESM using a common protocol accounting for observed changes in land cover changes, fossil fuel emissions and Nitrogen deposition [6 months].

KNMI: Evaluate interaction between carbon cycle and wetland hydrology in wetland dominated areas in high latitudes and tropics using present day simulations [5 months]

UiB: BCM simulation including the new components for 1850-2000 including land cover changes, fossil fuel emissions, and river load data for nutrients [6 months]

Deliverables (brief description and month of delivery)

D1.1: Written summary on incorporation and test of new components in the relevant ESM. [All Groups. month 18]

D1.2: Each ESM run with multiple new components fully coupled, and performance in control state evaluated. [All groups with more than 1 new component. month 30]

D1.3: Present day simulation with each ESM using common protocol. Evaluation and, where possible, constraint of new components using available observations. [All Groups. month 36]

Work package number	WP2	Start date or starting event:		Month 1		
Work package title	Aerosols, clouds and chemistry					
Activity Type[1]	RTD					
Participant number	3	10	11	14	15	
Participant short name	CNRS	ETHZ	FMI	WU	UHEL	
Person-months per participant:	31	31	16	16	16	

Objectives

- Provide an improved description of subgrid-scale aerosol-cloud interactions by:
  - Including aerosol interactions with warm, mixed-phase and ice clouds
  - Investigate the importance of aerosol-cloud interactions for the radiative forcing and for cloud feedbacks at a time of doubled CO_2 concentrations
- Couple tropospheric chemistry with aerosols and clouds to assess:
  - Effect of cloud processing on chemical composition and aerosols
  - Heterogeneous processes within cloud droplets and on aerosol surfaces
- Include feedbacks with vegetation considering the role of carbon- and nitrogen cycle:
  - Biogenic emissions and canopy exchanges of reactive NMVOC and nitrogen relevant to the uptake of CO_2 and ozone and production of biogenic aerosols containing organic carbon and nitrogen
  - N input to ecosystems through gaseous and aerosol deposition and its impact on biogeochemistry

Description of work

T2.1: Implementation and integration of new components

Implementation of stochastic treatment of clouds and radiative transfer to the COSMOS-ESM enables to account for the subgrid-scale clouds and their interaction with radiative transfer. The current treatment of subgrid-scale cloud effects in the COSMOS-ESM (ad hoc tuning of cloud optical thickness) will be replaced by cloud variability derived from model prognostic variables.

Implementation of a sectional aerosol module for large-scale applications to COSMOS-ESM enables to accurately account for aerosol micro-physical processes. Description of aerosol cloud activation in warm clouds, and possibly in ice-clouds, constitutes a sink term for the aerosol population thus to be estimated. This also enables to link the aerosol dynamics with the cloud properties.

Partners: ETHZ, FMI

T2.2: Simulations with improved aerosol-cloud interactions

The EC-EARTH, IPSL-ESM and the COSMOS model system will be used to investigate aerosol interactions with warm, mixed-phase and ice clouds as well as the importance of cloud-scale turbulence, mixing/entrainment, and cloud dynamics for aerosol indirect effects. New aerosol physics and microphysics approaches developed within the EU project EUCAARI will be integrated and tested in different ESMs. Subsequently, the importance of aerosol-cloud interactions for the radiative forcing and for cloud feedbacks at a time of doubled CO_2 concentrations will be investigated.

Partners: ETHZ, FMI, CNRS

T2.3: Simulations with coupled tropospheric chemistry with aerosols and clouds

IPSL-ESM and the COSMOS-ESM will be used to study heterogeneous processes on aerosol surfaces and on cloud droplets for major species involved in the O_3 cycle. Also the impact of cloud

[1] Please indicate one activity per work package:
RTD = Research and technological development; DEM = Demonstration; MGT = Management of the consortium; OTHER = Other specific activities, if applicable (including any activities to prepare for the dissemination and/or exploitation of project results, and coordination activities).

processing of aerosols and chemical modifications of aerosol surfaces for subsequent cloud formation will be assessed. The improved parameterization of these processes will then be merged with the improved aerosol-cloud-interactions described in T2.1 to investigate the impact on the radiative forcing and for cloud feedbacks.
Partners: ETHZ, WU, CNRS

T2.4: Analyse feedbacks of aerosols with vegetation, and the carbon- and nitrogen cycle
An explicit canopy model to simulate reactive trace gas and aerosol exchanges for implementation in a selection of ESMs (COSMOS, EC-Earth) will be coupled to the ESMs representation of energy, water and CO_2 exchanges to assess the role of reactive carbon and nitrogen in vegetation feedbacks and to assess global N ecosystem exchanges including biogenic emissions and wet and dry deposition of gases and aerosols. Here the emphasis will be placed on assessing with the ESM's changes in atmosphere-biosphere exchanges to climate change (in WP7), its impact on tropospheric ozone, formation of biogenic aerosols and N deposition to ecosystems.
Partners: UHEL, CNRS, WU

T2.5: Merging the efforts in T2.1,T2.2, T2.3, and T2.4
The different improved parameterizations developed in T2.1, T2.2, T2.3 and T2.4 will be merged in the different ESMs to investigate the impact on the radiative forcing and for cloud feedbacks. Differences in the response of radiative forcing and cloud feedback among the different ESM will be analyzed in detail in order to understand the different processes and feedbacks within the ESMs.
Partners: ETHZ, FMI, CNRS, WU,

Deliverables (brief description and month of delivery)

D2.1: Implementation of a stochastic treatment of clouds and radiative transfer to the COSMOS-ESM to account for the subgrid-scale cloud effects (FMI, 18).

D2.2: Implementation and first simulations with improved aerosol-cloud interactions in EC-EARTH and COSMOS (ETHZ, FMI, 18)

D2.3: Results of the importance of heterogeneous processes on aerosols surfaces and on cloud droplets for major species involved in the O_3 cycle (CNRS, 24).

D2.4: First investigations of the importance of chemistry-aerosol-cloud interactions for the radiative forcing and for cloud feedbacks at a time of doubled CO_2 concentrations in EC-EARTH, COSMOS and IPSL-ESM (CNRS, ETHZ, 24)

D2.5: Simulations with vegetation coupled to the carbon and nitrogen cycles in EC-EARTH and COSMOS (WU, UHEL, 24)

D2.6: First simulations with coupled aerosol-cloud-chemistry to vegetation, C+N cycles as described in T2.4 (ETHZ, WU, CNRS, 36)

Work package number	WP3	Start date or starting event:			Month 1	
Work package title	Stratosphere					
Activity Type[1]	RTD					
Participant number	1	2	3	4	8	
Participant short name	MPG	METO	CNRS	CMCC	DMI	
Person-months per participant:	12	36	12	30	12	

Objectives

- Improve the understanding and the modelling of the stratosphere - troposphere dynamical feedback. Evaluate the implication of the stratosphere troposphere feedback for surface climate predictability on seasonal to decadal timescales.
- Reduce uncertainties in the exchange of water vapor and other gases between the troposphere and the stratosphere. Reduce uncertainties in the distribution of water vapor in the upper troposphere

Description of work

T3.1: Stratosphere in ESMs
Resolve the stratosphere in the ESMs by increasing the vertical resolution, raising the model top and including physically based parameterization of the momentum flux deposition from sub-grid scale (gravity) waves. Demonstrate the capability of the new model systems in control simulations. Perform hindcasts for the 20th Century for providing the initial model state (including atmosphere and ocean) for WP6 predictability runs and for model validation against standard observationally based tests. Evaluate stratospheric variability on decadal timescales from the hindcasts of the 20th Century.
[MPG, METO, CNRS, CMCC, DMI]

T3.2: Stratosphere – Troposphere Dynamical Feedback
Assessment of stratosphere-troposphere dynamical feedbacks in the decadal predictability and prediction runs performed in WP6. Determine the mechanisms of the influence of the extra-tropical stratosphere, acting at intra-seasonal time scales, on the tropospheric winter climate, with focus on the Arctic and Europe. Include supporting numerical experiments and their analysis with the respective atmospheric subcomponent of the ESMs to assist the interpretation of the decadal and centennial runs. Analyze differences between the ESMs to understand the mechanisms of stratosphere-troposphere dynamical coupling.
[MPG METO, CNRS, CMCC, DMI]

T3.3 Troposphere-Stratosphere System in the Tropics
Evaluate the influence of the QBO and the improved vertical resolution on the troposphere-stratosphere exchange, cold-point tropopause temperature and its variations, upper troposphere water vapour distribution and the representation of tropical clouds. Analyze how radiative-cloud feedbacks in the ESMs are affected by increased vertical resolution and the QBO and their implications for tropical tropospheric variability. Determine which of the mentioned aspects of the stratosphere-troposphere system are robust across the available models.
[MPG, METO, CNRS, CMCC, DMI]

[1] Please indicate one activity per work package:
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Deliverables (brief description and month of delivery)
D3.1: Report on the incorporation of the stratosphere in ESMs [CMCC, METO, MPG, DMI 18]
D3.2: Report on the stratosphere troposphere dynamical feedback [METO, CMCC, CNRS, DMI 30]
D3.3: Report on the troposphere-stratosphere system in the tropics [CMCC, METO, MPG, CNRS, DMI, 36]

Work package number	WP4	Start date or starting event:	1			
Work package title	Cryosphere					
Activity Type[1]	RTD					
Participant number	1	2	3	5	8	13	17
Participant short name	MPG	METO	CNRS	MF-CNRM	DMI	SMHI	UCL
Person-months per participant:	9	0	33	15	21	12	18

Objectives

- Coupling of Greenland and Antarctic ice sheet models to ESMs with water and energy conserving schemes.
- Development of new components in sea ice models and improvement of sea ice coupling in ESMs.
- Implementation, in ESMs, of models representing the thermal and hydrological aspects of permafrost (the carbon cycle aspects of permafrost will be implemented in WP1).

Description of work

WP4 is organised in three tasks which objectives are to implement the ice sheet (T4.1), sea ice (T4.2) and permafrost (T4.3) components in present ESMs. In each of these tasks, which will run in parallel, a new component will be implemented in ESMs and its coupling will be evaluated. The following table summarises the effort and models provided by each partner.

Partner	*ESM*	*Greenland ice-sheet*	*Antarctica ice-sheet*	*Sea-ice*
MPG	COSMOS	SICOPOLIS		
METO	HadCM	GISM		
CNRS	IPSL-ESM	GREMLINS	GRISLI	LIM3
UCL	IPSL-ESM			LIM3
MF-CNRM	CNRM-CM	GREMLINS	GRISLI	GELATO
DMI	EC-Earth	SICOPOLIS	PISM	
SMHI	EC-Earth			LIM3

T4.1: Incorporation of polar ice-sheets in ESMs

Coupling ice-sheet models to AOGCMs involves computing the surface mass balance of the ice sheets from atmospheric output, as well as computing the changes that potentially have feedbacks to the AOGCMs, such as changes in ice cover, topography, coastlines and freshwater fluxes from the ice sheet to the ocean. For Antarctica, ice-shelf–ocean interactions have also to be taken into consideration.

- T4.1a Atmosphere – ice sheet coupling

The challenge in coupling an ice-sheet model to an atmospheric model is the computation of surface mass balance at the fine resolution of the ice-sheet model (typically ~20 km). The current coupling methods applied for stand-alone ice sheet models forced by AGCM outputs involve downscaling of temperatures and precipitations on grids of ice sheet models and empirical computation of snow mass on ice-sheet surface. These methods could result in model drifts when directly used for coupling an ice-sheet model to an AOGCM, because they do not intrinsically

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conserve water and energy between the atmosphere and the ice-sheet surface. In this task the existing coupling methods will be redesigned or modified, so that they satisfy the criteria of water and energy conservations in the Earth system. Errors diagnosed from the existing methods will be corrected at the scale of ice sheet (for Greenland) or ice-sheet regions (for Antarctica). Land-surface models including a detailed description of snow processes (such as the SISVAT model of CNRS-LGGE or ISBA-ES of MF-CNRM) will then be used to compute a realistic and physically-based mass balance over the ice sheets.

[DMI, CNRS, MPG, METO, MF-CNRM]

- T4.1b Coupling methods: ice sheet – ocean

The Antarctic ice shelves are key players in the behaviour of the whole Antarctic ice sheet because they buttress the ice flow from the interior of the ice sheet to its boundary. Ice shelves are more sensitive to ocean temperature underneath than to atmospheric temperature variations. Ocean models used in global AOGCMs are usually too coarse to allow a satisfactory representation of the ocean characteristics in the cavities under the ice shelves. We will therefore develop parameterisations of the ice-shelf–ocean interactions based on existing ones (such as the one proposed by Beckman and Goosse, 2003) but with special care for water and energy conservations.

[DMI, CNRS, METO, MF-CNRM]

- T4.1c Validation of the new coupling methods in ESMs

Coupling methods will be validated step by step, against available observations or regional model output, provided by CNRS-LGGE and DMI. First tests will be performed in forcing mode and with short coupled simulations. The full-scale test in a coupled mode will be to examine the behaviour of the ice-sheet, atmosphere and ocean in the pre-industrial simulation run in WP7.

[DMI, CNRS, MPG, METO, MF-CNRM]

Task 4.2: Inclusion of new processes associated with sea ice

In this task, two sea-ice models will be used and implemented in three ESMs. The Louvain-la-Neuve sea-ice model, LIM, developed at UCL, and its coupling to the atmosphere will be improved. The new version will be implemented in two ESMs, IPSL-ESM and EC-Earth, which will allow a comparison of the model responses to different atmospheric models. The coupling between sea ice model GELATO and CNRM-CM will be improved along the same lines, i.e. including a better representation of processes at the ice surface (snow, melting ponds).

- T4.2a: New processes in sea-ice models.

LIM has recently been improved: inclusion of a C-grid elastic-viscous-plastic rheology, incorporation of a subgrid-scale ice thickness distribution and introduction of an explicit representation of brine entrapment/drainage and of the salinity impact on sea-ice growth and decay. Within COMBINE, UCL plans to refine the representation of newly-formed ice. More specifically, based on an analysis of sea-ice data from the marginal ice zone in the Southern Ocean, they will combine a simple wave model and a parameterization for ice growth to compute the thickness and concentration of ice pancakes in LIM3. This modification should lead to a better simulation of the average ice growth and thickness in the Southern Ocean, where ice pancakes are frequently observed. A better representation of new-ice formation is also important in the Arctic especially at the Siberian coast. In addition, a parameterization of melt ponds and an improved albedo scheme will be introduced to overcome the deficiencies of summer sea ice melting in the Arctic. The sensitivity of heat fluxes to the atmosphere and the atmospheric circulation in the Arctic to these improvements in the sea ice representations will be analyzed in WP6 and WP7.
[UCL, CNRS, SMHI]

- T4.2b. New processes at the sea-ice surface and coupling methods

In the current generation of sea-ice models, including LIM3 and GELATO, the representation of snow processes, despite their importance, is rather crude. UCL will therefore replace the snow module of LIM3 by the more detailed SISVAT model (developed at CNRS-LGGE) and CNRM will

implement the surface model ISBA-ES in their sea-ice model GELATO. This will ensure a better representation of heat fluxes at the sea-ice – atmosphere interface, hence potentially affecting heat exchanges at the sea-ice – ocean bottom interface. Special consideration will be given to the use of flux-conserving algorithms and adequate tiled coupling techniques. In addition, a more sophisticated parameterisation of melting ponds at the sea ice surface will be implemented in both models (by SMHI for LIM). This will lead to more realistic sea-ice radiative properties which are extremely important in the polar response to anthropogenic forcing.
[SMHI, CNRS, UCL, MF-CNRM]

- T4.2c: Model validation

These sea-ice model developments in WP4 will be made in close collaboration with the sea-ice initialisation effort in WP5 to ensure maximum coherence in the parallel developments. Once developed, these new sea-ice components and coupling methods will be thoroughly tested by conducting simulations of the pre-industrial climate in WP7. As final step, they will be used in the climate change predictions and projections performed in WP6 and WP7.
[UCL, CNRS, MF-CNRM, SMHI]

Task 4.3: Development of permafrost modules in ESMs

The development of permafrost modules will be carried out in collaboration with WP1, which will deal with the carbon cycle aspect of permafrost.

The POPCARN model (Khvorostyanov, 2007), which includes physical and carbon cycle processes related to permafrost, will be introduced in the IPSL-ESM model. This model computes temperature and humidity profiles in the soil from energy and water conservation principles. Its domain in the vertical is much deeper than the current surface model included in IPSL-ESM, which will therefore be updated to account for input from the permafrost model. METO will perform a similar implementation with their permafrost model. In CNRM, the calculation of the depth of the active layer of the permafrost, i.e. the surface layer that melts during summer, will be implemented. The consequences of permafrost melting on surface hydrology (wetlands and runoff) will be computed and analysed in WP7.
[CNRS, MF-CNRM, METO, in cooperation with WP1]

Deliverables (brief description and month of delivery)

D4.1: Report on preliminary validation of AOGCMs including new sea-ice representation [UCL, CNRS, MF-CNRM, SMHI, month 30]

D4.2: Report on validation of permafrost modules implemented in AOGCMs (in collaboration with WP4) [CNRS, MF-CNRM, METO, month 30]

D4.3: Report on assessment of performance of AOGCMs coupled to Greenland and Antarctic models [DMI, CNRS, MPG, METO, MF-CNRM, month 36]

Work package number	WP5	Start date or starting event:		Month 1		
Work package title	Initialisation					
Activity Type[1]	RTD					

Participant number	1	2	4	5	9	13	16
Participant short name	MPG	METO	CMCC	MF-CNRM	ECMWF	SMHI	CERFACS
Person-months per participant:	6	25	12	8	26	8	18
Participant number	17						
Participant short name	UCL						
Person-months per participant:	8						

Objectives

- Implement and asses initialisation of the ocean
- Implement and assess initialisation of sea ice
- Implement strategies for dealing with model error
- Initialize the decadal forecasts to be carried out in WP6
- Assessment of the suitability of different initialisation strategies.

T5.1: Ocean Initialisation
[Task partners: METO,ECMWF,MPG,CERFACS,CMCC]

Initial conditions for the WP6 decadal integrations will be produced. These will sample the uncertainty in ocean initial conditions using reanalyses from previous EU projects (ENACT, ENSEMBLES). The initial conditions for the "real time" decadal forecast will make use of the forcing fluxes provided by the ECMWF ERA-Interim atmospheric reanalysis, which is being updated continuously (the fluxes from ERA40 end in 2002).
The following ocean initialisation strategies will be implemented:

1. Offline empirical hindcast correction (HadCM3,EC_EARTH,CMCC-ESM)
2. Anomaly initialisation/model attractor (HadCM3, HadGEM, EC_EARTH, COSMOS)
3. Integrated empirical forecast correction/Real world attractor (HadCM3, EC_EARTH)

METO will initialize HadGEM-L60 for the decadal forecasts in WP6, The initialisation of HadGEM will be done using anomaly initialisation. In addition, METO will implement the different initialisation strategies in HadCM3, aiming at an assessment of initialisation strategies for decadal forecasts, and taking advantage of the work carried out in ENSEMBLES and THOR.

CERFACS will adapt the OPAVAR ocean variational data assimilation system developed in the ENSEMBLES project to the new version of the NEMO ocean model and enable higher resolution ocean analysis. The new system, called NEMOVAR, will be used to produce ocean initial conditions using observations of surface and subsurface temperature and salinity, altimeter-derived sea level anomalies and possibly geoid information from the gravity missions.

CMCC will initialize the ocean component of CMCC-ESM for the decadal integrations in WP6. The initialisation procedure falls into strategy 1, where the ocean initial conditions will be created by assimatling the available observations of temperature, salinity and sea level with the new ocean data assimilation system.

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ECMWF will use the NEMOVAR system developed by CERFACS to create ocean initial conditions for NEMO, which is the ocean component of EC-EARTH, at 1 degree and possibly 0.5 degree resolution. These initial conditions will allow the implementation of initialisation strategies 1, 2 and 3. For strategy 2 the ocean analysis produced with the NEMOVAR system will need to be projected into the model space, by doing anomaly initialisation and possibly additional remapping. Initialisation strategy 3 requires the estimation of empirical terms for the on-line correction of model error. Both strategies 2 and 3 will be implemented in the version of the coupled model NEMO/IFS with new components.The different initialisation strategies will be assessed in WP6

MPG will use several of the existing ocean analyses in the ENSEMBLES data base for the anomaly initialisation of ECHAM5/MPIOM.

T5.2: Sea ice Initialisation
[Task partners: METO,SMHI,UCL,MF-CNRM]

Initialisation of sea ice will be implemented in three models, namely LIM, GELATO and HadCM3. The impact of sea ice initialisation will be assessed through comparison with satellite observations in a set of test cases. The second phase integrations in WP6 will make use of the results of this task, together with developments in WP4, to enable a detailed assessment of climate impacts in the Arctic to be made in WP8.

METO will be responsible for the initialisation of the sea-ice component of HadCM3, by using information from sea surface temperature and ice concentration.

UCL and SMHI will contribute to the initialisation of the sea ice model LIM for some of the decadal simulations conducted with EC-Earth in WP6. The initial state will be derived from hindcast simulations covering the last decades and using assimilation of ice concentration, velocitiy and possibly thickness of draft observational data where available. This work will be performed in a coherent way with the initialisation of the ocean model NEMO, to which LIM is coupled.

MF-CNRM will be responsible for the sea-ice initialisation of GELATO, the ice model component of CNRM-CM. As a first step, MF-CNRM will produce sea ice initial states by constraining sea ice surface temperature with ERA40/ERA-interim reanalyses, then as a second step, available satellite data will be used. In particular, the use of snow depth satellite observations to constrain the depth of snow that covers sea ice will be explored.

T5.3: Assessment of the initialisation strategies
[Task partner: ECMWF]
A specific objective assessment of the initialisation strategies developed in WP5 will be performed by ECMWF The assessment will be carried out using the EC-Earth ESM and will be based on a set of shorter climate integrations and specific case studies. The suitability of the different strategies for decadal predictions, and in general for a seamless prediction system, will be evaluated.

Deliverables (brief description and month of delivery)
D5.1: Report on implementation of ocean initialisation strategies [ECMWF, METO, CERFACS, CMCC, MPG, month 30]
D5.2: Report on implementation and assessment of sea ice initialisation [UKMO, SMHI, UCL, MF-CNRM, month 24]
D5.3 Report on the assessment of different initialisation strategies (ECMWF, month 40)

Work package number	WP6	**Start date or starting event:**			Month 1		
Work package title	Climate prediction						
Activity Type[1]	RTD						
Participant number	1	2	3	5	6	8	13
Participant short name	MPG	METO	CMCC	MF-CNRM	KNMI	DMI	SMHI
Person-months per participant:	9	31	30	12	30	12	12
Participant number	16	17					
Participant short name	CERFACS	UCL					
Person-months per participant:	24	6					

Objectives

- Quantification and analysis of decadal variability and prediction in CMIP5 simulations as compared to AR4 ESMs
- Assessment of the impact of new model components and initialisation procedures on decadal predictions.

Description of work

T6.1: Stream 1 Decadal Prediction runs.
Decadal prediction runs following the WCRP/CMIP5 protocol will be performed during the first year of the project. These runs serve as a benchmark for Stream 2 runs. Analysis of these runs and the assessment of the differences with respect to the IPCC AR4 runs will allow for a first estimate of the impacts of new components and initialisation on climate predictions.
Partners: CMCC, MPG, KNMI, CERFACS, DMI, SMHI

CMCC: Three ensemble runs with the CMCC model. Ocean initialisation will be from existing analysis. Sea-ice initialisation will be based on HADISST data set for the sea-ice extend, sea-ice thickness obtained from climatology. Analyze these runs and impact of new ocean analyses with respect to AR4 predictions. Focus will be on main modes of climate variability like NAO, AO and ENSO.

MPG: Ensemble experiments with the COSMOS model with high vertical resolution and inclusion of stratospheric processes. Ocean analysis from existing synthesis from the German contribution to the Estimating the Circulation and Climate of the Ocean (GECCO) project. Analysis with respect to AR4 runs.

KNMI: Ensemble runs with the EC-Earth model with ocean and sea-ice initialisation from anomalies incorporating the updated land surface scheme H-Tessel. These runs will serve as benchmark for the Stream 2 experiments.

SMHI: Ensemble runs with EC-Earth at T159L62 that will serve as benchmark for the Stream 2 experiments.

DMI: Ensemble runs with EC-Earth at T159L62 that will serve as benchmark for the Stream 2 experiments. In addition a small ensemble (2-3) with high resolution (T255) for analyzing the impact of high resolution.

[1] Please indicate one activity per work package:
RTD = Research and technological development; DEM = Demonstration; MGT = Management of the consortium; OTHER = Other specific activities, if applicable (including any activities to prepare for the dissemination and/or exploitation of project results, and coordination activities).

CERFACS: Ensemble runs with ARPEGE-NEMO model using oceanic initial states derived from either OPAVAR 3D-VAR analysis of from oceanic simulations forced with observed atmospheric fields. Analysis with respect of the AR4 simulations.

T6.2: Stream 1 Potential Predictability runs.
Potential prediction runs will be performed during the first year of the project to separately test the potential impact of the new initialisation procedures and the different new model components available at the start of the project. These runs are done at lower resolution than the Decadal Prediction runs.
Partners: CMCC, MPG, KNMI, SMHI, DMI, UCL, MF-CNRM, METO

CMCC: Separately testing the inclusion of realistic stratosphere from WP3. Initialisation will be taken from model spin-up.

MPG: Separately testing the impact of the inclusion of interactive carbon cycle and interactive aerosols.

KNMI: Testing of the impact of land-surface scheme

SMHI and UCL: Testing the impact of sea-ice parameterization and sea-ice initialisation.

DMI: Testing of the impact of the inclusion of high-top stratosphere.

METO: Decadal prediction runs using HadGEM(N96L38) with ocean from spin-up. No stratosphere. In the analysis the emphasis will be on the comparison with AR4 runs. This will provide a baseline upon with the impact of initialisation and stratosphere will be assessed in Streams 1 and 2.

MF-CNRM: Potential Predictability runs in collaboration with CERFACS. Same ocean/sea-ice model and ocean initialisation as CERFACS. Testing of these components by forcing ocean/sea-ice model with ERA40 reanalysis and satellite data.

T6.3 Stream 2 Decadal Prediction runs.
These runs will be carried out in the third year of the project and will follow the same protocol as the Stream 1 Decadal Prediction runs simulations. The new model components from WP1-4 will be included and the new initialisation procedure from WP5 implemented Analysis of these runs and assessment of the differences with the year 1 Decadal Prediction runs will also be conducted. There will be an explicit assessment of different initialisation strategies of WP5.
Partners: CMCC, MPG, KNMI, SMHI, DMI, CERFACS

CMCC: Decadal prediction runs with the inclusion of new stratosphere component from WP3.
New ocean initialisation procedure from WP5.

MPG: Inclusion of updated interactive carbon cycle and interactive aerosols. Inclusion updated stratospheric processes from WP3. New ocean and sea-ice initialisation procedure of WP5.

KNMI, DMI and SMHI: Inclusion of all the new components and new initialisation procedures developed in WP1-5 by those institutes of the EC-EARTH consortium and the collaborating partners ECMWF and UCL. The new components are sea-ice (SMHI, UCL) WP4, stratosphere (DMI) WP3, ocean initialisation (ECMWF) WP5, land-use and wetland parameterizations (KNMI) WP1. Analysis of the results. The coordination of the runs, data storage and data analysis will be done by the KNMI

METO: Ensemble runs with the ocean initialisation procedure developed in WP5 and the stratosphere component in WP3.

CERFACS: Ensemble runs using oceanic initial states with the NEMOVAR 3D-VAR system developed in WP5. Sea-ice initialisation produced by MF-CNRM in WP4. Anomaly nudging technique for generating initial coupled atmospheric and oceanic states.

T6.4 Stream 3 Potential Predictability runs.
Potential prediction runs to separately test the potential impact of the new initialisation procedures and the different new model components developed in WP 1-4 and the new initialisation procedure of WP5will be conducted in year 3.
Partners: MPG, CMCC, KNMI, SMHI, UCL, DMI, METO, MF-CNRM

CMCC: Testing the impact of the improved initialisation from WP5.

MPG: Inclusion updated interactive carbon cycle and interactive aerosols. New initialisation procedure of WP5. Testing and analyzing the impact of these new and updated components

KNMI: Inclusion and analysis of the upgraded land-use and wetland parameterizations of WP1 and analyzing its effects on the summer climate of Europe.

SMHI and UCL: Inclusion and analysis of the impact of the upgraded sea-ice model and initialisation of WP3 and WP5.

DMI: Testing the impact of the inclusion of high-top stratosphere component improved in WP3.

METO: Same as T6.2 but now with the stratosphere developed in WP3. Comparison with T6.2 will enable the impact of the stratosphere to be assessed. Comparison with T6.3 will enable the impact of initialisation to be assessed.

MF-CNRM: Same experiments as in T6.2 but with the upgraded sea-ice model of WP4 and the improved sea-ice initialisation from WP5. Analyzes of the results with respect to Stream 1 potential predictability experiments.

Deliverables (brief description and month of delivery)

D6.1: Report on Stream 1 decadal prediction experiments. This report contains a comparison with IPCC AR4 simulations. Data post-processed, archived and available for analysis and impact studies. Delivery of data set to CMIP5 data base (month 18). For CMCC: CMCC; for COSMOS: MPG; for EC-EARTH: KNMI, SMHI and DMI; for CNRM-CN, CERFACS
D6.2: Report on Stream 1 potential predictability experiments. This report contains the potential impact of different model components on decadal predictions. Data post-processed, archived and available for analysis and impact studies (month 18). For CMCC: CMCC; for COSMOS:MPG; for EC-EARTH: KNMI, SMHI, UCL, DMI; for HadGEM: METO; for CNRM-CM: MF-CNRM.
D6.3: Report on Stream 2 decadal prediction experiments. This report contains a statement on the impacts of new model components on decadal predictions and comparison between Stream 1 experiments and IPCC AR4 scenarios. Data post-processed, archived and available for analysis and impact studies. Delivery of data set to CMIP5 data base (month 48). For CMCC: CMCC; for COSMOS: MPG; for EC-EARTH: KNMI, SMHI and DMI; for HadGEM: METO; for CNRM-CN, CERFACS
D6.4: Report on Stream 2 potential predictability experiments. This report contains a statement on the potential impacts of new model components on decadal predictions and a comparison between Stream 1, Stream 2 experiments. Data post-processed, archived and available for analysis and impact studies. (month 48). For CMCC: CMCC; for COSMOS: MPG; for EC-EARTH: KNMI, SMHI, UCL, DMI; for HadGEM: METO; for CNRM-CM: MF-CNRM.

Work package number	WP7	**Start date or starting event:**			Month 1		
Work package title	Climate projections and feedback						
Activity Type[1]	RTD						
Participant number	1	2	3	4	5	7	8
Participant short name	MPG	METO	CNRS	CMCC	MF-CNRM	UiB	DMI
Person-months per participant:	24	54	37	10	35	21	12
Participant number	12	17					
Participant short name	MNP	UCL					
Person-months per participant:	9	11					

Objectives

1.) Quantification and analysis of climate feedbacks in CMIP5 simulations as compared to AR4 ESMs

2.) Assessment of the impact of new model components on climate sensitivity and climate feedbacks

Description of work

T7.1: CMIP5 simulations (Deliverable D7.1): Accomplishment and quality control of CMIP5 simulations, supply of output to CMIP5 database; explorative analyses of the differences in climate change signals between CMIP5 and AR4 simulations (3 simulations: control, 1%, RCP8.5)

- MPG: Quality control and diagnostics of COSMOS simulations
- METO: Simulations with HadGEM2-ES
- CNRS: Simulations, quality control, and diagnostics for IPSL-ESM
- CMCC: Simulations, quality control, and diagnostics for CMCC
- MF-CNRM: Simulations with CNRM-CM and analysis with a focus on energy conservation in the different components
- UiB: Quality control and diagnostics of NorClim simulations
- DMI: Simulations with EC-Earth (control and 1%)

T7.2: Feedback quantifications (Deliverables D7.2 and D7.3): Implementation and application of the forcing computations and "partial radiative perturbation" method for ESMs, quantification of the radiative feedbacks (water vapour, lapse rate, surface albedo, clouds)

- MPG: PRP implementation and radiative feedback quantification for COSMOS; contribution to model-intercomparison
- METO: Implementation of relevant feedback diagnostics to, but no full PRP implementation. Contribute to analysis and comparison of feedbacks across models.
- CNRS: PRP implementation and feedback quantification for IPSL-ESM; contribution to model-intercomparison
- CMCC: PRP implementation and feedback quantification for CMCC; contribution to model-intercomparison
- MF-CNRM: implementation and feedback quantification for CNRM-CM; contribution to model-intercomparison
- UiB: implementation of relevant feedback diagnostics to ESM, but no full PRP

[1] Please indicate one activity per work package:
RTD = Research and technological development; DEM = Demonstration; MGT = Management of the consortium; OTHER = Other specific activities, if applicable (including any activities to prepare for the dissemination and/or exploitation of project results, and coordination activities).

implementation, contribute to model intercomparison

T7.3: Centennial simulations including new components and feedback analyses (Deliverables D7.4 and D7.5, Milestone M7.1)
Set-up and evaluation of new ESM versions including the new components developed in WP1-4, accomplishment and quality control of new simulations. Quantification of the impact of the new components on climate sensitivity and radiative feedbacks. Analysis of the difference in climate change signals between phase I and phase II simulations.

- MPG: Set-up and evaluation of COSMOS including the new components (nitrogen cycle, dynamic vegetation; Greenland ice shield), control, 1%, and RCP8.5 simulations; quantification of climate sensitivity and radiative feedbacks; comparison to CMIP4 COSMOS simulations; contribution to model intercomparison .
- METO: Set-up and test HadGEM2-ES with multiple new components as delivered from WPs1-4. Set up and perform CMIP5 experiment design with new version of HadGEM2-ES components for 3 simulations (control, 1%, RCP8.5). Experiment set-up, quality control. Supply of output to COMBINE database, and contribute to analysis of feedbacks in new runs compared with phase 1.
- CNRS: Set-up and test IPSL-ESM with the new components as delivered from WPs1-4. Set up and perform CMIP5 experiment design with new version of IPSL-ESM components for 3 simulations (control, 1%, RCP8.5). Supply of output to COMBINE database, and contribute to analysis of feedbacks in new runs compared with phase 1.
- MF-CNRM: Set-up and test CNRM-CM with new components from WP1 and WP4. Three CMIP5 experiments will be performed (control, 1%, RCP8.5) .
- UiB: Set-up and evaluation of NorClim model including revised formulations of the ocean (nitrogen cycle, marginal seas effect) and land (permafrost effect) carbon cycles.
- UCL: Analysis of sea-ice feedback in the IPSL-ESM control, 1% and RCP8.5 simulations relative to CMIP5 simulations.

T7.4: Separation of feedbacks by new components (Deliverables D7.6 and D7.7)
Simulations with all but one new component for each of the new components developed by WP1-4, analysis of the differences in change of climate sensitivity and feedbacks.

- MPG: Control and 1%-simulations with COSMOS including all new components but the dynamic vegetation, diagnostics of the feedbacks through the nitrogen cycle; Control and 1%-simulations with COSMOS including all new components but the cryosphere, analysis of the cryosphere feedbacks.
- METO: Set-up and perform breakdown experiments to isolate contributions of different feedbacks. Contribute to diagnosis of component feedbacks including recently developed techniques and ideas for carbon cycle feedback analysis.
- CNRS: Control and 1%-simulations with IPSL-ESM including all new components but (a) the feedbacks through the nitrogen cycle and (b) the cryosphere.
- MF-CNRM: Control and 1%-simulations with CNRM-CM including all new components but the new components for the carbon cycle, analysis of carbon cycle feedbacks; Control and 1%-simulations with CNRM-CM including all new components but the cryosphere/sea-ice/new snow scheme, analysis of the cryosphere feedbacks.
- UiB: Control and breakdown experiments to separate the effects of new additions to the carbon cycle modules.
- DMI: Control and 1%-simulations with EC-Earth including all but ice sheets, analysis of ice-sheet feedbacks.
- UCL: Control and 1%-simulations with IPSL-ESM including all new components but the cryosphere (sea-ice), quantifications of sea-ice feedbacks.

Deliverables (brief description and month of delivery)
D7.1: CMIP5 simulations including report and data delivery to CMIP5 database [month 21]
D7.2: Report on radiative forcing/feedback quantifications for CMIP5 simulations [month 30]
D7.3: Report on carbon cycle feedback analysis in CMIP5 simulations [month 30]
D7.4: Brief report on evaluation of the updated ESM versions including all new components [month 42]

D7.5: Report on radiative forcing/feedback quantifications for phase II simulations and comparison to CMIP5 results [month 48] D7.6: Feedback analysis of new components in carbon/nitrogen cycle [month 48] D7.7: Feedback analysis of new components in cryosphere [month 48]

Work package number	WP8	**Start date or starting event:**			Month 13		
Work package title	Impacts and scenarios						
Activity Type[1]	RTD						
Participant number	1	2	3	12	13	14	20
Participant short name	MPG	METO	CNRS	MNP	SMHI	WU	Uni Kassel
Person-months per participant:	9	3	3	15	10	33	17
Participant number	21	22	23				
Participant short name	TUC	CYI	INPE				
Person-months per participant:	16	12	27				

Objectives

- Assessment of effects of new ESM components on greenhouse gas emission stabilisation scenarios
  and on temperature targets as input to future policy
- Assessment of global impact of climate change as simulated by improved ESM on water resources and water dependent sectors
- Assessment of additional regional feedbacks in three case study regions: the Arctic, the Mediterranean Case and the Amazon basin
- Impact assessment for water management and agriculture within the case study regions

Description of work

This WP will focus on two main areas: scenarios and impacts from current and new generations of ESMs on regional and global scale. Furthermore, impacts of additional regional feedbacks in three individual case study regions will be assessed. The regions under consideration are: the Arctic, with a very strong warming and major sea-ice albedo feedbacks, the Mediterranean, with aerosol cloud precipitation feedback in a hot spot area of global climate change and the Amazon, with its dominant role of land-use vegetation feedback. Decadal predictions runs will be dynamically downscaled to assess the addition regional feedback and to connect to local scale activities, like for Greece, Crete and Cyprus. Here the impact on water availability, water management and agriculture will be analysed.

T8.1 Implication of new generation ESMs for existing climate policy scenarios (MNP). We will interpret the information of the new ESM model experiments, using IMAGE, in terms of implications for: 1) stabilization and concentration peak scenarios; 2) achieving maximum warming targets (e.g. the EU goal of 2^{o}C). Implications will be reported in terms of required additional changes and costs in energy and land use in order to meet such policy targets.

T8.2 Impact assessment on global and regional scales

T8.2.1. Analysis of precipitation and temperature fields and of global and regional drought characteristics due to new feedbacks in ESMs (**WU**, **Princeton University and University of Seattle**). We will identify and statistically quantify changes in mean and extremes of precipitation and temperature due to incorporation of new components into ESMs through a multi-variant statistical and attribution analysis. Global and regional drought indices, for both sets of ECMs scenarios (with and without new components), will be derived using a VIC-GLDAS global hydrological model.

T8.2.2 Impacts of new component ESM scenarios on global water cycle and water resources

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1 Please indicate <u>one</u> activity per work package:
RTD = Research and technological development; DEM = Demonstration; MGT = Management of the consortium; OTHER = Other specific activities, if applicable (including any activities to prepare for the dissemination and/or exploitation of project results, and coordination activities).

(Kassel, WU). We will evaluate the vulnerability of water resources for the AR5 scenario's (from both current and new generation of ESMs, using existing global hydrological/water resources models Water-LPJ, VIC and WaterGap

T8.2.3. Impacts of new component ESM scenarios on biomass productivity and agriculture (WU, MNP) Again, we will use both AR5 and new components scenarios to investigate this time impacts on NPP and agriculture sector, both globally and for selected regions, both off-line using LPJ-M and the same model integrated into IMAGE. The latter allows to investigate feedbacks with agriculture and other global economic policies.

T8.3 Assessment of additional regional feedbacks and their influence on regional impacts

T8.3.1 The Arctic Case (SMHI) An ensemble of high-resolution Arctic regional climate scenarios will be produced using RCAO and its component models forced by current and improved ESMs. These scenarios will be run using decadal predictions made by the ESMs in WP6**.** The scenario runs will be documented and made available to the Arctic climate impact community. This exercise will be repeated for a subset of ESM scenarios, with an interactive treatment of permafrost implemented into RCAO, to analyse the regional feedback processes.

8.3.2 The Amazon case (WU, INPE Brazil, METO, CNRS) This case study will focus feedbacks especially relevant for the Amazon: stability of the soil and vegetation carbon pools and their feedbacks with climate. These feedbacks will be assessed, in order to revisit the Amazon dieback hypothesis, using LPJ and other DGVM's as improved in WP1. At INPE, a centennial time scale integration of a Global Climate Model with an improved DGVM will examine the synergistic effects of tropical deforestation, increased forest fire frequency and climate change.

T8.3.3 The Mediterranean case (MPG, TUC, CYI) We will first validate REMO(-NH) for the case study region, and use this to dynamically downscale the decadal prediction from WP6 for the Med. Region. Next we will quantify effects of additional regional feedbacks due to aerosol-cloud-precipitation interaction, as well as quantify topography induced biases. Then, after further downscaling to the islands of Crete and Cyprus impacts on water resources will be assessed using water resources management models

Deliverables

T8.1 Implication of new generation ESMs for existing climate policy scenarios

D8.1 Implication of new generation ESMs for existing climate policy scenarios (MNP, 48)

T8.2. Impact assessment on global and regional scales

D8.2 Effects on precipitation and temperature fields and on global and regional drought indices due to new feedbacks in ESMs (WU, 42)

D8.3 Impacts of new component ESM scenarios on global water cycle and water resources (Uni Kassel, WU, 48)

D8.4 Impacts of new component ESM scenarios on biomass productivity and agriculture (MNP, WU, 48)

T8.3 Assessment of additional regional feedbacks and their influence on regional impacts

D8.5 Assessment of additional regional feedbacks and their regional impacts in the Arctic (SMHI, 48)

D8.6 Assessment of additional regional feedbacks and their regional impacts in the Amazon (INPE, WU, METO, CNRS, 48)

D8.7 Assessment of additional regional feedbacks and their regional impacts in the Mediterranean (MPG, TUC, CYI, 48)

Table 1.3 e: Summary of staff effort

Partici-pant no.	Participant short name	WP0 (coord.)	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	Total person months
1	MPG (coord.)	18	18	0	12	9	6	9	24	9	**105**
2	METO	0	22	0	36	0	25	31	54	3	**171**
3	CNRS	0	29	31	12	33	0	0	37	3	**145**
4	CMCC	0	0	0	30	0	12	30	10	0	**82**
5	MF-CNRM	0	6	0	0	15	8	12	35	0	**76**
6	KNMI	0	18	0	0	0	0	30	0	0	**48**
7	UiB	0	22	0	0	0	0	0	21	0	**43**
8	DMI	0	0	0	12	21	0	12	12	0	**57**
9	ECMWF	0	0	0	0	0	26	0	0	0	**26**
10	ETHZ	0	0	31	0	0	0	0	0	0	**31**
11	FMI	0	0	16	0	0	0	0	0	0	**16**
12	MNP	0	0	0	0	0	0	0	9	15	**24**
13	SMHI	0	0	0	0	12	8	12	0	10	**42**
14	WU	0	0	16	0	0	0	0	0	33	**49**
15	UHEL	0	0	16	0	0	0	0	0	0	**16**
16	CERFACS	0	0	0	0	0	18	24	0	0	**42**
17	UCL	0	0	0	0	18	8	6	11	0	**43**
18	UNIVBRIS	0	7	0	0	0	0	0	0	0	**7**
19	UNI KASSEL	0	0	0	0	0	0	0	0	17	**17**
20	TUC	0	0	0	0	0	0	0	0	16	**16**
21	CYI	0	0	0	0	0	0	0	0	12	**12**
22	INPE	0	0	0	0	0	0	0	0	27	**27**
Total		**18**	**122**	**110**	**102**	**108**	**111**	**166**	**213**	**145**	**1095**

1.3 iv) Graphical presentation of the components showing their interdependencies (Pert diagram)

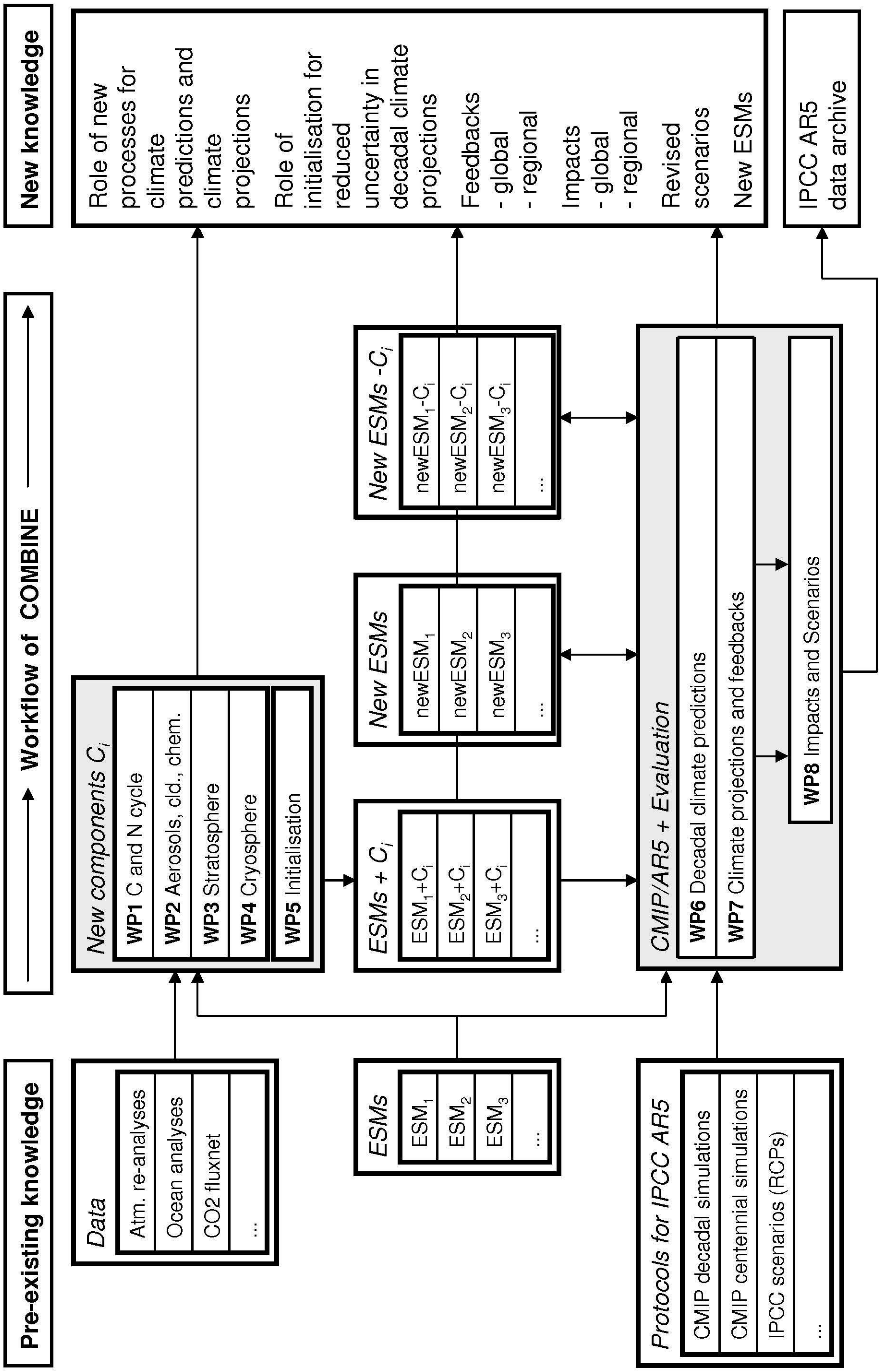

Figure 1.3 v) COMBINE depends on pre-existing knowledge consisting of data, Earth system models and protocols for climate predictions and projections for IPCC AR5. New components are incorporated in the initial ESMs and validated with available data (WP1 – WP5). Initial and new ESMs are used for decadal climate prediction and centennial climate projection following the specifications of the protocols for IPCC AR5 (WP6 + WP7). The simulations are evaluated with respect to the role of the new components for climate predictability and climate feedbacks. Global and regional impacts are analysed in WP8, where also revised scenarios are produces. Data from the 1st phase simulations can be submitted to the IPCC data archives. The work of WP1 to WP8 generates new knowledge, new ESMS and new data.

1.3 v) Significant risks, and associated contingency plans

General risks

COMBINE is designed to make (1) scientific progress towards the objectives of section 1, and (2) to contribute climate predictions and projections for IPCC AR5. Both general goals are associated with risks:

Timing of project achievements
Scientific work is generally risky, as no absolute certainty exists that all tasks of the projects are completed successfully and in time. COMBINE follows generally a strategy to limit risks through:

- Relying on experienced principal personnel in the scientific work as well as in the project management.
- Implementation of redundancy in the choice of scientific tools and in the work package leadership.
    - All work packages rely on typically 3 or more Earth system modelling systems. Should the quality of a particular ESM be poor, it would not jeopardize the scientific investigation pursued in the affected task and work package.
    - All work packages are co-lead by two PIs (WP1-7) or 3 PIs (WP8) from different institutions so that continuity in the leadership of work packages is not at risk in case a PI or an institution leaves the project.
- Careful monitoring of the progress in the project:
    - Checking achievement of milestones
    - Internal review of deliverables

Timing of IPCC AR5
(2) The planning of COMBINE is based on assumptions on the timing of the scheduling of the process leading to a 5^{th} Assessment Report of IPCC. Several members of the Scientific Steering and Executive Committee of COMBINE are personally involved in the different working groups that are preparing the protocols for coordinated experiments and scenarios. However, discussions and formal decisions by IPCC on a future 5^{th} Assessment Report are still pending, creating uncertainty on some aspects of the planned work. It is however expected that these decisions are made well before the beginning of the project and that the related protocols for internationally coordinated experiments and data archiving will be published in time. The Data Protocol Panel is responsible for a review of the existing protocols in the starting phase of the project and the formulation of the protocols for the COMBINE project.

Scientific risks

The project partners have ambitious scientific objectives, as it is the case for the international competitors in the field of Earth system modelling and climate projections. Risks exist in the achievement of sufficient quality in the simulations resulting from the new ESMs incorporating new processes and being used with new initialisation techniques:

New components in ESMs:
It is common experience that the incorporation of new processes in ESMs, which increases the number of degrees of freedom and allows additional feedback processes, in the beginning, deteriorates the overall performance of a climate model. It is part of the project to generate the knowledge to understand how the more complete ESMs can be adjusted in available control parameters so that a realistic climate simulation is possible for reference periods (19^{th}+20^{th} century). The usage of typically 3 or more model systems in each work package will strongly reduce the overall risk of a work package to achieve its scientific goals.

Initialisation of ESMs for climate prediction:
The field of climate predictions over decades is very young. Nevertheless it plays a key role in the experimental design of climate projections until 2030, as discussed for the experimental protocols for IPCC AR5. Considerable risks exist due to uncertainties in the description of “slow” components of the climate system, primarily in the observation and analysis of ocean and ice states. Risks are related (1) to the sparse observations of the ocean and sea ice state in the past resulting in an uncertainty in the analyzed states that can serve as initial conditions. The knowledge on the optimal use of such analyzed states of the ocean in Earth system models is still little developed. These uncertainties are there in the focus of Work Package 5 “Initialisation”, which is closely linked to WP6 “Climate Prediction”.
The risk of observation-based initialisation of ESMs is acknowledged in the discussion of the experimental protocols. Back-up experimental designs are therefore proposed for these protocols. WP6 is therefore

safeguarded against risks of failure of initialisation methods through alternative experimental designs explored in part in the beginning of the COMBINE project.

Recruitment risks

The COMBINE project will give the opportunity for numerous scientists, many at the post-doc level, to be active in the COMBINE project. It is expected that a substantial number of vacancies will be opened. In the current market with increasing demand for scientists in climate research, the recruitment is however getting more difficult and time consuming. The increasing difficulty creates a potential risk for the beginning phase of the project, especially for participants who need new personnel from the very beginning, while other activities starting later have more time for the recruitment. In order to keep this risk small, participants will:

- Rely on personnel at the partner institutions for key activities.
- Plan and start the recruitment of personnel as early as possible and suitable, using different advertisement channels as: scientific journals, web based services, personnel connections, conference presentations etc.
- Report in time to the coordinator if a delayed recruitment process is going to affect any deliverable or milestone, so that alternatives can be considered.

Management risks

The coordinator, supported by the project office, will be responsible for the monitoring of the risk factors explained above. If deviations from the project plan are identified, the coordinator will seek to achieve solutions together with the involved unit: work packages, tasks or partners. He will make use of the management structure in appropriate manner, contacting the Scientific Steering and Executive Committee, the Governing board, the panels, the financial administration or the European Commission. In case a conflict between participants emerges concerning the exploitation of knowledge from the project, the coordinator activates the litigation panel, which will work together with the involved parties to a proposal for solving the conflict.

The evolution of the project in terms of milestones and deliverables will be monitored closely through intensive communication with all WP leaders so that appropriate actions can be proposed if necessary.

The Max Planck Institute for Meteorology, where the coordination is located, has long experience in the overall coordination of European projects and in the financial administration related to such projects.

2. Implementation

2.1 Management structure and procedures

The management structure of COMBINE is designed to allow fast flow of information and money between partners, administration, the European Commission and the outside world. It is kept as simple as possible to minimize frictional energy losses along these paths. It addresses the specific challenges related to the complexity of the task, the size of the consortium and the duration of the project. Central will be the project administration at the Max Planck Institute for Meteorology (MPI-M) in Hamburg. All practical administration of FP7 instruments, financial and contractual, will be handled by experienced project administrators at the MPI-M, where the COMBINE project office will be located. The scientific management of the project will be integrated within a hierarchical but flexible decision-making structure involving the coordinator and the project office and the Scientific Steering and Executive Committee. Principle ways of communication are the internet (e-mail and web) and project workshops, including the general assemblies and specific workshops. Figure 2.1 shows the general implementation structure of COMBINE, as outlined below.

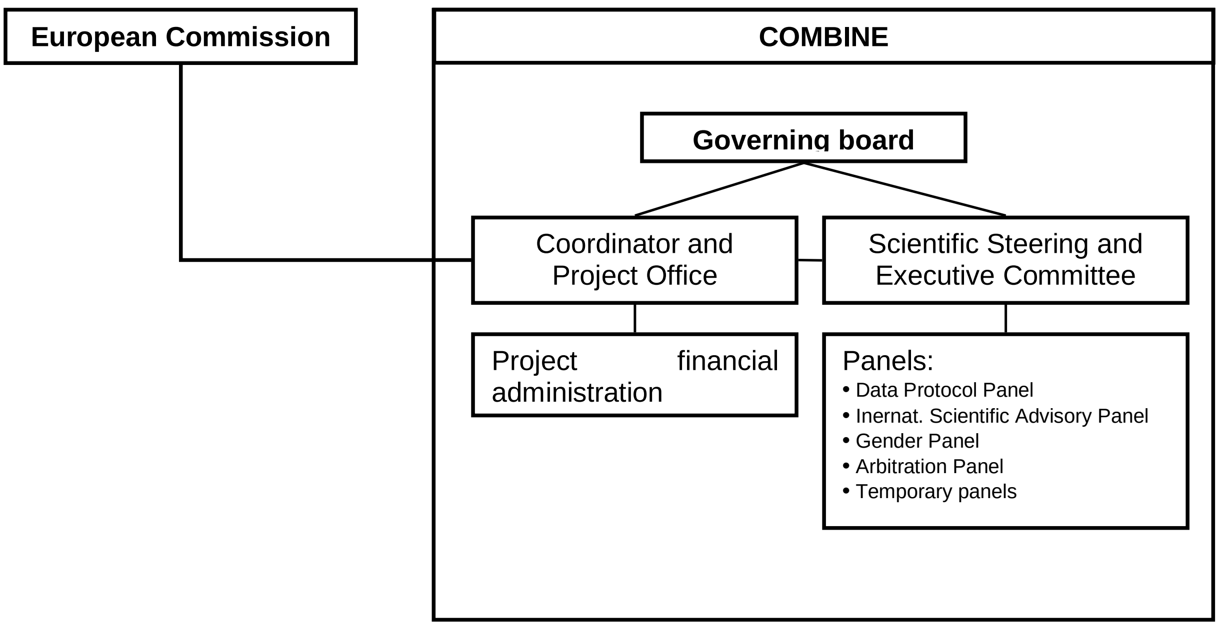

Figure 2.1. Implementation structure of the COMBINE project

2.1.1 Decision making and executive bodies

2.1.1.1 The Governing Board (GB)

The governing board is the overall decisive body of the consortium and constitutes representatives from all institutions presented in “2.2 Individual Participants” and any additional contractors entering the project during its life time. It is this board which validates the major decisions concerning the project. The Governing Board is the arbitration body for all decisions proposed by the Scientific Steering and Executive Committee. Thus, any Contractor may submit for arbitration by the Governing Board any decision by the Scientific Steering and Executive Committee it deems to be contrary to its interests; the Governing Board is also the decision-making body for any issue concerning the proper operation of the Consortium. In principle, approval by the Governing Board shall be given by mail vote, upon proposition by the Scientific Steering and Executive Committee. It is anticipated that formal meetings of the Governing Board will be held only during the annual general assemblies of COMBINE. The matters to be acted upon by the Board include:

- political and strategic orientation of the project;
- the Consortium’s work plan and plan for using and disseminating the knowledge and their regular updates;

- the Consortium’s budget and the financial allocation of the EU’s contribution between the various activities on the one hand, and between the various Contractors on the other;
- Annual validation of the realised expenditure in accordance to the budget;
- Changes in the Consortium membership;
- Any major change in scientific plans relative to the initial agreed implementation plan;
- Any major reallocation of budget between partners (if >10% of EC contribution);
- Any alterations of the Consortium Agreements;
- The acceptance of new Contractors as well as any exclusion of Contractors;
- Any premature completion or termination of the project;

The chairman of the governing board will be elected from the members of the board for periods of 12 months and can not be member of the Scientific Steering and Executive Committee.

2.1.1.2 Scientific Steering and Executive Committee (SSEC)

The main role of the Scientific Steering and Executive Committee is to make propositions to the Governing Board on the project work plan, budgets, and other matters necessary for the project advancement and success; and to implement the project orientations approved by the Governing Board. Those responsibilities include:

- make progress reports on the state of advancement of the project;
- establish the Project Deliverables for the Commission;
- propose the Project budget to the Governing Board as well as the allocation of funding between the Contractors;
- propose and implement the competitive selection procedure for new contractors;
- make proposals to the Governing Board for changes in the consortium membership;
- more generally propose any and all decisions required for the proper conduct of the project.

The Scientific Steering and Executive Committee is composed of the Work Package leaders and of the Coordinator and his Deputy Co-ordinator. It is chaired by the Project Coordinator.

2.1.1.3 Project Coordinator and Project Office

The Coordinator will be responsible for the management of COMBINE and liaison with the European Commission on behalf of the consortium. He will also be the principle contact to the financial administration at the MPI-M. If and when necessary he can propose to convene full Scientific Steering and Executive Committee meetings. He reports to the chairman of the governing board.
The Coordinator, assisted in the day-to day work by the members of the project office, has the responsibility of overall co-ordination and management of the project, including:

- communication of all information in connection with the COMBINE project to the Commission.
- Preparation of the project deliverables and address them to the Commission, after validation by the Scientific Steering and Executive Committee;
- day to day co-ordination of the project; monitors project planning and progress, deadlines, bottlenecks, deliverables;
- communication within the project, to users, and to the general public;
- organisation of meetings and internal reviews;
- organisation of calls for proposals issued by the project, if required;
- oversation of the quality control and documentation plan;
- co-ordination with other EU – funded or other international projects;
- overall administrative and financial management,
- management of consortium-level legal and ethical issues

Implementation of the plans under knowledge and innovation-related activities, intellectual property issues and Gender Action Plan will be under the responsibility of the coordinator.
The coordinator heads the COMBINE Project Office, which will be established at the Max Planck Institute for Meteorology in Hamburg. The project office will comprise the coordinator, the project officer (PO) and an administrative project manager (APM). The PO assists the Coordinator in the day to day monitoring of progress of the Project (follow-up of planning schedule, issue reminders for task initiation or completion, all other issues listed above), identifies promptly and anticipates problems, proposes action to remedy. The PO maintains the project communication instruments: web site with public and restricted areas, mailing lists and newsletter. The

APM will assist the Coordinator in the preparation of the financial reporting and in the financial actions between the Commission and the project partners.

2.1.1.4 Project financial administration

The financial administration of COMBINE will be done by experienced staff in the project administration unit at the Max Planck Institute for Meteorology. Its responsibilities include:

- receiving the entire financial contribution from the Commission. With advice from the Project Coordinator it will manage this contribution by allocating it to the Contractors pursuant to the "Work Plan" and the decisions taken by the appropriate bodies.
- preparing annual accounts, if requested by the Commission or by the Contractors, to inform them of the distribution of funds among the Contractors;
- the overall financial management of the coordination,
- keeping track of budgets

2.1.2 Advisory panels

2.1.2.1 Data protocol panel (DPP)

The COMBINE project will generate large volumes of data for climate predictions and climate projections. The DPP will be responsible for the definition of a protocol that specifies the technical details of data storage and archival for the common use in the project. Further the DPP will specify the rules of access to these data by the international research community, with the intention to integrate the data of climate predictions and projections of COMBINE in the data archives, which will be set up for IPCC AR5. It is expected that the protocols which describe the data submission, archival and access for IPCC AR5 will be published by the beginning of the COMBINE project.

In the beginning phase of the project the DPP will review the protocols for data submission for IPCC AR5 and the available infrastructure in Europe for the archival of the data. The review will include new European infrastructures that may result from the *InfraStructure for the European Network for Earth System Modelling* (IS-ENES) proposal in response to the work programme topic "INFRA-2008-1.1.2.21: establishing a European e-Infrastructure for earth system's understanding and modelling". Based on the findings, the DPC will develop a data protocol for COMBINE, which will rely on the protocols for IPCC AR5 and define complementary rules for the data usage in COMBINE that goes beyond the specifications of the protocols for IPCC AR5. In the course of the project, the DPP will monitor the effectiveness of the data protocol and correct its details where necessary.

The DPP will be established at the kick-off meeting and will include representatives from the modelling centres generating active in WP6 and WP7 and from the data users (WP8). The DPP will cooperate with the coordinator and the project office, which will produce the data protocol reports for the project participants.

2.1.2.2 International Scientific Advisory Panel (ISAP)

COMBINE will establish an International Scientific Advisory Panel of international distinguished scientists to ensure external evaluation of the project and links to other programme activities outside Europe. Distinguished researchers are contacted especially from the international groups involved in the preparation of the coordinated experimentation for IPCC AR5. The functions of the ISAP will be:

- advising on the project's scientific approach and orientation by liaison with the SSEC and the coordinator;
- providing a link to related activities outside Europe;
- providing an international perspective of developments in the field of Earth system modelling for climate prediction and climate projection, with focus on the internationally coordinated effort for the 5th assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC);
- making recommendations for new actions and activities in this area

2.1.2.3 Gender Panel (GP)

The gender panel will propose to the governing board a gender action plan and give advice to the SSEC on its implementation.

2.1.2.4 Arbitration Panel (AP)

The purpose of the arbitration panel is to resolve conflicts occurring between partners of the consortium in relation to the project. It may for example become active in conflicts on authorship on publications resulting from the research in COMBINE. The AP will review the conflicts together with the involved partners and propose solutions. This process will be detailed in the consortium agreement.

2.1.2.5 Temporary panels

Special panels may be created if needed to solve problems identified during the course of the project. If requested to the coordinator, a temporary panel is established to review the problem and propose a solution to the SSEC.

2.1.3 Management of knowledge

The consortium agreement will spell out and identify pre-existing knowledge and the provisions for intellectual property safeguards.

COMBINE will take due account of the recommendations of the CMIP protocol on the issue of data archiving of climate projections for IPCC AR5, with the goal of making climate predictions and projections, which are made in the COMBINE project based on the CMIP protocol, accessible to the international research community under the rules to be explained in the CMIP protocol.

All those issues will be addressed first during the negotiation phase, as part of the consortium agreement.

The appropriate unit of the Max-Planck-Gesellschaft (Legal affairs) will be involved in the drafting and negotiation of the all important Consortium Agreement, with the Commission and the partners. They will also assist in the follow-up of the implementation and compliance with the terms of the agreement.

2.1.4 Project meetings

The project kick-off meeting marks the effective launch of the project. It reinforces the common sense of all partners, and identifies the responsibilities of each in the endeavour. Unresolved technical issues are identified and debated; co-operation between Work Packages is initiated. Protocols for IPCC AR5, expected to be finalized and published at the time of the kick-off meeting, and their implications for COMBINE will be discussed and necessary actions proposed and decided. The management exposes what is expected of each in terms of results, performance and reporting. The detailed course for the first 12 months of the project is confirmed and fine-tuned.

Other project meetings are timed with the preparation of the annual reports. They will involve all the participants, and take place at months 12, 24, 36 and 48 or very soon thereafter. They will be complemented and prepared by Scientific Steering and executive Committee meetings to be held in the same time frame. Additional SSEC meetings may be convened as requires. Topical working meetings will be organised by the Work Package leaders as needed for the progress of their tasks.

COMBINE will organize an international conference on Comprehensive Earth System modelling for Climate Prediction and Projections towards the end of the 3rd year or the beginning of the 4th year of the project. The 3rd year general assembly will be embedded in this conference.

2.1.5 Internal Communication

The communication strategy adopted in the project aims at keeping all the partners fully informed about the status of the different activities underway. The target is to reach maximum transparency for all involved parties and hence increase synergy. All reports produced (like meeting and project reports, publications etc) will be communicated to the project office and channelled to other partners when appropriate. The project office will likewise distribute to the partners relevant information obtained from sources outside the project (about other projects, international programmes, coordination for IPCC AR5, from the Commission, or from various agencies). All documents will be properly indexed and available to all partners on a project web-site. The web site will consist of a public area and a restricted access area.

2.1.6 Addition of new participants

If the project progress or circumstances require modifying the partnership, the Scientific Steering and Executive Committee prepares the calls, organises the review of responses, assisted if needed by external experts, and selects the new partner. Large publicity will be given to the opportunity to join the project, through the communication network of the project (mailing lists of international programmes, announcement at conferences, postings in electronic newsletters). The results will be submitted to the governing board for approval.

2.2 Individual participants

Partner 1 (coordinator): Max Planck Society (MPG) – Max Planck Institute for Meteorology (MPI-M)

Expertise and experience of the organization

The **Max Planck Institute for Meteorology** (MPI-M) is dedicated to fundamental climate research. The overall mission of the MPI-M is to understand how physical, chemical, and biological processes, as well as human behaviour, contribute to the dynamics of the Earth system. Among the tools used are advanced numerical models that simulate the dynamics of the atmosphere, the ocean, the cryosphere and the biosphere, and their interactions. MPI-M has developed a comprehensive Earth system model (ESM), the COSMOS ESM, which is made available to the scientific community in Europe and elsewhere. MPI-M is committed to informing decision-makers and the public on questions related to climate change and global change. Finally, the MPI-M is managing the International Max Planck Research School on Earth System Modelling.

Role and contribution

MPI-M is the coordinator of this project. The COSMOS ESM, will be improved in WP1, WP3, WP4 and applied to climate change simulations in WP6 and WP7. WP1 will focus on the incorporation of the N-cycle and its coupling to the C-cycle. In WP3, the stratospheric dynamics will be improved. In WP4, an ice sheet model will be included. Uncertainties in the initialisation of will be investigated in WP5 and WP6. A major effort will be put in the investigation of feedbacks and in the analysis of the role of new components. Further MPI-M will investigate regional climate change and feedbacks in the Mediterranean and in the Amazon.

Principal personnel involved

Prof. Dr. Jochem Marotzke is director of the department "The Ocean in the Earth System". He has been working in ocean and climate theory, modelling, and observations for over twenty years. He was the principal author of the funded proposal to monitor the Atlantic THC at 26ºN. He is currently a member of the Joint Scientific Committee of the WCRP. **Dr. Marco Giorgetta** leads the Global Modelling Group and the cross-cutting Model Integration Group. He is member of the Working Group on Coupled Modelling of WCRP. **Dr. Daniela Jacob** leads the regional climate modelling activities at MPI-M. She develops mesoscale models for more than 15 years. Her main interests are in the applicability of physical parameterizations for scale dependent phenomena and the investigations of flows on different scales. **Dr. Johann Jungclaus** is a Senior Scientist and research group leader in the Ocean in the Earth System department and leads the cross-cutting "Simulation of the Last Millennium" project. He is member of the Arctic Climate Panel of WCRP. **Dr. Johannes Quaas** leads the Cloud-Climate Feedbacks group at MPI-M. His main research interests are in global modelling and satellite data analysis for cloud, aerosol, and precipitation processes. He actively participates to international model intercomparison projects for clouds (CFMIP) and aerosols (AEROCOM). **Dr. Christian Reick** is head of the Global Vegetation Modelling Group and founder of the GINKGO network for climate and global ecosystem modelling, **Dr. Joachim Segschneider** is a member of the marine biogeochemical modelling group at MPI-M.

Selected relevant publications:

Baehr, J., H. Haak, S. Alderson, S. A. Cunningham, J. H. Jungclaus, and J. Marotzke, Timely detection of changes in the meridional overturning circulation at 26°N in the Atlantic. Journal of Climate, 20, 5827–5841, 2007.

Giorgetta, M. A., E. Manzini, E. Roeckner, M. Esch, and L. Bengtsson, Climatology and forcing of the quasi-biennial oscillation in the MAECHAM5 model, J. Climate, 19, 3882-3901, 2006.

Raddatz, T., C. Reick, W. Knorr, J. Kattge, E. Roeckner, R. Schnur, K.-G. Schnitzler, P. Wetzel, J. Jungclaus, Will the tropical land biosphere dominate the climate-carbon cycle feedback during the twenty-first century? Climate Dynamics, 29, 565-574, 2007.

Ringer, M. A., B. J. McAvaney, N. Andronova, L. E. Buja, M. Esch, W. J. Ingram, B. Li, J. Quaas, E. Roeckner, C. A. Senior, B. J. Soden, E. M. Volodin, M. J. Webb, and K. D. Williams, Global mean cloud feedbacks in idealized climate change experiments, Geophys. Res. Lett., 33, L07718, doi:10.1029/2005GL025370, 2006.

Jungclaus, J.H., M. Botzet, H. Haak, N. Keenlyside, J.-J. Luo, M. Latif, J. Marotzke, U. Mikolajewicz, and E. Roeckner, 2006: Ocean circulation and tropical variability in the coupled model ECHAM5/MPI-OM. Journal of Climate, 19, 3952-3972.

Partner 1: Max Planck Society (MPG) – Max Planck Institute for Biogeochemistry (MPI-BGC)

Expertise and experience of the organization

The Max-Planck-Institute for Biogeochemistry (MPI-BGC) is a new research institute of the German Max-Planck Society, founded in 1997. Its research mission is the investigation of the global biogeochemical cycles and their interaction with the climate system. The institute combines strong observational and process-based studies (soil carbon, plant community structure, nutrition and growth, vegetation-atmosphere fluxes, convective boundary layer) with global scale modelling (e.g. vegetation dynamics, global carbon cycle, aerosol modelling). The MPI-BGC is one of the pivotal European biogeochemical cycle research institutions, and as such is co-coordinating the EU-funded CARBOEUROPE-IP project, and within the project the "Continental Integration" component. Moreover the Institute is strongly involved in the EU-funded NITROEUROPE, CARBOAFRICA and CIRCE-IP projects. MPI-BGC currently hosts the European scientific office of CarboEurope and has proven skills in co-ordination of international projects. MPI-BGC regularly advised policy makers and has frequent contacts with media and the broad public.

Role and contribution

The main contribution of MPI-BGC is to WP1, on the one hand on co-development and implementation of carbon related soil processes with MPI-MET, on the other hand by contributing to a model component evaluation against global carbon cycle data such as from FLUXNET and the newly established NPP database. Instead of a point evaluation of the models, which is strongly hampered by scale representation issues, we will aim at generating general patterns from the available data via data oriented up-scaling techniques and data mining/pattern recognition approaches. The co-development of soil carbon processes will be facilitated by a related ERC Grant to the Research Group of Markus Reichstein, and will include formulations of temperature and moisture sensitivity of carbon decomposition and inclusion of transport processes.

Principal personnel involved

Dr. Markus Reichstein, Head of Independent Junior Research Group, Graduated in Landscape Ecology, University of Münster, Germany. PhD in Plant and Ecosystem Ecology, University of Bayreuth, Germany, on the interpretation and modelling of Mediterranean eddy covariance carbon and water fluxes in response to drought. Strongly involved in EU-Projects VOCAMOD, MEDEFLU (FP4), CARBOEUROFLUX, MIND (FP5) and CARBOEUROPE-IP Ecosystem and Integration components (FP6), and partner in CARBOAFRICA, CIRCE-IP. Expertise in the processing and synthesis of eddy covariance carbon and water flux as well as soil respiration data, robust ecosystem model-data integration techniques and diagnostic ecosystem modelling using remote sensing information. Coordinated the ecosystem flux and remote sensing data harmonization and interpretation for the analysis of the European 2003 heatwave (Ciais et al. 2005). Expert in modelling soil carbon related processes.

Dr. Christian Beer, scientist, graduated in Mathematics and Chemistry at the Friedrich Schiller University Jena, and obtained his PhD in Geography with a thesis on linking and constraining soil and vegetation process modelling with remote sensing in the EU funded project Siberia II. Designated expert of the Dynamic Global Vegetation modelling, diagnostic up-scaling and currently developing soil model formulations for global-scale models.

Selected relevant publications:

Heimann, M., Reichstein, M. (2008) Terrestrial ecosystem carbon dynamics and climate feedbacks. Nature, 451, 289-292.

Beer, C., Lucht, W, et al. (2007) Effects of soil freezing and thawing on vegetation carbon density in Siberia - A modelling analysis with the LPJ-DGVM. Global Biogeochemical Cycles, 21 doi:10.1029/2006GB002760.

Reichstein, M., Papale, D., et al. (2007) Determinants of terrestrial ecosystem carbon balance inferred from European eddy covariance flux sites. Geophysical Research Letters 34 L01402.262.

Reichstein, M., P. Ciais, et al. (2007) A combined eddy covariance, remote sensing and modelling view on the 2003 European summer heatwave. Global Change Biology, 13, 634–651.

Ciais, P., M. Reichstein, et al. (2005) Europe-wide reduction in primary productivity caused by the heat and drought in 2003. Nature 437:529-533.

Partner 2: Met Office (METO)

Expertise and experience of the organization

The Met Office Hadley Centre is a world-leading centre which provides a focus in the United Kingdom for the scientific issues associated with climate change. The main aims of the Hadley Centre are 1/ to understand physical, chemical and biological processes within the climate system and develop state-of-the-art climate models which represent them, 2/ to use climate models to simulate global and regional climate variability and change over the last 100 years and to predict changes over the next 100 years, 3/ to monitor global and national climate variability and change, 4/ to attribute recent changes in climate to specific factors, and 5/ to understand, with the aim of predicting, the natural interannual to decadal variability of climate. It currently employs around 160 staff and uses NEC SX-6 and SX-8 supercomputers. Most of its funding comes from contracts with the Department for Environment, Food and Rural Affairs (Defra), other United Kingdom Government departments and the European Commission. The Met Office has considerable experience in the field of climate and Earth System modelling as well as in decadal to centennial simulations. The Met Office Hadley Centre has made significant contributions to the successive assessment reports of the IPCC and WMO ozone assessment reports.

Role and contribution

The Met Office will co-lead WP1 (Carbon and Nitrogen cycles), WP3 (Stratosphere), WP5 (Initialisation) and contribute to WP6 (Decadal climate prediction) and WP7 (Centennial climate projections and feedbacks). The Met Office also has a small contribution in WP4 (Cryosphere). Our current earth system model, HadGEM2-ES, will be developed to include a better treatment of land-use change through a new dynamic vegetation model, terrestrial and oceanic nitrogen cycles, and treatment of carbon dioxide and methane emissions from permafrost and wetlands. In the initialisation (WP5) and decadal forecasting (WP6) work packages, the Met Office will deliver initialisation of sea ice and assessment of its impact, an assessment of different initialisation strategies to deal with model drift, enabling an objective choice of initialisation for HadGEM3, initialised forecasts to 2030 for AR5 based on HadGEM (L38) in addition to HadCM3, and initialised forecasts to 2030 using HadGEM L60. The Met Office also has substantial input to the work package on centennial simulations (WP7). This work package will deliver the simulations for the IPCC 5th assessment report. We will also deliver feedback analyses of these simulations, and repeat the simulations and analysis later in the project with the new model components.

Principal personnel involved

A large number of Met Office scientists will be involved in the COMBINE proposal. **Dr. Olivier Boucher** (Head Climate, Chemistry and Ecosystems Team) will coordinate the overall contribution of the Met Office to COMBINE. He published more than 50 articles in the peer-reviewed literature in the field of aerosol, radiation, and climate and has extensive experience with FP projects. **Dr. Chris Jones** (Manager Terrestrial Carbon Cycle) will lead the Met Office contribution to WP1. He has pioneered coupled climate-carbon cycle modelling in the Met Office, has extensive experience of both model development and analysis and contributed to the IPCC 4th assessment report. **Dr. Neal Butchart** will lead the Met Office contribution to WP3. He has over 20 years of research experience on stratospheric processes. He is a member of the steering committees of the SPARC Chemistry-Climate model evaluation activity and the SPARC DynVar project on the dynamics and variability of the coupled stratosphere-troposphere system. **Dr. Jeff Ridley** will lead the Met Office contribution to WP4. **Dr. Doug Smith** will lead the Met Office contribution to WP5 and WP6. He developed the Met Office decadal climate prediction system, and demonstrated significant improvements to decadal forecasts resulting from initialisation. **Dr. Bill Collins** will lead the Met Office's contribution to WP7. Other scientists from the Met Office Hadley Centre will be called for their expertise when required. New members of staff will also contribute to the project.

Selected relevant publications:

Butchart et al. Simulations of anthropogenic change in the strength of the Brewer-Dobson circulation, Climate Dynamics, 27, 727-741, 2006.

Cox et al. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model, Nature, 408, 2000.

Smith et al., Improved surface temperature prediction for the next decade, Science, 317, 796, 2007.

Partner 3: Centre National de la Recherche Scientifique (CNRS) - Institut Pierre-Simon Laplace (IPSL)

Expertise and experience of the organization

IPSL is a federative institute composed of 5 laboratories working on global environmental and climate studies. The main laboratories involved in COMBINE are Laboratoire des Sciences du Climat et de l'Environnement (LSCE) and Laboratoire de Météorologie Dynamique (LMD). LSCE employs 200 people and has a 20 year expertise in the fields of biogeochemical cycles modelling and observation, past and future climate studies and isotopic markers in the environment. LMD employs 150 people, in the field of atmospheric measurements and modelling of atmospheric processes. LSCE and LMD are heavily involved in the development of the IPSL Earth System Model. IPSL has been involved in several European projects such as ENSEMBLES, PRISM, GEMS, MINATROC, SCOUT-O3, QUANTIFY, CARBOEUROPE, CARBOOCEAN, PMIP, MOTIF and the NICE RTN.

Role and contribution

IPSL will develop the IPSL-ESM, including development in WP1, WP2, WP3 and WP4. In WP7, IPSL will also perform climate simulation for the IPCC Fifth Assessment and beyond, using the IPSL-ESM developed within COMBINE. IPSL will co-coordinate WP1 (P. Friedlingstein) and WP4 (M. Kageyama).

Principal personnel involved

Dr. Pierre Friedlingstein is central in the biosphere modelling activity at IPSL and has 15 years research experience in the field of carbon cycle modelling and climate-carbon cycle feedback analysis at the global scale. He coordinates the coupled climate carbon cycle inter-comparison project (C4MIP). He was lead author of the chapter on Future climate projections of the Fourth assessment of the IPCC Report. He is member of IGBP/AIMES and ESSP/GCP.

Dr. Masa Kageyama has a 10 year experience in present and past climate modelling, with GCMs (IPSL) and models of intermediate complexity (CLIMBER). She took part in the coupling of this model to the LGGE ice-sheet models, which allowed her to analyze the ice-sheet feedbacks on the climate system. Her scientific interests are the evaluation of the role of climate system components and external forcings in climate change and paleoclimate model-data comparisons.

Dr. Yves Balkanski has been working for now more than 12 years on global aerosol modelling. He coordinated the European project MINATROC (FP5). His role entails the implementation in the IPSL ESM of the aerosol interactions with clouds and the treatment of heterogeneous chemistry on aerosol surfaces.

Dr. Jean-Louis Dufresne has a 20 year research experience in climate modelling and heads the "climate modelling and global change" team at LMD. He is involved in the development of the LMDZ AGCM, he is central in the development of the IPSL Coupled Model and in the achievement of climate change runs in projects such as CMIP, IPCC AR4, ENSEMBLES. His current main research topics are model coupling, global climate change studies, cloud feedbacks, climate-carbon cycle feedbacks analyses.

Dr. François Lott has been Chargé de Recherche" at CNRS, Laboratoire de Météorologie Dynamique, for more than 10 years. He first specialised in the dynamical influence of mountains on meteorology and climate. In this respect he developed parameterisations of sub-grid scale orography in atmosphere GCMs. More recently he took in charge the development of the stratosphere in the IPSL GCM.

Selected relevant publications:

Balkanski, Y., et al., Reevaluation of mineral aerosol radiative forcings suggests a better agreement with satellite and AERONET data, Atmos. Chem. Phys., 7, 81–95, 2007.

Dufresne J-L et al, Contrasts in the effects on climate of anthropogenic sulfate aerosols between the 20th and the 21st century Geophys. Res. Lett., Vol. 32, No. 21, L21703, 2005.

Friedlingstein, P., et al., Climate-carbon cycle feedback analysis, results from the C4MIP model intercomparison, J. Climate, 19, 3337-3353, 2006.

Kageyama, M., et al, Quantifying ice-sheet feedbacks during the last glacial inception. Geophys. Res. Lett. 31, 24203, doi:10.1029/2004GL021339, 2004.

Lott, F., et al, The stratospheric version of LMDz: Dynamical Climatologies, Arctic Oscillation, and Impact on the Surface Climate. Clim. Dynam., 25, 851-868, 2005

Piao, S., P. Ciais, P. Friedlingstein, et al ., Net carbon dioxide losses of northern ecosystems in response to autumn warming, Nature, 451, 49-52, 2008.

Partner 3: Centre National de la Recherche Scientifique (CNRS) - Laboratoire de Glaciologie et Geophysique de l'Environnement (LGGE)

Expertise and experience of the organization

LGGE has built its scientific reputation on its research on past climates and compositions of the atmosphere, based on the natural archives of ice and snow accumulated over the ages. LGGE has other very competitive fields of competence based on ice and snow, e.g. the physical and mechanical study of ice, chemical exchanges between air and snow, as well as data acquisition in the field and via satellite. Finally, and of most importance for the COMBINE project, LGGE has a strong experience in ice-sheet and glacier model development, and in regional atmosphere modelling in the polar and mountain regions, at very fine scales.

Role and contribution

Involvement in combine: within WP4, LGGE will provide: 1/ Greenland and Antarctic ice-sheet models to CNRM and IPSL; along with analyses on model results 2/ the surface model SISVAT to IPSL and UCL (for sea-ice and ice-sheet coupling); 3/ high resolution climatologies for the Greenland and Ross Sea (Antarctic) regions

Principal personnel involved

Dr. Catherine Ritz, has 25 year experience in ice-sheet modelling and the head of the ice sheet modelling group at LGGE. She has developed 3D, thermo-mechanically coupled models that simulate the evolution of ice sheets under various climatic conditions. These models have been applied to present ice sheets, such as Greenland and Antarctica, but also to past ice sheets that covered part of the northern hemisphere during the glacial periods. She also participated to the ice cores interpretation and for instance provided the glaciological dating of the Vostok ice core. From 1994 to 1999, she was the French member of EISMINT (European Ice Sheet Modelling Initiative, and in this framework she coordinated an inter-comparison experiment (concerning the Greenland ice sheet).

Dr. Hubert Gallée is research director at CNRS (LGGE, France) since 2002. During his stay at UCL, he developed the LLN-2D model, one of the first Earth system Models of Intermediate Complexity (EMICs), with which he performed some of the first simulations of the quaternary glacial interglacial cycle. For the past 15 years, he developed the polar mesoscale model MAR, with which he studied meteorological processes specific to the Antarctic ice sheet, such as Antarctic katabatic jumps. He also developed a detailed snow model including a description of blowing snow and coupled it to MAR. He now investigates the surface mass balance of the Antarctic and Greenland ice sheets at LGGE and develops a regional model of the Antarctic climate system by coupling MAR with the French sea-ice ocean model NEMO. He also collaborates with the Italian Antarctic programme on the implementation of his model as a limited area numerical weather prediction model over the Ross Sea (Antarctica)..

Selected relevant publications:

Fettweis, X., J.-P. van Ypersele, H. Gallée, F. Lefebre, and W. Lefebvre 2007, The 1979–2005 Greenland ice sheet melt extent from passive microwave data using an improved version of the melt retrieval XPGR algorithm, Geophys. Res. Lett., 34, L05502.

Gallée, H., V. Peyaud and I. Goodwin, 2005. Temporal and spatial variability of the Antarctic Ice Sheet Surface Mass Balance assessed from a comparison between snow stakes measurements and regional climate modeling. Annals of Glaciology 41, 17--22.

Peyaud, V., C. Ritz, and G. Krinner. 2007. Modelling the Early Weichselian Eurasian ice sheets: role of ice shelves and influence of ice-dammed lakes. Climate of the Past, 3, 375-386.

Philippon, G., G. Ramstein, S. Charbit, M. Kageyama, C. Ritz, C. Dumas, Evolution of the Antarctic ice sheet throughout the last deglaciation: A study with a new coupled climate-north and south hemisphere ice sheet model. Earth and Planetary Science Letters, 248, 750–758, 2006.

Partner 4: Centro Euro-Mediterraneo per i Cambiamenti Climatici (CMCC)

Expertise and experience of the organization

The Centro Euro-Mediterraneo per i Cambiamenti Climatici (CMCC) is a Research Consortium consisting of different Italian public and private research institutions and focused on climate-related research. The Centre is financially supported by the *Italian Ministry for the Environment and Territory*, the *Ministry for Education, University and Research* and the *Ministry for Economy*. The headquarters of CMCC is based in Lecce (Italy) but there are also local offices in Bologna, Venezia, Capua and Sassari. The areas of activity of the Centre are: numerical simulations and production of climate scenarios; impact studies (socio-economic, on health, agriculture, carbon cycle, desertification and coastal zones); adaptation and mitigation policies. A significant component of the research is on the monitoring of the eco-environmental resources and specifically water.

Role and contribution

CMCC contributes to COMBINE with expertise in global modelling and analysis of the Earth System, including atmosphere-ocean interaction, the stratosphere, and the carbon cycle, as well as with expertise in ocean data assimilation and in the initialisation of coupled atmosphere ocean models. Within COMBINE, the CMCC contribution focuses on the development of a climate prediction system including the stratosphere (WP3) and initialisation from the observed state of the ocean (WP5). CMCC has a substantial contribution in delivering the decadal runs in WP6 that will provide input to the impact work in WP8. CMCC has a small contribution in WP7 concerning the IPCC 5th assessment report simulations with the carbon cycle. Dr Manzini co-leads WP3 on the stratosphere and Dr Gualdi co-leads WP6 on climate prediction.

Principal personnel involved

Dr. Silvio Gualdi is senior scientist and has more than 10 years of experience in climate modelling and analysis. During this period, he has developed the climate model SINTEX and performed a number of climate scenario (IPCC) simulations. He has worked at the SINTEX, DEMETER, ENSEMBLES and CIRCE EU Projects.

Dr. Elisa Manzini has a Ph.D. in Atmospheric and Oceanic Sciences from Princeton University. She is senior scientist and has more than 10 years of experience in the modelling of the troposphere and stratosphere system. Her scientific research focuses on the role stratospheric dynamics and chemistry in the climate system. She was or is involved in a number of international committees, including: Review Editor for Chapter 8 IPCC 4th assessment report; Climate Dynamics Editor, and Member of SPARC's WCRP. She has worked for the IGWOC, ENSEMBLES, and SCOUT-O3 EU projects.

Dr. Simona Masina has a Ph.D. from the Geophysical Fluid Dynamics Laboratory of the Princeton University. She is senior scientist and has more than 10 years of experience in global ocean modelling and ocean data assimilation. Her scientific activity focuses on the study of the role of the ocean in the global climate system. She has worked for the PREDICATE, ENACT, and DYNAMITE EU project.

Dr. Antonio Navarra is President of CMCC and has more than 20 years of experience in the investigation of the dynamical mechanisms which control climate on the global and regional scale.

Selected relevant publications:

Bellucci A., Masina S., Di Pietro P., Navarra A. Using temperature-salinity relations in a global ocean implementation of a multivariate data assimilation scheme. Monthly Weather Review, 135, pp. 3785-3807.

Carril A., S. Gualdi, A. Cherchi, and A. Navarra, 2007: Heatwaves in Europe: Areas of homogeneous variability and links with the regional to large-scale atmospheric and SSTs anomalies. Clim. Dyn., DOI 10.1007/ s00382-007-0274-5

Manzini, E., M.A. Giorgetta, M. Esch, L. Kornblueh, and E. Roeckner, 2006: The influence of sea surface temperatures on the Northern winter stratosphere: Ensemble simulations with the MAECHAM5 model, J. Climate, 19, 3863-3881.

Masina S., Di Pietro P., Navarra A., 2004. Interannual-to-decadal variability of the North Atlantic from an ocean data assimilation system. Climate Dynamics, 23, 531-546. DOI: 10.1007/s00382-004-0453-6.

Navarra A., S. Gualdi, S. Masina, S. Behera, J-J Luo, S. Masson, E. Guilyardi, P. Delecluse, and T. Yamagata, 2007: Atmospheric horizontal resolution affects tropical climate variability in coupled models. J. Climate, accepted, in press.

Partner 5: Météo-France - Centre National de Recherches Météorologiques (MF-CNRM)

Expertise and experience of the organization

Meteo-France is the French weather service. In COMBINE, Meteo-France is represented by its research centre, the « Centre National des Recherches Météorologiques » (CNRM). The CNRM is the department responsible for conducting the largest part of the meteorological research activities, and for coordinating research/development undertakings conducted within other departments. To carry out its missions, CNRM hosts approximately 275 permanent positions (one third being research scientists), and about 60 students and visitors, working in specialised divisions. The climate group « GMGEC » is one of these divisions in charge of the studies of present climate variability and of the impact of human activities on climate. Its main specific research activities concern the development of climate models, the studies of climate variability, of the projection of climate at global and regional scales, of long-range forecasting, of atmospheric chemistry and of ocean-air interactions.

Role and contribution

Within the context of WP1, the partner will contribute to investigate the feedback of land-use on the carbon cycle. In WP4, MF-CNRM plans to couple its global coupled climate model CNRM-CM with GRISLI and GREMLINS ice sheet models in close collaboration with CNRS. MF-CNRM also plans to update the land snow cover and sea ice snow cover schemes, as well as the sea ice model included in CNRM-CM. In WP5, the partner will focus on exploring new sea ice model initialisation techniques. These techniques will be applied in WP6 to perform potential predictability decadal simulations. In WP7, after running the CMIP5 simulations, MF-CNRM will test the impact of the introduction of the new earth system components developed in the framework of the COMBINE project. On the one hand, this will be done for every new component by comparing the climate response of the new earth system with and without this component. On the other hand, new diagnostics will be introduced in CNRM-CM in order to better assess the associated feedbacks.

Principal personnel involved

Dr. Anne-Laure Gibelin and **Dr. Aurore Voldoire**, junior scientists, are in the climate division since 2001 and both contribute to the development of CNRM-CM. Anne-Laure Gibelin specializes in studying the terrestrial carbon cycle and the interactions between the land surface and the atmosphere, and Aurore Voldoire studies the impact of land-use on climate.

Dr. David Salas-Mélia, scientist, is in the climate division since 1996. His main research activities include sea ice modelling and the study of polar climate variability. Since 1999 he is in charge of coordinating the development of CNRM-CM, one of the CMIP3 models.

Selected relevant publications:

Calvet, J.-C., A.-L. Gibelin, J.-L. Roujean, E. Martin, P. Le Moigne, H. Douville, and J. Noilhan (2008), Past and future scenarios of the effect of carbon dioxide on plant growth and transpiration for three vegetation types of southwestern France, Atmos. Chem. Phys., 8, 397-406.

Gibelin, A.-L., J. Calvet, J. Roujean, L. Jarlan, and S. O. Los (2006), Ability of the land surface model ISBA-A-gs to simulate leaf area index at the global scale: Comparison with satellites products, J. Geophys. Res., 111, D18102, doi:10.1029/2005JD006691.

Guemas V. and D. Salas-Mélia (2007) : Simulation of the Atlantic meridional overturning circulation in an atmosphere-ocean global coupled model (in two parts), Climate Dynamics. DOI : 10.1007/s00382-007-0336-8 and 10.1007/s00382-007-0328-8.

Salas-Mélia, D., F. Chauvin, M. Déqué, H. Douville, J.-F. Gueremy, P. Marquet, S. Planton, J.-F. Royer and S. Tyteca (2005): Description and validation of the CNRM-CM3 global coupled model, CNRM Tech. Report 103.

Voldoire A., B. Heickhout, M. Schaeffer, J.-F. Royer, F. Chauvin, 2007: Climate simulation of the twenty-first century with interactive land-use changes. Clim. Dyn., 29(2-3):177-193, DOI: 10.1007/s00382-007-0228-y.

Partner 6: Het Koninklijk Nederlands Meteorologisch Instituut (KNMI)

Expertise and experience of the organization

The KNMI (Royal Netherlands Meteorological Institute) is the Dutch national weather service and centre for climate research. Climate research at KNMI is aimed at observing, understanding and predicting changes in the climate system. KNMI produces climate scenarios for use by stakeholders for developing adaptation and mitigation strategies. Climate research is carried out in various divisions: Global Climate Division (global climate change, coupled modelling, ocean circulation, sea level rise), Regional Climate Division, Chemistry and Climate Division, Earth Observation and Climate Division and Climate Advice and Analysis Division.

Role and contribution

The KNMI is work package leader of WP6 and participates in WP1. In WP6 it will coordinate the research effort of the different participants. The contribution of KNMI to this work package is performing climate prediction experiments with EC-EARTH. EC-EARTH is a a joint project of member states of the EU on earth system modelling. KNMI coordinates this project. The atmosphere component of EC-EARTH is based on the Integrated Forcecast System (IFS) of the ECMWF. The ocean model is OPA. KNMI coordinates the different contributions to WP6 of the EC-EARTH consortium that consists for this work package of KNMI, SMHI and DMI. Apart from performing the experiments it will also play a central role in the analysis of the results of WP6. In WP1 it will contribute to the development of wetland and land-use representations.

Principal personnel involved

Dr. Reindert Haarsma is staff member of the Global Climate Division of the KNMI.. He has a background in large scale atmospheric dynamics and a profound experience in coupled atmosphere-ocean modelling. He has worked on the development of coupled climate models and is now involved in the EC-EARTH project. His recent research focus has been on interannual to decadal variability in the Atlantic basin.

Dr. Wilco Hazeleger is head of the Global Climate Division of the KNMI.. He is a physical oceanographer with a wide experience in coupled atmosphere-ocean modelling. His research has been directed at interannual to decadal variability in the ocean-atmosphere system. He is co-chair of the Atlantic implementation Panel of WCRP CLIVAR and he is member of of the steering committee of IGBP IMBER. Currently he coordinates the EC-EARTH project.

Prof. dr. Bart vd Hurk is senior researcher at KNMI. He has a PhD in land surface modelling, and contributed to the various versions of the ECMWF scheme TESSEL. He is also involved with many projects dealing with local climate change scenario's and impact assessment. As a professor at Utrecht University he is supervising 6 PhD students.

Selected relevant publications:

Haarsma, R.J. en W. Hazeleger, Extra-tropical atmospheric response to equatorial Atlantic cold tongue anomalies J. Climate, 2007, 20, 10, 2076-2091.

Haarsma, R.J., F.M. Selten, S.L. Weber en M. Kliphuis, Sahel rainfall variability and response to greenhouse warming Geophys. Res. Lett., 2005, 32, doi:10.1029/2005GL023232.

Hazeleger, W. en S. Drijfhout, Subtropical Cells and Meridional Overturning Circulation pathways in the tropical Atlantic J. Geophys. Res., 2006, 111, doi:10.1029/2005JC002942.

Hazeleger, W., Can global warming affect tropical ocean heat transport? Geophys. Res. Lett., 2005, 32, 22, L22701, doi:10.1029/2005GL023450.

Hurk, B.J.J.M. van den, M. Hirschi, C. Schaer, G. Lenderink, E. van Meijgaard, A. van Ulden, B. Rockel, S. Hagemann, L.P. Graham, E. Kjellstroem and R. Jones, Soil Control on Runoff Response to Climate Change in Regional Climate Model Simulations J. Climate, 2005, 18, 3536-3551.

Hurk, B.J.J.M. van den, P. Viterbo and S. Los, Impact of Leaf Area Index seasonality on annual land surface evaporation in a Global Circulation Model, J. Geophys. Res., 2003, 108, 4191-4199.

Partner 7: University of Bergen (UiB)

Expertise and experience of the organization

UiB is the primary academic marine research organisation in Norway with key expertise in physical oceanography, climate research, biogeochemistry, ecology, paleoclimatology and meteorology. UiB has coordinated a series of EU projects in the field of climate research, among others TRACTOR, PACLIVA, and currently EU FP6 IP CARBOOCEAN. UiB has participated in IPCC AR4 (coordinating lead author E. Jansen, lead author C. Heinze) and IPCC special report on carbon storage (lead author P. Haugan). The Geophysical Institute of UiB includes the key marine carbon research group in Norway (observations and global modelling). UiB hosts the Bjerknes Centre of Climate Research which has the status of a national centre of excellence funded by the Norwegian Research Council (UiB, Nansen Centre, and Institute of Marine Research work together in this centre). It is one of the leading climate research centres worldwide focusing on polar and sub-polar regions. The Bjerknes Centre has participated in the IPCC AR4 through climate scenarios with the coupled ocean-seaice-atmosphere Bergen Climate Model.

Role and contribution

UiB will contribute to COMBINE with revised carbon cycle modules for the ocean, including a more detailed simulation of the marine nitrogen cycle, continental inputs of nutrients and carbon from rivers, and accounting for continental margin effects. UiB uses as the only group in the consortium an isopycnic ocean model for both the physical and the biogeochemical process simulations (MICOM ocean model provided by University of Miami with Bergen modifications coupled to the HAMOCC5 biogeochemical model originating from Max Planck Institute of Meteorology with adjustment to isopycnic coordinates). The unique ocean model will in particular be interesting to the carbon cycle climate feedback when it comes to changes in ocean circulation and respective modifications of downward mixing of anthropogenic carbon from the ocean surface. UiB will further run scenarios with their Earth system model and contribute to a quantification of the centennial feedback between carbon cycle changes and climate and the analysis of the most critical processes to this feedback. UiB will co-lead (together with MPI Hamburg) the work package 7 on centennial feedbacks.

Principal personnel involved

Prof. Dr. Christoph Heinze (contact PI for COMBINE); expertise: biogeochemical ocean modelling; professor in chemical oceanography at the Geophysical Institute, leader of Research Group 4 on biogeochemical cycles of the Bjerknes Centre for Climate Research; lead author of ch. 7 on climate-biogeochemistry couplings of the IPCC 4th Assessment Report of Working Group I; coordinator of the FP6 Integrated Project CARBOOCEAN on marine uptake of anthropogenic carbon). **Prof. Dr. Helge Drange** expertise: climate modelling; leader of the national NFR project NorClim on 21st century simulations of the climate inclding development of a Norwegian Earth system model; leader of the Rieber climate research Institute at the Nansen Environmental and Remote Sensing Center. **Dr. Karen Assmann** (research scientist; physical oceanographer) has coupled the MICOM and HAMOCC5 models together and has profound experience in ocean modelling..**Dr. Jerry Tjiputra** (post-doctoral researcher) has coupled actual ocean and terrestrial carbon cycle modules to the Bergen AOGCM; J.T. has experience in computer science, physical and biogeochemical oceanography and data assimilation.

Selected relevant publications:

Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S. Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007, Couplings Between Changes in the Climate System and Biogeochemistry. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Furevik, T. Æ M. Bentsen Æ H. Drange, I. K. T. Kindem Æ N. G. Kvamstø Æ A. Sorteberg, 2003, Description and evaluation of the Bergen climate model: ARPEGE coupled with MICOM, Climate Dynamics, 21, 27–51.

Heinze, C., 2004, Simulating oceanic $CaCO_3$ export production in the greenhouse, Geophysical Research Letters, 31, L16308, doi:10.1029/2004GL020613.

Partner 8: Danish Meteorological Institute (DMI)

Expertise and experience of the organization
DMI is the national meteorological service for Denmark, Greenland and the Faeroe Islands. The Danish Climate Centre (DKC) at DMI has extensive experience in climate modelling, including researches in climatic sensitivity to external forcing, natural climate variability and seasonal prediction as well as developments of stat-of-the-art global and region climate models. In recent years ice sheet dynamics has also been taken up as a key research area, and the ice sheet modelling has become an integrated part of the climate modelling. The stratospheric research is another focus at DKC, which involves in numerous studies and experimental field campaigns related to upper air dynamics and chemistry processes, long-term monitoring and satellite validation. DKC has taken part in numerous EU projects on global and regional climate modelling and stratospheric science, including ENSEMBLES, PRUDENCE, SCOUT-O3.

Role and contribution
DMI will work on inclusion of the dynamical stratosphere and coupling of ice sheet models for Greenland and Antarctic in EC-Earth. The model with the new components included will be validated, and the impact and feedbacks induced by these new components on decadal and centennial scales will be quantified. DMI will, together with other groups in the EC-Earth consortium, perform decadal predictions using the EC-Earth with new components developed in the project. DMI will co-lead WP4 the cryosphere.

Principal personnel involved
Dr. Jens Hesselbjerg Christensen is a Principle Scientist employed at DMI since 1990 and scientific head of the Danish Climate Centre since 2006. He started regional climate modelling at DMI and is one of the key developers of the regional climate model HIRHAM. He has been the principal investigator for DMI in numerous Danish, Nordic and EU funded projects including ENSEMBLES, GLIMPSE and WATCH, and coordinated the EU project PRUDENCE under FP5. He was a coordinating lead author on the contribution from Working Group 1 to the IPCC Fourth Assessment Report.
Dr. Shuting Yang is a senior scientist employed at DMI since 1996. She has a long experience in areas of climate modelling, climate variability and climate change using both simplified circulation models and general circulation models. She has been in charge of development of the Danish climate model and the atmospheric-ocean coupled system at DMI, and is currently involved in the development of the EC-Earth.
Dr. Bo Christiansen has studied a number of topics focused on stratospheric dynamics, the Arctic Oscillation, climate sensitivity, atmospheric circulation regimes, the coupling between the troposphere and stratosphere, error growth, and climate sensitivity, using extensively a general circulation model and simpler idealised models. Bo Christiansen has co-ordinated two EU projects, CliChem and ROCS.
Dr. Guðfinna Aðalgeirsdóttir has worked at DMI since October 2006. She is a glaciologist and has worked with numerical models for ice caps including predictions of the response of Icelandic glaciers to climate change. She has glaciological experience from Iceland, Alaska and Switzerland.

Selected relevant publications:

Aðalgeirsdóttir G., *et al*., 2006, The response of Hofsjökull and southern Vatnajökull, Iceland, to climate change. J. Geophys. Res., 111, F03001, doi:10.1029/2005JF000388

Christensen, J.H. and O.B. Christensen, 2003: Severe Summer Flooding in Europe, Nature: 421, 805-806.

Christensen, J.H. and O.B. Christensen, 2006: A summary of the PRUDENCE model projections of changes in European climate by the end of this century, Clim. Change, doi: 10.1007/s10584-006-9211-6

Christiansen, B., 2003: Temporal growth and vertical propagation of perturbations in the winter atmosphere. Q. J. R. Meteorol. Soc., 129, 1589-1606.

Christiansen, B., 2005: Downward propagation and statistical forecast of the near surface weather. J. Geophys. Res., 110, D14104, doi:10.1029/2004JD005431.

Stendel, M., I.A. Mogensen, and J.H. Christensen, 2005: Influence of various forcings on global climate in historical times using a coupled AOGCM, Clim. Dyn. 25, 10.1007/s00382–005-0041-4.

Yang, S., B. Reinhold and E. Källén, 1997: Multiple weather regimes and baroclinically forced spherical resonance, J. Atmos. Sci., 54, 1397-1409.

Yang, Shuting, 2004: The DKCM atmospheric model: The atmospheric component of the Danish climate model, Danish Climate Centre report 04-05, 23pp...

Partner 9: European Centre for Medium-Range Weather Forecast (ECMWF)

Expertise and experience of the organization

ECMWF is an international organisation supported by 28 European states. Its primary duties are in operational forecasting of weather and climate on seasonal timescales, for which it is a world leader. To achieve these operational tasks, ECMWF has one of the most advanced coupled ocean-atmosphere models and ocean-atmosphere data assimilation systems in the world. ECMWF has pioneered the development of ensemble forecast techniques for weather and climate prediction and variational techniques for data assimilation.

Role and contribution

ECMWF will be responsible for the implementation and assessment of different ocean initialisation strategies described in WP5 for the EC-EARTH (NEMO/IFS) coupled model. The initial conditions provided by ECMWF will be used by the EC-EARTH consortium in the decadal integrations in WP6. Specific contributions include: the real-world initialisation, using the NEMOVAR system developed in collaboration with CERFACS, needed for forecast strategies (1) and (3); the development of an empirical forecast correction scheme for forecast strategy (3); and the anomaly initialisation of the coupled model (forecast strategy 2). The different initialisation strategies for the EC-Earth model will be assessed regarding their suitability for seamless prediction in general and decadal predictions in particular.

Principal personnel involved

Dr. Magdalena Balmaseda. Senior Scientist in Seasonal Forecast Section and expert in ocean data assimilation, ocean reanalysis, and initialisation of coupled models for seasonal forecasts.
Dr. Franco Molteni. Head of Seasonal Forecast Section and expert in nonlinear climate dynamics

Selected relevant publications:

Balmaseda M.A., Dee D.P., Vidard A.P. and Anderson D.L.T. 2007. A Multivariate Treatment of Bias for Sequential Data Assimilation: Application to the Tropical Oceans. Q. J. R. Meteorol. Soc.,133, 167-179.

Balmaseda, M., D. Anderson, and A. Vidard, 2007: Impact of Argo on analyses of the global ocean, Geophys. Res. Lett., 34, L16605, doi:10.1029/2007GL030452.

Balmaseda, M. A., G. C. Smith, K. Haines, D. Anderson, T. N. Palmer, and A. Vidard ,2007: Historical reconstruction of the Atlantic Meridional Overturning Circulation from the ECMWF operational ocean reanalysis, Geophys. Res. Lett., 34, L23615, doi:10.1029/2007GL031645.

Balmaseda, M.A., A. Vidard and D.L.T. Anderson, 2008: The ECMWF ocean analysis system ORA-S3. To appear in Mon. Wea. Rev.

Alves O., M. Balmaseda, D Anderson, T Stockdale, 2004: Sensitivity of dynamical seasonal forecasts to ocean initial conditions. Q. J. R. Meteorol. Soc.,130, 647-668.

Burgers G., M. A. Balmaseda, F. Vossepoel, G. J. van Oldenborgh, P.J.van Leeuwen,2002: Balanced ocean-data assimilation near the equator. JPO, 32, 2509-2519.

Stephenson, D. B., Coelho, C. A. S., Doblas-Reyes, F. J. and Balmaseda, M., 2005: Forecast Assimilation: A unified framework for the combination of multi-model weather and climate predictions. Tellus 57A: 253-264.

Anderson D., M. Balmaseda and A. Vidard 2005: The ECMWF perspective. In Godae book on Data Assimilation. Ed E Chassignet and J Verron.

Partner 10: Eidgenössische Technische Hochschule Zürich (ETHZ)

Expertise and experience of the organization

The Institute for Atmospheric and Climate Science (IACETH) at ETH Zurich is part of the Department of Environmental Sciences (D-UWIS). IACETH straddles the inter-related disciplines of atmospheric and climate science. It pursues leading-edge research on atmospheric physics, chemistry and dynamics, and on global and regional past, present and future climate, and it pioneers activities at the interfaces of these sub- component fields and the interfaces to other disciplines. IACETH has 110 members and consists of six research groups. The Atmospheric Physics group, led by Prof. Lohmann, focuses on aerosol-cloud interactions in warm, mixed phase and ice clouds and their importance for the radiation budget and the hydrological cycle. It develops instrumentation and observation methods, applying these to aerosol and cloud microphysics in field experiments and in the laboratory. It maintains a suite of numerical models ranging from cloud- resolving models over regional weather prediction models to global climate models.

Role and contribution

Ulrike Lohmann is leading WP2. Her role is to help with the implementation of the improved parameterizations of aerosol interactions with warm, mixed-phase and ice clouds in both COSMOS and EC-Earth and to study their importance with regard to radiative forcing, the hydrological cycle and cloud feedbacks in a warmer climate. She will also help to implement the improved description of cloud processing within COSMOS and its effect on aerosols and subsequent cloud activation.

Principal personnel involved

Prof. Ulrike Lohmann leads the WP2 on aerosols, clouds and chemistry. She has published more than 110 peer-reviewed articles. She works or has worked in several international committees, among them as a lead author for the Fourth Assessment Report of the Intergovernmental Panel for Climate Change (IPCC) and as a member of the scientific steering committees of ICCP, IGAC and the GEWEX Cloud System Studies (GCSS) Panel. She is editor for the magazine "Atmospheric Chemistry and Physics". Prof. Lohmann was awarded the AMS Henry G. Houghton Award (2007) "For pioneering contributions to the representation and quantification of the effects of cloud-aerosol interactions on climate." She became a "fellow" of the American Geophysical Union in 2008.

Selected relevant publications:

Hoose, C., U. Lohmann, B. Verheggen, E. Weingartner and P. Stier, Aerosol Processing in Mixed-Phase Clouds in ECHAM5-HAM: Model Description and Comparison to Observations, J. Geophys. Res., in press, 2008.

Lohmann, U, Global anthropogenic aerosol effects on convective clouds in ECHAM5-HAM, Atmos. Chem. Phys. Disc. 7, 14639-14674, 2007.

Lohmann, U., P. Stier, C. Hoose, S. Ferrachat, S. Kloster, E. Roeckner and J. Zhang, Cloud microphysics and aerosol indirect effects in the global climate model ECHAM5-HAM, Atmos. Chem. Phys. 7, 3425-3446, 2007.

Lohmann, U. and K. Diehl, Sensitivity studies of the importance of dust ice nuclei for the indirect aerosol effect on stratiform mixed-phase clouds, J. Atmos. Sci. 63, 968-982, 2006.

Stier P., Feichter J., Kinne S., Kloster S., Vignati E., Wilson J., Ganzeveld L., Tegen I., Werner M. , Schulz M., Balkanski Y., Boucher O., Minikin A., Petzold A.: The Aerosol-Climate Model ECHAM5-HAM, Atmospheric Chemistry and Physics, 5, 1125-1156, 2005.

Pozzoli, L., I. Bey, J. S. Rast,M. G. Schultz, P. Stier, and J. Feichter : Trace gas and aerosol interactions in the fully coupled model of chemistry-aerosol-climate ECHAM5-HAMMOZ, PART I: Model description and insights from the spring 2001 TRACE-P experiment. J. Geophys. Rese., in press, 2008.

Storelvmo, T., J.-E. Kristjansson and U. Lohmann, Aerosol influence on mixed-phase clouds in CAM-Oslo, J. Atmos. Sci., in press, 2008.

Partner 11: Finnish Meteorological Institute (FMI)

Expertise and experience of the organization

FMI is a research and service organisation under the Ministry of Transport and Communications Finland. The main objective of FMI is to provide the Finnish society with the best possible information about the atmosphere in and around Finland. FMI has about 550 employees of which about 250 in the “Research and Development” sector. Climate change research of FMI covers a wide spectrum of issues. Regarding the COMBINE proposal, aerosol research of FMI is of special interest. It covers measurements and modelling on research topics such as biogenic emissions, new particle formation and growth processes, size-segregated aerosol characteristics and aerosol cloud activation. New schemes are developed in a box-model context and tested in the COSMOS-ESM, especially those regarding aerosol microphysics, cloud-aerosol interactions and sub grid-scale cloud radiative effects.

Role and contribution

The role of FMI is to co-lead WP2. In WP2, FMI will improve representation of subgrid-scale clouds and their interaction with radiative transfer in the COSMOS-ESM. Additionally, representation of aerosol micro-physical processes will be enhanced in the COSMOS-ESM.

Principal personnel involved

Prof. Heikki Järvinen is a co-leader of WP2. He coordinates climate modelling activities in Finland and has published some 35 research articles, mainly in the field of atmospheric dynamical systems and data assimilation.
Prof. Veli-Matti Kerminen has published 102 research articles in the field of atmospheric aerosols. He is the president of Finnish Association for Aerosol Research and Editor of Boreal Environment Research.
Prof. Ari Laaksonen is the head of Climate change research of FMI, He has published some 120 research articles in the field of aerosol microphysics and cloud activation.

Selected relevant publications

Kokkola, H, Korhonen, H, Lehtinen, K E J, Makkonen, R, Asmi, A, Järvenoja, S, Anttila, T, Partanen, A-I, Kulmala, M, Järvinen, H, Laaksonen, A and V-M Kerminen (2007) SALSA – a Sectional Aerosol module for Large Scale Applications. Atmos. Chem. Phys. Discuss., 7, 17705-17739.

McFiggans, G, Artaxo, P, Baltensperger, U, Coe, H, Facchini, C, Feingold, G, Fuzzi, S, Gysel, M, Laaksonen, A, Lohmann, U, Mentel, T, Murphy, D, O'Dowd, C and J Snider (2006) The Effect of Aerosol Composition and Properties on Warm Cloud Droplet Activation. Atmos. Chem. Phys., 6, 2593-2649.

Romakkaniemi, S, Kokkola, H and A Laaksonen (2005) Parameterization of the nitric acid effect on CCN activation. Atmos. Chem. Phys., 5, 879-885.

Romakkaniemi, S, Kokkola, H, Lehtinen, K E J and A Laaksonen (2006) The influence of nitric acid on the cloud processing of aerosol particles. Atmos. Chem. Phys., 6, 1627-1634.

Räisänen, P, Järvenoja, S, Järvinen, H, Giorgetta, M, Roeckner, E, Jylhä K and K Ruosteenoja (2007) Tests of Monte Carlo Independent Column Approximation in the ECHAM5 atmospheric GCM. J. Climate, 20, 4995-5011.

Sorjamaa R, Svenningsson, B, Raatikainen, T, Henning, S, Bilde, M and A Laaksonen (2004) The role of surfactants in Köhler theory reconsidered. Atmos. Chem. Phys., 4, 2107-2117.

Tunved, P, Hansson, H-C, Kerminen, V-M, Ström, J, Dal Maso, M, Lihavainen, H, Viisanen, Y, Aalto, P P, Komppula, M and M Kulmala (2006) High Natural Aerosol Loading over Boreal Forests. Science, 312, 261 – 263.

Partner 12: Netherlands Environmental Assessment Agency (MNP)

Expertise and experience of the organization

The Netherlands Environmental Assessment Agency (MNP) supports national and international policymakers by analysing the environmental impact of policies and of trends in society. MNP provides independent integrated assessments on topics such as sustainable development, energy and climate change, biodiversity, transport, land use and air quality. MNP acts as the interface between science and policy. MNP is a government-funded assessment agency, working in close collaboration with national and international partners, to assess future policies and the effects of policies already in place. MNP's independence is anchored in law. MNP has considerable expertise in building and applying models and scenarios for policy purposes. The Energy and Climate Programme explores and evaluates energy and climate policy options at the national, European and global levels. MNP explores greenhouse gas mitigation options, and assess synergies and trade-offs between climate objectives, and other energy and environmental goals. One of the main tools used for this purpose is the IMAGE integrated assessment modelling framework. This framework links energy modelling, agricultural and land use modelling and climate modelling to provide an integrated description of global change. IMAGE has been extensively involved in activities of IPCC, as one of the models developing the IPCC SRES scenarios, contributing to analysis of the Fourth Assessment Report. IMAGE is also involved in developing the new IPCC scenarios to be used for next assessments.

Role and contribution

MNP's involvement in COMBINE is providing information on scenarios for ESM model runs in WP6, WP7 and other WPs, and by interpreting the results of ESM scenario analysis in terms of implications of post-Kyoto climate policy. The latter is done by developing new mitigation scenarios based on revised parameter estimates for climate and greenhouse gas budgets based on the ESM runs that include the new components (and thus the associated feedbacks). Results include estimates of required emission reductions for achieving the EU 2 degree climate target (and/or other climate targets) and associated costs, vis-à-vis earlier scenarios not taking into account new insights obtained in the current project. Analysis will also focus on the consequences of uncertainties associated with the range of model results.

Principal personnel involved

Dr. Detlef van Vuuren's work at MNP is focused on assessment of global environmental problems, specifically in relation to energy use. He participated as Coordinating Lead Author and Lead Author in the scenario work for the Millennium Ecosystem Assessment, UNEP's Global Environment outlook and the IPCC 4AR. He is an active contributor to the Energy Modelling Forum coordinated by Stanford University. On the issues of Climate Policy, his work concentrates on identifying long-term mitigation pathways.

Dr. Elke Stehfest worked as PhD-student at the Center for Environmental Systems Research, Kassel, within the graduate program „International Max Planck Research School on Earth System Modelling". In 2006, she joined as scientist the Netherlands Environmental Assessment Agency (MNP) coordinating work on the IMAGE Integrated Assessment Framework with respect to land use and climate modelling.

Selected relevant publications:

Den Elzen and Van Vuuren, 2007 Peaking profiles can achieve global temperature targets with more likelihood at lower costs. PNAS 2007; vol. 104 (no. 46): 17931-17936

Van Vuuren et al., 2007. Stabilizing greenhouse gas concentrations at low levels. Climatic Change. 81 (2). 119-159.

den Elzen M., Meinshausen M., van Vuuren D. Multi-gas emission envelopes to meet greenhouse gas concentration targets: Costs versus certainty of limiting temperature increase. Global Environmental Change. 17. 2

Partner 13: Swedish Meteorological and Hydrological Institute (SMHI)

Expertise and experience of the organization
SMHI is a governmental institute under the auspices of the Swedish Ministry of the Environment, providing operational services and research in the fields of climate, oceanography, meteorology and hydrology. The Rossby Centre at SMHI conducts both model development and applications for climate change research and impact studies. SMHI is/was active partner in climate related EU projects such as PRUDENCE, ENSEMBLES, PRISM, GLIMPSE and DAMOCLES.

Role and contribution
SMHI is a member of the international EC-EARTH consortium, with a focus on the Arctic and relevant climate processes. The high susceptibility of the Arctic climate to global change requires a better understanding of a number of key climate processes. SMHI will work on an improved representation and initialisation of sea-ice in Earth System Models. Other research themes include decadal prediction, using the EC-Earth system and the generation of an ensemble of decadal regional climate predictions for the Arctic,

Principal personnel involved
Dr. Colin Jones is the Head of the Rossby Centre and was previously the Director of the Canadian Regional Climate Modelling and Diagnostics Network. Dr Jones worked at the Rossby Centre between 1998 and 2004 and was responsible for the development of the atmospheric component of the coupled Rossby Centre Regional Climate Model (RCAO). He is an invited expert on the WCRP Working Group on Numerical Experimentation and is a member of the EC-Earth Steering committee. He contributes to WP6 and WP8
Dr. Ralf Dösche is senior researcher at Rossby Centre at SMHI, with expertise in numerical oceanography. He is interested in climate related aspects of the ocean circulation, ocean-atmosphere coupling, and sea ice dynamics. Ralf is/has been work package leader in EU projects on coupled modelling in the arctic (GLIMPSE, DAMOCLES) and in general (PRISM). Current activities are sensitivity and predictability studies and the first ever regional Arctic climate scenario simulations. He contributes to WP4, WP5and WP8.
Dr. Klaus Wyser, is a researcher at Rossby Centre at SMHI, working with regional and global climate models, He is involved in the development of EC-EARTH, working on the coupling between atmosphere, ocean, and sea-ice. The focus of the EC-EARTH development will be on decadal prediction and sea-ice processes. Within COMBINE, Klaus will contribute to WP4, WP5, WP6 and WP8
Dr. Torben Königk Joined SMHI in 2008. Before, he worked at Max-Planck-Institute for Meteorology (Hamburg/Germany) with research focus on climate variability and predictability in high northern latitudes. He was involved in the SFB512 project (Cyclones and the North Atlantic Climate System) and contributed to the ASOF project (Arctic Subarctic Ocean Fluxes). Within COMBINE, Torben will be involved in WP4 and WP5.

Selected relevant publications:

Koenigk, T, U. Mikolajewicz, H Haak, J Jungclaus 2006: Variability of Fram Strait sea ice export: causes, impacts and feedbacks in a coupled climate model. Clim Dyn 26:17-34, doi: 10.1007/s00382-005-0060-1

Koenigk, T, U. Mikolajewicz, H Haak, J Jungclaus 2007: Arctic freshwater export in the 20th and 21st centuries. J Geophys Res 112, GS04S41, doi: 10.1029/2006JG000274

Wyser K., C. G. Jones, P. Du, E. Girard, U. Willén, J. Cassano, J. H. Christensen, J. A. Curry, K. Dethloff, J.-E. Haugen, D. Jacob, M. Koltzow, R. Laprise, A. Lynch, S. Pfeifer, A. Rinke, M. Serreze, M. J. Shaw, M. Tjernström, and M. Zagar, 2007 An evaluation of Arctic cloud and radiation processes during the SHEBA year: simulation results from eight Arctic regional climate models. Clim. Dyn., doi:10.1007/s00382-007-0286-1

Partner 14: Wageningen University & Research Centre (WU)

Expertise and experience of the organization

Wageningen University & Research Centre is a cluster of internationally-leading knowledge institutions offering applied and scientific research to promote the sustainable use of our environment. Research focuses on land use, water management and environment in rural and semi-urban areas and is implemented in close collaboration with stakeholders and private and public research partners. WU has a longstanding record of successfully conducting and coordinating large European projects within the current and past EU Frameworks. The Earth System Sciences and Climate Change (ESS-CC) of the Environmental Science Group of WU participates in COMBINE. ESS-CC is expert on interactions between biogeochemistry, land use change and climate change. The group develops detailed stand alone LSMs based on long-term flux monitoring projects and uses the same LSMs in acoupled RCM and GCM to study interactions between land use change, atmospheric chemistry and weather. Issues at large scale are studied with integrated assessment models.

Role and contribution

The Earth System Sciences group will be involved in three COMBINE work packages:

Dr L.N. Ganzeveld will participate in WP2: to include feedbacks between atmospheric chemistry and vegetation wrt biogenic emissions and canopy exchanges of reactive NMVOC and nitrogen relevant to the uptake of CO_2 and ozone and production of biogenic aerosols containing organic carbon and nitrogen

Prof P Kabat, Dr A.F. Bouwman, Dr M.R. Hoosbeek, Dr R.W.A. Hutjes and Ir HW ter Maat in WP8 are responsible for respectively coordination and analsysis wrt the impacts of new component ESM scenarios on global water cycle, biomass productivity and agriculture and for the case study Amazon

Principal personnel involved

Dr L.N. Ganzeveld is assistant professor in the ESS-CC Group whose main interests are in atmospheric chemistry, climate, reactive trace gas- and aerosol exchanges, boundary layer processes, land use and land cover..**Dr RWA Hutjes** is senior scientist in the ESS-CC group whose main interests are in measuring & modelling of land cover-atmosphere exchange processes using aircraft and mesoscale meteorological models, carbon and nutrient cycling and greenhouse gas emissions from nature and agriculture**. Prof Pavel Kabat** is chair of the ESS-CC group and director of the national research programme ‘Climate changes Spatial Planning’. His research focuses on land use–hydrology interactions; climate impacts on water resources and global environmental change processes. He (co)-authored over 200 reviewed publications and six books. He is (co-)chair of IGBP-iLEAPS and WCRP-GEWEX–ISLSCP. He acted as PI and research co-ordinator in over 25 EU supported projects**. Ir HW ter Maat** is junior scientist in the ESS-CC Group whose main interests are in Climatology, Mesoscale meteorology, Micrometeorology, Soil physics, Land-atmosphere interactions

Selected relevant publications:

Ganzeveld, L., and J. Lelieveld, Impact of Amazonian deforestation on atmospheric chemistry, Geophys. Res. Lett., 31, L06105, doi:10.1029/2003GL019205, 2004.

Ganzeveld, L., Klemm, O., Rappenglück, B., Valverde-Canossa, J., Evaluation of Micrometeorology over a Coniferous Forest in a Single-Column Chemistry-Climate Model, Atmos. Environ., 40, S21-S27, 2006.

J. Lelieveld, T. M. Butler, J. Crowley, T. Dillon, H. Fischer, L. Ganzeveld, H. Harder, D. Kubistin, M. G. Lawrence, M. Martinez, D. Taraborrelli & J. Williams (2008) Tropical forest sustains atmospheric oxidation capacity. Accepted for Nature.

ter Maat, H.W., R.W.A. Hutjes, R. Ohba, H. Ueda, B. Bisselink, T. Bauer (2006). Meteorological impact assessment of possible large scale irrigation in Southwest Saudi Arabia. Global and Planetary Change 54 (1-2): 183-201

Kabat P, P. Vellinga, W. Van Vierssen, J. Veraart and J. Aerts, 2005. Climate proofing of the Netherlands. Nature 438: 283-284.

Kabat, P, P,Gleick, J.Alcamo, R.E.Schultze, H.van Schaik and C, Jacobs, 2006. Managing Water Resources under Changing Climate. Climatic Change, Special Issue / 2 Volumes/32 papers (in press).

Kabat, P.; M. Claussen, P. Diemeyer, J.H.C. Gash, L. Guenni, M. Meybeck, R. Pielke, Ch. Vorosmarty, R. Hutjes & S. Lutkemeier (eds.) (2004) "Vegetation, water, humans and the climate: a new perspective on an interactive system ". Springer Verlag; 600 pp.

Partner 15: University of Helsinki (UHEL)

Expertise and experience of the organization

The Department of Physical Sciences at the University of Helsinki has over 25 years tradition in atmospheric and urban air pollution research. 70 scientists and doctoral students are currently engaged in this area. The main research subjects are aerosol dynamics (nucleation, condensation, coagulation, deposition), formation and growth of atmospheric aerosol particles and cloud droplets, atmospheric chemistry, urban aerosols, air quality, forest-atmosphere interactions (fluxes, photosynthesis, water transport), and aerosol-cloud-climate interaction. The basic theoretical resources consist of detailed computer codes describing basic phenomena such as multicomponent nucleation and condensation, photosynthesis, and of extensive model for aerosol dynamics, atmospheric chemistry, cloud microphysics as well as regional and climate models. The basic experimental resources consist of three field stations (SMEAR I and SMEAR II and Urban SMEAR) and a state-of-art aerosol laboratory. In the field stations e.g. aerosol dynamics, atmospheric chemistry, micrometeorology, urban particulate matter are measured continuously.

Role and contribution

UHEL participates in WP2. The main contribution is comparison and parameterization of different explicit canopy models and to implement them to ESMs particularly to COSMOS. The emphasis is on biosphere-atmosphere interactions including the different feedbacks between climate change and atmosphere-biosphere like BVOC formation, ozone, biogenic aerosol formation nad N deposition. UHEL will participate also on improving parameterizations of aerosol interactions with warm, mixed-phase and ice clouds in COSMOS.

Principal personnel involved

Prof. Markku Kulmala (University of Helsinki, Department of Physical Sciences) acts as a Research Unit leader in the Research Unit on Physics, Chemistry and Biology of Atmospheric Composition and Climate Change (Centre of Excellence, Academy of Finland). The research unit consists of 120 scientists. M. Kulmala is also the head of one Nordic centre of Excellence (Research Unit on Biosphere – Aerosol – Cloud – Climate Interactions) as well as the corresponding NordForsk Graduate school (Carbon - Biosphere – Aerosol – Cloud – Climate Interactions). He coordinates also the European Integrated project on Aerosol Cloud Climate and Air Quality Interactions (EUCAARI). M. Kulmala has published over 400 original research papers, 6 of them in Nature, 5 in Science and 5 in Physical Review Letters. He has received the Smoluchovski Award in 1997, The Finnish Science Award in 2003, The International Aerosol Fellow Award in 2004, Doctor Honorus Causa, University of Stockholm in 2005, and Wilhelm Bjerkenes medal (EGU) in 2007. He has participated in 26 (3 as coordinator) EU projects and has procured 30 M€ in research income.

Selected relevant publications:

Kulmala, M., A. Laaksonen, R.J. Charlson, P. Korhonen, 1997, Clouds without supersaturation. Nature 388, 336-337.

Kulmala M., L. Pirjola, J.M. Mäkelä, 2000, Stable sulphate clusters as a source of new atmospheric particles. Nature, 404, 66-69.

O'Dowd, C.D., P.P. Aalto, K. Hämeri, M. Kulmala, T. Hoffmann, 2002, Aerosol formation: atmospheric particles from organic vapours. Nature, 416, 497-498.

Kulmala M., Vehkamäki H., Petäjä T., Dal Maso M., Lauri A., Kerminen V.-M., Birmili W., McMurry P.H., 2004, Formation and growth rates of ultrafine atmospheric particles: A review of observations. J. Aerosol Sci., 35, 143-176.

Kulmala M, 2003, How Particles Nucleate and Grow. Science 302, 1000-1001.

Tunved P, Hansson HC, Kerminen VM, Strom J, Dal Maso M, Lihavainen H, Viisanen Y, Aalto PP, Komppula M, Kulmala M , 2006, High natural aerosol loading over boreal forests, Science 312, 261-263

Spracklen, D.V., K.S. Carslaw, M. Kulmala, V.-M. Kerminen, G.W. Mann and S.-L. Sihto, 2006, The contribution of boundary layer nucleation events to total particle concentrations on regional and global scales, Atmos Chem Phys 6, 5631-5648

Kulmala, M., Riipinen, I., Sipilä, M., Manninen, H., Petäjä, T., Junninen, H., Dal Maso, M., Mordas, G., Mirme, A., Vana, M., Hirsikko, A., Laakso, L., Harrison, R M., Hanson, I., Leung, C., Palmer, R., Lehtinen, K. E. J., and Kerminen V.-M., 2007, Towards direct measurement of atmospheric nucleation, Science, 318, 89-92, 10.1126/science.1144124.

Partner 16: European Centre for Research and Advanced Training in Scientific Computation (CERFACS)

Expertise and experience of the organization

Established in 1987, CERFACS is one of the world's leading research institutes in the development of algorithms and modelling techniques for high-performance scientific computers. The CERFACS Climate Modelling and Global Change team conducts basic and applied scientific research in climate modelling and data assimilation as well as developing high-level coupling and data assimilation software. The main software for climate applications include 1) OASIS - a coupler designed to perform synchronized exchanges of information between individual model components of state-of-the-art climate models on a variety of computer platforms; and 2) OPAVAR - a variational ocean data assimilation system for the community ocean model OPA (aka NEMO) which has been used in the EU projects ENACT and ENSEMBLES for multi-decadal global ocean reanalysis and seasonal/decadal forecast initialisation. OASIS and OPAVAR are widely used in France and abroad. The Climate team has participated in over 12 EU-funded projects.

Role and contribution

CERFACS will contribute to both WP5 and WP6. In WP5, CERFACS will be responsible for adapting the OPAVAR system developed for ENSEMBLES to the new version of the ocean model (NEMO) and to higher resolution analysis. The new system, called NEMOVAR, will be used by ECMWF for the production of ensembles of initial conditions and the testing of the "real-world" initialisation strategies 1 and 3 with NEMO/IFS. In WP6, CERFACS will perform the decadal prediction experiments with the high-resolution ARPEGE-NEMO (TL159 for atmosphere, 0.5 degree for the ocean) coupled model initialized with oceanic states provided first, by an ocean-only experiment forced by observed atmospheric fields (stream 1) and second, with observed initial states provided by WP5 (stream 2).

Principal personnel involved

Dr. Weaver, Anthony is a senior scientist at CERFACS. He leads the ocean data assimilation activities at CERFACS and is a principal developer of the NEMOVAR system. He was a WP leader in the ENACT project and is involved in the ENSEMBLES project. He is a member of the CLIVAR Global Synthesis and Ocean observations Panel (GSOP) and is an Associate Editor for the AMS journal Monthly Weather Review.

Dr. Terray, Laurent has worked in the field of climate modelling for more than 15 years. He has been a principal coordinator of climate research activities within the CLIVAR French program PNEDC. He is a member of various scientific committees including the CLIVAR Atlantic Implementation Panel and French National Research Agency. He has participated in several EU projects (e.g., PREDICATE, ENSEMBLES, and DYNAMITE) concerned with climate prediction. He was the original developer of the OASIS coupler.

Selected relevant publications:

Cassou C., L. Terray and A. S. Phillips, 2005: Tropical Atlantic influence on European Heatwaves. J. Climate, 18, 2805-2811.

Collins M., N. Botzet, A. F. Carril, H. Drange, A. Jouzeau, M. Latif, S. Masima, O. H. Otteraa, H. Pohlmann, A. Sorteberg, R. Sutton and L. Terray, 2006: Interannual to Decadal Climate Predictability in the North Atlantic: A Multimodel-Ensemble Study. J. Climate, 19, 1195-1203.

Ricci, S., Weaver, A. T., Vialard, J. and P. Rogel, 2005: Incorporating state-dependent temperature-salinity constraints in the background-error covariance of variational ocean data assimilation. Mon. Wea. Rev., 133, 317–338.

Terray, L., Demory, M.-E., Déque, M., de Coetlogon, G. and Maisonnave, E., 2004: Simulation of late twenty-first century changes in wintertime atmospheric circulation over Europe due to anthropogenic causes. J. Climate, 17, 4630-4635.

Weaver, A. T., Deltel, C., Machu, E., Ricci, S. and N. Daget, 2005: A multivariate balance operator for variational ocean data assimilation. Q. J. R. Meteorol. Soc., 131, 3605–3626.

Weaver, A. T., Vialard, J. and D. L. T. Anderson, 2003: Three- and four-dimensional variational assimilation with an ocean general circulation model of the tropical Pacific Ocean. Part 1: formulation, internal diagnostics and consistency checks. Mon. Wea. Rev., 131, 1360–1378.

Partner 17: Université Catholique de Louvain (UCL) – Institut d'Astronomie et de géophysique Georges Lemaître

Expertise and experience of the organization

The Institut d'Astronomie et de Géophysique Georges Lemaître belongs the Physics Department of the Université Catholique de Louvain (Louvain-la-Neuve, Belgium). Over the last 30 years, it has gained a worldwide reputation for the study of climate dynamics and mesoscale meteorology. In particular, it is widely known for its contributions to the astronomical theory of paleoclimates and for the development a comprehensive sea-ice model (LIM), which is used in a number European research laboratories involved in climate modelling and operational oceanography. Its present research activities deal with (1) climate variability in polar regions, with focus on the role of sea ice and ocean, (2) past climate changes, (3) human impacts on climate, (4) regional climate and atmospheric processes, (5) lakes and shallow seas, and (6) development of modelling tools. All this research is well integrated in Belgian and international research programmes. For further information, see www.ucl.ac.be.

Role and contribution

UCL will contribute to WP4 by adding new components to its sea-ice model LIM, by developing an interface for coupling this model to atmospheric general circulation models and by participating with other teams to the implementation of the new version of LIM in some ESMs. In WP5, it will contribute to the set-up and assessment of the sea-ice initialisation techniques (WP5) that will be used in the decadal climate predictions conducted with EC-Earth in WP6. A thorough analysis of the impact of the improvements made to LIM on these predictions will also be undertaken. This work will be done in close collaboration with SMHI. Finally, UCL will lead in WP7 the analysis of sea-ice feedback mechanisms in the centennial simulations carried out by IPSL with IPSL-ESM.

Principal personnel involved

Dr. Thierry Fichefet is the Head of the Institut d'Astronomie et de Géophysique Georges Lemaître and is Professor of physics, meteorology, climatology, physical oceanography and climate modelling at the Université catholique de Louvain. He has about 25 years of experience in global climate modelling, with focus on cryosphere–climate interactions. He is author or co-author of 135 scientific papers, most of them published in international peer-reviewed journals or books. Thierry Fichefet was member of the Scientific Steering Group of CliC up to 2008 and is the Belgian representative in CLIVAR. He was Contributing Author of the IPCC Third Assessment Report and Lead Author of the Fourth Assessment Report. Besides, Thierry Fichefet was principal investigator in 14 R&D projects funded by the European Commission and coordinator of 3 research projects financed by the Belgian Federal Science Policy Office.

Dr. Hugues Goosse is Research Associate with the Belgian National fund for Scientific Research, part-time lecturer at UCL and invited professor at the Unversiteit Gent. He has about 15 years of experience in global climate modelling and his research interest is presently focused on decadal-to-centennial climate variability in mid- and high latitudes and on the evolution of polar climate over the last few millennia. Hugues Goosse is author or co-author of more than 80 papers in international refereed journals and was Contributing Author of the IPCC Fourth Assessment Report.

Selected relevant publications:

Fichefet, T., and M.A. Morales Maqueda, 1997 : Sensitivity of a global sea ice model to the treatment of ice thermodynamics and dynamics. *J. Geophys. Res.*, **102**, 12,609–12,646.

Goosse, H., and T. Fichefet, 1999 : Importance of ice-ocean interactions for the global ocean circulation : A model study. *J. Geophys. Res.*, **104**, 23,337–23,355.

Timmermann, R., H. Goosse, G. Madec, T. Fichefet, C. Ethé, and V. Dulière, 2005 : On the representation of high latitude processes in the ORCALIM global coupled sea ice–ocean model. *Ocean Modell.*, **8**, 175–201.

Arzel O., T. Fichefet, H. Goosse, 2006 : Sea ice evolution over the 20th and 21st centuries as simulated by current AOGCMs. *Ocean Modell.*, **12**, 401–415.

Vancoppenolle, M., C. Bitz, and T. Fichefet, 2007 : Summer land fast sea ice desalination at Point Barrow, Alaska : Model and observations. *J. Geophys. Res.*, **112**, C04022, doi : 10.1029/2006JC003493.

Partner 18: University of Bristol (UNIVBRIS)

Expertise and experience of the organization

The group of Professor Prentice at the University of Bristol is world-leading in the development of terrestrial biosphere models and their application to global changes, both past and future. Recent and current research has focussed on modelling organic soil (peatland) hydrology and permafrost dynamics, nitrogen-carbon cycle coupling, fire-vegetation interactions, and emissions of trace gases from these processes. The group participates in the European HYMN (Hydrogen, Methane, Nitrous Oxide) project where it is responsible for prognostic modelling of trace-gas emissions from the biosphere.

Role and contribution

UNIVBRIS will provide expertise for this project specifically in the representation of temperature and freezing profiles in organic soils and the consequences for hydrological and biological processes, including microbial activities and ecosystem structure, composition and productivity. They will make their recently developed "off-line" model codes available to the project, assist in their implementation in Earth System modelling frameworks, provide key data sets for evaluating model performance and participate in evaluations of the relevant model components.

Principal personnel involved

Professor I. Colin Prentice is Professor of Earth System Science and also leads the QUEST (Quantifying and Understanding the Earth System) research programme of the UK Natural Environment Research Council. He is a world leader in modelling the terrestrial biosphere and its interactions with the atmosphere, having led the development of the BIOME and LPJ model families, work for which he was awarded the Milankovitch Medal by the European Geophysical Society in 2002. He was co-ordinating lead author for "The carbon cycle and atmospheric carbon dioxide" in the IPCC Third Assessment Report and has published extensively on the interactions of the biosphere and atmospheric CO2.

Dr. Pru Foster is an experienced numerical modeller, with a PhD in astrophysics from the University of Virginia and subsequent experience in modelling global change impacts on the biosphere. She manages biosphere modelling for the HYMN project.

Selected relevant publications:

Xu-Ri and I.C. Prentice, in press at Global Change Biology, "Terrestrial nitrogen cycle simulation with a dynamic global vegetation model"

Wania, R. and I.C. Prentice, in revision at Global Change Biology, "Integrating peatland and permafrost into a dynamic global vegetation model: evaluation and sensitivity to climate change"

Sitch, S., B. Smith, I.C. Prentice, A. Arneth, A. Bondeau, W. Cramer, J.O. Kaplans, S. Levis, W. Lucht, M.T. Sykes, K. Thonicke and S. Venevsky, 2003, "Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model", Global Change Biology 9, 161-185

Thonicke, K., A. Spessa, I. C. Prentice, S. P. Harrison, and C. Carmona-Moreno, in revision at Global Change Biology, "The influence of vegetation, fire spread and fire behaviour on global biomass burning and trace gas emissions"

Prentice, I.C. 2001, Coordinating lead author on "Chapter 3. The Carbon Cycle and Atmospheric Carbon Dioxide" in the Third Assessment Report of the IPCC Working Group I: The Scientific Basis

Pounds, J.A., Bustamante, R., Coloma, L.A., Consuegra. J.A., Fogden, M.P.L., Foster, P.N., La Marca, E., Masters, K.L., Merino-Viteri, A., Puschendorf, R., Ron, S.R., Sanchez-Azofeifa, S., Still, C.J. & Young, B.E. 2006, "Widespread amphibian extinctions from epidemic disease driven by global warming", Nature 439, 161

Partner 19: University of Kassel (Uni Kassel) - Center for Environmental Systems Research (CESR)

Expertise and experience of the organization

The Center for Environmental Systems Research (CESR) is one of four interdisciplinary, non-profit research centres at the University of Kassel which is a public body. The Center is unique in its concentration on environmental research from the systems perspective. It is well known for its work on global environmental modelling and for its studies of society-environment interactions. Researchers are involved in many international research activities including the International Geosphere-Biosphere Programme, the International Human Dimensions Programme on Global Change, the Intergovernmental Panel on Climate Change, and the European Forum for Integrated Environmental Assessment. The Center is one of the most active centres in Europe for the assessment of world water resources. Researches are focusing on the development and the application of simulation models, (i) addressing different aspects of land use change and their environmental and socioeconomic impacts, and (ii) changes in the hydrologic cycle and water use in different water using sectors such as households or agriculture, thus focusing on water and land related topics. Therefore two global models have been developed at CESR: the LandShift model, an integrated land use change model for global and continental scale applications and the WaterGAP model, the first global model that simulates both water availability and water use on the river basin scale. Many original European and global data sets have been developed by the Center's researchers to support European and global water and land use related assessments.

Role and contribution

One research objective will be to assess the vulnerability of water resources to global environmental, social, and economic change. The WaterGAP model will be used for modelling global water availability and water use. WaterGAP provides a framework to take into account the impact of major driving forces on future water resources. To assess the impact of land use changes on future water resources, model simulations will be carried-out with LandShift, which combines human and environmental aspects of the land system. The coupling of both models, LandShift and WaterGAP, will enable a consistent analysis of AR5 climate impacts on changes in land and water resources on a global scale.

Principal personnel involved

The project team will be led by **Prof. Joseph Alcamo**, Professor of Environmental Systems Science and Technology at the University of Kassel. Prof. Alcamo has led international policy-relevant projects over more than two decades and in three different European countries, including 9 years at the International Institute for Applied Systems Analysis near Vienna. He has led many complex projects that have contributed to international environmental assessments, e.g. the EU-financed European Consortium of AIR-CLIM, the Global Modelling Consortium for the Millennium Ecosystem Assessment and GEO-4. Currently he is co-coordinating the integrated project SCENES, funded by the EU under the 6th Framework Programme. He is particularly experienced in leading interdisciplinary projects that combine perspectives of natural sciences, social sciences and economics.

Selected relevant publications:

Alcamo, J., Döll, P., Henrichs, T. Kaspar, F., Lehner, B., Rösch, T., and Siebert, S.: 2003a, Development and testing of the WaterGAP 2 global model of water use and availability. Hydrological Sciences 48(3), 317-337.

Alcamo, J., Döll, P., Henrichs, T. Kaspar, F., Lehner, B., Rösch, T., and Siebert, S.: 2003b, Global estimation of water withdrawals and availability under current and "business as usual" conditions. Hydrological Sciences 48(3), 339-348.

Alcamo, J., Schaldach, R. (2006) LandShift: Global Modelling to Assess Land Use Change In: Tochtermann (2006). EnviroInfo 2006. Managing Environmental Knowledge. Proceedings of the 20th International Conference "Informatics for Environmental Protection: 223-230.

Schaldach, R., Priess, J., Alcamo, J. (2007) Simulating the impact of bio-fuel development on country-wide land-use change in India. Biomass and Bioenergy (submitted).

Partner 20: Technical University of Crete (TUC)

Expertise and experience of the organization

The Technical University of Crete (http://www.tuc.gr) is a modern technological institution that has established a reputation both in Greece and abroad. Although relatively new, the University has already contributed in many ways to the improvement of the community. The Faculty participates actively in the international science and engineering network. The University enrolls about 1800 undergraduate students and 500 graduate students and employs about 250 researchers and lectures, including 80 tenured professors and 60 externally funded professors. The Department of Environmental Engineering has three divisions (a) Environmental Hydraulics & Geo-environmental Engineering (b) Environmental Management and (c) Environmental Process Design. The Laboratory of Water Resources Management and Coastal Engineering is involved in areas such as Water Resources Modelling & Management, Environmental Hydraulics and Hydrology, Floods and Droughts, Environmental Information Systems and Coastal Engineering Modelling.

Role and contribution

TUC will contribute to the examination of the local impacts in water resources and agriculture through the use of a modelling chain. The case study site will be Crete Island. The role of TUC in COMBINE project can be summarized to the following: 1: quantification of the underestimation of precipitation by comparing the results over a flat terrain (Thessaly plain) and mountainous island of Crete, 2: Downscaling the climate change results down to 1 km x 1km, 3: Definition of the trends of water needs (tourism, agriculture) under climate change, 4: Application of a non-hydrostatic model to simulate orographic precipitation, 5: Validation of the new non-hydrostatic climate change model and reduction of predicted uncertainty - more accurate prediction of the climate change trends, 6: analysis of extreme events.

Principal personnel involved

Prof. **Ioannis K. Tsanis** (Ph.D. 1986) is director of the Water Resources Management and Coastal Engineering Laboratory. He is a Full Professor at the Department of Environmental Engineering at the Technical University of Crete (TUC) since July 2001. He was a Professor at the Department of Civil Engineering at McMaster University in Hamilton, Ontario, Canada from 1988, till June 2001 on leave of absence and on reduced work load till present. He published 3 books and over 150 scientific papers and reports and managed 48 projects from which 7 were international in areas of hydroinformatics, integrated watershed/coastal management, storm kinematics and floods, extreme events and climate change and hydraulic/hydrological/water quality modelling. Since July 2001 in TUC published more than 40 journal papers and reports and he is currently participating in three EC funded projects (WATCH, HYDRATE, SCENES, in extreme events (floods and droughts) and climate change and integrated water resources management, a bilateral cooperation program (Greece & USA/Canada) on flash floods forecasting with the use of C-band.

Mr. **Aristeidis Koutroulis** (M.A.Sc. degree - Ph.D candidate). His involvement will be as a Research Engineer in climate change projections and validation (spatio-temporal distribution) with GIS.

Mr. **Ioannis Daliakopoulos** (M.A.Sc. degree - Ph.D candidate). His involvement in this project will be as a Research Engineer to develop-apply algorithms for downscaling and enrichment of climatic model output.

Mr. **Emmanuil Gryllakis** (M.A.Sc. degree - Ph.D candidate). His involvement in this project as a Research Engineer will be to develop and apply algorithms for processing and visualization of climatic model output.

Selected relevant publications:

Tsanis, I.K., Koutroulis, A., Daliakopoulos, I., Michaelides, S., “Storm analysis and precipitation distribution of the flash flood in Almyrida basin, Crete", EGU2008 Session IS31-Flash floods: observations and analysis of atmospheric and hydrological controls, European Geosciences, Vienna, Austria, 13-18 April 2008.

Manios, T. and Tsanis, I.K., “”Evaluating Water Resources Availability and Wastewater Reuse Importance in the Water Resources Management of Small Mediterranean Municipal Districts, Resources Conservation & Recycling, 47, 3: 245-259, 2006.

Naoum, S and Tsanis, I.K., “Orographic Precipitation Modelling with Multiple Linear Regression”, Journal of Hydrologic Engineering, ASCE, 9(2), 79-102, 2004.

Partner 21: Cyprus Research and Education Foundation (CYI)

Expertise and experience of the organization

The Energy, Environment and Water Research Center (EEWRC) is intended as a scientific resource for the eastern Mediterranean, the Middle East and North Africa, located in Cyprus, and as a gateway between the EU and the region for addressing energy, environment and water issues. The EEWRC has been established in the framework of the Cyprus Institute (CyI; see http://www.cyi.ac.cy), a novel non-profit research and educational institution, which will also include the development of several research centres in other fields, including archaeology, computational sciences, biology and economy. The CyI aims at the highest standards of excellence with an emphasis on international partnerships with world-class research organizations. The EEWRC is being established in close collaboration with the Massachusetts Institute of Technology (MIT), a collaboration that includes in particular the launching of a common research program - hosted at MIT - for which graduate students and post-docs are currently being recruited.

Role and contribution

The EEWRC will be responsible for one of the case-study regions, i.e., the eastern Mediterranean and North Africa. In this context, we will carry out downscaling of GCM scenario results to spatial scales adequate for regional climate impact assessments ($1\text{km} \leq \Delta x \leq 5\text{km}$). The focus will be primarily on water scarcity and water management under conditions of climate change. A secondary focus will lie on agricultural activities and their role in affecting land surface properties. Climate scenarios at high spatial resolution will enable

a) better planning of storage facilities (e.g., dams) based on expected spatial and temporary rainfall patterns,
b) better founded understanding of water recharge as a result of combining detailed maps of precipitation and its timing with a hydrological modelling framework;
c) a more appropriate distribution/cultivation of agricultural production based on the expected water availability (and other relevant climatic factors) in comparison to water requirements of specific agricultural plants and fruits.

Since processes controlling clouds and precipitation occur primarily on scales smaller than the grid size of GCMs, an assessment of aerosol and (Saharan) dust particles in the framework of regional climate modelling will be of particular importance. Moreover and somewhat linked to the aforementioned issue of agriculture, an increase in fire frequencies as a result of enhanced summer temperatures and decreasing precipitation and the accompanying input of aerosols will constitute a positive feedback mechanism that will be investigated.

Principal personnel involved

Prof. Dr. Manfred Lange is geophysicist with experiences in climate impact research and water management studies. He is director of the Institute of Geophysics from 1995 and Director of the Center for Environmental Research at the University of Münster Germany from 1998 to 2007. Since September 2007, and founding Director of the EEWRC. Extensive experiences in coordinating and carrying out EC-funded research projects.

Dr. Pavlos Tsiartas is a Chemical Engineer with experiences in semiconductor microlithography and in particular the development, fundamental study, and optimization of resist materials used in deep UV lithography, as well as modelling experience in developing a comprehensive simulation model for the entire lithographic process.

Selected relevant publications:

Lange, M. A. (2000) Integrated global change impact assessments, in The Arctic: Environment, People, Policy, Nuttal, M. and T. V. Callaghan (eds.), Harwood Academic Publishers, Amsterdam, 517-553.

Lange, M. A. and BASIS consortium (2003) The Barents Sea Impact Study (BASIS): Methodology and First Results, Continental Shelf Research 23 (17-19), 1673-1694.

Lange, M. A. and Donta, A. A. (2006) Climate change and vulnerabilities to drought on Mediterranean islands, in: Water Management in Arid and Semi-Arid Regions, Koundouri, P., Karousakis, K., Assimacopoulos, D., Jeffry, P. and Lange, M. A. (eds.), Edgar Elgar Publishing Limited, Glos, U. K., 107-135.

Partner 22: Instituto Nacional de Pesquisas Espaciais (INPE)

Expertise and experience of the organization

The Instituto Nacional de Pesquisas Espaciais (INPE), established in 1963, is the main civil organization responsible for the development of space activities in Brazil. INPE has a total work-force of about 2000 employees, 350 PhD's, 300 engineers and annual budget is about Euro 110 million. INPE develops, builds, tests and integrates environmental satellites. INPE has consolidated its leadership in the region as the most advanced centre for meteorological forecast and climate studies in Latin America. With its newly-created Center for Earth System Science, INPE will step up its contribution to global environmental change research. In 2009, a new, state-of-the-art 40 TFlop/s supercomputing system will be inaugurated at INPE, bringing Brazil into a select group of countries with high performance processing facilities dedicated to Earth System modelling and generation of scenarios of global and regional climate change. Amazonian studies form a large portion of INPE's activities. INPE was the organization which established the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA).

Role and contribution

INPE will contribute with studies focusing on two sets of feedbacks especially relevant for the Amazon: a. regional land use – atmospheric chemistry – climate feedbacks; and b. stability of the soil and vegetation carbon pools and their feedbacks with climate drawing heavily on knowledge and data gained in the Large Scale Biosphere- Atmosphere Experiment in Amazonia (LBA). At INPE, a centennial time scale integration of a Global Climate Model with an improved DGVM will examine the synergistic effects of tropical deforestation, increased forest fire frequency and climate change.

Principal personnel involved

Dr. Carlos Nobre is a senior scientist in INPE. He is Chair of the International Geosphere-Biosphere Programme (IGBP) and Scientific Coordinator of FAPESP Research Programme on Global Climate Change. He is also a former Director of CPTEC-INPE (1991-2003). Professor of Biosphere-Atmosphere Interactions at INPE´s Graduate Program in Meteorology; his expertise is in biosphere-atmosphere interactions, climate modelling, tropical meteorology, global change and the Amazon. **Dr. Jose Marengo** is a senior scientist at INPE. He is co-chair of VAMOS-CLIVAR (Variability of the South American Monsoon), member of many IPCC activities. He is the coordinator of INPE's climate change studies. His expertise lies in climate studies for South America. **Dr Javier Tomasella** is a senior scientist at INPE with expertise in the hydrological cycle in the Amazon region. **Dr. Tatiana Tarasova** is an associate researcher at INPE with expertise in atmospheric radiation and radiative transfer models. **Dr. Manoel Cardoso** is a post-doctoral fellow at INPE with expertise in biosphere-atmosphere interactions, and specially the modelling of vegetation fires.

Selected relevant publications:

Cardoso, M.F., Nobre, C.A., Lapola, D.M., Oyama, M.D. and Sampaio, G., 2008. Long-term potential for fires in estimates of the occurrence of savannas in the tropics. Global Ecology and Biogeography, 17: 222-235.

Cardoso, M.F., Hurtt, G.C., Moore, B., Nobre, C.A. and Bain, H., 2005. Field work and statistical analyses for enhanced interpretation of satellite fire data. Remote Sensing of Environment, 96(2): 212-227.

Marengo, J.A., Nobre, C. A., Tomasella, J., Oyama, M.D., Sampaio, G., Oliveira, R., Camargo, H., Alves, L. M., Brown, I. F., 2008. The drought of Amazonia in 2005. Journal of Climate, 21, 495 - 516.

Oyama, M.D. and Nobre, C.A., 2004. Climatic consequences of a large-scale desertification in northeast Brazil: A GCM simulation study. Journal of Climate, 17(16): 3203-3213.

Oyama, M.D. and Nobre, C.A., 2003. A new climate-vegetation equilibrium state for tropical South America. Geophysical Research Letters, 30(23).

Salazar, L.F., Nobre, C.A. and Oyama, M.D., 2007. Climate change consequences on the biome distribution in tropical South America. Geophysical Research Letters, 34(9).

Sampaio, G., Nobre, C. A., Costa, M. H., Satyamurty, P. Soares, B. S. Cardoso, M.. 2007. Regional climate change over eastern Amazonia caused by pasture and soybean cropland expansion. Geophysical Research Letters, 34.

Tomasella, J., Hodnett, M. G., Cuartas, L. A., Nobre, A. D., Waterloo, M. J., Oliveira, S. M., 2007. The water balance of an Amazonian micro-catchment: the effect of interannual variability of rainfall on hydrological behaviour. Hydrological Processes, 21, 1-2, doi: 10.1002/hyp.681.

2.3 Consortium as a whole

2.3.1 Quality of the consortium

The COMBINE consortium comprises leading European research institutions: involved are research institutes, universities and operational meteorological agencies. Collectively, the consortium has a broad base of expertise reaching from the understanding of processes in the Earth system to their modelling in comprehensive Earth system models (ESMs), the application of ESMs to climate predictions and projections, the assessment of global and regional impacts and the development of scenarios, as necessary to address the work programme topic ENV.2008.1.1.4.1 and the research proposed in Section 1.

- Strong expertise is available for the proposed work on new components, including ETHZ for cloud microphysics, FMI for sub grid-scale cloud effects, UHEL for aerosol microphysics, CNRS, METO, UiB and MPG for the C- and N-cycle, CMCC, METO and MPG for stratospheric dynamics, and DMI, UCL, SMHI and CNRS for ice sheets and sea ice.

- The consortium includes research institutions with long experience in Earth system modelling. Among them MPG, METO, CNRS, CMCC, MF-CNRM, who provided climate projections for the 4^{th} assessment report of IPCC. This core is enlarged with partners working with newer climate models (UiB, EC-Earth consortium).

- The consortium has strong partners in the relatively young research field of decadal climate prediction, including meteorological agencies (ECMWF, METO and KNMI) and climate research institutes (MPG). Important is the expertise in ocean analysis (ECMWF, METO, CMCC, CERFACS), as this is a crucial factor for the climate prediction.

- For the impact studies, the consortium includes excellent partners for the global impacts (WU, CESR), as well as for the regional study cases (MPG, SMHI, WU), including partners with specific expertise for the regions (TUC and CYI for the Eastern Mediterranean, SMHI for the Arctic, INPE for the Amazon region).

- Concerning the contribution towards new scenarios, COMBINE includes MNP, which operates the IMAGE model, from which the mitigation scenario origins that is currently under discussion for AR5.

Several principal investigators in COMBINE are directly involved in the international committees and working groups under IGBP and WCRP, including the Working Group on Coupled Modelling that designs the protocols for internationally coordinate experiments for IPCC AR5, which will be of particular interest for this project.

2.3.2 Complementarity of the consortium

The selection of the consortium members ensures that the diverse expertise and skills are delivered to the project. The breadth of the expertise is already outlined in the previous section, reaching from the understanding of specific processes to their modelling and coupling in a comprehensive Earth system modelling, to the application the ESMs for climate predictions and projections, to the global and regional impacts in sectors, and the assessment of new scenarios. This broad basis is achieved with 22 partners.

Due to the ensemble strategy chosen for risk containment, there is a wanted overlap in skills and expertise between the groups developing and applying the different ESMs in the project. Typically 3 or 4 different ESMs are employed in tasks and work packages to exclude failure due to problems with a single model system.

2.3.3 Suitability of partners for participation in a European project

The project partners of the COMBINE consortium have long experience in the participation in cooperative projects under the framework programmes of the European Union. As such they have shown their motivation and capability to pursue research in Europe-wide projects involving many partners. The partners are generally familiar with the reporting duties towards the European Commission and the existing funding schemes connected with EU projects.

2.3.4 Geographical origin of partners

The consortium comprises a total of 22 partners from 13 European countries and 1 partner from Brazil (Table 2.3.4).

Table 2.3.4. Country of origin of participants

Country status	No.	Countries of Participants
EU Member States	11	Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Sweden, United Kingdom
Associated Countries	2	Norway, Switzerland
International Cooperation Partner Country	1	Brazil

i) Sub contracting

Sub-contracting is not planned in the COMBINE consortium.

ii) Other countries

There are no participants from countries other than the EU Member States, the Associated Countries or the list of International Cooperation Partner Countries.

iii) Additional partners

The management structure allows including new partners at a later stage. This process depends on the Governing Boards.

2.4 Resources to be committed

2.4.1 Overall financing plan and cost justification:

COMBINE requires a total budget of 11.6 million €, of which the budget for RTD amounts to 11.1 million € and that for the management to 0.46 million €. The total request of the COMBINE consortium to the EC amounts to 7.9 million €.(cf. form A3.2). The project is exploiting results from earlier EU and nationally funded research projects on Earth system research. Examples are ERA-40, DEMETER, ENSEMBLES, CARBOEUROPE, EUCAARI.

The consortium intends to start the project in spring or early summer of 2009. The project is planned for the duration of 48 months.

2.4.1.1 Personnel costs

The largest fraction of the costs results from personnel costs. COMBINE will require funding for approximately 1100 person months of activity spread between 22 partners over 4 years. The large costs from MPG, METO and CNRS result from their broad field of expertise and consequently the activity in the majority of the work packages. It should be noted that the total effort includes a substantial number of person months contributed by the partners, as detailed in Table 2.4.1.1. …

Table 2.4.1.1. Person month effort from institutional or national funding sources

Number	*Short name*	*Effort in Person Months*
1	MPG	36 PM
3	CNRS	120 PM
7	UiB	27 PM
8	DMI	19 PM
16	CERFACS	24 PM

2.4.1.2 Consumables and durables

Money is required to cover expenses for working means of the involved scientists, including laptops, computer software and software licenses. Further, COMBINE plans to keep a budget of 30000 € for costs resulting from the coordinated storage of model data, depending on the final protocols for storage of IPCC AR5 simulations. It will be important for the project and for the dissemination of the results to store the data in a (virtual) data archive. Current costs for data archival are typically 0.50 €/GB (= current cost for storing data in the CERA database of the Model&Data Group, Hamburg, which hosts the World Data Center for Climate).

2.4.1.3 Travel & subsistence

Support of travelling and subsistence is needed for attending project meetings and workshops, for presenting COMBINE results on conferences.

2.4.1.3 Computing costs

The requested budget does not include the substantial costs incurred by the computing and data storage resources consumed for the large amount of simulation years using comprehensive Earth system models, as planned in COMBINE, especially in WP6 and WP7. A substantial part of the costs for CPU time on supercomputing facilities will be brought into COMBINE by the partners and from external sources. Such costs are difficult to anticipate, and hence not quantified here.

3. Impact

3.1 Expected impacts listed in the work programme

The COMBINE project will deliver new ESM components and new ESM simulations meeting specific user needs. By the end of 2010, the COMBINE project will deliver a new set of simulations for the IPCC Fifth Assessment Report (AR5) multi-model ensemble. This set of experiments will cover both the near-term (2030) and long-term (2100) experiments currently envisaged by the IPCC experts (Moss et al., 2008) and the WCRP Working Group on Coupled Modelling (WGCM). By the end of 2012 the COMBINE project will deliver a further set of simulations that will demonstrate the improvements in Earth System modelling and its usefulness for adaptation to and mitigation of climate change. As discussed extensively in what follows, the results obtained will contribute not only to the anticipated next Assessment Report of the IPCC, but also directly to European climate policies. Harmonisation and standardisation of climate simulations and climate model data will contribute to further strengthen the European climate modelling community.

3.1.1 Benefits for the Sixth Community Environment Action Programme

The Sixth Community Environment Action Programme's key environmental priorities [EAP, Art 1.4] include the following areas:

- climate change,
- nature and biodiversity,
- environment and health and quality of life,
- sustainable use of natural resources.

We discuss here how the COMBINE project will advance the agenda of the Environment Action Programme in these areas. In the priority area of climate change, COMBINE will help place the Community in a strong position to advocate an international agreement on more stringent reduction targets for a possible post-Kyoto Protocol. The COMBINE project will provide scientifically sound results to establish a Community framework for the development of effective CO_2 emissions trading with the possible extension to other greenhouse gases [Art 5.2 (b)]. COMBINE will certainly improve knowledge of the carbon cycle required for the Internal Burden Sharing Agreement [Art 5.2 (c)]. Elements of the COMBINE project will contribute to the improvement of regional climate modelling to be used for the climate change assessments requested in [Art 5.3].

In the priority area of nature and biodiversity, the improved climate modelling capability and the new climate simulations provided by COMBINE will contribute to protection and appropriate restoration of nature and biodiversity from climate change [EAP Art 6.1]. New ESM components will be of considerable value to study vegetation dynamics under climate change, as well as being of great value in studying the impacts of climate change. The analysis of impacts will be performed at the global scale and for a few selected regions, Arctic, Mediterranean and Amazon, where additional regional feedbacks may be active. For the first time, simulated data from ESMs will be used for integrated assessment and impact models of selected, important sectors (climate policy, hydrology/water resources, primary production/agricultural production), with the aim to understand and quantify additional impact characteristics which may result from incorporating the new components into ESMs. This will help quantifying uncertainty ranges and possible corridors of development in individual sector for adaptation strategies.

In the priority area of environment and health and quality of life, COMBINE activity in atmospheric chemistry will play a key role in developing the European capability in air quality modelling to inform air quality control policy and the negative impacts on and risks to human health and the environment [EAP Art 7.1].

Furthermore the development of new components for Earth System modelling, as planned under this project, will eventually diffuse towards the models used for monitoring and forecasting at shorter time scales, especially in the framework of the Global Monitoring of the Environment and Security (GMES). A number of institutes in COMBINE are involved in GMES projects such as GEMS and MACC (GMES Atmospheric Service) and MERSEA (GMES Marine Service).

3.1.2 Benefits for the EU position in the international environmental arena

The COMBINE project involves the key European players in Earth System modelling with considerable experience for converting climate science into policy-relevant information. The consortium has played a major role in the Fourth Assessment Report (AR4) of the IPCC, by providing climate simulations to the IPCC AR4 multi-model ensemble, as well as scientific results and expertise during the writing phase of AR4. A number of participants to the COMBINE project were lead and contributing authors of chapters for the reports of Working Group I (Climate Science) and Working Group III (Mitigation). Individuals in the consortium have also experience with briefing policymakers on environmental and climate change issues.

This project is very much phased with a possible Fifth Assessment Report of the IPCC. Preparatory work has started to i) develop new socio-economic scenarios to drive Earth System models and ii) design the next set of climate simulations for near- and long-term projections. Several participants to the COMBINE project have been involved at the outset of these preparatory actions: workshop of the Aspen Global Change Institute on “the Next Generation of Earth System Models” (Meehl et al., 2006) and IPCC expert meeting on “New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies” (IPCC, 2008). The COMBINE consortium is therefore very well placed to make the COMBINE project fully relevant to the Fifth Assessment Report of the IPCC. The COMBINE project also fosters collaboration between the three traditional Working Groups of the IPCC, which is expected to result in novel approaches and policy-relevant science.

The COMBINE project relies on and will benefit from considerable international cooperation. The international dimensions of the four environmental priority areas of the EAP include the pursuit of ambitious environmental policies at the international level paying particular attention to the carrying capacity of the global environment [EAP Art 9.1]. By creating the scientific and technical capabilities for modelling the carbon cycle, atmospheric chemistry and aerosol, as proposed here, the EU will considerably strengthen its position in international bodies such as the United Nations Framework Convention on Climate Change (UNFCCC) and the International Panel on Climate Change (IPCC). In addition, the excellent and transparent science of the COMBINE project will help EAP attain this objective by means of the following priority actions [Art 9.2], mainly in the modelling arena:

- work towards strengthening international environmental governance by the gradual reinforcement of the multilateral cooperation and the institutional framework including resources;
- intensify efforts at the international level to arrive at consensus on methods for the evaluation of risks to health and the environment, as well as approaches of risk management including the precautionary principle;
- promoting cross-border environmental cooperation with neighbouring countries and regions.

The EU’s environment policymaking is based on participation and best available scientific knowledge. The COMBINE strategic approach is to build the most advanced Earth System model with traceable validation and demonstration of their applications to end-user questions. This approach will meet those requirements using the best possible science.

The COMBINE project is also highly relevant to the European Commission Green Paper on Adapting to Climate Change in Europe (EC, 2007). More specifically COMBINE will contribute towards the third pillar of “reducing uncertainty by expanding the knowledge base through integrated climate research”. COMBINE will cover some of the aspects listed in Section 5.3 of the EC Green Paper, such as “develop comprehensive and integrated methodologies for the assessment of impacts, vulnerabilities and cost effective adaptation”, “improve the basic understanding and prediction of impacts in Europe”, “clarify the expected impacts of climate change and ozone layer depletion on ecosystems”. In particular adaptation requires better near-term forecast of expected climate change, which will greatly benefit from the Initialisation work package of the COMBINE project. Moreover some of the partners in COMBINE will use this broadening knowledge base to engage with the business sector for the preparation of adaptation strategies. As an example, in the Mediterranean regional water resources are already under severe pressure and the effects of climate change could pose serious threats to regional sustainability, including food security and wildfires. Climate scenarios at high spatial resolution for Crete and Cyprus will enable (i) better planning of storage facilities (e.g., dams) based on expected spatial and temporary rainfall patterns, (ii) better founded understanding of aquifer recharge, and (iii) the distribution/cultivation of more appropriate agricultural productions

The ESM model runs will provide new insights into the relationship between greenhouse gas emissions and climate targets, such as the EU's 2 degree target or greenhouse gas stabilisation levels. Therefore, the deliverables of the project will include revised scenarios that explore the implications of these insights for climate targets, based on the combined use of Earth system models (ESMs) and integrated assessment modelling (IAM). This novel approach will provide the European Union with information on the mitigation actions required for a consistent evolution of the global and European climate and the socio economic parameters (in particular emissions and mitigation costs). This information is intended to contribute to the negotiations of post-2012 climate policies by providing a solid scientific basis for future international negotiations.

3.1.3 Benefits for the citizen

The COMBINE proposal will improve our knowledge of climate change impacts and will provide the modelling capability for predicting changes in the frequency and intensity of extreme weather events and their impacts. By providing the best tools to inform climate mitigation policies the COMBINE project will contribute to more ambitious climate mitigation policies and less drastic climate change impacts. This will eventually benefit the Member States, their industry as well as the European citizen.

3.1.4 Benefits for training

The COMBINE project will provide extensive opportunities for advanced on-the-job training at the doctoral and post-doctoral level, across a wide range of disciplines in Earth system modelling, climate impacts, model validation, and advanced computing. All things else being equal, preference in hiring young scientists will be given to candidates from the Accession countries which are not represented in the COMBINE consortium.

3.2 Dissemination and/or exploitation of project results, and management of intellectual property

3.2.1 Dissemination

The major output will be improved scientific information. The scientific results will be discussed widely in the scientific community to establish their validity and importance at an international level. They will be presented at major international scientific meetings, and they will be published in the peer-reviewed scientific literature and in official media of the EC. The COMBINE web site will be used to reach out to the more general audience. Academic teaching, in which many COMBINE participants are involved, will communicate the project findings to young scientists and students.

3.2.2 Exploitation of project results

Data of the reference climate prediction and climate projections simulations, which are made in COMBINE in WP6 and WP7 for the IPCC AR5, will be submitted to the data archives that will be in place for IPCC AR5 in accordance with the respective protocols. This will make the data accessible to the international scientific community and will support the further scientific evaluation beyond the scope of the COMBINE project. This data dissemination will ensure a wide usage of the data produced in the COMBIBE project, in the international scientific community that will be involved in the 5th assessment report for IPCC.
The project results should be directly usable to inform and support the environmental policy of the European Commission. DG Research will be one of the main stakeholders regarding scientific knowledge and tools generated by COMBINE. Further, project results and members will be readily available to DG Environment representatives to give them the possibility to explain their requirements and to get feedback from them. Finally, the expected direct involvement of COMBINE partners and scientists in the writing of the 5th assessment report of IPCC will assure a direct access of the writing teams to the scientific results generated by COMBINE.

3.2.3 Management of Intellectual Property Rights (IPR)

The Data Protocol Panel will propose to the Scientific and Executive Committee a COMBINE Data Protocol based on general rules that will be defined in the Consortium Agreement. The COMBINE Data Protocol will aim at promoting the publication of results in scientific literature and their presentation at conferences, while protecting the intellectual property rights of the project participants. It will regulate the access to data generated for the COMBINE project. Where possible it will adopt the protocol for the archival of data in IPCC AR5 archives for the simulations qualifying for the archival in these archives.

Each party will have the right to exclude specific pre-existing know-how from the other parties’ access, as far as the restrictions are announced before the signature of the funding contract or before the effective joining of a new party. The procedure to handle these cases will be settled in the Consortium Agreement. Access rights granted needed for the project execution according to the agreed work-plan are granted on a non-exclusive basis, expressly exclude any rights to sub-license and shall be made free of any transfer costs. The procedure will be defined in the Consortium Agreement. The project partners will respect their individual Intellectual Property Rights. In the event of an invention being the work of a single party of the project and solely the result of this intrinsic skills rather than shared knowledge, this party will be the exclusive owner of the results, subject to granting access rights to the other participants where necessary for their execution of the project or to the utilisation of their own results. The conditions will be fixed in the Consortium Agreement. In cases the designated owner of the results waives its option to start registration proceedings the Consortium Agreement will outline a procedure to open other project partners the opportunity to obtain or maintain such protection.

4. Ethical Issues

None of the ethical issues listed in the table below apply to this proposal.

ETHICAL ISSUES TABLE

	YES	PAGE
Informed Consent		
• Does the proposal involve children?		
• Does the proposal involve patients or persons not able to give consent?		
• Does the proposal involve adult healthy volunteers?		
• Does the proposal involve Human Genetic Material?		
• Does the proposal involve Human biological samples?		
• Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?		
• Does the proposal involve Human Foetal Tissue / Cells?		
• Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
• Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Does the proposal involve tracking the location or observation of people?		
Research on Animals		
• Does the proposal involve research on animals?		
• Are those animals transgenic small laboratory animals?		
• Are those animals transgenic farm animals?		
• Are those animals cloned farm animals?		
• Are those animals non-human primates?		
Research Involving Developing Countries		
• Use of local resources (genetic, animal, plant etc)		
• Impact on a local community		
Dual Use and potential for terrorist abuse		
• Research having direct military application		
• Research having the potential for terrorist abuse		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	**YES**	

5. Consideration of gender aspects

The Women and Science (EC, 2005) working document presents an analysis of the participation of women in science in Europe gender and presents progress towards the target of 40% participation of women at all levels research. The necessity for a gender action plan in FP7 projects is explained. The following text outlines the situation of gender balance in the COMBINE consortium and the plans for the project to have a high women participation in this project. These actions will contribute to reach the targets of the European Council, adopted in May 2003, for mathematics, science and technology.

5.1. Diagnosis of the gender balance situation in the COMBINE consortium at the stage of proposal preparation

The COMBINE consortium includes women scientists at the level of work package leaders, **6 of 13.** The 46% women participation at the level of work package leaders will be beneficial for the evolution of the gender balance in the project, and for the prospect of women scientist in higher research positions in the field of Earth system modelling.

5.2 Proposed actions in the COMBINE consortium

The initial consortium has a good gender balance at the leadership level from the beginning. Nevertheless a gender action plan will be proposed by the gender panel and implemented by the project office. The gender action plan will aim at maintaining or improving the gender balance in the project consortium, at measures to help reconcile work and private life, and at improving the awareness for gender equality within the consortium:

- Maintain the good gender balance of the consortium, as described in 5.1, through out the project.
- Document gender ratio at all organizational levels of the project, at the beginning and end.
- Reconcile work (project events) and private life (school holidays, weekends)
    - Project events will be organized so that travelling does not interfere with weekends.
    - Project events will be held outside of holiday seasons of the participating scientists.
    - Minimize travelling, through adequate use of teleconferencing
- Implement a mentor/mentee scheme for women scientists

5.3 Proposed actions aimed at a wider public

The following actions aim at raising awareness in the wider public:

- Participation of partner institutes in annual Girls’ Day events.
- Foster networking of women scientists
- Support the promotion of women scientist to international working groups and panels in climate science

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