RT4 ENSEMBLES Periodic Activity Report – 1Sep04-31Aug05

RT4: Understanding the processes governing climate variability and change, climate predictability and the probability of extreme events

Overview of activities carried out during the reporting period

1. RT4 objectives and major achievements during the reporting period

1.1 RT4 Aims

The purpose of RT4 is to advance understanding of the basic science issues at the heart of the ENSEMBLES project, focusing on the key processes that govern climate variability and change, and that determine the predictability of climate. Particular attention is given to understanding linear and non-linear feedbacks that may lead to climate "surprises", and to understanding the factors that govern the probability of extreme events. Improved understanding of these issues will contribute to the quantification and reduction of uncertainty in seasonal to decadal predictions and projections of climate change.

1.2 RT4 Primary Objectives for the reporting period

O4.a: To establish the coordination mechanisms within RT4, and to develop the methodologies for coordinated experimentation to explore major uncertainties in climate variability and change.
O4.b: To investigate and quantify feedbacks in the Earth system, and their potential to lead to abrupt climate change or other climate "surprises" in existing transient climate change simulations.
O4.c: To determine the impact of climate change on climate variability, and to investigate the mechanisms that govern regional patterns of climate change, including ocean heat uptake.
O4.d: To develop methodologies which will elucidate the climate processes that determine the probabilities of extreme weather events, and the ways in which these probabilities may change in future climates.
O4.e: To develop the tools for identifying and understanding the sources of predictability in current and future climates by exploiting existing seasonal to decadal hindcasts.

1.3 RT4 Overview of major achievements during months 1-12

WP4.0: Management of RT4

The RT4 web site has been set up at http://www.cgam.nerc.ac.uk/research/ensembles-rt4/index.html RT4 email lists have been established for the various work packages. The RT4/RT5 kick-off meeting in Paris (February 2005) achieved its objectives of coordination and linkages between the two Research Themes. The joint RT4/RT5 Workshop is scheduled for 5/6 September as part of the Athens General Assembly.

WP4.1: Feedbacks and climate surprises

For the first 12 months of the project WP4.1 made use of existing simulations in order to develop tools to analyse feedback regimes. Three specific diagnostics techniques are being developed and tested to estimate the cloud radiative forcing in coupled climate simulations. The first conclusions are that cloud feedback remains the major uncertainty for climate sensitivity and this is mainly due to low level clouds. Coupled climate-carbon cycle simulations were analyzed; a feedback analysis methodology is proposed to estimate the respective roles of land versus ocean in the climate-carbon cycle feedback. The study of non-linear feedbacks and risks of abrupt climate change/climate surprises in the Arctic and North Atlantic regions has commenced by analysing sea-ice extent in climate change simulations, including a specific abrupt increase in sea ice in the Bering Sea, which occurs in both the control run and ocean observations.

WP4.2: Mechanisms of regional-scale climate change and the impact of climate change on natural climate variability

WP4.2 has made use of existing Stream 1 simulations to explore and characterize the main modes of climate variability in specific key areas (such as Arctic, North Atlantic, Tropical Indian and Pacific Oceans), and their interactions via global teleconnections. The ability of coupled models to simulate the main modes of variability has also been assessed, focusing especially on the influence that mean state errors and ocean-atmosphere coupling strength might have on the physical processes at work. It has been shown that model mean state errors compromise the ability to simulate El Nino and its teleconnections.

A proposed design of the coordinated experiments in RT4 has been developed and discussed at the RT4/RT5 meeting in Paris in February. After a further discussion that involved all of the partners, the set of coordinated experiments has been defined, which will seek to explore the mechanisms involved in the land-sea warming ratio under increased CO2 concentrations. This activity has involved collaborations with RT5. In particular, synergies with WP5.2 have been exploited.

WP4.3: Understanding extreme weather and climate events

A workshop on extremes was organised in Chateau d’Oex. Statistical work needed for WP4.3 was extensively discussed at this workshop and collaborations were arranged. The choice of software for doing extreme value analysis was discussed and it was decided to use the R language instead of the originally envisaged MATLAB/IDL. The development, testing and evaluation of modules for the statistical software programme R has started. Preliminary studies of existing Stream1 simulations were performed to assess the links between large-scale circulation patterns and the occurrence of a selected set of extreme events in different regions - global, France, Euro-Mediterranean region and the Arctic.

WP4.4: Sources of predictability in current and future climates

The work accomplished in the first year relies on three main axes. The first one includes the realization of new Stream1 ensembles of both coupled and SST-forced atmospheric simulations driven by anthropogenic and natural forcings. This has shown that it s necessary to include time varying anthropogenic forcing to realise improvements in predictability at seasonal and decadal timescales. The second one is a first attempt to explore the influence of the land surface hydrology on climate predictability through a sensitivity study performed with an AGCM. Finally, the third one gathers various contributions to the development and validation of methodologies to study climate variability and its predictability including tropical intra-seasonal variability.

2. Research Theme 4 Progress of the period

2.1 WP4.0: Management of RT4

Partners	UREADMM, CNRS-IPSL, INGV, CERFACS
Person(s) who provided this information	Maria Noguer (UREADMM)

WP4.0 - Objectives and starting point at beginning of reporting period

The objective of WP4.0 is the management and coordination of all RT4 activities. The tasks set for months 1-18 are:

- **Task 4.0.a**: Follow-up of the deliverables and milestones.
- **Task 4.0.b**: Completion of the progress reports.
- **Task 4.0.c**: Set up and manage the internal web site for RT4.
- **Task 4.0.d**: Organization of a workshop during the first year to discuss key science issues.
- **Task 4.0.e**: Arrange meeting with those participating in coordinated time slice experiments to design the integrations and formulate a detailed plan.

WP4.0 - Progress towards objectives

During the first year of the project, the RT4 coordinators and work package leaders of WP 4.1-4.4 have provided management and coordination of activities within RT4. Integration across the RTs has been achieved by the organisation of meetings and the design of the coordinated time slice experiments as follows:

- ENSEMBLES RT4/RT5 kick-off meeting in Paris (10-11 February 2005). The meeting served its purpose in identifying overlaps and links especially concerning variability and extreme events studies. It also focused on ensuring coordination of activities between RT4 and RT5 and it undertook a preliminary review of the 18 month Milestones and Deliverables. (5 year task – ensure linkages with other RTs)

- Coordinated time slice experiments: Discussions regarding the design of the coordinated time-slice experiments were held at the Paris meeting and further discussions were conducted by email with the participating partners. Currently six groups have committed to undertake the experiments. The design of the coordinated time slice experiments has been preliminary defined and detailed planning are available at: http://www.cgam.nerc.ac.uk/research/ensembles-rt4/gen_info/Coordinated_Experiments_revised.pdf. The idea is to undertake controlled experiments repeated with several different climate models to advance understanding of the factors/processes controlling future climate and related uncertainty in climate forecasts (Task 4.0.e).

- The submissions of the 6 month reports by all WPs was a very useful exercise to help follow-up the state of deliverables and milestones for the project, and to try to find suitable solutions for any delays in delivering (Task 4.0.a, Task 4.0.b).

- The Web site for RT4 has been set-up and is managed by UREADMM: http://www.cgam.nerc.ac.uk/research/ensembles-rt4/index.html. It holds information regarding contacts, WPs, meeting reports, progress reports, the coordinated time slice experiments, and it will include all the relevant publications as they start appearing (Task 4.0.c).

- Email lists have been set up for each WP to communicate with their partners. They have been very useful for general discussions, regarding reporting and also for the design of the coordinated time-slice experiments.

- A meeting will be held in September 2005, before the General Assembly, to discuss the RT4 key science issues and research priorities and to agree priorities for years 2-5 (Task 4.0.d).

WP4.0 - Deviations from the project work programme and corrective actions

No deviation from the work programme has been incurred. However linkages with other RTs will be reinforced even more in the next years.

WP4.0 - List of deliverables, including due date and actual/foreseen submission date

Table 1: WP4.0 Deliverables List

Del. no.	Deliverable name	Research Theme no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
4.0.1	Development of the RT4 Website	4.0	Month 12	Month 6	2	2	UREADMM
4.0.2	Design specification for the coordinated time-slice experiments	4.0	Month 18	Month 18	3		UREADMM

***) if available**

WP4.0 - List of milestones, including due date and actual/foreseen submission date

Table 2: WP4.0 Milestones List

Milestone no.	Milestone name	Research Theme no.	Date due	Actual/Forecast delivery date	Lead contractor
4.0.1	Workshop on RT4 key issues and research priorities, and specification of the RT4 coordinated experimentation	4.0	Month 12	Month 12	UREADMM

2.2 WP4.1: Feedbacks and climate surprises

Partners	CNRS-IPSL, METO-HC, UCL-ASTR, CNRM, NERSC
Person(s) who provided this information	Pierre Friedlingstein (CNRS-IPSL)

WP4.1- Objectives and starting point at beginning of reporting period

The two main objectives of WP4.1 are: a) to quantify the role of different feedbacks in the Earth system on the climate predictions uncertainty, and b) to investigate the risk of abrupt climate changes.

Starting point:

Previous inter-model comparisons of modelled climate feedbacks have been hampered by lack of suitable diagnostics and availability of relevant parallel simulations from a range of models. As a result, we have a poor understanding of the reasons of the wide range of climate feedbacks among climate models. To address this problem, international programs were started to study the cloud radiative forcing (CFMIP), and to perform coordinated experiments with coupled models and with various forcings (CMIP and AR4-IPCC scenarios). At the start of the reporting period, diagnostic techniques had been applied to individual models and were usefully found to help in understanding cloud feedbacks mechanisms and for evaluation of aspects of cloud feedbacks against observations.

Hadley Centre and CNRS-IPSL have previously performed coupled climate-carbon simulations, and obtained a positive feedback, but there was a factor of 4 between the Hadley Centre response and the CNRS-IPSL response. The sensitivity of the terrestrial biosphere to climate is the main source of uncertainty. There is a need to better understand the vegetation and soil response to climate change and variability. The ability of coupled climate-carbon model to produce both a realistic historical trend and a realistic ENSO variability in term of carbon cycle will be crucial. This will be done with ENSEMBLES simulations in which both models are forced with the same emission scenario and land use change scenario for the past and the future, following a detailed protocol. At the beginning of the reporting period only a few groups in the world had performed fully coupled climate-carbon cycle simulations, a complete analysis of the large differences obtained in the magnitude of the climate-carbon cycle feedback still has to be done. New simulations will be performed within ENSEMBLES with a strict protocol that will allow better comparison.

Highly non linear feedbacks are known to occur in the Arctic and North Atlantic regions and abrupt climate changes have occurred in the past. The thermohaline circulation (THC) play a key role in these changes, but its stability has been investigated mainly with reduced complexity models. The IPCC TAR showed a range of responses in models from a marked slowing down of the THC to almost no change at all, and there is a clear need to reduce this uncertainty using complex state-of-the-art climate models. CNRM, NERSC and UCL-ASTR have started this study by analysing the freshwater fluxes to the ocean, the ocean vertical profiles and the sea-ice in the Arctic regions in both observations, models for control climate conditions and models under climate change.

WP4.1 - Progress towards objectives

Task 4.1a: *Analysis and evaluation of the physical processes involved in the water vapour and cloud feedbacks.*

Cloud feedbacks in mixed-layer and coupled-ocean experiments have been analysed from both the Cloud Feedback Model Inter-comparison Project (CFMIP) and the CMIP model intercomparison project for IPCC AR4 in order to develop methodologies for application to the ENSEMBLES multi-model system when available.

Two diagnostic techniques have been studied by **METO-HC**. Williams et al (2005) have composited cloud radiative forcing changes by changes in vertical velocity and saturated lower tropospheric stability and found that a component of the local mean climate change response can be related to the present-day variability in all the models tested. This would suggest that evaluation of the present-day response in these models would represent a direct evaluation of this component of the cloud feedback to climate change. Webb et al (2005) have analysed the range of global climate sensitivity and the mechanisms of cloud feedbacks by applying a regional feedback classification system. They find that the range of equilibrium warming has not reduced since the IPCC TAR and that the largest uncertainty remains due to cloud feedbacks.

Another approach has been pursued at **CNRS-IPSL** (Bony and Dufresne 2005) using a regime sorted analysis to interpret the range of tropical cloud responses to climate warming (Figure 1). Both Webb et al (2005) and Bony and Dufresne (2005) show that the cloud feedback uncertainty is dominated by uncertainties in the shortwave cloud radiative forcing response and that these are largely driven by changes in lower level clouds. In addition, Bony and Dufresne (2005) also highlight major deficiencies of current climate models in reproducing the observed sensitivity of cloud radiative forcing to surface temperature at interannual time scale (cf. also WP5.2). All these analyses contribute to the completion of Milestone 4.1.1.

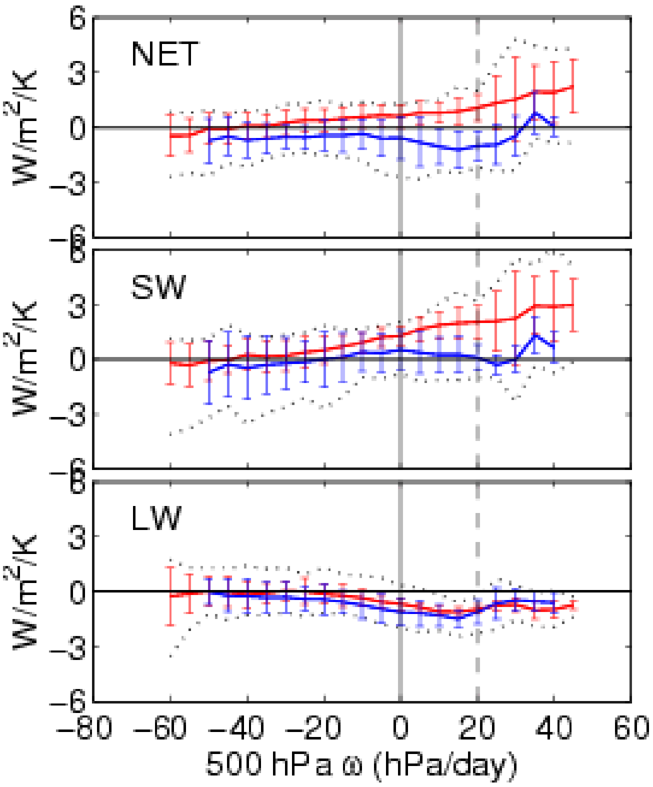

Figure 1: Analysis of tropical cloud feedbacks produced by 15 coupled ocean-atmosphere GCMs, decomposing the tropical cloud feedbacks in terms of dynamical regimes defined from the large-scale, 500 hPa vertical velocity. Half of the models predict a reduced cooling effect of clouds (high-sensitivity models, in red), half predict the opposite (low-sensitivity models, in blue). The spread in tropical cloud feedbacks primarily arises from inter-model differences in the SW radiative response of low-level clouds to climate warming.

Task 4.1b: *Quantification of the climate-carbon cycle feedback, with a specific focus on terrestrial carbon cycle sensitivity to climate change.*

METO-HC have completed simulations investigating the sensitivity of the terrestrial carbon cycle feedback to the representation of soil carbon dynamics, and the results of these simulations have been published (Jones et al. 2005). These simulations used the HadCM3LC coupled climate-carbon cycle model run online with its single pool soil carbon model, and driving data from these runs were used to drive the multi-pool RothC (Coleman & Jenkinson, 1996) soil carbon model offline from 1860-2100. This work showed that whilst both approaches still predicted a positive carbon cycle feedback, the soil carbon feedback predicted by the RothC model was considerably smaller than that predicted by the HadCM3LC soil carbon model. The multipool carbon dynamics of RothC cause it to exhibit a slower magnitude of transient response to both increased organic carbon inputs and changes in climate. Work is in progress to include the RothC soil carbon model within the Hadley Centre GCM.

CNRS-IPSL coordinated the coupled climate-carbon cycle model intercomparison project (C4MIP). The comparison includes existing coupled simulations from METO-HC and CNRS as well as simulations from 8 other climate modelling groups. All models simulate a positive feedback between the climate and the carbon cycle, as previously found by METO-HC and CNRS. CNRS performed a feedback analysis on all models results in order to isolate the key uncertainties in future coupled climate-carbon cycle projections. At the global scale, the sensitivity of the land carbon cycle to climate explains a large fraction of the models uncertainty (Friedlingstein et al 2005).

Task 4.1c: *Explore the effects of non-linear feedbacks in the atmosphere-land-ocean-cryosphere system and the risks of abrupt climate change/climate surprises.*

UCL-ASTR estimated the ability of current coupled models to reproduce the observed sea-ice over the 20th century (within RT2A) and conduct a comparison of sea-ice projections over the 21st century for the IPCC AR4 simulations (within RT4.1). UCL-ASTR found that the annual mean sea ice volume reduction decreases twice rapidly in the Northern Hemisphere than in the Southern Hemisphere in response to increasing greenhouse gases concentration. This is explained by a thermodynamic feedback which implies that thinner ice does need not to thin as much as thicker ice to increase its growth rate, thus stabilizing the thinner ice pack.

CNRM analysed the simulations performed by the CNRM-CM3 model, with a focus on the Arctic. A particular sea ice event was detected in the pre-industrial experiment in the Bering Sea (anomalously high sea ice concentrations for about 20 years). It could be shown that a key element contributing to the remarkable sea ice anomaly in this area is the position of the Aleutian low. This particular configuration led to intense sea ice advection towards southern Bering Sea, together with the inflow of cold Siberian air into the Central Arctic. The conjunction of these events with a persisting negative phase of the North Atlantic Oscillation (NAO) reducing sea ice outflow through Fram Strait, contributed to a simultaneous increase of the Arctic total sea ice volume.

The role of ENSO in determining the position of the Aleutian low was investigated, but it was not found to be of paramount importance. More work, including sensitivity studies will be necessary to better understand which physical processes play a role in the displacement of the Aleutian low. The study of modelled sea ice conditions in the Arctic in the 21st-23rd century scenarios has also begun, with mean state and trends being the initial focus rather than large negative or positive sea ice anomalies.

NERSC analysed available ocean observations and simulated fields of key importance for the Atlantic THC, notably salinity (or equivalent, the fresh water content). The result of the analyses is conditionally accepted for publication. The next step will be to explore the findings in the paper in control and scenario integrations with coupled climate models. This analysis will work as a test-bed to assess the degree of realism, and an important part of the stability properties, of simulated THC in the current generation of GCMs.

WP4.1 - Deviations from the project work programme and corrective actions

None

WP4.1 - List of deliverables, including due date and actual/foreseen submission date

Table 1: WP4.1 Deliverables List

Del. no.	**Deliverable name**	**Research Theme no.**	**Date due**	**Actual/Forecast delivery date**	**Estimated indicative person-months *)**	**Used indicative person-months *)**	**Lead contractor**
4.1.1	Characterisation of the water vapour and cloud feedbacks in response to anthropogenic forcing	4.1	Month 18	Month 18	4		CNRS-IPSL
4.1.2	Analysis of the results from the first phase of the Coupled Climate Carbon Cycle Intercomparison project (C4MIP).	4.1	Month 18	Month 18	4		CNRS-IPSL

***) if available**

WP4.1 - List of milestones, including due date and actual/foreseen submission date

Table 2: WP4.1 Milestones List

Milestone no.	**Milestone name**	**Research Theme no.**	**Date due**	**Actual/Forecast delivery date**	**Lead contractor**
M4.1.1	Development of methodologies to explore climate feedbacks, tested initially on exiting simulation, for use with the ENSEMBLES multi-model system	4.1	Month 12	Month 12	CNRS-IPSL
M4.1.2	Assessment of feedbacks in existing simulations to provide benchmark against which the new ENSEMBLES multi-model system can be judged	4.1	Month 18	Month 18	CNRS-IPSL

2.3 WP4.2: Mechanisms of regional-scale climate change and the impact of climate change on natural climate variability

Partners	CERFACS, CNRM, ICTP, IfM, INGV, MPIMET, NERSC, UREADMM
Person(s) who provided this information	Silvio Gualdi (INGV)

WP4.2- Objectives and starting point at beginning of reporting period

The objective of WP4.2 is to study the mechanisms to assess the regional features of climate change, including changes that may results from a modification of the natural variability patterns. The tasks for months 1-18 are:

- **Task 4.2.a**: Study the low-frequency variability of the meridional overturning circulation (MOC) in the coupled integrations performed within the PREDICATE project. Design and set up a set of coordinated time-slice experiments to study the role of the land-ocean contrasts and ENSO.
- **Task 4.2.b**: Validation and use of ESMs to study interannual variability in long multi-century experiments or large ensembles of multi-decadal experiments. Study of the solar 11-year cycle and its impacts on the climate system.
- **Task 4.2.c**: Study the processes responsible for regional climatic variability in key areas (Indian Ocean, ocean heat uptake areas).

Starting point

In the recent past a number of studies and research projects have explored the possible impacts of climate change on the main modes of the natural variability. Both simplified and complex coupled models have been used to investigate the effects that changes in the mean climate might have on ENSO (e.g., Fedorov and Philander 2001; Timmermann et al. 2001). The EU FP5 project PREDICATE showed that the strong interdecadal variability over the North Atlantic/European region has the potential to mask an anthropogenic climate signal for many decades. But, the mechanisms underlying this low-frequency mode of variability are still unclear. In the EU FP5 project PROMISE, climate scenario experiments suggested that the anthropogenic climate change might induce a more intense monsoon activity and variability both in Africa and India. However, the uncertainties in the results are still high. One of the primary factors of uncertainty is that different CGCMs can produce different regional changes even when the external (anthropogenic) forcing is the same. Giorgi et al. (2001) showed that a comprehensive assessment of the regional change projections can be based on the collective information from an ensemble of CGCM simulations. The ENSEMBLES multi-model system offers a unique opportunity for WP4.2 to investigate the mechanisms that govern the natural climate variability and to assess the effects that human induced climate change might have on them.

WP4.2 - Progress towards objectives

During the first year of the project, work has been undertaken by all partners for deliverable D4.2.1 to be completed on time. The activity has involved collaborations with RT5. In particular, synergies with WP5.2 have been exploited.

A proposed design of the coordinated experiments in RT4 has been developed by UREADMM and was discussed at the RT4/RT5 meeting in Paris in February. After a further discussion, involving all of the partners, the set of coordinated experiments has been defined and the description is available at: http://www.cgam.nerc.ac.uk/research/ensembles-rt4/gen_info/Coordinated_Experiments_revised.pdf. (Task 4.2.a).

The research activity has concerned all of the work package tasks. The contribution from the partners is briefly summarized below:

CERFACS has performed a preliminary assessment of the influence of Indian Ocean SST low frequency trend on the extra-tropical atmospheric variability (decadal variability of the annular modes, NAM and SAM). Results from numerical experiments performed with the ARPEGE AGCM forced by observed SSTs, contrasting the two periods 1950-1976 and 1977-2002, suggest that the Indian Ocean may play an important role in explaining the recent low-frequency trends of the annular modes. Furthermore, a study of the seasonal-to-interannual variability of summer atmospheric circulation regime over the North Atlantic European region and links to the ITCZ variability has been conducted (Task 4.2.c)

CNRM has commenced a study aimed to address the role of Arctic sea-ice in climate variability. To this goal, existing simulations (pre-industrial and historical) performed with the CNRM-CM3 model have been analysed (Task 4.2.c). Consistent with previous studies, preliminary results indicate that a key element contributing to sea ice variability in this area is the position of the Aleutian low. The role of ENSO in determining this position was investigated, but it was not found to be of paramount importance. More work, including sensitivity studies will be necessary to better understand which physical processes play a role in the displacement of the Aleutian low.

CNRM has also started the analysis of the influence of land surface hydrology on climate variability, from interannual to climate change time scales. As a first step, a statistical analysis of existing coupled climate simulations available in the IPCC4 data base has been initiated (Task 4.2.b). The second step is the set up of sensitivity experiments and the participation in coordinated time-slice experiments (Task 4.2.a). The aim of these experiments is to explore the impact of different soil moisture (SM) boundary conditions on global atmospheric simulations using the ARPEGE-Climate AGCM driven by observed SST. Besides a control experiment with interactive SM, a first sensitivity experiment will be performed in which more realistic SM boundary conditions will be derived from the Global Soil Wetness Project (GSWP). Each experiment consists of an ensemble of ten 10-year simulations over the 1986-1995 period. This 10-year period has been chosen to take advantage of the GSWP project that was launched to produce a global SM reanalysis. Given the lack of both in situ and satellite SM observations, GSWP is aimed at producing global SM datasets by driving land surface models with 3-hourly atmospheric analyses and monthly land surface parameters available on a 1° by 1° horizontal grid. The ISBA land surface model of CNRM has participated in GSWP and the resulting SM data set can be used to prescribe SM boundary conditions in the ARPEGE-Climate AGCM. Later on, a similar sensitivity experiment could be done with snow mass boundary conditions.

ICTP has implemented an intermediate-complexity coupled model to investigate the statistical significance of inter-decadal variations and trends in teleconnection between tropical oceans and extra-tropical variability (Task 4.2.b). The model, based on the 8-level ICTP AGCM and the MICOM 2.9 OGCM, has been set up and tested in three different configurations. The first configuration uses full coupling in the tropical Indian Ocean and prescribed SST elsewhere. In the second configuration, the coupling domain covers the Indo-Pacific Ocean from 30S to 30N; here, the AGCM uses the SST anomaly generated by the ocean model, superimposed to an observed climatology, while the ocean model gets heat and momentum fluxes computed from the uncorrected SST. These two configurations have been used in ensemble mode to investigate the relationship between ENSO and the Indian Ocean Zonal Mode, and the respective teleconnection patterns (Task 4.2.c). One paper on this subject has been published, and a second one is in preparation. In the third configuration, the SST-anomaly coupling occurs over a larger domain, including the full North Pacific up to 60N. This model is being used to investigate the relationship between decadal-scale variations of tropical SST in the Indo-Pacific basin and Northern Hemisphere extra-tropical variability (Task 4.2.b).

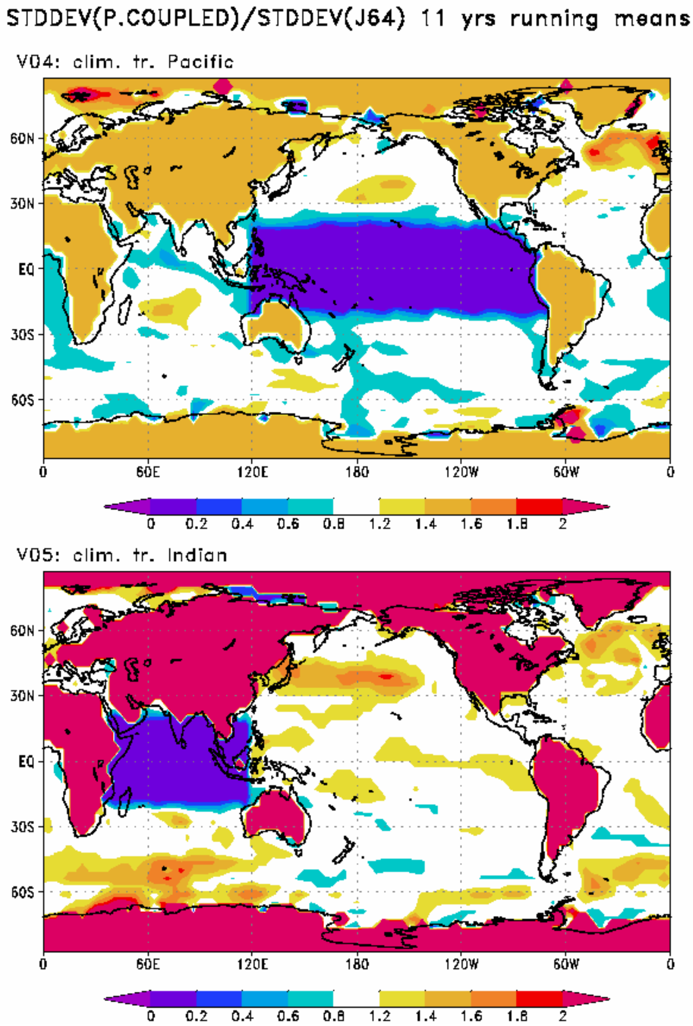

Figure 2: Results from two 500 year partially coupled experiments in which coupled variability is suppressed in the Pacific (top panel) and Indian Ocean (lower panel) by insertion of climatological SST in the respective basins. The ratio of standard deviation of a the respective sensitivity experiments to a fully coupled control simulation are shown. The data have been smoothed with a 11 year running mean. Note how North Pacific and North Atlantic variability are strengthed by almost a factor of 2 in the Indian-Off experiment. Similar changes are seen in the North Atlantic for the Pacific-Off case. Following Semenov et al. 2005.

IfM has initiated an analysis of the causes of North Pacific and North Atlantic variability and its interaction with the tropical oceans, using an existing 2000-year coupled simulation and partially coupled run experiments (Task 4.2.b). Preliminary results indicate some evident effect of the Indian Ocean SST variability on the low-frequency variability over both the extra-tropical northern Pacific and Atlantic. Furthermore, IfM has contributed to the definition of the RT4 coordinated experiments, and is in the processes of setting up some preliminary time-slice experiments using conditions taken from the IPCC simulations of the MPI climate model (Task 4.2.a).

INGV has investigated the effects of the Tropical Indian Ocean (TIO) (Task 4.2.b and c) and the Tropical Pacific Ocean (TPO) SSTs on the Indian Summer Monsoon (ISM) and its variability. In agreement with previous studies, TIO SSTs are found to have a strong impact on the ISM precipitation. Furthermore, using a new statistical technique, the TIO SST anomalies have been separated in a component independent (“free”) and in a component remotely forced from the TPO variability (“forced”). The results suggest that it is the “forced” TIO SST anomaly component that has the stronger impacts on the ISM precipitation. A paper based on this study has been submitted.
Using existing model experiments, INGV has investigated the effects of the model resolution on the simulation of the tropical Pacific climate variability (Task 4.2.c). The results indicate that with a low resolution atmospheric component the coupling between ocean and atmosphere is poor. When the horizontal resolution of the atmospheric model, on the other hand, is sufficiently high to resolve the details of the oceanic SST features, than the ocean-atmosphere coupling becomes much more

realistic. This work has been performed in collaboration with WP5.2. A paper describing the results is in preparation. Finally, INGV has commenced analysis for exploring the mechanisms that drive the climate variability in the Indian Ocean region and its relationship with the tropical Pacific variability. In particular, the differences between possible mechanisms of IODM (Indian Ocean Dipole Mode) occurring during El Niño and non-El Niño years will be investigated (Task 4.2.c).

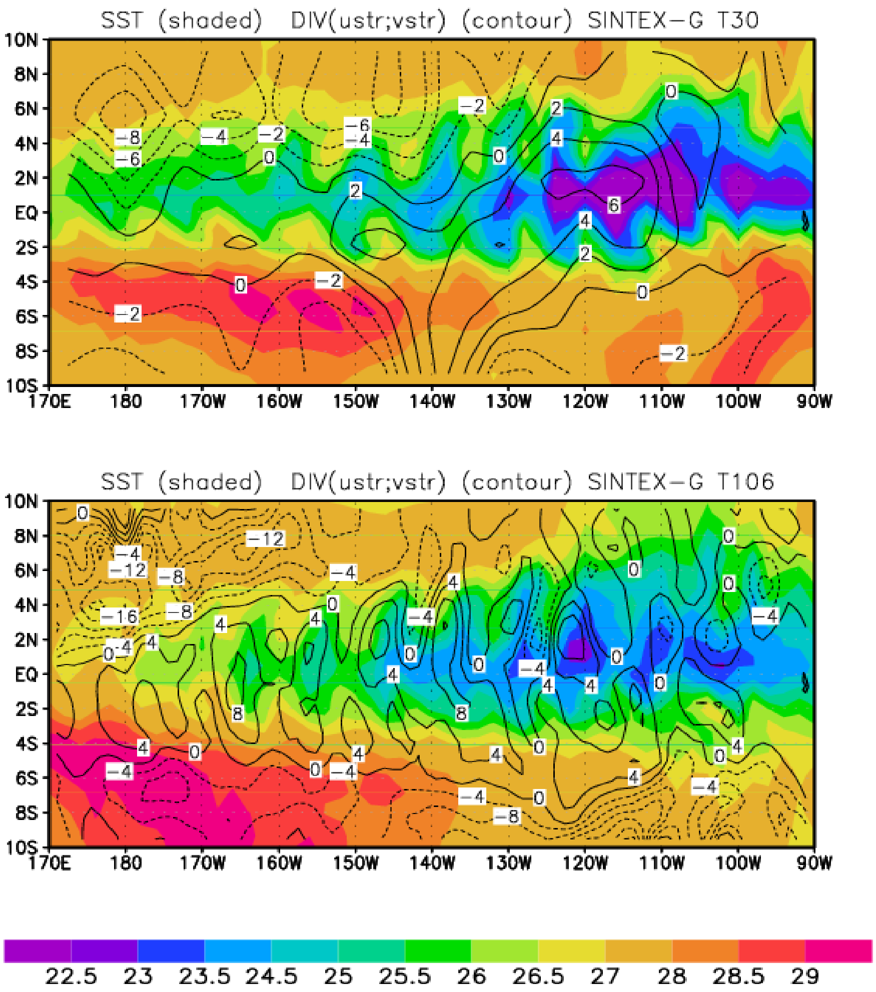

Figure 3: Snapshot of the SST (shaded) and the divergence of the surface stresses (contours) for pentads. Upper panel: low-resolution model (T30). Upper panel: high resolution model (T106). The ocean model produces readily tropical instability waves in both models at T30 and at T106, however the results show that the atmosphere reacts to the tropical instability waves (TIW) only at T106. The low resolution model is effectively decoupled from the atmosphere at this spatial scales and there is no signature of the TWI in the atmosphere. The T106 shows the typical signature for the TWI as it has been shown by Chelton (J. Clim, 2005) in an area close to the equator, between 5N and 5S. A consequence of the coupling at the scale of the TWI is that the average surface stress over an area, like for instance the NINO3 area, is decreased by the coupling.

MPIMET has analyzed the effects of the 11-year solar cycle in the stratosphere. To this aim, two steady-state simulations with the HAMMONIA general circulation and chemistry model over 20 years each for solar maximum and solar minimum conditions of the 11-year solar cycle have been used. Though the response in winds seemed to confirm analyses by Kodera and Kuroda (JGR, 2002), the response in temperature and ozone was smaller in magnitude than suggested by observations. Therefore, a new set of simulations with an improved model version (e.g. by increasing the spectral resolution of solar irradiance) has been performed and analysed. The magnitude of the response in ozone and temperature corresponds now well to available observations. However, the response pattern in stratospheric dynamics seems not to be robust (Task 4.2.b).

NERSC has commenced analysis to assess to what extent, and on what time-scales the Atlantic Meridional Overturning Circulation (AMOC), the North Atlantic Oscillation (NAO) and the climate of the high northern latitudes are coupled at present and in the future (Task 4.2.a). A working hypotheses is that stronger than normal ocean heat transport by AMOC leads to a positive north Atlantic SST anomaly that a) influences the decadal-scale mode of NAO and b) the provides heat to the Arctic. Inherent in these considerations is the ocean uptake of heat caused by global warming.

To initially address the above stated hypotheses, a five-member ensemble of the Bergen Climate Model (BCM), compared to a 15-member multi-model ensemble, is used to examine the effects of natural variability on climate projections for the high northern latitudes. The BCM members are initialized from a 300 years control experiment, each starting from different strengths and phases (and by that pole-ward heat transports) of the AMOC. The ensemble members are then integrated for 80 years with a 1% per year increase in the atmospheric concentration of CO_2. The main findings are that on decadal time scales, the multi-model spread of estimated temperature changes in the high northern latitudes might be attributed to internal variability of the climate system. During weak CO_2 forcing the internal variability may mask the strength of the anthropogenic signals for several decades. The implications of the findings are that attribution of any Arctic climate change trends calculated over a few decades is difficult.

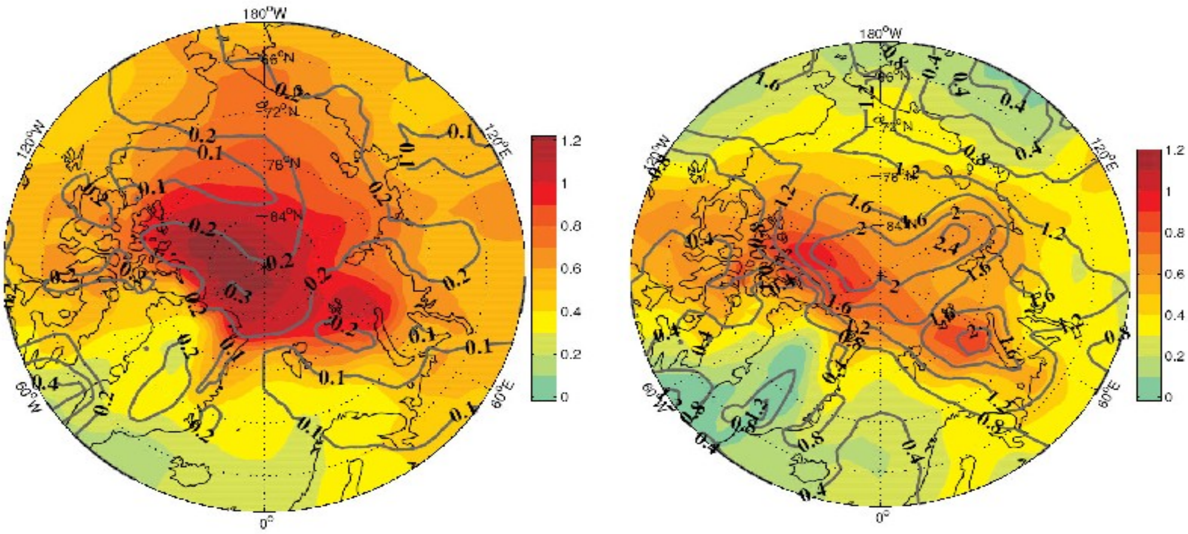

Figure 4: Projected Arctic temperature trends over years 1-80 (left) and years 1-25 (right) in five CMIP2-forced members with the Bergen Climate Model (BCM). Color shading indicates ensemble-mean 2 m temperature trends (°C/decade), and solid lines show the spread in trends among the various ensemble members (contour interval is 0.1 and 0.4 °C/decade for left and right panel, respectively). Implications of the presented findings are that observed or simulated Arctic climate change trends calculated over a few decades may be strongly influenced by internal variability, making it hard to attribute the changes to any specific external forcings. From Sorteberg et al., Geophys. Res. Lett., in press.

UREADMM has developed a proposed design for the coordinated experiments that will be performed in RT4 (Task 4.2.a). Furthermore, UREADMM has commenced analysis to understand the spatial patterns of climate change, in particular the land/sea contrast in surface warming in the multimodel CMIP 1% pa CO_2 increase scenario integrations. The land/sea warming contrast has been analysed as a function of latitude and the multi model results have been compared with observations. A short paper based on early results is in preparation. UREADMM has also started analysis to understand the ocean heat uptake in response to anthropogenic forcing in isopyncal coordinates (Task 4.2.c). This work uses the HadCM3 climate model. Finally, UREADMM has analysed ENSO in control simulations of HadCM3 and HadGEM1 and investigated the influence of mean state errors on ENSO characteristics (amplitude, frequency) using different forms of flux correction (Task 4.2.c). A paper describing these results is in preparation.

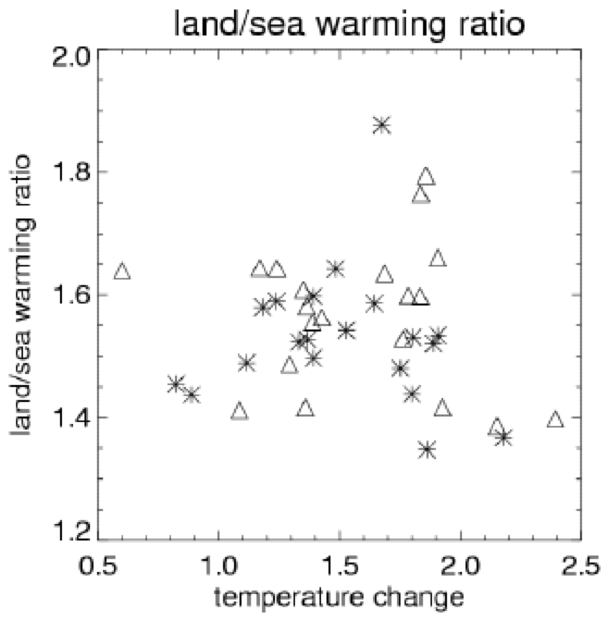

Figure 5: Land/sea warming ratio as a function of mean temperature response to 2xCO2 forcing for the globe (triangles) and for the tropics (stars; 40N-40S).

WP4.2 - Deviations from the project work programme and corrective actions

As reported above, CNRM intends to perform a set of (control and sensitivity) experiments to explore the impact of different soil moisture (SM) boundary conditions on global atmospheric simulations. The control experiment has already been performed, but the perturbed experiment is still waiting for a reasonable SM climatology. A first climatology has been produced over the 1986-1995 period with the ISBA land surface model driven by the standard GSWP inputs. Then, the GSWP soil and vegetation parameters have been replaced by the ECOCLIMAP data base used in the ARPEGE-Climate model. Moreover, the baseline GSWP precipitation forcing has been replaced by an alternative product in which empirical satellite and wind corrections have been removed. The resulting water budget simulation is currently evaluated after converting the ISBA runoff into river discharge with the help of a river routing model. While the results are globally satisfactory, the simulations still show some delay in the melting of the northern hemisphere winter snow cover. This problem will be hopefully solved within the next few months.

Also, CNRM made progress in the analysis of the Arctic sea ice coupled variability, though this activity was not explicitly planned before month 19.

Due to funding problems, MPIMET is not sure about when they can start a series of new simulations with a higher vertical model resolution (necessary for simulating the QBO which is supposed to be important in the solar response). A subsequent analysis of the solar influence on modes of climate variability can also not be scheduled, yet. This is an unfunded activity within ENSEMBLES.

WP4.2 - List of deliverables, including due date and actual/foreseen submission date

Table 1: WP4.2 Deliverables List

.Del. no.	Deliverable name	Research Theme no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
4.2.1	Characterization of modes of large scale, low frequency climate variability in existing climate model control simulations	4.2	Month 18	Month 18	18		INGV

***) if available**

WP4.2 - List of milestones, including due date and actual/foreseen submission date

Table 2: WP4.2 Milestones List

Milestone no.	Milestone name	Research Theme no.	Date due	Actual/Forecast delivery date	Lead contractor
M4.2.1	Design and commence a set of co-ordinated time-slice experiments	4.2	Month 18	Month 18	INGV

2.4 WP4.3: Understanding extreme weather and climate events

Partners	UREADMM, KNMI, CERFACS, INGV, IfM, NERSC, AUTH, UEA, UNIFR
Person(s) who provided this information	David Stephenson (UREADMM)

WP4.3- Objectives and starting point at beginning of reporting period

The objective of WP4.3 is to assess the statistics of extreme weather conditions, or extreme climatic events, study their statistics and the conditions that favour their occurrence, and their modifications through climate change. The main three tasks that the Work-package will undertake are:

- **Task 4.3.a**: Development and use of methodologies for the estimation of extreme event probabilities.
- **Task 4.3.b**: Exploring the relationships between extreme events, weather systems and the large-scale atmospheric circulation/climate regimes.
- **Task 4.3.c**: The influence of anthropogenic forcings on the statistics of extreme events.

Starting point:

This WP builds on research on extremes carried out within the EU FP5 PRUDENCE, MICE and STARDEX projects. However, to make more progress in exploiting multi-model climate simulations, a more rigorous probability model-based approach needs to be developed. Furthermore the extent to which large scale factors influence the incidence of local extreme events needs to be explored.

WP4.3 - Progress towards objectives

Several of the WP4.3 partners attended the kick-off meeting in Hamburg (September 2004). Once the project started, some preliminary studies were performed to assess the links between large-scale circulation patterns and the occurrence of a selected set of extreme events over France (CERFACS). Preliminary analysis of extreme events and regime shifts were carried out on data from a time slice experiment with a previous version of the MPI coupled model (IfM). NERSC‘s starting point was to identify and quantify extreme weather situations in the Arctic region. In the initial phase of the work, pressure was chosen as the key analysed quantity. Later, temperature will also be considered.

There have been slight delays due to the time needed to recruit personnel but work is now on progress towards the first deliverables. A very useful extremes meeting was organised in Chateau D’Oex in Spring 2005 that helped coordinate activities of partners involved in developing new methodologies for the analysis of extreme events.

UREADMM: Main activities included:

- Preparing and presenting an overview presentation of WP4.3 aims and objectives at the Paris meeting 10-11 February 2005.
- Organising and attending an extremes workshop for ENSEMBLES 5-8 March in Chateau D’Oex. Statistical work needed for WP4.3 was extensively discussed at this workshop and collaborations were arranged. The choice of software for doing extreme value analysis was discussed and it was decided to use the R language instead of the originally envisaged MATLAB/IDL. The R software is more powerful statistically than either of these other languages, runs faster, and is freely available for most platforms (UNIX, Windows PC, Apple MAC, etc.).
- The development of R language software functions to do statistical analysis of extreme events in gridded data sets. Work has progressed well on this in collaboration with NERSC aided by a 2-week visit of Dag Steinskog to Reading. This will lead to deliverable D4.3.1 to be delivered in month 18 (Feb 2006) (Task 4.3.a).

- Writing proposals for RT8 young scientist mobility funding to enable both Dr Coelho and Dr Ferro to make 1-2 week working visits to KNMI scheduled for Autumn 2005. This will facilitate collaboration within the project for WP4.3, 5.3, and 5.4.
- Presentation of extremes work by Dr Chris Ferro at the 4th Conference on Extreme Value Analysis in Gothenburg, August 15-19, 2005.
- The purchasing and installation of fast computer hardware (UNIX machine and desktop) and fast hard disks to be able to do statistical analysis of large gridded data sets.

KNMI: Frank Selten and Adri Buishand attended the ENSEMBLES extremes Workshop in Château d'Oex (5-8 March 2005); Frank Selten gave a talk at that workshop about recent work concerning circulation changes and daily temperature extremes in model simulations made with ECBilt-Clio and NCAR-CSM models. The NCAR-CSM simulations, consisting of a 62 member ensemble of scenario integrations over the years 1940-2080, were found to be suitable for testing methods that will be developed in WP4.3 (Task 4.3.a).

CERFACS: Main activities included:
- Preliminary assessment of the influence of large-scale circulation patterns (NCEP and ERA-40 daily weather regimes obtained from the k-means algorithm) upon a limited set of observed (data from French meteorological stations) extreme events (heavy precipitation and heat waves) defined by very simple indexes (quantiles and threshold exceedances) (Task 4.3.b).
- Numerical case study of the influence of remote tropical Atlantic forcing upon the occurrence of mid-latitude atmospheric circulation regimes and related daily summer temperature extremes (application to the European 2003 heat wave) (Task 4.3.b).
- Participation of Laurent Terray and Christophe Cassou at the RT4 kick-off meeting held in Paris, February 10-11, 2005.
- Oral presentation of atmospheric regimes and extreme work by Dr. Emilia Sanchez at the EGU Conference in Vienna, April 25-29, 2005

INGV: They have commenced an analysis of the occurrence of extreme events of summer surface temperature in the Euro-Mediterranean region and their possible link with the large scale circulation. The analysis is performed using the NCEP re-analysis data set, and the extreme events are defined on the basis of very simple indices (quantiles and threshold exceedances) computed for the period 1958-2003 (Task 4.3.b).

IfM: Analysis of extreme events and regime shifts in time-slice experiments of the previous version of the MPI climate model has continued. In particular, the STARDEX extremes analysis software has been applied to data from these simulations. How changes in extreme statistics are linked to low frequency climate variability is being studied (Task 4.3.b). (Contribution to Milestone 4.3.2)

NERSC: The following questions concerning Arctic extreme events are being addressed:
- What characterise extremes in pressure (and thereafter temperature) and how are their spatial structures?
- Which climate states favour extremes in pressure?
- Are there changes in extremes related to pressure during the re-analyses period/in climate control integrations, and what can be expected for the future based on climate scenario integrations?

Available literature has been reviewed, and data sets of relevance have been evaluated. In addition, the key features of the Arctic climate system have been reviewed. Jointly with UREADMM modules for the statistical software programme *R* are under development (Task 4.3.a). Initial test analyses addressing polar lows and highs have been carried out. The development, testing and evaluation of the software packages will continue in 2005. A paper addressing polar lows is under writing (Task 4.3.b).

AUTH: Participation in the RT4 kick-off meeting held in Paris, February 10-11, 2005.

UEA: Exploration of methods using GCM time series as proxy data, in particular examining covariates and running R routines from Matlab

UNIFR: Nothing to report.

WP4.3 - Deviations from the project work programme and corrective actions

As reported above, the R language will be used instead of MATLAB or IDL for deliverable D4.3.1 – this represents the best available choice and has the advantage of been freely available and so no expensive software licences need to be purchased by ENSEMBLES partners who wish to use the code. The reports for D4.3.1 will be written clearly so that people can code up the methods in other languages if so desired.

Due to personnel problems the start of KNMI's contribution to Task 4.3.a (development and use of methodologies for the estimation of extreme event probabilities) has been considerably delayed. Because of a long-duration illness of the KNMI leading scientist in WP4.3, Dr Frank Selten, it was decided that Dr Debabrata Panja will start to work on WP5.3 in September 2005. Although this will speed up the KNMI contribution to WP5.3, it will cause a further delay for WP4.3; in particular Deliverable D4.3.1 cannot be delivered in Month 18 as far as KNMI concerns.

No significant deviations or nothing to report from the rest of the partners. (CERFACS, INGV, IfM, NERSC, AUTH, UEA and UNIFR).

WP4.3 - List of deliverables, including due date and actual/foreseen submission date

Table 1: WP4.3 Deliverables List

Del. no.	Deliverable name	Research Theme no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
4.3.1	Statistical methods for regimes and extremes	4.3	Month 18	Month 18 (possible delay by 2-3 months)	24		UREADMM

***) if available**

WP4.3 - List of milestones, including due date and actual/foreseen submission date

Table 2: WP4.3 Milestones List

Milestone no.	Milestone name	Research Theme no.	Date due	Actual/Forecast delivery date	Lead contractor
M4.3.1	Development of methods	4.3	Month 18	Month 12	UREADMM
M4.3.2	Assessment of methods	4.3	Month 18	Month 24	NERSC

2.5 WP4.4: Sources of predictability in current and future climates

Partners	CERFACS, CNRM, UREADMM, ECMWF, IfM, CNRS-IPSL, ISAC, DMI
Person(s) who provided this information	Laurent Terray (CERFACS)

WP4.4- Objectives and starting point at beginning of reporting period

The primary focus of WP4.4 is to advance understanding of the physical processes that give rise to predictability of both the first (initial condition) and second kind (boundary condition). The importance of both sources of predictability will be investigated on timescales from seasonal to multidecadal and over a wide range of space scales. This will be achieved through carefully designed sensitivity experiments coupled to the analysis of the core multi-model simulations performed within RT2A. The tasks for months 1-18 are:

- **Task 4.4.a**: Design a general framework for the analysis of participating models.
- **Task 4.4.b**: Assess the role of snow and hydrology in the predictability of climate.
- **Task 4.4.c**: Assess the potential predictability of the North Atlantic region at interannual and decadal timescales.
- **Task 4.4.d**: Investigate the vertical structure of weather and climate regimes in several re-analysis products and the potential role of the stratosphere.

Starting point:

The PROVOST and DEMETER projects have shown that climate models have some skill in predicting seasonal fluctuations, in particular in the tropics, although weak but not negligible skill exists also in the extra-tropics, for instance over Europe. The PROVOST and DEMETER projects have used global SST-forced AGCMs and CGCMs integration ensembles, respectively. They have also both shown that the multi-model ensemble approach provides a pragmatic and efficient solution to account for model uncertainty in the seasonal prediction problem.

The PREDICATE project has shown that there is potential decadal predictability for the tropical and extra-tropical parts of the North Atlantic European region. On interannual-to-decadal time scales, the North Atlantic European climate is influenced by ENSO but also by Atlantic SST. PREDICATE also suggested that the thermohaline circulation is an active player in modulating Atlantic SSTs on long time scales, and that changes in the THC can dominate an anthropogenic climate signal. WP4.4 will extend these studies and provide new assessments of the predictability using a new generation of coupled models run over both seasonal and decadal timescales.

WP4.4 - Progress towards objectives

The work accomplished in the first year relies on three main axes. The first one includes the realization of new ensembles of both coupled and SST-forced atmospheric simulations driven by anthropogenic and natural forcings. These new sets of experiments will be used to extend and complete the results obtained within the PREDICATE project on (potential) predictability of the North Atlantic region at seasonal-to-decadal timescales. The second one is a first attempt to explore the influence of the land surface hydrology on climate predictability through a sensitivity study performed with an AGCM. Finally, the third one gathers various contributions to the development and validation of methodologies to study climate variability and its predictability (tropical intra-seasonal variability, vertical structure of circulation regimes as well as the relevance of various non linear methods to detect multi-modality in the atmospheric state space).

A brief description of the work performed by each partner can be found below:

CNRM: The main objective of CNRM in WP4.4 is to study the influence of the land surface hydrology on climate predictability. A sensitivity study has started to explore the impact of different soil moisture (SM) initial conditions on global dynamical seasonal hindcasts using the ARPEGE-Climat AGCM driven by observed sea surface temperatures (SST). The control experiment (which has been performed) with interactive SM consists of an ensemble of ten 10-year simulations over the 1986-1995 period. A sensitivity experiment will also be performed in which more realistic initial conditions of SM will be derived from the Global Soil Wetness Project (GSWP). This sensitivity experiment will mainly explore the impact of SM initialization at the end of boreal spring, for month 2 to 4 of JJAS (June to September) seasonal hindcasts. (Task 4.4.b)

ECMWF: An experiment to determine the relevance for seasonal predictions of the increase in greenhouse gas concentration recorded in the last 50 years has been carried out. Preliminary diagnostics show that there is a substantial increase in the predictability of global average air temperature since the first month of the integration. In addition, probabilistic skill scores for the Northern Hemisphere, Southern Hemisphere and tropics are systematically better during boreal summer with regard to a control experiment with constant greenhouse gas concentration. However, no improvement in the seasonal predictability of the NAO has been detected. (Task 4.4.a, c)

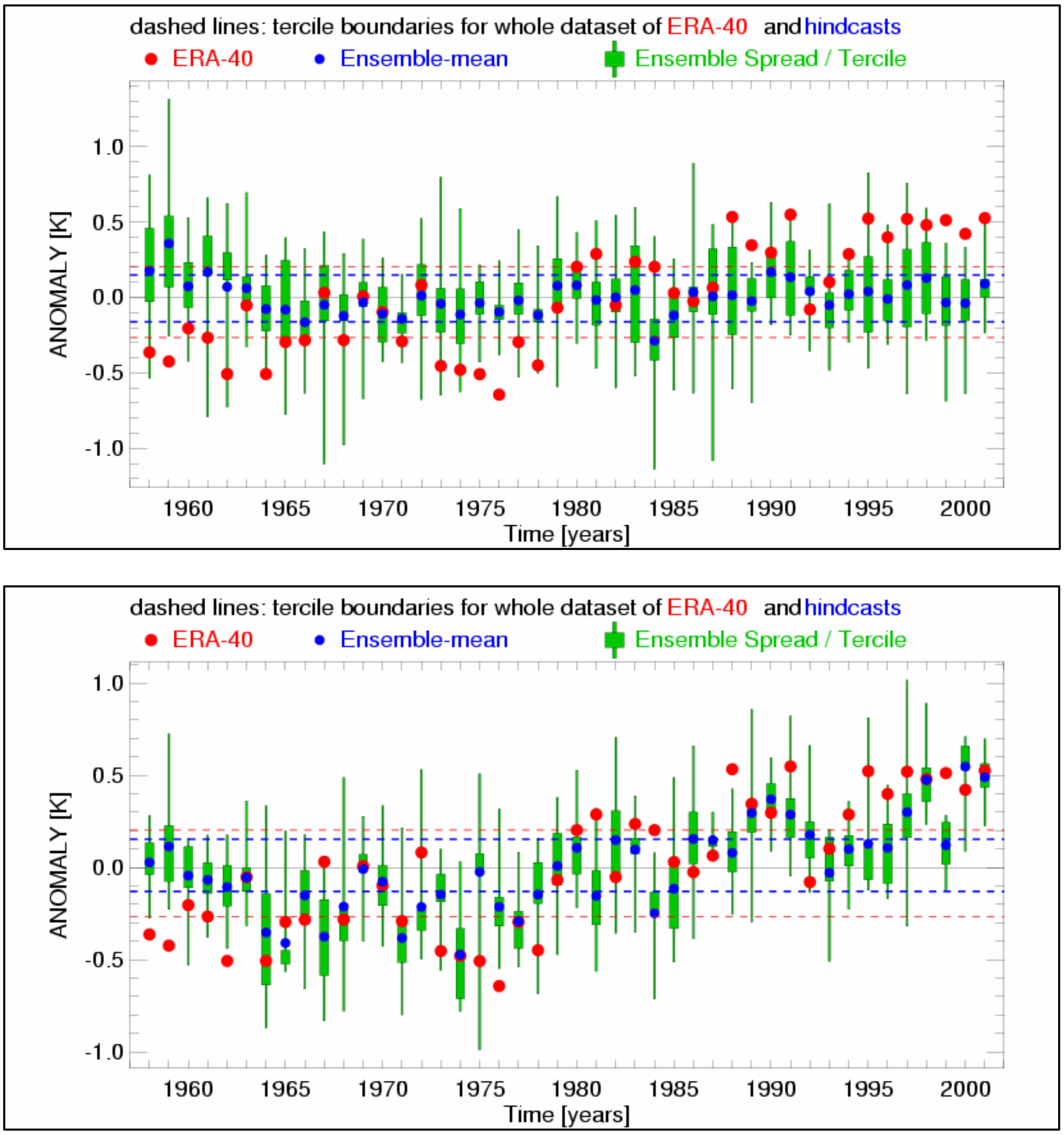

Figure 6: ECMWF 3 month lead time hindcasts of global 2 metre temperature for August – October without (upper panel) and with (lower panel) time varying anthropogenic greenhouse gases (GHG). In the upper panel the correlation between the ensemble mean and the observations is only 0.29 whereas this increases to 0.68 with variable GHGs.

IfM: A set of high (T106) and low (T31) resolution 20th century atmospheric simulations underway. 5-member low resolution and 2 member high resolution ensembles completed. The high resolution 20th century atmospheric ensemble simulation is being extended from 2 to 5 members. These simulations will be used to investigate potential predictability (i.e. Atmospheric predictability assuming perfect (ocean) boundary forcing. (Contribution to task 4.4c, Milestone 4.4.2) (Task 4.4.c)

CERFACS: Several new ensembles with large number of members (15) of SST-forced AGCM experiments have been started with the ARPEGE model (at T63 resolution) and various anthropogenic and natural forcings over the 1950-1999 period. Some work relying on sensitivity AGCM experiments has also been done to relate tropical diabatic forcing to the occurrence of specific mid-latitude weather regimes in summer over the North Atlantic European region. (Task 4.4.a,c)

UREADMM: We have commenced more detailed analysis of the decadal predictability experiments carried out in the PREDICATE project in order to understand the processes that give rise to forecast skill. The initial analyses are focussing on the evolution of subsurface and surface ocean fields, primarily temperature and salinity. (Task 4.4.c)

DMI: We have implemented and tested several of the methods previously used in the atmospheric sciences to identify circulation regimes. These methods include k-means clustering, finite mixture modelling, and a nonlinear extension of Principal Component Analysis (NLPCA). We have reviewed the usefulness of NLPCA as a tool for detection of multimodality and found severe problems and limitations. We have shown that multimodality is abundant in NLPCA when applied to sufficiently isotropic data even if these data are inherently unimodal. (Task 4.4.a,d)

CNRS-IPSL: We have started the development of diagnostic tools to assess the representation of the Intraseasonal Variability in hindcast ensemble integrations of coupled model using DEMETER in the framework of WP5.3. (Task 4.4.a)

ISAC: The 50-yr NCEP/NCAR reanalysis dataset has been used to explore the vertical structure of (global) circulation regimes. The main results are as follows: the 3 cluster-partition corresponds to COWL, NAM (in its positive phase) and NAO (in its negative phase). When a 4 cluster-partition is considered both phases of COWL and NAM are found. The increase in hemispheric-mean temperature in recent years seems, in part at least, directly associated with an increase in the frequency of cluster-A flow which is related to a positive surface temperature anomaly over Western North-America, North Europe and Siberia. ENSO does affect the regime frequencies and structure: the significance of the global cluster partition (from 2 to 6 cluster-partition) decreases to 79-71% when the major cold events are discarded (i.e. when the warm events weight more). (Task 4.4.a,d)

WP4.4 - Deviations from the project work programme and corrective actions

None

WP4.4 - List of deliverables, including due date and actual/foreseen submission date

Table 1: WP4.4 Deliverables List

Del. no.	Deliverable name	Research Theme no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
4.4.1	Synthesis of current estimates and mechanisms of predictability	4.4	Month 18	Month 18	11		CERFACS

***) if available**

WP4.4 - List of milestones, including due date and actual/foreseen submission date

Table 2: WP4.4 Milestones List

Milestone no.	Milestone name	Research Theme no.	Date due	Actual/Forecast delivery date	Lead contractor
M4.4.1	Development of methodologies to explore climate variability and predictability	4.4	Month 18	Month 18	CERFACS
M4.4.2	Assessment of climate variability, predictability in existing simulations	4.4	Month 18	Month 18	CERFACS