RT1 ENSEMBLES Periodic Activity Report – 1Sep05-31Aug06

Executive Summary

Work performed and results achieved: RT1

- A new set of complex Earth System models has been constructed, and provided for ensemble climate prediction.
- A first-generation ENSEMBLES system for seasonal to decadal predictions has been provided, comprising multi-model, stochastic physics and perturbed parameter techniques for ensemble simulation using complex climate models, plus methods for initialising the models with analyses of observations.
- A first-generation ENSEMBLES system for decadal to centennial predictions has been provided, comprising perturbed parameter and multi-model ensemble techniques for ensemble simulation using complex climate models.
- Improved ocean data assimilation systems have been provided to initialise the forthcoming second stream of ENSEMBLES seasonal to decadal hindcast experiments.
- The perturbed parameter approach to decadal to centennial prediction has been further developed, to include very large ensembles of transient climate change simulations run by the general public, and to include experiments based on more than one climate model.
- Interim probability distributions have been provided of climate change during the 21st century, based on HadCM3 perturbed parameter experiments, and available for use in testing selected methods for the prediction of climate impacts.

Expected end results : RT1

- Further development and assessment of methods to represent uncertainties arising from initial conditions and modelling of Earth System processes in ensemble prediction systems, on both seasonal to decadal and longer time scales.
- Further development and assessment of methods to construct probabilistic forecasts from the results of the ensemble prediction systems, on both seasonal to decadal and longer time scales.
- Assessment of the potential for a unified prediction system covering both seasonal to decadal and longer time scales.
- Recommendations for the design of an improved ensemble prediction system by month 60.
- Changes since last year: The first three bullets in “work performed” have migrated from “expected results” to “achieved outputs”.

Intentions for use and impact

The ensemble prediction system produced by RT1 will be used by other ENSEMBLES RTs to provide detailed predictions of climate variability and change, and its impacts, using a suite of modelling tools. The development of systematic approaches to the quantification of uncertainties is expected to provide a significant and original contribution to worldwide research into global climate prediction, and the combination of techniques used previously for seasonal and long term forecasting will lead to a new facility to predict climate variations on interannual to decadal time scales.

Overview of activities carried out during the reporting period

1. Project objectives and major achievements during the reporting period

Aim

The purpose of RT1 is to build an ensemble prediction system based on global Earth System Models developed in Europe, for use in the generation of multi-model simulations of future climate in RT2. The scope includes assembly and testing of Earth System Models, testing of schemes to represent modelling uncertainties, initialisation of models and construction and testing of methodologies for both seasonal-decadal and centennial prediction, based on a multi-model ensemble approach. The ensemble prediction system provides the basis for the production and use of objective probabilistic climate forecasts within ENSEMBLES.

1.1a Primary Objectives

Provision of a set of tested Earth System Models for use in the ensemble prediction system.

Development and assessment of methods to represent uncertainties arising from initial conditions and the modelling of Earth System processes in the ensemble prediction system.

Development and assessment of methods to construct probabilistic forecasts from the results of the ensemble prediction system.

Provision of a tested first release (Version 1) of the ensemble prediction system by month 24, comprising methodologies for prediction on both seasonal-decadal and centennial time scales.

Recommendations for the design of an improved ensemble prediction system (Version 2) by month 60.

1.1b Relation to state of the art

RT1 is enhancing the current state of the art in ensemble climate prediction by:

- Constructing a European multi-model ensemble for seasonal to decadal prediction, developed from the DEMETER seasonal prediction system and initialised using ERA-40 atmospheric reanalyses, and a dataset of ocean observations and advanced data assimilation schemes developed from the products of ENACT.

- Developing a new approach to ensemble climate prediction based on sampling stochastic parameterisation uncertainties.

- Building on recent development of a perturbed parameter approach to the sampling of modelling uncertainties, to apply the approach for the first time to the simulation of both seasonal to decadal climate and time-dependent climate change on multi-decadal time scales.

- Building new Earth System models from existing component modules, and using these to construct multi-model ensembles which sample modelling uncertainties in the representation of biogeochemical as well as physical processes. The perturbed parameter approach will also be extended to sample uncertainties in biogeochemical feedbacks.

- Providing the first realistic assessment of the practical predictability of climate on the decadal timescale.

- Providing a systematic approach to probabilistic prediction of long term climate change, through a system which has been validated on seasonal and decadal timescales.

1.2 Summary of recommendations from previous reviews

The review of year 1 of ENSEMBLES commented as follows:

"RT1 and RT2A: (i) Increased communication, possibly through a common workshop with RT4 and RT5, regarding the physical processes that govern climate sensitivity and the usage of global datasets to constrain model simulations of the most significant physical processes. The aim near the project's end should be to connect statistical climate sensitivity estimations with physical interpretations."

In an initial response to this, RT4 were invited to give a presentation on "Understanding the processes governing climate variability and change, climate predictability and the probability of extreme events", and to participate in subsequent discussions, at an RT1/2A workshop held at ECMWF during June 2006. In addition, RT1 and RT2A partners will participtate in a workshop in Paris during spring 2007, in order to address how the physical understanding of key climate feedbacks, developed in ENSEMBLES and in other projects such as CFMIP, can be used to constrain climate predictions.

http://www.ecmwf.int/research/EU_projects/ENSEMBLES/meetings/presentations_June2006.html

1.3 Overview of achievements during months 13-24

- New Earth System models have been constructed and tested by MPIMET, METO-HC, CNRS and INGV. I addition, new physical climate system models have been constructed and tested by DMI, CNRM and FUB. This work is summarised in D1.6. The new models will be available for use in the forthcoming ENSEMBLES stream 2 simulations of climate change, thus achieving Major Milestone MM1.1.
- The multi-model ensemble for seasonal to decadal prediction was installed on the ECMWF supercomputer (deliverable D1.4), and used to produce a set of "stream 1" seasonal to decadal hindcasts. A common list of output variables was archived in MARS, the Meteorological Archival and Retrieval System at ECMWF, and is available to ENSEMBLES partners.
- The stream 1 multi-model simulations have been compared to parallel ensemble simulations generated using two alternative techniques for the representation of modelling uncertainties, based respectively on stochastic parameterisation and perturbed parameter approaches within a single model framework. A report for milestone M1.2 summarised preliminary results from these experiments, updated in a later report for major milestone MM1.2. The multi-model, stochastic parameterisation and perturbed parameter approaches constitute

three ensemble prediction methods which together constitute the first-generation ENSEMBLES system for seasonal to decadal prediction.

- The perturbed parameter approach has also been further developed for use in decadal to centennial predictions, including the generation of new ensemble simulations which (a) reduce simulation biases in simulated historical climate through improved spin-up strategies; (b) demonstrate the potential of public resource distributed computing to provide very large ensembles of transient climate change simulations; (c) extend the perturbed parameter approach in the HadCM3 model to begin experiments perturbing parameters in the ocean and sulphur cycle modules, building on atmospheric perturbation experiments considered previously (d) extend the perturbed parameter approach to a new model framework (the EGMAM coupled model, adding to previous work based entirely on the HadCM3 model).
- Perturbed parameter simulations of 21^{st} century climate change have been compared against corresponding multi-model ensemble simulations. Major milestone MM1.2 summarises the results, concluding that a first–generation ENSEMBLES prediction system combining both types of ensemble provides a basis from for production of a wide range of probabilistic predictions of climate variables at global and large regional scales during the remainder of the project, thus providing input for other RT2 to use in deriving predictions at finer scales of climate change and its impacts.
- Ocean data assimilation systems have been further improved, in order to provide better initialisation of the forthcoming stream 2 seasonal to decadal hindcast set later in the ENSEMBLES project. This work is summarised in deliverable D1.3.
- The inputs to the ocean data assimilation systems have also been improved, through the generation of perturbation methodologies to generate alternative wind stress and SST fields (see D1.3), and also through a further and significant update to the ENACT ocean observation database (milestone M1.4) to include the latest world ocean database release 2005 and an improved quality control process.
- Distributions of European climate change during the 21^{st} century have been produced from the HadCM3 perturbed physics ensembles (deliverable D1.7). These assume that all model versions are equally likely, and will only sample uncertainties arising from surface and atmospheric processes in a single model framework. However, they serve as interim pdfs available for use in testing methodologies for the prediction of climate impacts by ENSEMBLES partners.
- A second joint meeting of RT1 and RT2A was held in Reading in June 2006, reviewing progress against deliverables and milestones for months 1-24, and coordinating development of plans for months 25-42. We have delivered all deliverables and milestones due during months 1-24, and are on track to meet future commitments.

2. Research Theme Progress

WP1.0: Management of RT1

a) Objectives and starting point at beginning of reporting period

During the first year, plans for the creation and testing of “first generation” ensemble prediction systems had been produced, for both seasonal to decadal (s2d) and centennial time scales. A joint RT1/2A workshop had been held in Toulouse (June 2005), at which early progress had been reported by RT1 partners, and plans for the delivery of major milestones MM1.1 (Provision of a set of tested Earth System Models) and MM1.2 (Provision of a "first generation" ensemble prediction system (Version 1) for use in RT2) had been further discussed, and updated. In particular, the scientific design of the multi-model system for seasonal to decadal prediction had been agreed, including hindcast start dates, initialisation techniques, inclusion of forcings and archiving of diagnostics. An

RT1 web site had been set up:
http://www.ecmwf.int/research/EU_projects/ENSEMBLES/index.html.

Objectives for months 13-30 are:

Task 1.0.2: The RT1 website will be maintained and developed, containing information such as location of model documentation, model output data, contact details, progress reports, summaries of meetings and key scientific developments etc.
Task 1.0.3: Timely delivery of milestones, deliverables and progress reports and representation of RT1 at ENSEMBLES management meetings will be ensured.
Task 1.0.4: A second meeting of RT1 participants will be held between months 18 and 24 to review progress and finalise contributions to Major Milestones 1.1 and 1.2, "Provision of a set of tested Earth System Models", and "Provision of a "first generation" ensemble prediction system (Version 1) for use in RT2.

b) Progress towards objectives

The RT1 web site (see above) has been updated through the year with details of experiments, data archiving, results, meetings and links to other ENSEMBLES RTs. RT1 was represented at the ENSEMBLES Annual General Assembly in Athens, and at six monthly Management Board meetings, at which presentations of plans and progress were given. Scientific discussions were held during the Annual Assembly, which were documented and circulated to partners afterwards. RT1 also led a cross-RT discussion on integration of ENSEMBLES results, and contributed to another cross-cutting session on model weighting for the construction of probabilistic scenarios. Subsequently an informal group was convened to pursue options for testing methodologies for "end-to-end" predictions of climate impacts, derived from climate model simulations. This has led to the identification of interim datasets from perturbed physics ensemble simulations (see deliverable D1.7 on "Interim probability distribution of transient climate change over Europe will be produced, for use by other RTs in testing methodologies for prediction of climate change impacts"), which will be provided for use by selected impacts models.

A second RT1/2A workshop was held in Reading during June 2006, at ECMWF (see http://www.ecmwf.int/newsevents/meetings/workshops/2006/ensembles/index.html). Presentations were given summarising progress to date in RT1 and RT2A, and in several other RTs with direct links to RT1 and RT2A. Breakout sessions were held to review the status of our major workstreams on the development of Earth system models, s2d ensemble predictions and centennial ensemble predictions, and to produce updated workplans during months 24-42 of ENSEMBLES. These include plans for further development of probabilistic centennial prediction techniques, and plans for a second stream of s2d simulations covering a wider range of initial dates, with multi-model and stochastic physics simulations in RT2A coordinated with perturbed physics simulations in RT1. Following the meeting, reports on major milestones MM1.1 and MM1.2 (see above), and an updated Detailed Implementation Plan (for months 25-42) were produced. Further deliverables and milestones scheduled for months 13-24 have also been met, and future deliverables and milestones are currently on track. RT1 activities will be further assessed during two meetings to be held during year 3 of ENSEMBLES. One (to be held in Barcelona during June 2007) will focus on s2d activities, as part of a larger meeting of the CLIVAR Working Group on Seasonal to Interannual prediction. The other (organised by RT4) will be held in Paris during spring 2007, focusing on how to use physically-based understanding of climate feedback processes to inform the construction of improved methods of constraining probabilistic climate predictions.

c) Deviations from the project work programme and corrective actions

None

WP1.1: Construction of Earth System Models for ensemble climate prediction

a) Objectives and starting point at beginning of reporting period

The objective of work package 1.1 is the construction of a range of Earth system models (ESMs) from existing models of Earth system components or coupled model systems, for subsequent application in the "stream 2" simulations of RT2 (by CNRS, INGV, METO-HC, MPIMET), and the development of an efficient high resolution physical climate system model (by DMI) for application during selected time slices of the simulation period covered by the forthcoming stream 2 simulations.

At the start of this reporting period all partners had already made progress towards the WP objectives. Different ESMs had been constructed and tested. The status of these models was described in Deliverable "D1.1 Progress report on the construction and testing of Earth system models", which was delivered in month 13. Based on developments during the previous year, the work in the current period aimed at the continuation of model development towards ESMs in three categories: physical models, carbon cycle models and aerosol system models.

b) Progress towards objectives

Representatives of all work package partners met at the General Assembly in Athens in September 2005, and the majority of the partners were also represented at the joint RT1/RT2A workshop at ECMWF in June 2006 to discuss the ongoing work in WP1.1. All partners have made progress towards the development of ESMs in the categories: physical models, carbon cycle models and aerosol system models. The table below shows the current model matrix.

Partners	***Physical models***	***Carbon cycle models***	***Aerosol system models***
DMI	X		
CNRS	X	X	
INGV	X	X	
METO-HC		X	X
MPIMET	X	X	X
CNRM(1)	X		
FUB(1)	X		

(1) unfunded in WP1.1, but will use their models in RT2A

This reporting period ends with the Major Milestone "MM1.1 Provision of a set of tested Earth System Models", for which the status is reported in the Deliverable "D1.6 Report on the developed and tested ESMs". For this reason this following reports by each partner are kept brief to avoid duplication. In each case we summarise the starting point at month 13, and progress during the current year.

METO-HC

Starting point of work at beginning of reporting period
Development was already complete and documentation largely complete of the new HadGEM1 global environmental model, which includes atmospheric aerosols coupled to the physical climate. Model performance in the HadGEM1 control run had been analysed and documented in three submitted papers. ENSO variability had been identified as HadGEM1's main area for improvement and work had started to investigate the causes and correct this problem within the HadGEM1a development project which would feed into stream two simulations.

Progress towards objectives
Task 1.1.4: Documentation of HadGEM1 was completed and the constant pre-industrial forcings control run was extended to more than 1000 years. Three papers documenting the performance of HadGEM1 were published in Journal of Climate (Martin et al., 2006; Ringer et al., 2006; Johns et al., 2006) and a fourth paper is soon to appear in Journal of Geophysical Research (McLaren et al., 2006).

Substantial improvement to some HadGEM1 performance deficiencies (tropical mean state, aerosols, and land surface biases) were achieved in the HadGEM1a development project. The resulting model is undergoing a final tuning phase and expected to be spun up ready for hindcast and scenario experiments to begin by early 2007. The tuned model (named "HadGEM2-OA") is intended to form the basis for stream 2 simulations including the physical system plus aerosol system.
For the coupled climate-carbon cycle studies in stream 2 in RT2A we intend to use a recently developed variant of the HadCM3 model ("HadCM3C") for the sulphur cycle plus carbon cycle system. HadCM3C has the same atmosphere and ocean resolution as HadCM3, but differs in having an improved land surface scheme (MOSES2.2) which can simulate vegetation and soil fluxes of carbon, and also incorporates the dynamic vegetation model TRIFFID. The ocean biogeochemistry incorporates the HadOCC model, a simple nutrient-phytoplankton-zooplankton-detritus (NPZD) ecosystem model with coupled carbon flows, using the UTOPIA scheme for tracer advection. HadCM3C represents a significant developmental step forward on the earlier, lower resolution but much used, HadCM3LC model (Cox et al., 2001). It should be noted that HadCM3C, like HadCM3LC, uses flux adjustments, which reduce its regional SST biases compared to HadCM3.

Task 1.1.5: Parameters specific to the sulphur cycle and terrestrial carbon cycle schemes used in the METO-HC model have been identified, along with plausible perturbed ranges, for the purpose of exploring uncertainty ranges associated with sulphur cycle and carbon cycle processes. That work will be done in WP1.6 in parallel with the stream 2 RT2A centennial simulations using HadCM3C.

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CNRS

Starting point of work at beginning of reporting period

The new climate / carbon cycle model, coupling the OPA ocean model, the LIM sea-ice model, the LMDZ atmosphere model, the full ORCHIDEE soil/vegetation model (including carbon component) and PISCES for ocean biogeochemistry, has been assembled. The generic and public version of the VOC (volatile organic compounds) in ORCHIDEE is developed, and will be coupled to the atmospheric chemistry model.

Progress towards objectives

The new climate-carbon cycle model IPSL_CM4_LOOP has been successfully assembled. Control simulations as well as scenario simulations have been performed in order to feed into the IPCC AR4 report. Scenario simulations used the SRESA2 CO_2 emission pathway. Analysis of the simulations has been initiated in WP4.1.

A version of the coupled climate-carbon cycle model that allows for transport of passive tracers (such as CO_2) is currently under development in order to allow direct comparisons with the atmospheric CO_2 data.

The sub-model of Volatile Organic compounds released by the living biosphere is been included in ORCHIDEE. The surface schema also includes a parameterization to represent the impact of ozone deposition on plant productivity. This version of ORCHIDEE will be coupled to the IPSL coupled model when the climate –chemistry coupling is finalized.

References

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DMI

Starting point of work at beginning of reporting period

The first version of the atmospheric component of the Danish Climate Model (A-DKCM), using the ARPEGE climate version 4 dynamical core and the physical package of ECHAM5 (v5.2), had been constructed and tested. The model simulated present day climatology reasonably well with systematic errors that were generally comparable with those in ARPEGE and ECHAM5. However, the simulated precipitation seemed to be overestimated in A-DKCM in comparison with both the observation and the models ARPEGE and ECHAM5, and the global mean precipitation and evaporation in DKCM were not in balance.

Progress towards objectives
The problem of exaggerated precipitation simulated by the A-DKCM was identified as a post-processing error. The characteristics of the corrected model precipitation were found to be realistic, and of similar quality to that simulated by ARPEGE and ECHAM5 (Yang, 2006). The above mentioned model version was also upgraded using the ARPEGE climate version 4.4 dynamical core and the physical package of the new version of ECHAM5 (v5.3), in order to include new features of more frequent mass correction in the ARPEGE v4.4 and varying greenhouse gas concentrations and aerosols in ECHAM5.3. Both features are important for scenario simulations. The model has also been tested and modified for employment at high horizontal resolution (T159) for use in RT2A time-slice experiments with forcing by MPI's coupled model, and including time-varying greenhouse gas concentrations.

In addition, DMI has been developing the fully coupled Danish climate model (DKCM). The fully coupled DKCM is composed of the A-DKCM, the ocean model NEMO that includes the OPA9 ocean general circulation modelling system and the LIM2 sea-ice model, which interacts through the OASIS (v3) coupler. The different components of the DKCM have been put together, and the model is expected to be ready to use for stream 2 centennial integrations in RT2A within the next 18 months.

References
Yang, Shuting, 2005: A note on the correctness of precipitation in the Danish climate model, *Danish Climate Centre report **05-05,*** 10pp.

INGV

Starting point of work at beginning of reporting period
At the beginning of the second year of the project, the new physical core of the INGV Earth System Model had been assembled and coupled to the marine biogeochemistry model PELAGOS. The physical core is based on the ECHAM5 (atmosphere) model and OPA8.2 (ocean and sea-ice) model. The ECHAM5 model had been developed by Roeckner et al (2003) and the OPA model by Madec et al (1998). The marine biogeochemistry model PELAGOS had been developed by Vichi et al. (2006). The PELAGOS model (formerly called MMEM in the description of work) is the global and generalized version of the Biogeochemical Flux Model (BFM, http://www.bo.ingv.it/bfm). Preliminary tests with the full system were performed.

Progress towards objectives
During the second year of the project, the technical tests and necessary modifications to the physical core have been completed. Currently the physical core can be integrated and it is stable for several decades, with the atmosphere at T31L19 and T63L31. Concerning the ocean, the 2 degree OPA (ORCA2 grid) is used. Test simulations with the PELAGOS component assembled in the Earth System Model have also been completed. The biogeochemistry model has shown a significant sensitivity to the frequency of the radiative forcing, which is currently being investigated. The technical coupling of PELAGOS with the OPA ocean general circulation model has been documented in Vichi et al. (2006).

The implementation of the SILVA (Surface Interactive Land VegetAtion) model has started. The SILVA model has been documented in Alessandri (2006). It includes a hydrology module (2 layers), a soil thermodynamics module (7 layers), and the VEGAS dynamical vegetation and carbon model.

SILVA allows for the interactive computation of surface fluxes and state variables for coupling with the atmospheric component. The coupling of SILVA with ECHAM5 is under development.

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MPIMET

Starting point of work at beginning of reporting period

At the beginning of year 2 the physical ESM ECHAM5/MPIOM was already completed and experimental ESMs including the carbon cycle and the aerosol system, respectively, were in testing phase.

Progress towards objectives

The carbon cycle and aerosol ESMs have been used to run 20th century and IPCC scenario experiments analogous to the integrations with the physical climate model ECHAM5/MPIOM, which have been provided for IPCC-AR4. Aspects of the carbon cycle and aerosol system models have been analysed and publications have been submitted, and are currently under review or in press (Jungclaus et al. 2006, Stier et al. 2006, Wetzel et al. 2006). Tests of a new vertically extended physical ESM (MAECHAM5/MPIOM) that is extended to the middle atmosphere to 0.01 hPa have been started.

Technical aspects of the ECHAM5/MPIOM based ESMs have been improved. Specifically, the model infrastructure has been upgraded to allow the execution of the ECHAM5 or MPIOM circulation models in OpenMP, MPI or OpenMP+MPI mode, so that the properties of computer architectures can be exploited better. A new packaging of the ESM source codes, model compile environment and model runtime environment has been created following the PRISM recommendations. This new so-called COSMOS package allows selected ESM configurations to be extracted, compiled and run in a standardised way. This packaging simplifies the employment of the model system on different platforms.

References

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c) Deviations from the project work programme and corrective actions

None.

WP1.2: Developing and testing schemes to represent model uncertainty in seasonal to centennial prediction

a) Objectives and starting point at beginning of reporting period

METO-HC: The Hadley Centre had collaborated with Durham University in the use of Bayesian statistics to analyse perturbed physics ensembles.

UOXFDC: Oxford University had published work in Frame et al (2005) on the role of prior assumptions in predicting climate sensitivity. Frame et al (2005) showed that any probabilistic estimate of climate sensitivity, and hence of the risk that a given greenhouse gas stabilisation level might result in a "dangerous" equilibrium warming, is critically dependent on subjective prior assumptions of the investigators, not simply on constraints provided by actual climate observations. They resolved this apparent arbitrariness by focussing on the intended purpose of the forecast: while uncertainty in long-term equilibrium warming remains high, they found an objectively determined 10 – 90% (5 – 95%) range of uncertainty in climate sensitivity that is relevant to forecasts of 21st century transient warming under nearly all current emission scenarios is 1.4 – 4.1 °C with a median of 2.4°C, in good agreement with the "traditional" range.

ECMWF: The multi-model ensemble forecast system for seasonal-to-decadal predictions had been designed during the first year of ENSEMBLES. A new scheme for medium-range weather forecasting to account for the effects of unresolved processes using stochastic perturbations (Shutts, 2005) had been developed at ECMWF during the previous couple of years. Preliminary tests of this system had been carried out in seasonal forecast mode during the first year of the project.

FUB: As preliminary work for a detailed climate sensitivity study to parameter perturbations, different values in the cloud parametrization had been tested in control runs of the EGMAM-model. In cooperation with project partners it had been investigated how to implement existing perturbed-physics schemes in EGMAM, with the aim of generating multi-model ensembles of perturbed physics runs.

b) Progress towards objectives

METO-HC: The Hadley Centre have continued their collaboration with Durham University and have applied the Bayesian prediction framework outlined in Rougier (2006) to their perturbed physics ensemble. The method requires the use of an emulator, a statistical model trained on the available model data, which relates model output to the values of the model input parameters. The emulator can then predict the model output at any point in parameter space. The Bayesian approach uses an emulator to predict a prior distribution of a forecast variable for any given distribution of the parameters perturbed in the ensemble. Rougier et al (in preparation) describe how to build an emulator in general, and also develop a method to construct an emulator based on data from two perturbed physics ensembles with an overlapping set of parameters. In the study, information from ensembles from the Hadley Centre and climate*prediction*.net were combined. The two ensembles complement each other well as each has different advantages. Therefore, the emulator of Rougier et al has provided the best estimate yet of the probability distribution of the climate sensitivity of the HadAM3 climate model.

In tandem with the work on emulators, pattern-scaling techniques have been further refined to allow the production of PDFs of transient climate change. An ensemble of HadCM3 coupled simulations, run in WP1.6, has been used with equivalent atmosphere-slab (HadSM3) configurations to develop statistical relationships between equilibrium and transient change. Examination of the robustness of these statistical relationships for different variables has been a focus of research in this year. The techniques have been used to deliver interim PDFs to selected users (Deliverable 1.7).

UOXFDC: Oxford University have continued to work on alternative methods of analysing large ensembles and have begun analysis on the new climate*prediction*.net coupled model ensemble (see contributions to WP1.6).

ECMWF: The multi-model ensemble forecast system for seasonal-to-decadal predictions has been successfully installed at ECMWF. It has capabilities to run, in addition, perturbed parameterisations and stochastic physics. Unified output and archival routines were developed and documentation is available as part of WP1.4. A preliminary set of hindcast experiments (stream 1) on seasonal-to-decadal time scales has been performed and analysed.

A new approach to ensemble climate prediction, based on sampling stochastic parameterisation uncertainties, has been further developed in the IFS/HOPE coupled model environment. The Cellular Automaton Stochastic BackScattering (CASBS) scheme used here introduces streamfunction perturbations on the near-gridscale and is motivated by the notion that a fraction of the dissipated energy will scatter upscale and inject kinetic energy into the resolved flow. For this purpose a cellular automaton is utilised to generate a spatially and temporally correlated pattern which is weighted with the flow-dependent dissipation rate from numerical dissipation and friction from deep convection and gravity/mountain wave drag.

CASBS version 1.0 has been tested in seasonal-to-interannual hindcast simulations for the 1991-2001 period, based on start dates in November and May, using IFS/HOPE with the atmospheric model cycle CY29R2. For the decadal simulations starting in November 1965 and 1994 a revised version of CASBS (v1.1) was used, while at the same time the latest changes to the atmospheric IFS cycle (CY30R1) have been introduced in the coupled IFS/HOPE system. The forecast skill of these preliminary simulations, compared to other approaches to model uncertainty (multi-model and perturbed physical parameters), has been evaluated and documented in WP1.5.

Work has been carried out to further develop the stochastic physics scheme. An updated version CASBS (v1.2) is currently being tested in the medium range ensemble forecasting system at ECMWF.

FUB: FUB have developed a perturbed physics approach to represent model uncertainties in EGMAM by perturbing selected cloud parameters in cooperation with project partners METO-HC and Oxford University (see FUB contributions to WP1.6). A 30 member perturbed physics ensemble of EGMAM versions has been generated and integrated under present day conditions. The perturbed physics ensemble was used as a first step towards the development of a stochastic parametrization scheme. The uncertainties and ranges of parameter values sampled within the perturbed physics ensemble, and the estimated climate sensitivities of the ensemble members, were then used to select appropriate parameter values for a stochastic parametrization scheme in EGMAM (Niehoerster et al, 2006).

LSE: The weighting of multi-model ensembles in the context of climate-like predictions using simple non-linear equation sets, specifically imperfect versions of the Moran-Ricker equation, has been investigated. In addition, techniques for the combination of ensemble forecasts have been developed along with methodologies for determining significant skill in those combinations.

References:

Frame, D. J., Booth, B. B. B., Kettleborough, J. A., Stainforth, D. A., Gregory, J. M., Collins, M. and Allen, M. R.. Constraining climate forecasts: The role of prior assumptions. Geophys Res Lett, 32, L09702.

Niehoerster, F., Spangehl, T., Fast, I., Cubasch, U., 2006: Quantification of model uncertainties: Parameter sensitivities of the coupled model ECHO-G with middle atmosphere; Geophysical Research Abstracts, 8, EGU06-A-08526

Rougier, J., 2006: Probabilistic inference for future climate using an ensemble of climate model evaluations. Accepted for Climatic Change.

Rougier, J., D. M. H. Sexton, J. M. Murphy, D. Stainforth, in preparation: Emulating sensitivity of the HadAM3 climate model using ensembles from different but related experiments.

c) Deviations from the project work programme and corrective actions

None.

WP1.3: Initialisation procedures for ocean component based on observed states

a) Objectives and starting point at beginning of reporting period

CERFACS:
Most improvements made to the variational assimilation system developed for ENACT were reported last year. Work had mainly concerned the perturbation and ensemble generation strategy.

ECMWF:
Based on the output of previous projects, especially the EC-FP5 projects DEMETER and ENACT, further developments in order to improve the ocean assimilation system at ECMWF were in progress.

INGV:
a number of alternative assimilation strategies aimed to improve the salinity representation had been tested.
experiments using bivariate EOFs calculated at each model gridpoint and derived from different time periods had been performed.

METO-HC:
A new ocean in situ dataset for 1958-2004 of all available ocean observations had been provided in May 2005, this representing a significant upgrade relative to the previous ENACT version. Data had been made widely available to all partners and is also to be used in EU FP6 MERSEA by Coriolis/ Mercator, France. See www.hadobs.org. A paper had been submitted: Ingleby,B. and M. Huddleston, 2004: Quality control of ocean profiles - historical and real-time data. Submitted to Journal of Marine Systems.

Following assessment of the ENACT ocean analysis further development of the ocean analysis system was in progress. Work was also in progress to a perturbation strategy has been tuned and an analyses ensemble generated for initialising hindcasts in WP1.5 and WP2A.1

IfM-GEOMAR
1. Three coupled initialisation runs had been performed.
2. Plans had been made for generating ocean initial conditions using the EnKF scheme developed at KNMI.

KNMI:
1. The EnKF for MPI-OM1 ocean model, the data assimilation system developed in the ENACT project, had been documented in a paper (submitted) and a technical report *).

*) O. Leeuwenburgh, Implementation and testing of an Ensemble Kalman Filter assimilation system for the Max Planck Institute Ocean General Circulation Model, Technical Report TR-274, KNMI, available on request from KNMI.

2. An analysis scheme had been implemented for the OPA model in the ECMWF environment that uses the set-up developed by KNMI in ENACT, see details below.
The results of the ENACT project were the starting point: prototype Ensemble Kalman Filter (EnKF) systems for MPI-OM1 ocean model (made by KNMI) and for the OPA ocean model (made by NERSC).

It had been concluded that the analysis scheme of the KNMI set-up was more promising, because of the use of a more robust analysis scheme and a realistic data constraint error model, and the capability to assimilate temperature and salinity. The decision had therefore been made to set up a comparable system for OPA based on the MPI-OM-1 results. EnKF systems result in larger ensembles than can be handled in hindcast runs in ENSEMBLES. A method to reduce the size of the ensembles output by the EnKF was developed earlier in the project.

b) Progress towards objectives

CERFACS:
Perturbed sets of ocean model analyses and simulations have been obtained by perturbing the surface wind stress, sea surface temperature (SST), and observations used for assimilation. The perturbations for the surface forcing fields were constructed from differences between different forcing products (ERA40 and CORE), while the perturbations for the observations were defined so that they have statistical properties consistent with the observation-error covariances used in the assimilation algorithm. Some ensemble experiments with 16 members have been done over the period 1987-1990. Ensemble methods provide an attractive way of obtaining global error statistics for the model background state. Initially, the ensemble method is being used to provide flow-dependent estimates of the variances of background error in a 3D-Var version of the assimilation system. Comparisons between these new ensemble variance estimates and the parameterized (weakly flow-dependent) variances currently used in the system are being evaluated. The best system will be used to produce future deliverables.

ECMWF:
ECMWF has produced ocean analyses with HOPE/IFS over the period 1991-2001 to be used in the stream 1 seasonal-to-decadal simulations for May and November start dates. As a set of preliminary decadal hindcasts has been designed for stream 1 to be initialized in November 1965 and November 1994, additional sets of ocean analyses have been produced for these periods.

The impact of wind stress and SST perturbations has been studied. A document which describes the impact of the wind stress perturbations has been made available at
http://www.ecmwf.int/research/EU_projects/ENSEMBLES/exp_setup/ini_perturb/index.html.

INGV:
An upgrade of the previous data assimilation system has been done through the implementation of seasonally dependent (versus stationary) bivariate EOFs computed at each model gridpoint. A paper on this work is under review (see below). The final INGV data assimilation system has been adapted to the OGCM used in ENSEMBLES and a new in situ data set produced by the Met. Office (v1a/v1b) has been implemented. A global analysis covering the period 1957-2001 has been produced with the latest system. An analysis of the heat content calculated over the upper 300 and 3000 m revealed that the largest differences, with respect to the analyses produced using the previous data base of ocean subsurface temperature and salinity, are found in the equatorial region and in the southern hemisphere. The northern hemisphere heat content seems to be less affected by the impact of the XBT double correction.

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

METO-HC:
A paper has been accepted: Ingleby, B. and M. Huddleston, 2006: Quality control of ocean profiles - historical and real-time data, Journal of Marine Systems.

TASK 1.3.1/M1.3: The ocean data assimilation system and the required ensemble of ocean analyses were completed on time.

TASK 1.3.2 / M1.4 (delayed from month 20 due to late release of World Ocean Database 2005 by NOAA, USA): Upgrade of ocean observation database from version EN2 to EN3, to include the latest world ocean database release 2005 and tuning of the quality control process. This was released at month 24.

IfM-GEOMAR:
1. Representation of initial condition uncertainties in ensemble predictions: Results from the "stream 1" set of seasonal hindcasts demonstrated the benefit of sampling uncertainties in ocean initial conditions, as opposed to sampling atmospheric uncertainties only.
2. Improved methods of initialising the ocean module for seasonal to decadal predictions: The decadal hindcasts have not been performed yet, because of large initial condition errors in the North Atlantic. In particular, the strength of the meridional overturning circulation and its variability is far too strong. These errors appear related to the nudging of full SST as opposed to anomalies. These experiments however demonstrate that the nudging strategy may indeed provide a method for initialising the thermohaline circulation, and future experiments are planned assimilating anomalies, instead of full SST.

KNMI:
Due to lack of manpower, KNMI did not contribute directly towards WP1.3 objectives during this period, except for attending the RT1/RT2A meeting at Reading on June 8-9 2006.

c) Deviations from the project work programme and corrective actions

IfM-GEOMAR:
The implementation of the EnKF scheme into the new version of the MPI ocean model has been delayed due to lack of manpower. A PhD student is currently being sought to provide support on this activity.

KNMI:
KNMI has started an initiative to build, together with European partners, an Earth System model ECEARTH that uses the ECMWF IFS model for its atmospheric core. The ECEARTH activities will have many interactions with the ENSEMBLES work.

WP1.4: Assembly of a multi-model ensemble system, with common output, with installation on a single supercomputer, where appropriate

a) Objectives and starting point at beginning of reporting period

Development of and preparations for the multi-model initial-condition ensemble system for climate prediction on seasonal, interannual and decadal time scales to be installed at the ECMWF supercomputer were ongoing. The ENSEMBLES s2d multi-model system is based on the experiences of the FP5 DEMETER system and the operational multi-model seasonal forecast system (EUROSIP) installed at ECMWF. Since the end of the DEMETER project, a significant amount of work had been devoted to upgrade many of the climate model components and to port the models to the newer supercomputer architecture. In some cases the pre-production simulations were already in progress. A common list of output variables and formats had been defined

DePreSys (METO-HC) was installed at ECMWF and initial performance tests had been done. The latest version of GloSea (METO-HC) had been installed at ECMWF. Preparation of runs using burst and lagged averaged initialisation methods and development of physics perturbation methods were ongoing.

A new version of IFS/HOPE (ECMWF) had been prepared to be run in seasonal and interannual forecast mode. Model level output every 6 hours and scripts to transform model level output into pressure levels for use in downscaling had been prepared and made available to RT2B partners. In order to ensure efficient data archiving and dissemination, a common list of variables had been used as a basic design template for data encoding and archiving for the other partners running their models at ECMWF.

CNRM, in close collaboration with CERFACS, had upgraded the atmosphere model ARPEGE for seasonal forecasting. The system had been installed and tested at ECMWF's computer environment.

IfM-Kiel had worked on the installation of the latest version of the coupled model ECHAM5/OM1 on the supercomputer at ECMWF.

CNRS-IPSL had developed a set up of a hybrid coupled model based on a statistical atmosphere coupled to the ORCA2 ocean component.

b) Progress towards objectives

The new multi-model initial-condition ensemble is currently built from five coupled climate models, namely IFS/HOPE (ECMWF), ARPEGE4.5/OPA (CNRM), ARPEGE/OPA (CERFACS), GloSea (METO-HC), and ECHAM5/MPI-OM1 (IfM-Kiel). Simulations from the METO-HC DePreSys/PPE model systems to contribute to the multi-model initial-condition ensemble are currently under way.

Task 1.4.1:
The latest versions of the ECMWF, METO-HC, CNRM, CERFACS and IfM-Kiel global coupled climate models have been installed at the IBM supercomputer at ECMWF. Initialisation procedures have been taken from the FP5 ENACT programme and developments from WP1.3 and RT2A (5-year Task 1.4a). For a detailed documentation of the multi-model components and initialisation procedures, see Deliverable 1.4 and Major Milestone MM1.2.
The latest version of the INGV coupled model has been installed at the NEC supercomputer at INGV to be used in the stream 2 seasonal-to-decadal integrations. The atmospheric component of the coupled model has been updated by implementing an improved representation of the surface physics. Studies on how to improve the ensemble forecasts initialization procedure, especially the perturbation of the oceanic initial conditions, have commenced.
At CERFACS significant efforts have been made to build a new coupled model for later use in the stream 2 simulations. This model couples NEMO, the latest version of the OPA ocean general circulation model, including an ice-model, and the version 4 of ARPEGE Climat. Lots of work has been done to tune the model for long integrations, especially with the aim of reducing the drift. This will be most useful for the decadal hindcast experiments.

Task 1.4.2:
The METO-HC seasonal and decadal versions of the coupled model with perturbed parameterisation schemes have been installed, and the ECMWF model with stochastic physics has been installed (5-year Task 1.4a).
An s2d perturbed physics ensemble (PPE) system has been implemented on the ECMWF computer. The s2d PPE system employs a subset of perturbed physics HadCM3 model versions used in the METO-HC centennial prediction system (WP1.2), but designed to produce s2d hindcasts. The system consists of eight member perturbed physics parameter versions, picked to represent a wide range of climate sensitivities (2.6 – 7.1°C) and a wide range of ENSO amplitudes (NINO3.4 SST anomaly standard deviation ranging from 0.5 – 1.2°C), plus one standard parameter HadCM3 version. In each model version, flux adjustments are applied to correct for local SST errors and to prevent model drift. The earlier perturbed initial condition version of the METO-HC s2d system (DePreSys), which does not employ flux adjustments, is available for comparison. An anomaly assimilation technique is used to generate initial conditions. ERA-40 provided prognostic variables for the assimilation of the atmosphere, whereas monthly salinity and temperature analyses were used for the ocean. Forecast anomalies for each model version are produced by removing corresponding model climatology used for assimilation.
A new approach to ensemble climate prediction based on sampling stochastic parameterisation uncertainties has been further developed and applied by ECMWF in the IFS/HOPE coupled model environment. This used the Cellular Automaton Stochastic BackScattering (CASBS) scheme, which introduces streamfunction perturbations on the near-grid scale and is motivated by the notion that a fraction of the dissipated energy will scatter upscale and inject kinetic energy into the resolved flow. For this purpose a cellular automaton is utilised to generate a spatially and temporally correlated pattern which is weighted according to the flow-dependent dissipation rate from numerical dissipation and friction from deep convection and gravity/mountain wave drag.

Task 1.4.3:
Unified output and archival routines have been developed, so that atmosphere and ocean data can be output into ECMWF MARS archive (5-year Task 1.4b).The archiving of the stream 1 multi-model simulations in MARS following the common output and archiving strategy has been finished for some partners and is still ongoing for others.

Task 1.4.4:
Additional development of the stochastic physics scheme and sets of experiments as in WP1.5 have been carried out by ECMWF (5-year Task 1.4a). CASBS version 1.0 has been tested in s2d hindcast simulations for the 1991-2001 period, based on start dates in November and May, using IFS/HOPE with the atmospheric model cycle CY29R2. For the decadal simulations starting in November 1965 and 1994 a revised version of CASBS (v1.1) was used, while at the same time the latest changes to the atmospheric IFS cycle (CY30R1) have been introduced in the coupled IFS/HOPE system. The forecast skill of these preliminary simulations compared to other approaches to model uncertainty (multi-model and perturbed physical parameters) has been evaluated and documented in WP1.5. Work has been carried out to further develop the stochastic physics scheme. An updated version CASBS (v1.2) is currently being tested in the medium range ensemble forecasting system at ECMWF.

Task 1.4.5:
METO-HC has started work on porting its next generation ESM (HadGEM) to the ECMWF supercomputer, and testing its performance. This work is ongoing.

c) Deviations from the project work programme and corrective actions

None.

WP1.5: Generation of pre-production ensemble predictions of climate on the seasonal to decadal timescale, initialised from observations

a) Objectives and starting point at beginning of reporting period

Development of and preparations for the multi-model initial-condition ensemble system for climate prediction on seasonal, interannual and decadal time scales to be installed at the ECMWF supercomputer were ongoing. All partners had considerably updated their coupled forecast models and tested their performance. In some cases the pre-production simulations for stream 1 were already in progress.

The new stochastic physics scheme at ECMWF had been in the process of being developed and coupled to the IFS/HOPE model.

Initial analyses with the perturbed physics scheme using DePreSys at METO-HC had been undertaken to provide a first indication of the prospects for achieving useful forecast skill on interannual to decadal timescales. Regional patterns of decadal temperature change had been compared with predictions that only included anthropogenic forcing.

b) Progress towards objectives

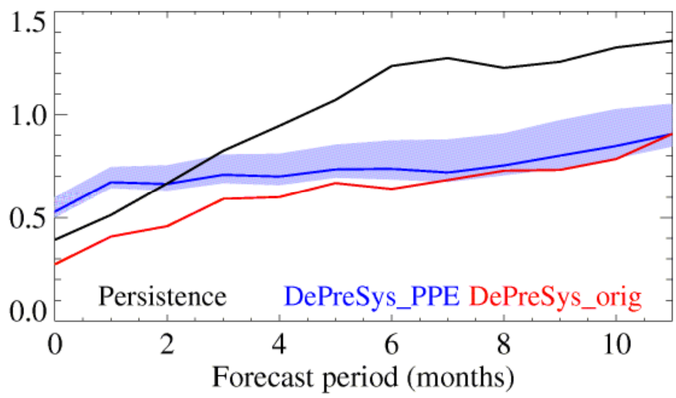
Task 1.5.1:
Seasonal and decadal timescale ensemble integrations have been made using a) the multi-model ensemble system, b) the perturbed parameter system, and c) the stochastic physics system. Seasonal-to-interannual hindcasts covering the period 1991-2001 have been carried out. The integrations are 7 months long for the 1st May start dates and 14 months long for the 1st November start dates. Decadal (10-year long) integrations over two contrasting decades from the 20th century starting 1st November 1965 and 1994 have been completed by almost all partners. ECMWF ERA-40 data have been used to provide atmospheric initial conditions and atmospheric verification (5-year Task 1.5a).
Further to the stream 1 standard experiment design, additional seasonal hindcast experiments have been done by the METO-HC using lagged ocean analyses rather than perturbed analyses. A set of hindcasts has been initialised 2 weeks prior to the standard start dates to enable studies on information retention and decay in the forecasting system.

Task 1.5.2:
The forecast quality has been estimated for each system, and a combination of them, using a set of deterministic scores (5-year Tasks 1.5b and 1.5c). A summary of these analyses can be found in the Milestone 1.2 (delivered month 18), which provides a preliminary assessment of the relative merits of the three approaches to tackle the problem of model uncertainty. An updated analysis was produced for Major Milestone MM1.2 (delivered at month 24), which will be further updated in the Deliverable D1.8, due month 30.

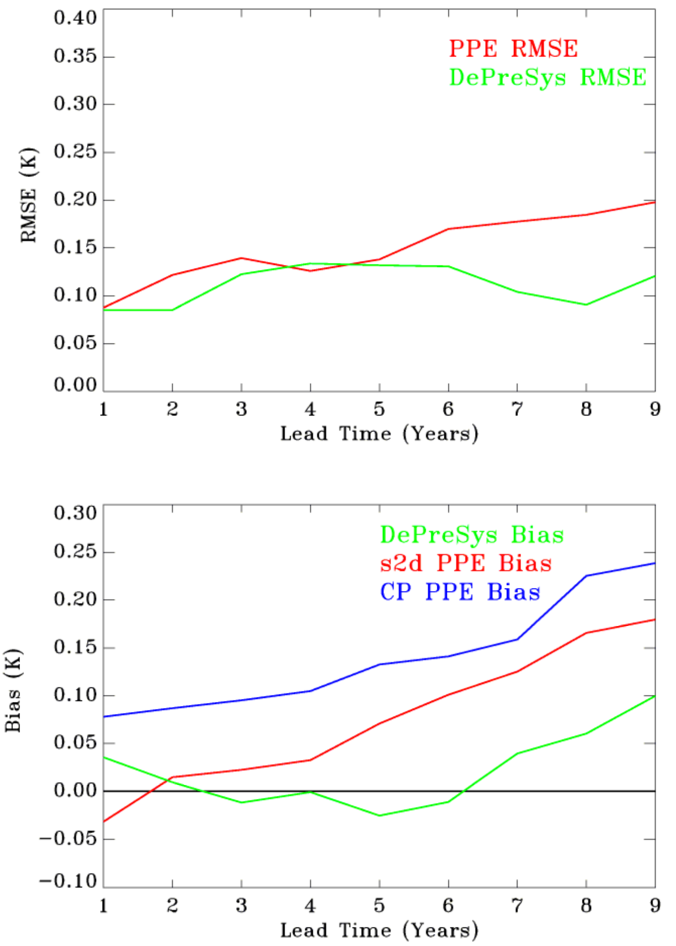
Task 1.5.3:
At the METO-HC a set of nine member ten-year long Perturbed Physics Ensemble (PPE) retrospective forecasts have been carried out for years 1991-2001, using May and November start dates. A small set of perturbed initial condition ensemble hindcasts using the standard version for May start dates for years 1991-92 and November start dates for years 1993-94 have also been completed.

The ENSO-related seasonal hindcast skill of s2d PPE system is relatively weaker than the original DePreSys system (Figure 1). Even a persistence forecast beats the PPE system at short lead times of up to two months. The new s2d PPE system differs from the original DePreSys in several ways. The main changes are: 1) flux adjustments have been applied at the atmosphere-ocean interface; 2) a fully interactive sulphur cycle scheme has been implemented replacing the partial sulphur cycle scheme; and 3) the external radiative forcing agents (trace gases, ozone, aerosols) have been updated with recent data sets. Reasons for the reduction in skill at short lead times are currently under investigation. One possibility is that there is a mismatch between the PPE model versions and the ocean analyses, as the covariance statistics used in the ocean analyses has been derived from the standard parameter setting run without flux adjustments. In addition, it is known that flux-adjustments influence the intrinsic behaviour of the ENSO mode in HadCM3, resulting in a weakening of the coupling of the atmosphere and subsurface thermocline in the east Pacific.

The decadal PPE performance in predicting the annual global mean surface air temperature anomalies is encouraging at short lead times (up to five years), as it compares reasonably well with the DePreSys prediction (upper panel, Figure 2). However the increased RMSE values at longer lead times reflect the larger warming bias predicted by the PPE system in this particular decade (lower panel, Figure 2). This relatively increased rate of decadal warming may not necessarily indicate a fundamental error in the system, but could just reflect the faster warming nature of the contributing member versions. The averaged climate sensitivity (CS) of the slab-model versions corresponding to the flux adjusted transient versions included in the s2d PPE system is 4.10C, whereas the standard parameter setting version has CS of 3.5°C. Different levels of radiative forcing from the updated forcing inputs and interactive sulphur cycle may also contribute to a faster warming rate. For interannual to decadal predictions, a key question is whether the initialisation of models with analyses of observations improves skill at extended lead times, just as it does for seasonal predictions. In the lower panel of Figure 2, we assess this by comparing the averaged bias of global mean temperature predictions from the PPE decadal simulations (red curve) against that from the long-term historical climate simulations (initialised from pre-industrial conditions) from which the decadal ensemble was derived (blue curve). For the first year, the PPE bias is smaller, as would be expected, given the initialisation of observed values. In later years the PPE runs show a steadily increasing positive bias (as discussed above), however it is encouraging that this bias remains consistently below that found in the historical simulations. This suggests that the initial conditions continue to influence the predictions throughout the decadal period of the hindcasts, illustrating the potential for improved long-term predictions associated with initialisation from observations. Further work is underway to understand these results in greater detail.



WP1.5 Figure 1*: RMS error of the ensemble mean as a function of the lead time (months) for Nino3 surface air temperatures.*



WP1.5 Figure 2: *RMS error (upper panel) and average bias (lower panel) of the ensemble means for annual global mean surface air temperatures. PPE system produced 9-member ensemble with 22 start dates, while DePreSys generated 8-member ensemble from 22 start dates.*

c) Deviations from the project work programme and corrective actions

IfM-Kiel has not yet performed the decadal hindcasts, as unacceptable errors in ocean initial conditions were detected. To mitigate these errors a new set of initialisation runs, in which SST anomalies are assimilated will be performed. To support the activities in this WP a PhD student is being sought.

WP1.6: Generation of pre-production ensemble predictions of climate on the century timescale, initialised from model initial conditions

a) Objectives and starting point at beginning of reporting period

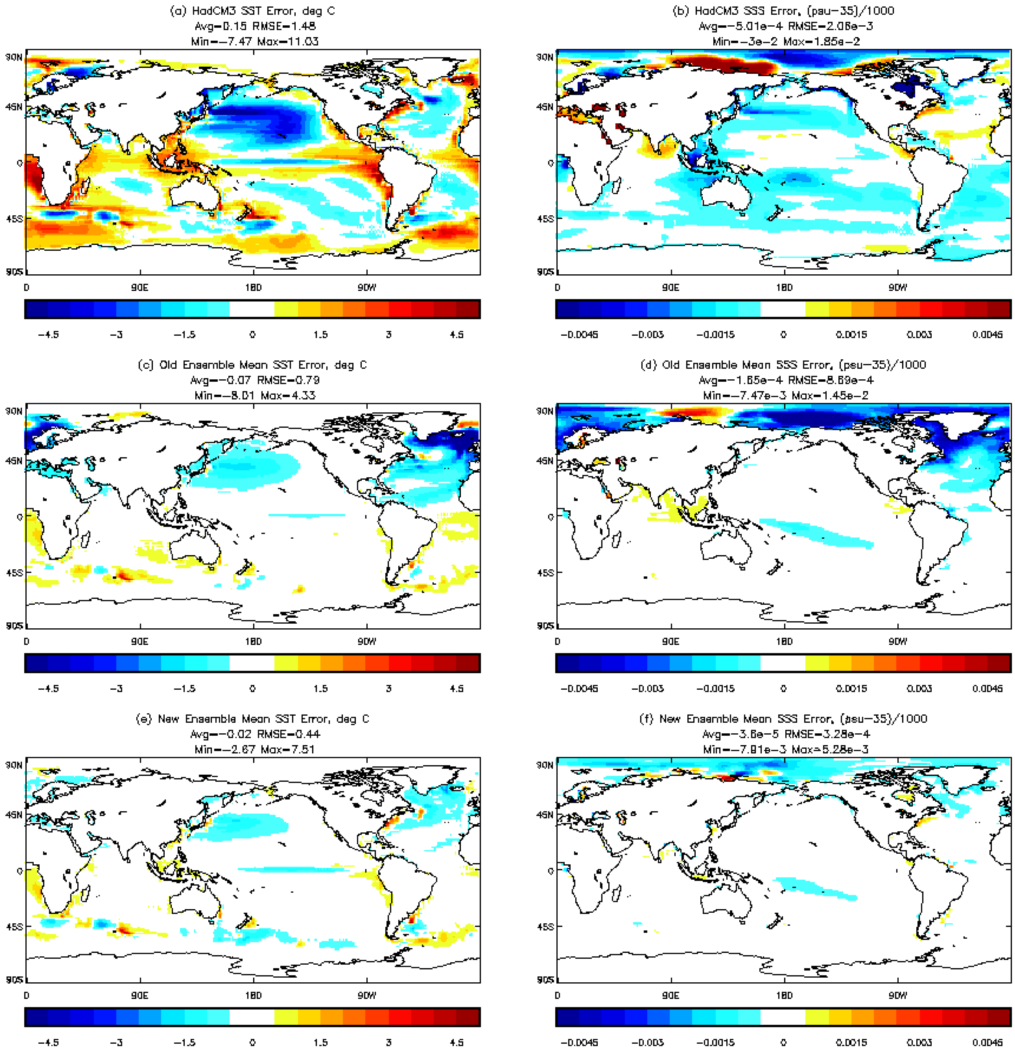
Starting point: By month 12 of ENSEMBLES, a 17 member ensemble of versions of the HadCM3 coupled model had been produced, with multiple perturbations to uncertain atmospheric parameters. Despite using flux adjustments, this ensemble showed biases in its sea surface climatology in some regions (notable the north Atlantic), which limited its usefulness for regional predictions. Multiple perturbation experiments using the atmosphere-mixed layer ocean version of HadCM3 had been performed by Oxford University and the Hadley Centre, showing a wide range of climate sensitivities and evidence of non-linear effects of combining uncertainties in different parameters. The EGMAM coupled model had been prepred for use within ENSEMBLES, and initial test simulations had been performed, including some with perturbations to uncertain cloud parameters. A new Earth System Model had been created by combining the CNRM-CM3 coupled model with the IMAGE2.2 integrated impact assessment model, and used to simulate the response to SRES A2 forcing.

Objectives for months 13-30

Task 1.6.1: Further ensemble experiments to quantify the sensitivity of time-dependent climate change to atmospheric parameter perturbations will be undertaken using the Hadley Centre coupled model HadCM3. In addition, parameter ranges which control the behaviour of other components of the model, specifically the ocean, the sulphur cycle and the carbon cycle will be quantified. Experiments will be initiated to test the spin-up of model versions with perturbed ocean parameters. Frequency distributions (interim PDFs) of transient regional change will be produced.
Task 1.6.2: Ensemble sizes in Task 1.6.1 will be limited by the availability of computer resources. During months 12-30 a version of the fully-coupled HadCM3 model will be prepared for release to the general public under the climateprediction.net project. This will involve solving a large number of both technical and scientific issues but will allow further assessment of perturbation techniques. In addition, a climateprediction.net experiment in which perturbations are made to sulphur-cycle parameters in the atmospheric-mixed-layer version of the model will be started.
Task 1.6.3: The sensitivity tests of the EGMAM model's time-dependent climate change to parameter perturbations will be continued. This will allow comparison of the EGMAM and the HadCM3 models and to give recommendations to the ENSEMBLES project concerning the design of the production ensemble system until month 18 (Milestone M1.3). Additionally, the most promising perturbation methods developed in RT1.2 will be used to start centennial forecast ensembles. The results of these ensemble runs provide the basis for the statistical analysis to document the performance of the methods. CNRM will start using its new earth-system model in a pre-production mode to generate a small ensemble of climate simulations in order to explore the sensitivity of the climate response to different ocean initial conditions.

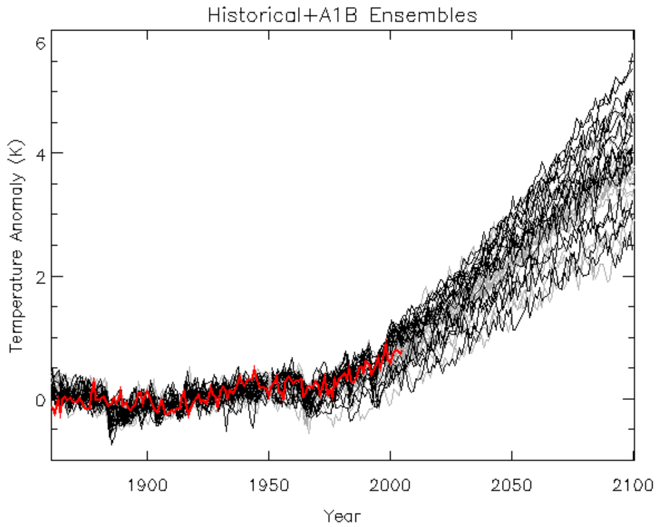
b) Progress towards objectives

Task 1.6.1: A new 17-member ensemble of HadCM3 with modified flux adjustments has been completed in which SST biases are reduced. This was achieved through the use of a longer time scale for relaxation to observed sea surface climatologies during the spin-up phase of the simulations (from which the flux adjustments are calculated). Figure 1 below shows a comparison of SST and SSS biases in the original un-flux-adjusted HadCM3, the original ensemble mean and the new ensemble. Biases are much reduced in the new ensemble, particularly in the North Atlantic and Arctic regions. This provides a much more credible basis for quantifying uncertainties in climate change and producing PDFs for impacts studies.



WP1.6 Figure 1. *Time mean SST biases (left panels) and SSS biases (right panels). The top row shows biases from the standard-parameter un-flux-adjusted version of HadCM3. The middle row shows the ensemble mean biases from the old perturbed-physics ensemble of HadCM3 with flux-adjustment but with significant drifts in climate in the N. Atlantic and Arctic regions. The bottom row shows biases from a new ensemble with adjusted Haney-forcing coefficients and no drifts.*

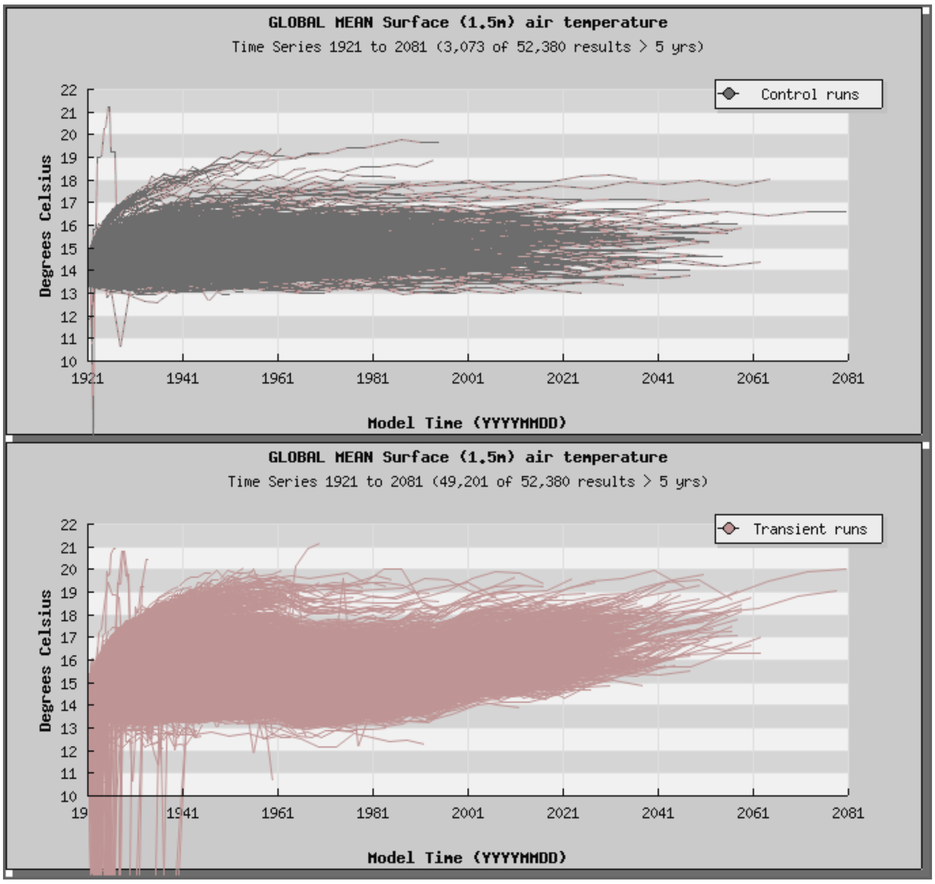
This new ensemble has been used to simulate historical climate change using estimates of both natural and anthropogenic forcing agents, and future change under the SRES A1B scenario (Figure 2 below). In addition to having reduced SST and SSS biases, the new ensemble explores a wider range of feedbacks and thus produces a slightly wider range of global mean change. These experiments have been employed in producing interim PDFs of future climate change for deliverable D1.7.



WP1.6 Figure 2. *Global annual mean temperature anomalies for perturbed physics ensemble experiments forced by estimates of natural and anthropogenic factors over the historical period and forced by SRES A1B into the future. The grey lines are temperatures from the ensemble with SST and SSS biases and the black lines are from the new ensemble with reduced biases. The observed global mean temperature change is shown in red.*

In the experiments described above, perturbations are only made to parameters in the atmospheric component of HadCM3. We have performed a small ensemble of HadCM3 experiments in which perturbations are made to ocean physics parameters. Analysis of these experiments shows that, when only a handful of parameters which control the vertical transport of heat in the ocean are perturbed independently, the effect on the time rate of change of global mean temperature is small. A larger ensemble with more ocean parameters perturbed simultaneously is now in the spin-up phase. In addition, experiments with simultaneous perturbations to parameters in the sulphur-cycle component of HadCM3 are also in their spin-up phase. We are also in the processes of defining a version of HadCM3 with standard parameter settings with an interactive carbon cycle.

Task 1.6.2: A new method for generating large numbers of fully-coupled versions of the HadCM3 model without the need for new ocean spin-ups has been demonstrated. The method produces relatively stable models when perturbing atmosphere physics using a new technique of surface flux adjustment described in Faull (2005). Over 100,000 models with varying initial conditions, forcing profiles and physics perturbations are currently being run by members of the general public (Figure 3 below).



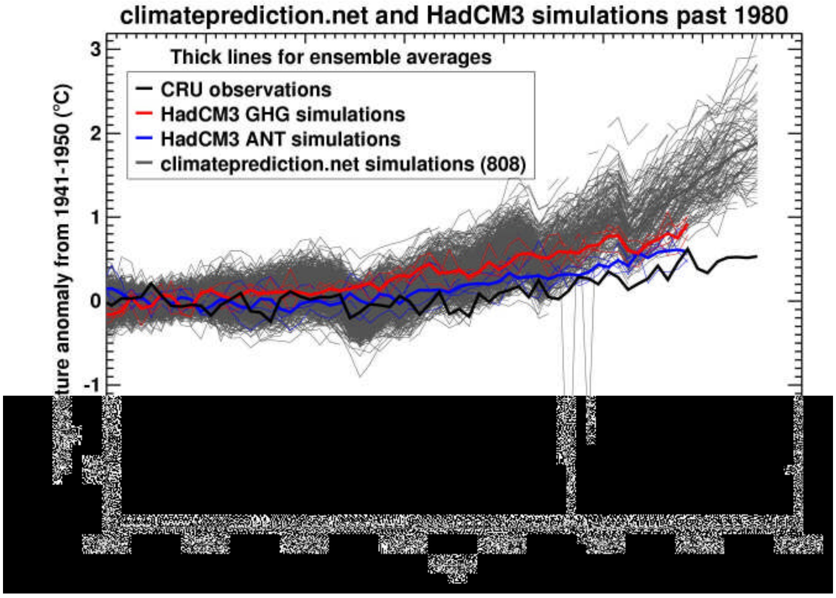
WP1.6 Figure 3. *Monthly mean surface air temperature time series for 52380 models including variations in initial conditions, forcing profiles and physics perturbations, currently being run by members of the general public. Upper panel: Control simulations with fixed greenhouse gases and other forcing agents. Lower panel: Experiments with variations in past and future forcing according to a number of different historical reconstructions and future scenarios.*

Task 1.6.3: The uncertainties in the climate change projections performed with the EGMAM model due to uncertainties in the cloud parametrization was further investigated by generating a 30-member perturbed physics ensemble, where 5 relevant cloud parameters were perturbed. The perturbation parameters were selected following expert advice and experiences of project partners (METO-HC and University of Oxford) to allow a comparison of the results. The 30 perturbed versions of EGMAM were integrated over at least ten years under present day conditions. In a first step, the results were used to quantify the parameter sensitivity of the model. Due to a strong sensitivity of the model to one particular parameter (sedimentation rate of ice crystals) a linear approach can explain nearly 80% of the global mean temperature variance in the ensemble. On the other hand, nonlinear effects on radiative quantities are found, when combining perturbations of different parameters.

An analysis of the simulation of CNRM-CM3 coupled to the impact assessment model IMAGE 2.2 from RIVM in a scenario SRES-A2 has shown a small impact of land-use changes on the simulated climate. After the introduction of an improvement in the parameterization of turbulent fluxes in stable conditions, a new control simulation (CT2) for pre-industrial conditions has been started with the CNRM coupled model. This new simulation has been run for 140 years and has proved successful in eliminating the cold bias of the previous CNRM-CM3 control simulation (CT1). Work is in progress for the reintroduction of the indirect effect of aerosols.

c) Deviations from the project work programme and corrective actions

Task 1.6.2: Because of a problem with an input file, too little sulphate aerosol was input into the models resulting in too great a warming in the latter half of the 20th century in the initial climateprediction.net HadCM3L experiment. This is clear by comparison with the observational CRU data and Hadley Centre "all anthropogenic forcing" (ANT) simulations (shown in Figure 4 below) which warm less. Despite this problem the data generated is useful for looking at aspects of climate that may have been affected by sulphate aerosol, for example, the Sahel Desert drought in the 1980s, to which sulphate aerosol might have contributed. However, the ensemble has now been regenerated with the correct sulphate forcing.



WP1.6 Figure 4. *Global warming rates in the initial climateprediction.net HadCM3L ensemble. Too little aerosol was included resulting in warming which was much larger than that seen in experiments run at METO-HC. This error has now been rectified.*

d) List of deliverables, including due date and actual/foreseen submission date (see Table 1)

Table 1: Deliverables List

List all deliverables, giving date of submission and any proposed revision to plans.

Del. no.	Deliverable name	Research Theme no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
D1.3	Advanced ocean data assimilations systems, based on improved optimal interpolation, Ensemble Kalman Filter, and variational methods, developed in the ENACT project, adapted to the OGCMs to be used in the ENSEMBLES system.	RT1	28.02.2006	28.02.2006	42	42	CERFACS
D1.4	A new multi-model coupled model ensemble system for seasonal to decadal forecasts will be created and installed at ECMWF, with capabilities to run, in addition, perturbed parametrisations, and stochastic physics.	RT1	28.02.2006	28.02.2006			ECMWF
D1.5	WP1.1 workshop	RT1	31.05.2006	09.06.2006	1	1	MPIMET
D1.6	Report on the developed and tested ESMs	RT1	31.08.2006	31.08.2006	60	60	MPIMET
D1.7	Interim probability distributions of transient climate change over Europe will be produced, for use by other RTs in testing methodologies for prediction of climate change impacts.	RT1	31.08.2006	31.08.2006	12	12	METO-HC

***) if available**

e) List of milestones, including due date and actual/foreseen achievement date (see Table 2)

Table 2: Milestones List

List all milestones, giving date of achievement and any proposed revision to plans.

Milestone no.	Milestone name	Research Theme no.	Date due	Actual/Forecast delivery date	Lead contractor
M1.1	Completion of the technical development needed to adapt the ENACT-based assimilation systems to the ENSEMBLES OGCMs	RT1	28.02.2006	30.04.2006	CERFACS
M1.2	Preliminary assessment of the relative merits of the multi-model approach, the perturbed parameter approach, and the stochastic physics approach, to representing model uncertainty in seasonal to decadal forecasts. Recommendations to the ENSEMBLES project concerning the design of the production ensemble system	RT1	28.02.2006	31.03.2006	ECMWF
M1.3	Preliminary assessment of the perturbed parameter approach to representing model uncertainty in centennial climate predictions. Recommendations to the ENSEMBLES project concerning the design of the production ensemble system	RT1	28.02.2006	31.03.2006	METO-HC
M1.4	Updated quality-controlled oceanographic database	RT1	30.04.2006	31.08.2006	METO-HC
MM1.1	Provision of a set of tested Earth System Models	RT1	31.08.2006	31.08.2006	MPIMET
MM1.2	Provision of a "first generation" ensemble prediction system (Version 1) for use in RT2	RT1	31.08.2006	31.08.2006	ECMWF/METO-HC