RT1 ENSEMBLES Periodic Activity Report – 1Sep07-31Aug08

Executive Summary

Work performed and results achieved: RT1

- A paper was published documenting the performance of the Cellular Automaton Spectral BackScatter stochastic physics scheme in (stream 1) seasonal hindcasts using the ECMWF coupled ocean-atmosphere model (Berner et al., 2008, also D 1.13). Progress has also been made in investigating new approaches to the treatment of stochastic aspects of modelling uncertainty.
- Substantial progress has been made in production and archiving of the stream 2 seasonal to decadal (s2d) hindcasts (joint work between WP1.5 in RT1 and WP2A.1 in RT2A), with completion expected by February 2009.
- A report (D1.11) was produced, documenting the improved skill found in the stream 2 hindcasts made using the ECHAM5/MPI-OM coupled model, compared with hindcasts using an earlier version of the model carried out in a previous EU project (DEMETER).
- The development and assessment of methods for multidecadal climate prediction based on perturbed physics ensembles has continued. Main developments include: (a) assembly of the required elements of a Bayesian method for producing probabilistic projections of large-scale regional climate change based on perturbed physics ensembles (of HadCM3 variants), and also including multi-model ensemble results; (b) Progress towards a method of producing projections of future climate from large (multi-thousand member) perturbed physics ensembles which maximise the role of observational constraints; (c) Comparison of climate sensitivities found in perturbed physics ensembles made using two different climate models (EGMAM and HadCM3), allowing similarities and differences between the impacts of corresponding cloud parameters in the two models to be compared.

Expected end results : RT1

- 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.
- Key changes since last year: The Stream 2 seasonal-decadal hindcast experiments have been substantially progressed, and will be completed within the next few months. The elements of a methodology for probabilistic climate predictions of climate change at multidecadal lead times are now in place, based on perturbed physics ensembles and also including results from multi-model ensemble simulations.

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 3 of ENSEMBLES made the following recommendations relevant to RT1:

Treatment of uncertainty *in climate change projections within the project threatens to remain uneven, leaving the users of the ENSEMBLES results in a confusing situation. While a relatively comprehensive treatment is possible for global projections in RT1 and RT2A, this is far more difficult for the regional projections to be produced in RT2B and for the impact studies in RT6. The ENSEMBLES products should therefore include – either as a separate deliverable or as a part of the final report – a pedagogic but comprehensive description of the treatment of uncertainty within different parts of the project. For example, this document might show how the pdfs for those aspects of climate change that can be treated most comprehensively (e.g., the global mean temperature change) would have looked like if they had been derived with methods analogous to those that were used for making the RT2B regional projections. This issue will require cross-RT discussion between most ENSEMBLES RT:s, but* ***particularly RT1, RT2A, RT2B, RT3 and RT6****, either in a separate workshop or as a side event in the 2008 General Assembly.*

Response: The ENSEMBLES partners acknowledge the comments on the challenges involved with providing a consistent treatment of uncertainty within the project. RT1, RT2A, RT2B, RT3 and RT6 agree to take up the idea of a side event at the fifth General Assembly in 2008 to continue the ongoing discussions on the treatment of uncertainty and probability in order that both be treated consistently and comprehensively throughout the project. The preferred option for describing the treatment of uncertainty and probability within the project is for it to be included within the Final Report instead of adding it as an extra deliverable.

The schemes adopted for weighting *global (****RT1*** *and* ***RT2A****) and regional (****RT2B*** *and* ***RT3****) climate change simulations should be evaluated rigorously. In addition to cross-verification, as recommended in the previous reviews, the project members should seek for a physical understanding on the effects of the weighting. A question that should be addressed is, whether the differences between weighted and unweighted projections of climate change can be traced to some specific features of present-day climate and/or 20th century climate change that are simulated better in models with a larger weight, and whether the impact of these differences onto the climate change response can be understood in physical terms.*

Response: RT1 agree, but first have to construct a system capable of underpinning analysis of this kind. The system for probabilistic regional climate change prediction being built in RT1 appears suitable for this, given that it is based on a methodological framework supporting the use of multiple historical metrics to jointly constrain multivariate predictions of future changes. It will be important to diagnose the physical mechanisms driving relationships between historical observables and future changes, in order to promote understanding of the results, and prevent the method from being seen as a "black box" whose outputs cannot easily be assessed. RT1 has relevant deliverables in the final year of the project. The content and nature of these will be reviewed to ensure that this important question is addressed, though we stress that this is very much an emerging field, so "final answers" on such physical linkages cannot be promised.

RT1 and RT2A*: It is recommended that the reasons for the delay in the completion and transfer of stream one daily data are identified as soon as possible and plans are made to avoid similar delays in the transfer of stream two data. If the problems reflect an underestimated need of manpower, reallocation of resources within the project is recommended.*

Response**:** Regarding data from seasonal to decadal simulations, delivery of stream 1 data has not been subject to significant delays, and we anticipate only minor delays in delivery of stream 2 data.

It is also recommended that contacts with RT4 and RT5 continue, with the intention to further explore methods for process-based evaluation of ensemble model output. The organization of a joint workshop with this narrower subject as its scope during year five of the project could be the end result of this exploration.

Response: RT1 agree with this recommendation. However, it is important to stress that the task of understanding the key processes is itself a demanding task that needs to be progressed first, before the definition and use of a set of metrics as constraints (an equally demanding task) can even be attempted in a convincing fashion. This is very much an emerging new field in the international climate community. It is realistic to expect ENSEMBLES to make progress in this task, but not to solve it, given the resources and time scale at its disposal. We therefore propose that a workshop be held at the final General Assembly (summer 2009), in order to give partners time to make meaningful progress, and with the purpose of using the knowledge gained within ENSEMBLES to make recommendations for the use of process-based constraints in a future ensemble prediction system. Such a workshop will be organised between RTs 1, 2A, 4 and 5.

1.3 Overview of achievements during months 37-48

- A paper was published documenting the performance of the Cellular Automaton Spectral BackScatter stochastic physics scheme in (stream 1) seasonal hindcasts using the ECMWF coupled ocean-atmosphere model (Berner et al., 2008, also D 1.13). ECMWF have also assessed the performance of an alternative spectral backscatter (SPBS) stochastic physics scheme, and are investigating a further alternative designed to maintain vorticity features close to the model gridscale, based on techniques adopted from the field of computer graphics and flow visualisation.
- Substantial progress has been made in production and archiving of the stream 2 seasonal to decadal (s2d) hindcasts (joint work between WP1.5 in RT1 and WP2A.1 in RT2A). The current status is summarised in milestone M1.8. Full completion and archiving of these hindcasts is expected by February 2009.
- A report (D1.11) was produced, documenting the improved skill found in the stream 2 hindcasts made using the ECHAM5/MPI-OM coupled model, compared with hindcasts using an earlier version of the model carried out in a previous EU project (DEMETER).
- The elements of a Bayesian method for producing probabilistic projections of large-scale regional climate change from perturbed physics ensembles (based on HadCM3) have now been assembled. Key progress during the past year has included the generation of ensembles perturbing terrestrial carbon cycle processes, the development of methods to attach weights to different model variants based on errors in simulations of recent climate and past climate change, and the estimation of the impacts of structural model errors based on the use of results from alternative climate models.
- Perturbed physics ensemble simulations using two different climate models (EGMAM and HadCM3) have been compared, allowing similarities and differences between the impacts of corresponding cloud parameters in the two models to be assessed. The results will be summarised in a forthcoming deliverable (D1.14).
- Methods of producing observationally-constrained projections of future climate from large (multi-thousand member) perturbed physics ensembles are being developed by UOXFDC, using results from public resource distributed computing obtained through climate*prediction*.net.
- A workshop on "Assessing and developing ENSEMBLES approaches to climate prediction from a season to a few decades ahead" was held during the Prague Annual Assembly (Nov 2007).

- Discussions were held concerning the question of whether ENSEMBLES partners should aim to set up a future project developing a coordinated approach to climate prediction from 0-25 years ahead, and options for pursuing such a proposal were circulated to interested partners.
- Deliverables and milestones due during months 37-48 were delivered on time, with the exception of D1.12, for which a delay to October 2008 has been agreed.

2. Research Theme Progress

WP1.0: Management of RT1

a) Objectives and starting point at beginning of reporting period

During the third year of ENSEMBLES, a workshop for the seasonal to decadal partners of RT1 had been held in Barcelona (June 2007), as part of a larger meeting of the CLIVAR Working Group on Seasonal to Interannual Prediction. This had offered the opportunity to expose the ENSEMBLES work to a wide international community of modellers and users. All standing management tasks (representation of RT1 at Management Board and Annual Assembly meetings, ensuring timely delivery of milestones, deliverables and other reports) had been carried out. A dedicated RT1 web site containing information such as location of model documentation, model output data, contact details, progress reports, summaries of meetings and key scientific developments, had been maintained and updated. Participation of selected RT1 partners had been arranged for the CFMIP/ENSEMBLES Workshop on assessment of cloud and water vapour feedback processes in GCMs, held in Paris in April 2007. A break-out session for the Fourth Annual Assembly (Prague, Nov 2007) had been proposed, on “Assessing and developing ENSEMBLES approaches to climate prediction from a season to a few decades ahead”.

Objectives for months 37-60 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 1.0.7: The RT1 management team will coordinate contributions from the RT1 workpackages to ensure delivery of Major Milestone MM1.3, “Specification of a “second generation” ensemble prediction system (Version 2)”. This will review results from our ensemble projection experiments for seasonal to decadal and longer timescales, and from techniques developed to convert these into expressions of uncertainty in climate predictions, in order to recommend a specification for an improved climate prediction system.
Task 1.0.8: Contributions from RT1 to cross-cutting activities in ENSEMBLES will be encouraged and supported as required, including workshops at General Assemblies, provision of results and advice in support of users of our ensemble global climate simulations, and contributions to the conference and publications planned to showcase the final results from the project in 2009.

b) Progress towards objectives

Task 1.0.2: The RT1 web pages at ECMWF at
http://www.ecmwf.int/research/EU_projects/ENSEMBLES/index.html

have continued to be maintained and updated. In particular, the table of experiments, which gives an overview to all partners of the set of s2d experiments carried out, has been further completed and maintained; a web site on the collaboration of ENSEMBLES s2d partners with the African Monsoon Multidisciplinary Analyses (AMMA) project has been included; analyses of ocean observations used to initialise our s2d hindccasts were documented on our web site; the latest publications from RT1 partners were listed and linked.

Task 1.0.3: Deliverables D1.11 and D1.13 were achieved on time. RT1 was represented at ENSEMBLES management meetings in Prague (Nov 2007) and Paris (May 2008), and presentations of progress and plans were given. A progress meeting was held during the Annual Assembly in Prague.

Task 1.0.7: Progress towards MM1.3 has been achieved through assessment of the stream 1 s2d hindcasts (WP1.2), investigation of new techniques for sampling model uncertainties (WP1.4), production of the stream 2 s2d simulations (WP1.5), production of new decadal to centennial climate projections (WP1.6) and of methods to obtain likelihood-weighted climate predictions from these (WP1.2). RT1 is currently on-track top achieve MM1.3.

Task 1.0.8: A workshop on "Assessing and developing ENSEMBLES approaches to climate prediction from a season to a few decades ahead" was held during the Prague Annual Assembly (Nov 2007). A presentation was given on assessment of the stream 1 seasonal to decadal (s2d) hindcasts, comparing results from separate multi-model, stochastic parameterisation and perturbed parameter approaches to sampling of modelling uncertainties. Another presentation and discussion followed on the question "Should ENSEMBLES partners develop a coordinated approach to climate prediction from 0-25 years ahead ?" Support was indicated for a potential project along these lines, and a summary of options was sent to interested partners following the meeting.

c) Deviations from the project work programme and corrective actions

Deliverable D1.12 is delayed, but it has been agreed that UOXFDC will complete this by October 2008.

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

The work of this WP was completed prior to the start of year 4 of ENSEMBLES.

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 had further developed a Bayesian framework for probabilistic climate prediction, performing initial testing of methods to generate likelihood-weighted PDFs of equilibrium climate change accounting for structural model errors, and developing emulation and timescaling techniques (trained on HadCM3 perturbed physics ensemble simulations) in order to allow estimation of equilibrium or time-dependent climate changes for parts of the model parameter space not sampled directly by GCM simulations. UOXFDC had produced a large perturbed physics ensemble of transient climate change simulations from the climate*prediction*.net project, and had started work on a method of presenting observationally-constrained forecasts from these. FUB had produced a perturbed physics ensemble of climate change simulations using the EGMAM model, and had compared the impacts of parameters affecting cloud processes with those of corresponding parameters in the HadCM3 model. ECMWF had further developed its scheme to represent stochastic parameterisation uncertainties. The new scheme (Spectral BackScattering SPBS) introduced a flow-dependent stream function forcing on the near-grid scale based on a spectral scale selection.

Task 1.2.11: The implementation of a Bayesian technique for generating probabilistic predictions from small ensembles of complex model simulations will be completed. The perturbed parameter experiments run under WP1.6 will be used, together with a number of statistical and reduced-complexity models, to produce PDFs of future changes at 300km-grid-scale for the European region. The PDFs will be conditional on the SRES A1B Scenario and expert prior assumptions for parameter ranges, will use emulation techniques to explore untried regions of parameter space, will use likelihood weighting based on time-mean observations and historical trends and will utilise multi-model output from ENSEMBLES and elsewhere to estimate a discrepancy term that accounts for the effects of structural model errors.
Task 1.2.12: Oxford will continue development of a methodology for probabilistic climate forecasting which seeks to minimise model bias and maximise the dependence of the forecast distribution on the data used to constrain it. This will feed into a report comparing the different methodologies developed by the Hadley Centre and Oxford (D1.12).
Task 1.2.13: A scientific paper on the seasonal hindcast skill of the new ECMWF stochastic physics scheme will be produced based on results from the stream 1 hindcasts. The scheme uses a Cellular Automaton Stochastic BackScatter (CASBS) approach. The paper will focus on both the impact of CASBS on systematic errors and on the impact of the skill in seasonal hindcasts.
Task 1.2.14: A new set of the stream 1 seasonal-to-decadal hindcasts will be produced with the latest version of the stochastic physics scheme being currently developed at ECMWF for applications in the medium-range. This scheme is now based on a SPectral BackScatter (SPBS) approach which uses a spectral Markov chain to generate the spatial pattern of backscatter of energy. The quality of these new simulations will be analysed and compared with the previous CASBS runs and with the other two approaches to tackle model uncertainty (multi-model and perturbed physics ensembles).
Task 1.2.15: An updated assessment of the performance on seasonal-to-decadal timescales of the multi-model, perturbed physical parameters and stochastic physics ensembles will be provided based on the latest set of hindcast experiments. Eventually, this will lead to some preliminary analysis of how the three individual approaches could be statistically combined into a 'grande model-error sampling ensemble'. Work will be needed to be carried out to test ways how to best weight and combine the different systems. This will partly be done using the em-tool software for ensemble interpretation methods developed by LSE. Other methods we are going to apply are principle component linear regression and calibration/combination based on conditional exceedance probabilities.
Task 1.2.17: A way of using weighting methods for the EGMAM perturbed physics ensemble simulations (see WP1.6, task 1.6.9), developed by project partners (LSE), will be investigated and implemented for the analysis of the perturbed physics experiments.
Task 1.2.18: The question of how a general framework for a multi-model, perturbed physics ensemble system should be designed will be investigated, in order to provide recommendations for future work (month 60, Major Milestone 1.3).

b) Progress towards objectives

Task 1.2.11: All the elements have now been assembled to implement a Bayesian technique for generating probabilistic climate predictions from perturbed parameter ensembles of simulations derived from configurations of the HadCM3 global climate model. During the past year, development has been completed of a method to generate large Monte Carlo samples of time-dependent climate change at large regional scales, based on a "timescaling" technique involving a simple global climate model allied to a pattern scaling method. The simple model samples uncertainties in climate sensitivity, ocean heat uptake and sulphate aerosol forcing derived from perturbed physics ensembles, and has also been generalised to include a representation of carbon cycle feedbacks, including parameters which can be trained to replicate feedbacks simulated in either perturbed physics (Task 1.6.7) or multi-model (C4MIP) simulations using global climate models containing an interactive carbon cycle module. The pattern scaling aspect is implemented by assuming that regional changes scale with the global temperature response, and is trained by matching patterns of equilibrium and transient climate change from perturbed physics ensembles, including offset and residual terms to account for both systematic and random differences between the regional characteristics of equilibrium and transient changes. The sampling of possible equilibrium changes has also been improved, by further developing an emulator which can be trained on an ensemble of ~300 climate model simulations to estimate results that would be obtained from any location in the HadCM3 parameter space of surface and atmospheric processes. The effects of structural model errors (i.e. those which cannot be resolved by varying uncertain model parameters in HadCM3) are included by using the perturbed physics ensemble to predict the results of an alternative multi-model ensemble of equilibrium climate change simulations (this technique has also been developed during the past year). Projections of time-dependent change can be made by combining the above tools, and are weighted according to the relative likelihood of different model variants, obtained using both a set of observations of recent time-averaged climate, and also a set of indices capturing key aspects of historical observed changes in global surface temperature patterns. The method is summarised in figure 1.2.1, and will be used in the final year of the project to produce probabilistic projections of regional climate change at spatial scales skilfully resolved by global models (D1.15).

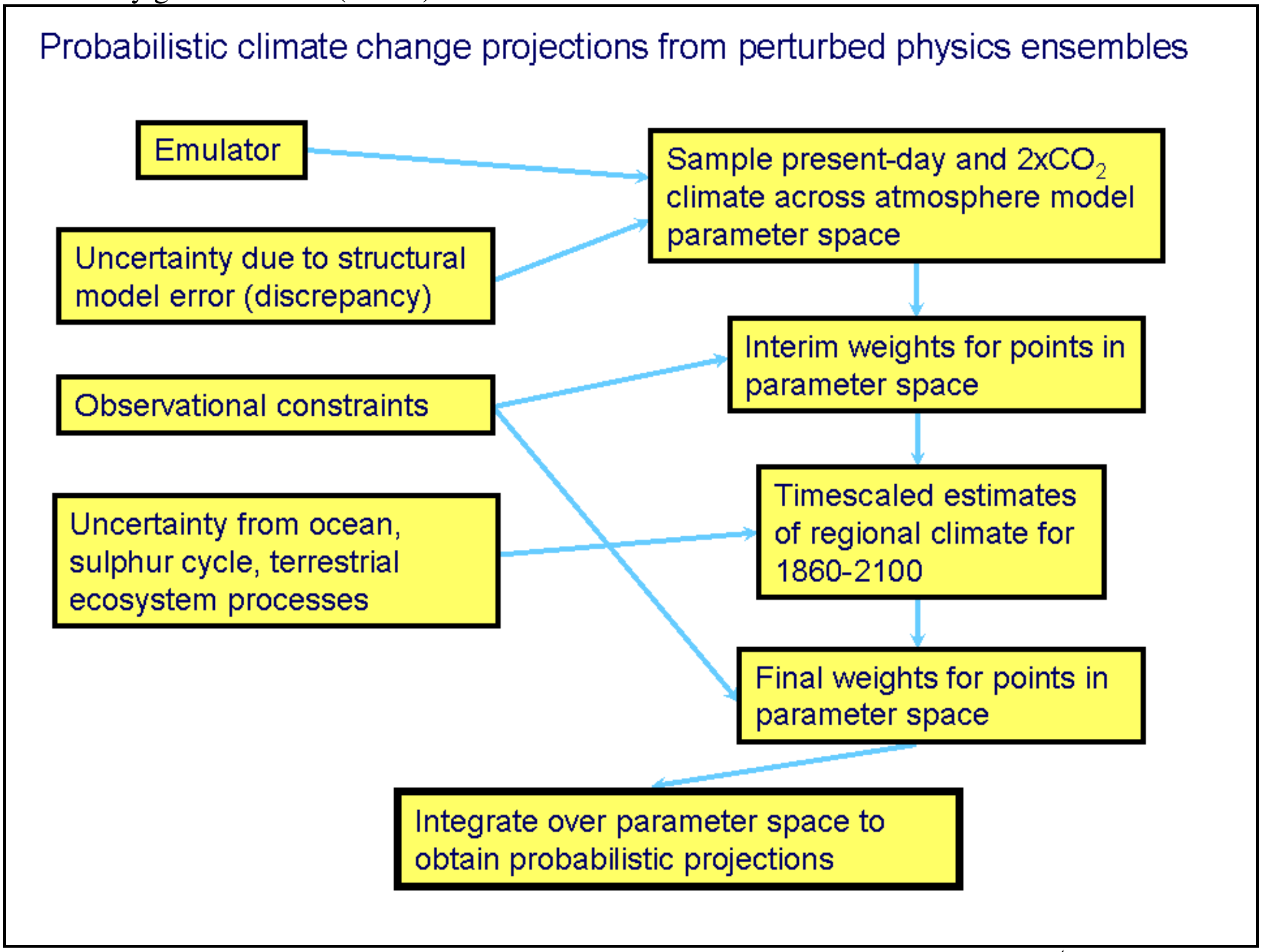

Figure 1.2.1. Schematic overview of methodology to produce probabilistic projections of 21st century climate change by combining perturbed physics ensembles simulations sampling uncertainties in Earth system processes with multi-model ensemble results and a set of observational constraints. A set of statistical techniques (emulation, timescaling, Bayesian calculations of likelihood-weighted probabilities over parameter space) are used to link the various elements together.

Task 1.1.12: Oxford continues to analyse output from the ensemble of order thousands of simulations of HadCM3L, forecasting climate to 2080, which have been returned under climate*prediction*.net. In particular methods are being investigated to assign likelihood weightings to ensemble members whilst maximising the constraints provided by observational data and minimising the influence of prior assumptions of the experimenters. Previously this methodology had been tested with an ensemble of order 250 members; recent work and simulations returned to climate*prediction*.net have enabled this to be extended to order of a few thousand. The continually expanding climate*prediction*.net database is available to the ENSEMBLES community. A journal paper with these initial coupled model results is nearing submission. Unfortunately it has not been possible to produce on time the comparison of probabilistic forecasting methods between a method of this type, and the Bayesian method developed by METO-HC (see Task 1.2.11), due to the large effort required to support development of the two techniques. However, D1.12 will be delivered by October 2008. A paper has been submitted documenting the design of climate*prediction*.net's coupled model experiment, in particular describing the success of the flux re-adjustment scheme and how it enables a massive perturbed physics ensemble with dynamical oceans to be generated, which would otherwise most likely be computationally prohibitive.

Task 1.2.13: A scientific paper documenting the seasonal hindcast skill in the stream 1 simulations, which used the Cellular Automaton Spectral BackScatter scheme (CASBS), has recently been published (*Berner et al., 2008*). This paper also forms Deliverable D1.13, completed in month 42.

Task 1.2.14: ECMWF has continued working on developing and testing the stochastic backscatter scheme for representing the effects of unresolved processes in the coupled IFS/HOPE model. In particular, the sensitivity of the new spectral backscatter scheme SPBS to the ratio of backscattered energy and the slope of the forced spectrum has been tested in stream1-type seasonal hindcast integrations. Both the systematic errors and the forecast quality have been analysed for different seasons. The overall improvement of the forecast due to the new scheme in terms of systematic errors and skill has been found to be moderate. Tests with and without stochastic perturbations using the most recent cycle of the IFS model (CY33R1) that include major changes to the physical parameterizations of convection and land surface processes are currently being carried out.

An alternative, and possibly additional, approach for extending current stochastic sub-gridscale parameterisation methods using techniques adopted from the field of computer graphics and flow visualization has been explored; see also *Shutts et al., 2008*. We have started to implement a vorticity confinement scheme to counter spurious dissipation and maintain vorticity features close to the model's gridscale. Studies on the impact of this new technique (stand-alone and in combination with SPBS) are ongoing.

Task 1.2.17: FUB and LSE considered validation techniques and weighting methods, but did not come to any final conclusion. Effort originally planned for this task had to redirected to Task 1.6.9, because some of the FUB perturbed physics runs had to be recomputed due to a problem with the applied changes in radiative forcing.

Task 1.2.18: The development of the probabilistic projection methodology by METO-HC (Task 1.2.11) allows the generation of diagnostics quantifying the contributions from its different elements to the total uncertainty quantified in the spread of probabilities. Also, sensitivity tests to alternative methodological assumptions can be performed. Such information will be used to help guide recommendations for possible improvements to the method in the future. The comparison of Climate sensitivity and feedback processes simulated by perturbed physics ensembles using different models, and against multi-model ensembles (Task 1.6.9) will also be used to inform these recommendations.

References:

Berner, J., F.J. Doblas-Reyes, T.N. Palmer, G. Shutts and A. Weisheimer (2008): Impact of a quasi-stochastic cellular automaton backscatter scheme on the systematic error and seasonal prediction skill of a global climate model. *Phil. Trans. R. Soc. A*, **366**, 2561-2579, doi:10.1098/rsta.2008.0033.

Shutts, G., T. Allen and J. Berner (2008): Stochastic parametrization of multiscale processes using a dual-grid approach. *Phil. Trans. R. Soc. A*, **366**, 2625-2641, doi:10.1098/rsta.2008.0035.

c) Deviations from the project work programme and corrective actions

None.

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

The work of this WP was completed prior to the start of year 4 of ENSEMBLES.

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

The purpose of this workpackage is to install a forecast system at ECMWF with common archiving to be used in the production of the hindcasts of Streams 1 and 2.

Starting point of work for WP1.4 (Participants: ECMWF, METO-HC, CNRM, IfM, CNRS-IPSL, LSE, INGV, CERFACS):
By the end of the third year of the project, all partners had forecast systems running on the supercomputer at ECMWF and, in the case of INGV on their own supercomputer. These systems were used for the production of the Stream 2 simulations as required in WP1.5 and WP2A.1. Most partners had carried out a substantial amount of work to support archiving in the common dataset the large quantity of hindcasts produced in ENSEMBLES.

b) Progress towards objectives

The progress in WP1.4 during the last year is as follows:

- Task 1.4.7: ECMWF has implemented the new stochastic physics schemes developed for the medium-range forecast system in the coupled model. ECMWF has provided technical support to all the partners to run and/or archive their hindcasts.
- Tasks 1.4.8, 1.4.9 and 1.4.10 were completed.

- IPSL-CNRS are investigating the use of optimal perturbations for ensemble forecasting. They have developed a package to compute a statistical atmosphere based on ocean forcing from ERA-40, which can be extended to use coupled model outputs, so that the atmospheric statistical model mimics the coupled model, thus supporting the identification of singular vectors (SVs) relevant to ensemble forecasting. An alternative method was set up to compute optimals which are closer to a sensitivity experiment using the adjoint, and hence much less costly than the full SV computation (only one adjoint model integration is required). This was tested in the tropical Pacific with a constant basic state. This work has been extended to account for a variable background state, which is being used to investigate the phase locking of ENSO to the annual cycle and the seasonal dependency of the predictability of ENSO.

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

The objective is to test methodologies for probabilistic climate prediction on seasonal to decadal time scales accounting for modelling and initial condition uncertainties in ensemble prediction.

Starting point of work for WP1.5 (Participants: ECMWF, METO-HC, CNRM, IfM, CERFACS, INGV):
The pre-production simulations for Stream 1 with the three approaches to deal with model uncertainty (multi-model ensemble, stochastic physics, and perturbed parameters) were completed, the skill of the hindcasts had been evaluated and the data disseminated. Additional experiments had been run by METO-HC to test the lagged initialization method and by ECMWF to test the new stochastic physics schemes. METO-HC had carried out an extensive assessment of the DePreSys_PPE and DePreSys_ICE hindcasts. IfM had completed their Stream 2 decadal integrations, performed an initial analysis and started the archival of the hindcasts. INGV had implemented a semi-automated procedure for seasonal hindcast production. This had been tested for the latest version of the INGV coupled model. Using the previous version of the INGV Seasonal Prediction System, as developed in the framework of the EU project DEMETER, a preliminary assessment of the impacts of the improved ocean initial conditions produced in WP1.3 on the hindcasts skill had been performed.

b) Progress towards objectives

The progress in WP1.5 during the last year is as follows:

- Task 1.5.4: ECMWF has used a new cycle of IFS/HOPE to test a new version of their Spectral BackScattering (SPBS) stochastic physics scheme, and an alternative vorticity confinement technique (see report on Task 1.2.14), using the Stream 1 experimental setup for seasonal hindcasts. The simulations await a careful analysis to assess the relative merits of those two techniques to address the impact of model uncertainty on forecast error.
- Task 1.5.5: ECMWF has carried out a thorough assessment of the skill of the Stream 1 simulations. This work will be submitted in the coming weeks to a journal for publication.
- Task 1.5.6: METO-HC have completed the standard Stream 2 decadal hindcasts (start dates November 1960, 1965, 1970, …, 2005) using the perturbed parameter system. The parallel “No_Assim” integrations using the same external forcings, but started from initial states statistically independent of the observations, have also been completed. Stream 2 seasonal hindcasts starting in May have also been completed.
- Task 1.5.7: IfM completed a report documenting the improved seasonal hindcast skill of the MPI model and the model improvements responsible for it (D1.11).
- Task 1.5.8: CNRM has completed their Stream 2 contribution. IFM completed the Stream 2 seasonal hindcasts. The article with the analysis of the Stream 2 decadal hindcasts was revised and is now published (Keenlyside, N.S., M. Latif, J. Jungclaus, L. Kornblueh, and E. Roeckner (2008): Advancing Decadal-Scale Climate Prediction in the North Atlantic Sector. Nature, 453, 84-88). The INGV Seasonal Prediction System has now been implemented and tested in the new CMCC supercomputer. Integration of Stream 2 seasonal hindcasts was started in April 2008 and completed by the end of August. Archiving of the atmospheric

model output follows the procedures developed at INGV for the DEMETER and MERSEA projects with some minor modifications to the scripts, while the ocean model archiving is done using the tools developed at CERFACS. The archiving is carried out in parallel with the production phase. Due to the time needed for interpolations, for the preparation of CF-compliant NetCDF ocean output and for the transfer of the data from INGV to ECMWF, the completion of the archiving is expected a few weeks after the production of hindcasts is finished.

- Task 1.5.9: METO-HC have extended their Stream 2 hindcasts starting in November 1965, 1975, 1985, 1995 and 2005 to 30 years in length. The parallel integrations using the same external forcings but started from initial states statistically independent of the observations have also been extended from the same start dates.
- CERFACS and CNRM did not have any effort allocated during this period.

The following table (from Milestone M1.8) summarises the current status of the stream 2 s2d experiments.

Forecast system	Hindcasts		Archiving		
	Seasonal/Annual	Decadal	Atmosphere	Ocean hindcasts	Ocean a
IFS/HOPE (ECMWF)	done	done	done	in progress (seasonal/annual completed; e.c*.: in 2 months)	do
ARPEGE/OPA (Météo-France)	done	n.a.	done	in progress (e.c.: in 1 month)	n
ECHAM5/OM1 (IfM Kiel)	done	in progress (1995 to be done; e.c.: in 1 month)	not done (e.c.: in 1 month)	in progress (e.c.: in 1 month)	In pro (e.c.: in
ARPEGE/OPA (CERFACS)	n.a.	done	not done (e.c.: in 1 month)	done	do
HadGEM (Met Office)	done (consistent from 1981 onwards)	in progress (e.c.: in 5 months [1)])	in progress (seasonal/annual complete; e.c.: in 5 months [1)])	in progress (e.c.: in 6 months [1)])	in pro (e.c mont
DePreSys (Met Office)	in progress (Feb and May start dates complete; e.c.: in 3 months)	done	in progress (decadal complete; e.c.: in 3 months)	in progress (e.c.: in 6 months)	not (e.c.: in (
ECHAM4/OPA (INGV)	done	n.a.	done	in progress (1960-1980 complete; e.c.: in 1 month)	in pro (e.c.: in

* e.c.: expected completion

c) Deviations from the project work programme and corrective actions

Due to lack of man power, IFM will no longer investigate alternative methods for ensemble member generation, nor apply the KNMI ensemble Kalman filter initialisation technique.
Due to lack in computing resources, INGV were unable to perform the Stream 2 annual integrations. As a consequence the hindcasts starting in November were performed in the same manner as the other start dates, the simulations covering seven months instead of the expected 14 months.

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

METO-HC had produced a 17 member perturbed physics ensemble of climate change projections under the SRES A1B scenario using HadCM3, sampling multiple perturbations to sulphur cycle parameters, augmenting a previous 17 member ensemble sampling uncertainties in atmospheric model parameters. Preliminary work towards further ensembles sampling uncertainties in ocean and terrestrial ecosystem parameters had been undertaken. UOXFDC had produced a very large ensemble (several thousand members) of transient climate change simulations using the HadCM3L model via public-resource distributed computing facilities through climate*prediction*.net, and had begun analysis of the results. EGMAM had commenced production of a perturbed physics ensemble of climate change simulations using the EGMAM model, looking at perturbations to five cloud parameters. CNRM had completed its involvement in WP1.6, producing an improved version of the CNRM-CM3 model, and testing these in a number of pre-production simulations as preparation for stream 2 simulations using the new CNRM-CM4 model in RT2A.

Objectives for months 37-60

Task 1.6.7: A small ensemble of HadCM3C, the Hadley Centre model including an interactive carbon cycle, will be performed in which perturbations are made to key parameters in the terrestrial component of the scheme (all parameters controlling physical feedbacks in the atmosphere and ocean will remain fixed). Methods to produce an ensemble with parameters perturbed simultaneously in physical, chemical and biological components will be investigated. Should that prove possible, and should computer resources (unfunded in ENSEMBLES) be available, an ensemble of runs will be performed.
Task 1.6.8: Analysis of the HadCM3L coupled model ensemble developed and launched under climatepredction.net will be continued with a view to publishing first results. The database of climate simulations made available to the ENSEMBLES community will be maintained and updated.
Task 1.6.9: The integration of the perturbed physic ensemble in the doubled CO2 concentration state will be finished. A detailed analysis of the uncertainty in the climate sensitivity of EGMAM due to parameterisations in the cloud physics will be performed. This analysis will be based on the perturbed physics ensemble and will include a statistical analysis of the ensemble. A physical interpretation of the feedback processes which lead to the differences in climate sensitivity will be made as well. A comparison between perturbed physics experiments with EGMAM and similar experiments from the Met Office-Hadley Centre and the University of Oxford will be carried out. (project month 54, Deliverable 1.9).

b) Progress towards objectives

Task 1.6.7
A 17 member perturbed physics ensemble of HadCM3 variants, containing multiple perturbations to ocean transport processes, was run from 1860-2100, using the SRES A1B emissions scenarios from 1990 onwards. A further 17 member ensemble of HadCM3C variants, with perturbations controlling terrestrial carbon cycle processes, was also produced. Analysis of the response shows a relatively wide range of global-mean temperature uncertainty under the A1B emissions scenario (figure 1.6.1), of a similar order of magnitude to that found when perturbing atmosphere-model parameters that control physical climate feedbacks, but larger than that found when perturbing either ocean-component or sulphur-cycle-component parameters. The range of CO_2 concentrations by the end of the century in these experiments, in which CO_2 emissions rather than concentrations are input, is

from around 600ppm to over 1000ppm. Work to evaluate and understand these experiments is ongoing, and a draft paper has been produced (Booth et al., 2008).

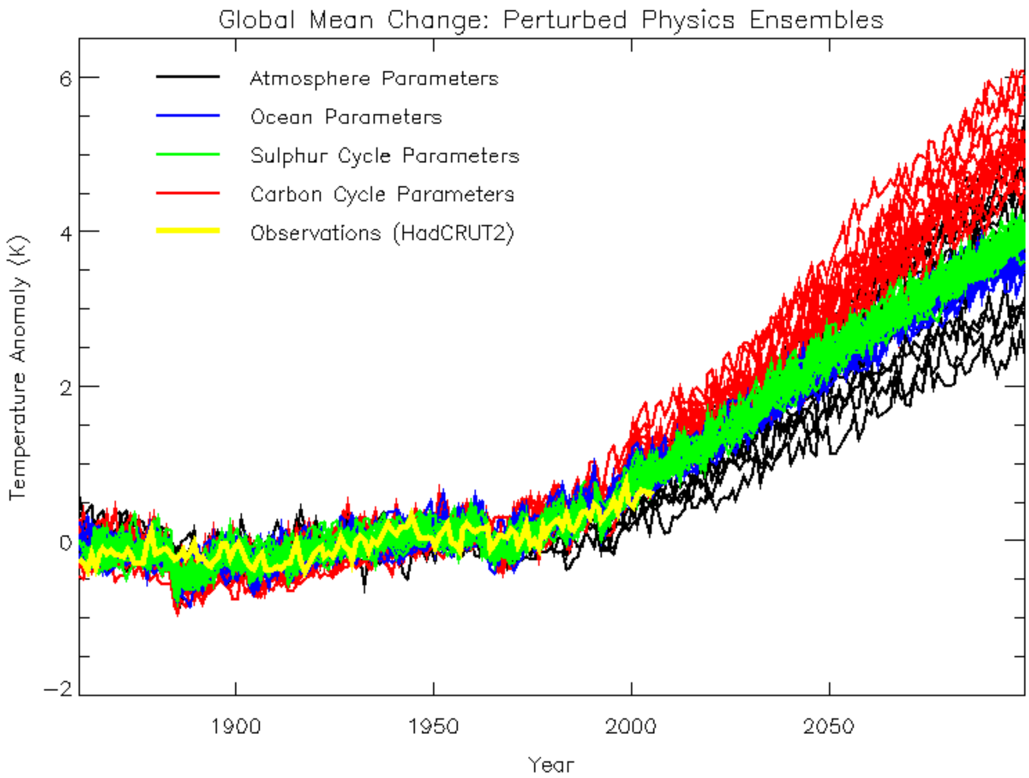

Figure 1.6.1. Global-mean temperature in HadCM3 experiments forced by historically observed changes in anthropogenic and natural forcing agents and future greenhouse gas emissions under the SRES A1B scenario. The different colours indicate ensembles with perturbations to parameters in different model components as indicated in the legend. In the most recent ensemble, perturbations to parameters in the terrestrial carbon cycle component of the model have been made (red lines).

Task 1.6.8 Analysis of the HadCM3L coupled model ensemble developed and launched under climateprediction.net is ongoing. An initial paper documenting the design of the experiment has been submitted; this describes in particular the success of the flux re-adjustment scheme and thus the viability of the use of this scheme to create an otherwise problematic massive perturbed physics ensemble of models with dynamical oceans (Frame, 2008). Results from the HadCM3L coupled model ensemble are being analysed, in particular to assign likelihood weightings to the ensemble members and to better inform the choice of new parameter combinations in future experiments. Initial likelihood computations with an ensemble of order 250 have been completed, validating the methodology, and are currently being extended to an ensemble of nearer 2500 as the climateprediction.net database of completed coupled model simulations, which is available to the ENSEMBLES community, is continually updated. A journal paper documenting these initial coupled model results is currently nearing submission.

Task 1.6.9: The integration of the 30 perturbed EGMAM model versions under a doubling of the CO_2 concentration has been finished. A comparison with the pre-industrial control simulations enables the analysis of uncertainty in the climate sensitivity of EGMAM due to uncertainties in the cloud parameterisations. The range of effective climate sensitivity in the ensemble is relatively small (0.8K) which is mainly caused by an anti-correlation between positive and negative cloud feedback processes across the ensemble members. During a visit at the Met Office-Hadley Centre and the University of Oxford, results of similar perturbed physics experiments performed by these groups were exchanged. Preliminary results show a consistent global signal in climate sensitivity across the models due to perturbations in corresponding parameters. But differences in the ensemble results for climate sensitivity and feedback processes indicate the influence of structural differences between the models, which result in different parameter uncertainties for climate sensitivity. A detailed comparison of the different perturbed physics ensembles will be given with deliverable report D1.14.

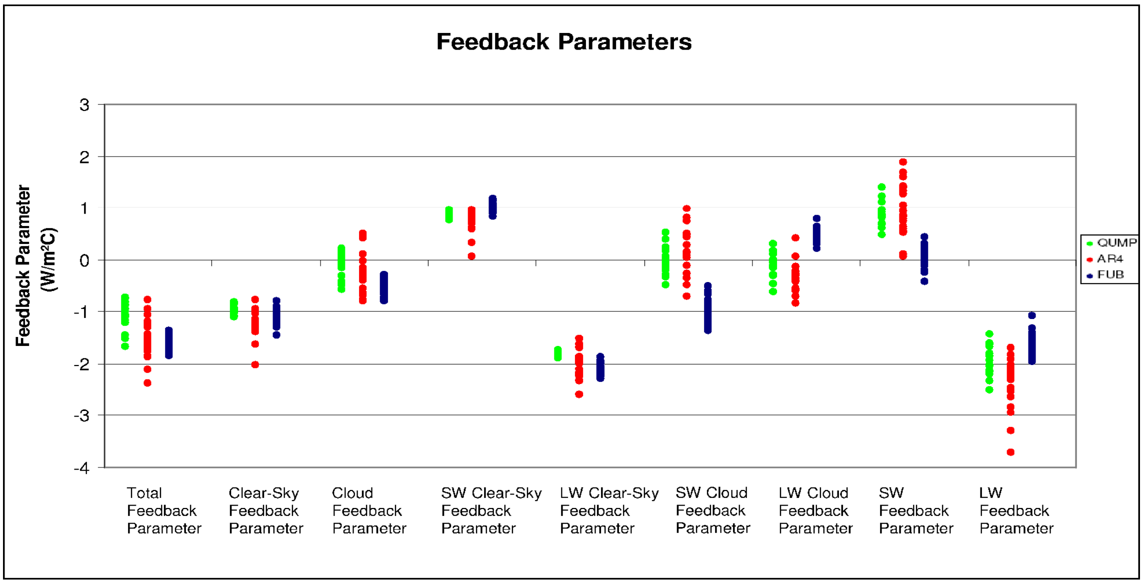

Figure 1.6.2 Inter-comparison of effective feedback parameters in different climate model ensembles. QUMP indicates perturbed physics ensembles with HadCM3 produced for the ENSEMBLES project (17-members with perturbations to atmosphere-model parameters only). AR4 indicates parameters computed from the CMIP3 AR4 IPCC coupled models. FUB shows results from the 30 perturbed physics version of EGMAM. The total feedback parameter is decomposed into various components as indicated on the figure.

Papers

Frame, D. The climateprediction.net BBC Climate Change Experiment Part 1: Design of the Coupled Model Ensemble. Submitted to Phil. Trans. Roy. Soc. A.

Booth, B.B.B., C. D. Jones, M Collins, I. J. Totterdell, P. M. Cox and S. Sitch, C. Huntingford, R. Betts 2008 Increased importance of carbon cycle feedbacks under global warming. In prep.

c) Deviations from the project work programme and corrective actions

None.

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

D1.12	A report/publication comparing the Oxford and Hadley Centre methods for obtaining probabilistic climate forecasts from perturbed parameter ensembles.	RT1	28.02.2008	31.10.2008	12		UOXFDC
D1.14	A comparison of perturbed physics ensembles constructed with different models.	RT1	28.02.2009	28.02.2009	10		FUB
D1.15	Report describing improved probabilistic predictions of 21st century climate over Europe, obtained by combining global model Hadley Centre perturbed physics ensemble results, multi-model ensemble results, and observational constraints.	RT1	31.05.2009	31.05.2009	8		METO-HC
D1.16	Assessment of relationships between errors in seasonal to decadal hindcasts and longer term climate predictions, found in perturbed physics ensembles using the DePreSys system	RT1	31.05.2009	31.05.2009	10		METO-HC
D1.17	Updated comparison of the multi-model, perturbed physical parameters and stochastic physics approaches to tackle model uncertainties in the seasonal-to decadal hindcasts and first attempt to combine the three methodologies into one system accounting for model error	RT1	31.08.2009	31.08.2009	6		METO-HC
D1.18	Forecast quality assessment of the seasonal-to-decadal Stream 2 hindcasts	RT1	31.08.2009	31.08.2009	2		ECMWF

D1.19	Paper on the influence of the seasonal cycle on ENSO predictability	RT1	31.08.2009	31.08.2009	24		IPSL-CNRS

***) 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
MM1.3	Specification of a "second generation" ensemble prediction system (Version 2).	RT1	31.08.2009	31.08.2009	ECMWF,METO-HC