Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects

PRUDENCE

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Content list

<u>P</u>rediction of <u>R</u>egional scenarios and <u>U</u>ncertainties for <u>D</u>efining Europea<u>N</u> <u>C</u>limate change risks and <u>E</u>ffects – PRUDENCE

PRUDENCE is a project funded by the European Commission under its fifth framework programme. It has 21 participating institutions from a total of 9 European countries. More than 6 institutions from 4 more European countries, Israel, Australia and Canada have expressed their interest in the projects and offered to carry out complimentary work. The ideas and objectives giving the basis of the project has been summarised as follows:

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

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

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

Expected impacts:
PRUDENCE provides a series of high-resolution climate change scenarios for 2071-2100 for Europe, characterising the variability and level of confidence in these scenarios as a function of uncertainties in model formulation, natural/internal climate variability, and alternative scenarios of future atmospheric composition. The project will provide a quantitative

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

Project start:
PRUDENCE was formally accepted by the European Commission as contract No. EVK2-2001-00156, which was duly signed on 29 October 2001. The project thus accordingly officially started on 1 November 2001. A kick-off meeting took place during 3 – 5 December, 2001 in Snekkersten, Denmark, while a second meeting took place during 2 – 4 October, 2002 in connection with *the Second ICTP Conference on DETECTION AND MODELING OF REGIONAL CLIMATE CHANGE,* 30 September - 4 October 2002, held at The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

The present document presents the minutes of the third meeting attended by the entire PRUDENCE consortium and many of the afore mentioned additional groups. It took place during 29 September - 3 October, 2003 and formed the scientific part of the

WENGEN-2003 Workshop
ESF Exploratory Workshop
PRUDENCE 3rd Annual Meeting
Regional Climate Change in Europe: Processes and Impacts

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Synopsis

The 3rd meeting of the PRUDENCE project was held with the aim to review progress of the project and stimulate further interactions between the involved partners and identify issues, which will require action in order for the project to progress smoothly according to the EU contract – here the description of work (DoW) document. Having the partners giving scientific presentation, highlighting the main activities relevant for PRUDENCE at their home institution, did this in combination with a set of keynote presentations by partners and invited external experts during the conference. As the project is now well under way, many results have already been achieved and this work shop gave an unique opportunity to communicate these results to an expert audience for further evaluation and discussion. The scientific presentations by the partners were given between 30 and 45 minutes each. This allowed enough time for questions and initial discussions. On days 2 - 5, the workpackage (WP) participants met in various constellations to monitor in detail the progress of the work, defined by deliverables and milestones. Further meetings for planning of the next phase of the project were also arranged. For more details, see the meeting agenda of the business part of the meeting and the abstract compilation. By following the procedure from the kick-off meeting, the PRUDENCE project intends to keep an ‘open door’ policy. This is reflected by the meeting being part of an open conference with participation by more than 70 scientist from a total of 20 countries. Also at the present meeting, a number of external participants were invited to attend the conference and feed back to the PRUDENCE project. A list of participants present during the full session is provided in the back of this report.

During the meeting, breakout sessions were scheduled with the aim that any outstanding issues in the seven WPs could be identified and strategies to amend these could be established. Break out groups were formed dealing with each of the WPs separately, and an *ad hoc* cross fertilisation group also met. Issues with respect to WP7 were dealt with in a steering committee meeting held during Wednesday evening of the meeting. Also the external advisory group met at that time. Separate minutes from the breakout groups and the combined steering committee and external advisory group meeting are provided elsewhere in this report.

After the meetings in the various break out groups, a final and short plenary session revealed that actions towards solving remaining issues had been initiated. The most pressing need for action seemed to be a final release of official PRUDENCE simulations to be used for impacts analysis. As it is envisaged that model simulations, which can be considered as part of PRUDENCE will continue to be supplied to the project manager until the very end of the project, <u>it was decided to set a dead line for data to be used by impacts as December 1st 2003.</u> Data archived later than this date, need not be considered by WP3-WP6.

Agenda; PRUDENCE business meetings

Tuesday 30th September

16:30 Starting PRUDENCE business meetings

Plenary session 1:
Defining break out task groups

1. Cross fertilisation	Headed by: CRU
2. WP1 + WP2	Headed by: Hadley and MPI
3. WP3 + WP4 + WP5	Headed by: SMHI, DIAS, UniReading
4. WP6	will join where appropriate

The groups will afterwards meet in separate rooms. The overall objective will be to follow up on the tasks defined at previous meetings and in the DoW, reporting on significant problems encountered so far, identification of further gaps in information flow and data needs, and identify how these can be amended.

Reference persons for cross WP issues must be identified prior to all separate meetings.

Rapporteurs to sum up for plenary must be identified.

Commitment is compulsory! This means that all issues discussed, which requires an action item, is written down and a decision is made on who will be in charge of solving the problem. Even more important, a time schedule for the solution is proposed.

17:30 Break out sessions start according to groupings (2-4) just identified. Cross fertilisation group meet later in the week

18:30 End of day!

Wednesday 1st October

16:45 Business meetings continued (all break out groups)

Project progress: Presentations by partners as needed – the assumption is that not all aspects of the work done have been shown during the formal scientific sessions. Focus could be on 1) aims of work, 2) results so far, 3) problems encountered, 4) integration with other parts of PRUDENCE, 5) timetable for the next phase up to 30 month management report (due May 2004) and to the extent possible until the final project meeting (September 2004).

Scientific publications – final report?
Rapporteurs are responsible for summarising the presentations and make sure that general issues are identified and put forward in plenary.

Cross fertilisation group complete its business to allow feedback into the other BGs on Thursday.

18:30 End of day for some!

After supper
CLOSED PRUDENCE MEETING: MANAGEMENT BOARD SESSION
We follow the procedure from the Trieste meeting and combine the SSG and EAG meeting. The meeting would be attended by (÷ *absent)*

All steering committee members
Jean Palutikof; for MICE (EU project)
Clare Goodess; for STARDEX (EU project)
Axel Michaelowa; for Hamburg Institute of International Economics (Germany)
Trond Iversen; for RegClim (Norway)
÷ *Gunner Hovsenius; for Elsforsk (Sweden)*
÷ *Jean-Yves Caneill; for Électricité de France (France)*
÷ *Manfred Lange; for University of Münster (Germany)*
÷ *Gerhard Berz; for Munich Re (Germany)*
÷ *Penny Whetton; for CSIRO (Australia)*
÷ *Ib Troen; for DG-XII*

Proposed agenda:
1. PRUDENCE management report by the coordinator
2. Technical Implementation Plan (TIP)
3. WP progress by deliverables and milestones by WP responsible PI.
4. Identification of issues missed during the meeting so far
5. Other issues

Thursday 2nd October

16:45 Business meetings continued (break out groups 2-4 only)

17:45 Plenary session 2:
Summary of break out sessions by rapporteurs

18:30 End of day

Friday 3rd October

15:00 Plenary Session 3: Wrap-up of PRUDENCE research in 2002/2003

Discussion based on reports from yesterday

15:45 Coffee break

16:15 Plenary Session 4: Outlook of PRUDENCE research to the end of the program, including

- brief feedback report from the EAG and discussion of TIP
- planned WGNE-WGCM RCM panel/IPCC/Prudence meeting in Lund next spring

18:30 Closing remarks and end of the meeting

Saturday 4th October

9:00 Any unfinished business to be discussed on Jungfraujoch?

Scientific Steering Group and External Advisory Group Meetings

The management of PRUDENCE will broadly follow the Project Management methodology of the PRINCE (Projects IN a Controlled Environment) system widely used in government and industry.A Scientific Steering Group (SSG) consisting of senior scientists from most of the contracting organisations will fulfil the role of the Project Board. A Project Manager (Dr. Ole B. Christensen) has been assigned to the PRUDENCE project to assist the Project Co-ordinator in maintaining the control on the various phases of the project. The leaders of the seven research Work Packages will fulfil the role of the Project Assurance Team, plus other experts co-opted as required. At this stage the SSG is formed by:

Jens H. Christensen, Co-ordinator and WP7
Ole B. Christensen, Project Manager
Daniela Jacob, WP1
Dawe Rowell, WP2
Phil Graham, WP3
Jørgen E. Olesen, WP4
David Stephenson, WP5
Kirsten Halsnæs, WP6
Tim Carter,
Filippo Giorgi,
Jean Palutikof

3rd SSG and EAG meetings

On the evening of the 1 October, the members of the PRUDENCE SSG and EAG met for the third time. As only three of the EAG members were able to attend the meeting, it was decided to hold only one common meeting. The EAG is presently formed by
All steering committee members &
Jean Palutikof; for MICE (EU project)
Clare Goodess; for STARDEX (EU project)
  ÷ Gunner Hovsenius; for Elsforsk (Sweden)
  ÷ Jean-Yves Caneill; for Électricité de France (France)
Axel Michaelowa; for Hamburg Institute of International Economics (Germany)
Trond Iversen; for RegClim (Norway)
  ÷ Manfred Lange; for University of Münster(Germany)
  ÷ Gerhard Berz; for Munich Re (Germany)
  ÷ Peny Whetton; for CSIRO (Austrlia)
  ÷ Ib Troen; for DG-XII

(Persons indicated with a ÷ were not able to attend the meeting)

The project co-ordinator welcomed the members of the SSG and the EAG and expressed his hopes and wishes for the role of the SSG and the EAG. The main aim for these groups should be to enable an efficient way to communicate key problems and developments within and between the individual WPs, as well as to make such information available to the co-ordinator as early as possible. Therefore, the WP task leaders should also be responsible for capturing the essentials from the break out sessions scheduled under the main meeting agenda and duly report this to the co-ordinator in a meeting summary. The proposed agenda with the following items was accepted:

1. PRUDENCE management report by the coordinator
2. Technical Implementation Plan (TIP)
3. WP progress by deliverables and milestones by WP responsible PI.
4. Identification of issues missed during the meeting so far
5. Other issues

It was agreed that Dr. Michaelowa and Prof. Iversen as independent external experts would provide written summary reports about their impression of the activities and the procedures adopted in the PRUDENCE projects. Their report follows these SSG and EAG meeting minutes.

The coordinator expressed his overall satisfaction with the punctuality of the consortium. Only minor deviations from the project work plan have been necessary so far. He expressed his concern that at the next report, it would be absolutely necessary for all partners to relate the cost statements to the person months efforts, which are reflected in Table 1 in the previous six months reports. In his call for the cost statements for the second year this will be underlined once more

The coordinator briefly described the compulsory TIP, which all 5FP project are required to fill in before the project can be finally accepted by the European Commission. Some of the SSG members expressed that they had experience in filling out the formal schemes, which constitutes the TIP. It was agreed that the coordinator would discuss this issue with the relevant persons before the call for contributions to the TIP would be send out in connection with the annual reporting and coming cost statements.

The WP leaders briefly gave an overview of the status within the different WPs. Overall, no substantial problems had so far been identified, except that it appears as if some of the central model simulations have not been fully supplied to the PRUDENCE server at DMI and that monthly data interpolated to the common CRU grid was not available. The project manager reminded the group about the fact that this requirement was somehow not part of the list of variables, which so far has formed the backbone of the data management. However, he insured the SSG that he would process all the daily data in the archive in order to provide such processed fields as well. The project manager furthermore explained that all partners have stated that they are in the process of providing any remaining data, and that the basic experiments should be available within this year. The SSG then decided to strive towards a dead line for 'prime data' to be made available on December 1st 2003. Data made available after this date can not be expected to be used within impacts studies, although some groups may still want to utilise all data sets coming in even at a late stage.

As a final point – raised at a very late hour – the coordinator mentioned that there seemed to be an apparent discrepancy between the model data available for impacts analysis and data to be used for model intercomparison within PRUDENCE. This discrepancy had been noted by the WP leaders in WP3-5 as a consequence of the decision made by the Hadley Centre to upgrade their PRECIS modelling system from version 'H' to version 'P'. This situation has previously been commented on by the Dr. Richard Jones and the coordinator. Two letters explaining this has been distributed to the consortium previously and can be found elsewhere in this report. In order to secure the successful termination of PRUDENCE reaching some of the central scientific objectives. The consequences of this was discussed at length and an agreement was reached on the usage of the two versions within PRUDENCE. The coordinator formulated the agreement reached in the following statement ('Hadley Centre global and regional model data availability for PRUDENCE'), which should be considered as a reference for the future. The Hadley Centre via Richard Jones as well as the SSG supports this formulation.

For reference the two previously issued documents (‘UKCIP02 scenarios and recent Hadley Centre model runs’ and ‘PRUDENCE models for WP1 and WP2’, respectively) discussing these issues are provided as well.

Hadley Centre global and regional model data availability for PRUDENCE

In two previous documents, the basic reasoning which has led to the decision by the Hadley Centre to adopt a revised version of HadAM3 and HadRM3 for future work with the PRECIS system was outlined. In addition, it was explained that in introducing the new model version HadAM/RM3P did not imply that the initial version HadAM/RM3H had been abandoned.

It was underlined that in order not to undermine the credibility of data from HadRM3H, released to UK impacts modellers, the basic climate change responses using the two sets of models over Europe should be similar

Given the advanced stage of the PRUDENCE project (about half way to completion, when HadAM/RM3P were ready and two-thirds of the way at present), it is realised that in order to enable a stringent comparison between RCMs and the driving GCM, the original HadAM3H and HadRM3H control and scenario A2 and B2 experiments (ensemble members No 1 only) are to be kept as part of the PRUDENCE series of experiments (daily and seasonal data provided as specified by the PRUDENCE data protocols).

At the combined SSG and EAG meeting during the PRUDENCE Wengen meeting, it was realised that this stringent comparison was also considered essential for a substantial part of the planned and already ongoing impacts studies within PRUDENCE. The board was of the opinion that there was no scientific argument for changing the model version within PRUDENCE at an advanced stage of the project. The board therefore recommended that the HadAM/RM3H-based experimental data, already made available for model intercomparison, validation and uncertainty assessments, should and could be used for impacts work as well. This would also allow the investigation of the issue of whether consistency between the driving GCM and the embedded RCMs would affect the uncertainty cascade introduced in impacts studies using output data from RCMs (though this was not explicitly identified in the work packages as an aim of PRUDENCE).

Also, the Hadley Centre data for use in PRUDENCE should include the HadAM/RM3P experiments in order to maintain consistency with future use of Hadley Centre data within Europe and, via applications of PRECIS, worldwide. This will help to reinforce the idea that the HadAM/RM3H experiments simply represent an earlier stage of model evolution rather than having been abandoned as having no value, and they still retain an important role in answering the scientific questions posed by PRUDENCE. Moreover, the PRUDENCE database will not be diminished in size as the HadAM/RM3P experiments will also be provided for analysis in all workpackages and then for use subsequently in any further impacts modelling outside the project.

In order to avoid any confusion with future usage of HadRM3P as the model at the heart of PRECIS, access to the HadAM/RM3H experimental data will, with the exception of seasonal mean fields, be prohibited after the termination of PRUDENCE. However, any pending work utilising data from the HadAM/RM3H experiments, which was initiated within PRUDENCE and is already at an advanced stage, can be duly completed and published.

Jens Hesselbjerg Christensen
on behalf of SSG and EAG

9 October 2003

UKCIP02 scenarios and recent Hadley Centre model runs

To generate the UKCIP02 climate change scenarios, we used the HadRM3 regional climate model (RCM), driven by predictions from the coupled climate model, HadCM3. To improve the climate of the driving GCM, for example North Atlantic storm tracks, we used an intermediate, 150km resolution, atmosphere-only GCM – which we called HadAM3H – to provide the lateral boundary conditions (LBCs). We believe the resulting climate scenarios are currently the best tools available for the UK impacts and adaptation community, and the same GCM and RCM have also been used for the new British-Irish Council "island" scenarios.

In order to allow similar regional predictions in other parts of the world, we have developed a PC-based regional climate modelling system, PRECIS. The prototype PRECIS system used HadRM3 as its RCM and LBCs from HadAM3H. However, studies with these models over other parts of the world (southern Africa and China) showed up biases in their surface climatology which could compromise their use in impacts studies in these regions. Some of these related to the representation of clouds and precipitation processes. This led us to refine these aspects of HadAM3H to deliver a GCM – which we call HadAM3P – providing high quality LBCs for the PRECIS RCM worldwide. This improved atmospheric model is then used as the basis for the PRECIS RCM and is what we are now making available as the latest Hadley Centre model for providing high resolution climate predictions worldwide.

As we are promoting these new models for detailed climate prediction it is important that they are thoroughly validated and tested. An essential element of this is validating the performance of the RCM, using it to predict climate change and understanding the predicted changes; a similar exercise is also required for the GCM. In this context we have used the PRECIS RCM driven by HadAM3P to predict climate change over Europe, essentially repeating the experiments we ran to provide the UKCIP data. This provides the material for documenting the models' performance as well as an example of its use to be emulated over other regions.

We are concerned that the impression is being given that the globally improved models will somehow invalidate the UKCIP02 scenarios. This is not the case. Predictions over the UK from HadAM3P were compared with those from HadAM3H to ensure that the differences were not statistically significant, so the two are consistent. Of course, being derived from one model, the scenarios do not take into account model uncertainty; we explain this issue clearly in UKCIP02 and suggest ways of handling it. We are looking forward to the results from comparisons of different RCMs driven by different GCMs that will emerge from the EC PRUDENCE project in due course, which we are already planning to use in the "UKCIPnext" scenarios.

Geoff Jenkins
Richard Jones
John Mitchell

05 June 2003

PRUDENCE models for WP1 and WP2

Climate models are dynamical in many senses. In particular new model versions seem to appear at an ever increasing frequency. This is not surprising and it should be this way, as this clearly documents that the research teams constantly work to improve the performance and skill of these models. The models within PRUDENCE present no exception to this. However, for the scientific questions we want to address within the project, it seems essential that the models, which take part, are consistent throughout the duration of the project.

Recent developments at the Hadley Centre (HC) has therefore prompted the need for some adjustments to work carried out within PRUDENCE both in terms of the HC contribution to PRUDENCE and work carried out by other partners using HC data. The present document is intended to serve as a clarification of what has possibly made its way to many of you via incomplete emails or as rumours based on incomplete information.

You may recall that the basic PRUDENCE simulations rely on control and scenario experiments carried out with a high-resolution version of the HC global atmospheric model HadAM3H. HadAM3H was originally built as a model to overcome shortcomings in HadCM3 (the HC global coupled model) with respect to generating RCM predictions for UKCIP (The UK Climate Impacts Programme) though with the important proviso that it was a model which performed globally as well as or better than HadCM3 (so its credibility for simulating climate or predicting climate change was not undermined). Clearly, the European dimension of the experiments was also important, as realised later when PRUDENCE was launched. Another dimension was its use over other regions, specifically southern Africa and India and then, somewhat less critical at the time, as a source of boundary conditions globally (i.e. for the portable RCM version of HadRM3: PRECIS – Providing Regional Climates for Impacts Studies). In the meantime, analyses of the model and its use over different regions has encouraged the HC to reformulate certain aspects of the cloud and precipitation physics which provide further improvements in surface climatology globally. The main motivation here is now PRECIS with current users in India, China and Africa all using the new model (the configuration of HadRM3H follows directly from that of HadAM3H). Thus, given that PRECIS is to provide the functionality for producing consistent high-resolution climate scenarios globally it was felt necessary to regenerate the initial set of European experiments using the PRECIS RCM (i.e. HadRM3P).

In order to enable a stringent comparison between RCMs and the driving GCM, it has been decided to keep the original HadAM3H and HadRM3 control and scenario A2 and B2 (ensemble members No 1 only) experiments as part of the PRUDENCE series of experiments (daily and seasonal data provided as specified by the PRUDENCE data protocols). Hence, the role of using the same model formulation in the GCM and RCM (in this case the HC model) in comparison to different formulations (in this case all the other RCMs) can be assessed for the first time ever.

When the new set of experiments have been completed, they will be added to the data set and will include the full ensemble. These data will be those available from the Hadley Centre for use in the impacts studies in Prudence to maintain consistency with future use of Hadley Centre data within Europe and, via applications of PRECIS, worldwide. In this way the original experiments will not be considered as abandoned, as they will retain their roles in answering the scientific questions posed in workpackages 1 and 2. Also, the PRUDENCE data base will not be diminished in size as the new HC experiments will be provided for analysis in these workpackages also and then for use subsequently in impacts modelling.

Jens Hesselbjerg Christensen
Richard Jones

23 June 2003

Notes on PRUDENCE

Trond Iversen, University of Oslo, Norway

The following points of view from an external advisor is based on reading the work description, participating in the third PRUDENCE workshop in Wengen, Switzerland 29/9-2/10 2003, and joining the internal "Business Meeting". I need to mention that the downscaling group of the Norwegian RegClim-project I am leading (at met.no), is an associated partner to PRUDENCE without financial commitments.

PRUDENCE is an ambitious and innovative project in climate change research over Europe. It is ambitious with respect to the number of models included and amount of data produced, as well as the wide participation of research-groups from widely different fields. It is innovative most importantly due to its systematic use of model-generated climate data to assess risks of adverse weather events, and uncertainties associated with scenarios of climate change and its potential impacts on nature and society. The project represents an important step forward towards a Pan-European evaluation of climate change and its effects. Its potential impact on European policy development and industry is strong, whilst at the same time high-quality research is highly probable.

The basis for all time-dependent climate scenario predictions for the next few hundred years are scenarios of external parameters that produce radiative forcing. Global climate models that fully couple the atmosphere, the deep oceans and sea-ice, and the land-surface (AOGCMs) calculate the climate response. Computer resources hamper the use of geographical resolution needed for most impact studies, and to represent geographical features important for the weather (mountains and coastlines), and dynamics associated with extreme weather. For these reasons, atmospheric models with higher resolution are run to downscale the AOGCM-results. PRUDENCE employs three types of downscaling models: high-resolution (typically 100 km) atmospheric global circulation models (AGCMs), and regional circulation models (RCMs) of high (typically 50 km) and very high (20 km and finer) resolution. The AGCMs and RCMs have a varying degree of sophistication with respect to the atmospheric processes and the description and coupling to land-surface and oceanic/lake processes.

In my opinion, a very important and unique feature of PRUDENCE is the systematic use of several AGCMs and RCMs. This enables quantifications of uncertainty in climate scenario predictions of different origins, such as choice of scenarios for anthropogenic climate forcing, approximations and weaknesses in the model formulations, and natural random variations in climate. A large number of RCMs downscale a set of ensemble members from a few high resolution AGCMs, and impact-studies use data from both as input to their models. In this way PRUDENCE has been designed to study different types of adverse weather events, to estimate their environmental and socio-economic impacts, and to quantify their uncertainties and allocations to causes.

Another aspect of this key feature is a number of practical issues related to scientists coming from very different fields and traditions. In PRUDENCE important issues such as data formats, the degree of match between data required for impact studies and what climate models can provide, have a high chance of being solved successfully.

Status

The participants in PRUDENCE are highly skillful and are able to comply with the commitments of their plans. My ability to judge this is mainly for the work-packages focusing on climate modeling (WP1 and 2) and impact-related work-packages linked to physical climate (WP3 and 5).

Based on presented scientific results and a reporting of status of deliverables and milestones, my clear impression is that PRUDENCE is in good shape with respect to its plans. There are a few minor delays, but none seems to be crucial for the progress, and it is my clear impression that no omissions or re-definitions of deliverables or milestones is needed. Some climate scenario-data have not been submitted to the PRUDENCE data-centre, but this is now well underway.

It is my clear impression that the management of PRUDENCE is well undertaken in order to secure that the targets are reached for the project.

Recommendations
PRUDENCE does not address all sources of uncertainties in climate modeling. One important uncertainty not fully addressed is associated with coarse-resolution AOGCMs. The 19 CMIP2-experiments submitted to the IPCC TAR (2001) revealed very large disagreements, in particular in Arctic and Sub-Arctic regions, possibly caused by sea-ice and overturning circulations in the Atlantic Ocean. Hence there are large differences between AOGCMs' large-scale circulations over Europe. When only a few AOGCMs are employed in PRUDENCE, conclusions about future climate change and their impacts may be strongly biased. This is not a failure of PRUDENCE as a project, as it was necessary to choose priority given the resources. However, the results I have seen so far are mainly based on only one AOGCM, namely the Hadley Centre's model. Since the circulation patterns from this model is considerably different from corresponding calculations from the Max-Planck-Institute, Hamburg, I strongly recommend that also the latter are included in PRUDENCE at all levels from RCM-calculations to impact studies.

As mentioned above, the success of PRUDENCE will be closely connected with the careful selection of models and climate change scenarios, and thus the allocation of uncertainties. It is imperative that this careful selection is kept for the entire PRUDENCE. During the course of three years, active modeling groups (such as those in PRUDENCE) will improve their models, and it may be tempting to change model-versions underway. Such changes should definitely not take place at this late stage.

I have mainly seen results for extreme temperatures and precipitation (or lack of precipitation), as well as associated hydrological consequences. More attention should be given to wind and associated impacts in the analyses to come.

Axel Michaelowa, University of Hamburg; Germany

I have to start with the fact that I as an economist can not value the details of natural science modelling done in PRUDENCE. So my viewpoints concerning these models are those of an "educated member of the general public".

The overall progress of the project looks impressive. Especially WPs 1 and 2 seem to have made great progress with a multitude of scenarios. However, there are two main issues of concern:

- The request by Hadley Centre to use a different version of its climate models HadAM3 and HadRM3 than originally envisaged. This amounts to a change of horses during a race and would lead to high adaptation costs as data input already started would have to be done again. Moreover, the added value of the new version is not entirely clear to me;

discussions during the workshop gave the impression that it may even decrease quality of simulations.

- The apparent gap between the climate modelling workpackages and the impacts ones. To me, it is not clear when the impacts workpackages can really start as they depend on the delivery on simulations. Moreover, climate modellers do not always seem to be aware of the needs of the impacts researchers with respect to the temporal resolution of the simulations. Increased communication between modellers and impact researchers would certainly be a plus.

As in every large consortium, there is a tendency of "cocooning" within each disciplinary community but the project management is well aware of this and thus I do not see it as major risk.

Further issues relate to the dissemination strategy, which still is in its infancy. Kirsten Halsnaes has rightly drawn attention to this issue, while many project participants feel that publication in scientific journals is already a sufficient dissemination strategy – it is not. Especially as recent extreme events have sharpened public awareness for impacts of and adaptation to climate change, PRUDENCE is situated in a benign environment if it comes to dissemination. However, given the lags in policymaking and the difficulties in access to policymakers which plague many well-intentioned research projects, it would be important to

- Develop a clear view which results are relevant for policymaking. The presentations sometimes give the impression that this is not clear.
- Identify pathways to access policymakers. Here especially climate negotiations and climate policy workshops would be relevant. Many countries are currently refining their climate policy strategies. As adaptation becomes a more important component of such strategies, PRUDENCE results could influence long-term policies.
- Forge links to research projects looking at adaptation to climate change and develop joint outreach strategies
- Carefully assess how to communicate uncertainties related to model simulations. Policymakers like specific numbers and are not used to uncertainty analysis

Status of activities in PRUDENCE WP1-WP2: Climate models and their analysis

(Tido Semmler, MPI)

Discussion of the proposed agenda from Dave Rowell

Daniela proposes to give the planned informal presentations within the discussion rather than in one block. There were no further comments to the proposed agenda.

Data and simulation issues

All regional 50-km-simulations are finished. From the high resolution regional climate model simulations (20 to 25 km) the ones from Hadley-Centre and DMI are completed; the ones from ETH and MPI are not started yet. SMHI has also performed a high resolution run, but they used their coupled regional model. Daniela proposes to work with sensible global climate model scenarios instead of using the Hadley Centre scenarios with excessive Baltic Sea SSTs. The MPI group will perform another 50-km-simulation with the Rossby-Centre-Baltic-Sea-SST and not start the high resolution simulation at the moment. Eventually this group will afterwards do an 18-km-simulation driven by the new 50-km-simulation on a similar domain (only skipping the boundary relaxation zone). In any case the MPI group will perform simulations with the Hydrological Discharge model (HD) driven by the available regional model simulations. The DMI group will perform an additional very high resolution 12-km-simulation directly driven by the 300 km Hadley-Centre global climate model output. There is a large scale jump from the driving GCM to the RCM - this is an experiment.

The global climate simulations from Hadley-Centre, Meteo France and ICTP are completed. From MPI ECHAM4 simulations are available. In addition Martin Wild (ETH) is running ECHAM5 with Hadley-Centre-SST with 19 levels. This simulation will be made available for the PRUDENCE community by the end of this year. A discussion about possible new ECHAM5 simulations with higher horizontal and vertical resolution (T106 L31) yields, that there is no interest in such additional simulation.

Common evaluation strategies:

It would be necessary to agree on some common evaluation strategies, which should be applied to as many as possible regional climate models. Otherwise there is no added value of performing many regional climate model simulations. In Hamburg we already discussed possible topics, which should be dealt with.

We could in addition take up the idea of Juerg Schmidli, who presented Taylor diagrams for the validation of the control runs for todays climate.

There are groups of models, who behave quite similar. We should find out, why this is the case (for example GKSS, MPI and ETH use a similar dynamics and vertical diffusion). Therefore half a page of model description is required from each partner until the 1st of January, 2004. In addition half a page about the model performance (known model deficiencies) is required.

A circulation statistics would be very important. Instead of applying a cyclone detecting system an easier possibility would be to look at the variance of for example the 500 hPa geopotential height. This should be done for each regional model. KNMI will take the responsibility for this.

Ole B. Christensen will calculate monthly means from the daily data (this has to be done for the impact people).

WP1+2 meeting:

Should be combined with IPCC meeting, because IPCC is very interested in RCM simulations. Should be not too late to leave time for discussions and publication. It has been agreed, that end of March/beginning of April will be an appropriate time for this meeting. The meeting will be held in Lund (Sweden) and will probably last 5 days.

Common evaluation strategies:

Jens will be responsible for the analysis of the mean parameters. For distribution functions and extreme values a validation will not be possible at DMI. Within the PRUDENCE project we have many interesting observations available. We should get an overview over these and use them for the validation. Maybe the impact people could define, what statistics they would be interested in in addition to the mean values. The validation results obtained up to now will be summarized in the summary of the presentations during the meeting, which every chairman will write about her or his session. In addition the presentations will be made available on the PRUDENCE web page.

Informal presentations:

Erasmo Buonomo: Precipitation Extremes simulated with HadRM3

He calculated 2- and 20-year return levels using the GEV distribution. The 2- and 20-year return levels for daily precipitation increase in the scenario compared to todays climate, where there are less significant points for the 20-year-return levels. Also the 20-year return levels of 30-day precipitation increase.

Heikki Tuomenvirta: Influence of climate change scenarios on energy issues in Finland

Climate scenarios from IPCC for Finland investigated. According to both the A2 and B2 scenario the energy generation from water power will increase and the heating energy consumption will decrease.

Miguel Angel Gaertner: Sensitivity studies with PROMES

In the first PROMES control simulation there is a strong dry bias in summer precipitation. The main reason for this obviously are the used vegetation parameters from Olson. There is too much grassland and too few forest, which leads to a too small evaporation. Introducing more forest and a larger LAI leads to a clearly improved simulation. In the 2m-temperature there is a cold bias in some regions in the improved simulation instead of a warm bias in the first simulation. The temperature and precipitation response in the A2 scenario is surprisingly very similar in both simulations. Only in the Eastern Mediterranean the temperature change is 1/2 K less.

Dave Rowell: Merged deliverables

MD1: Uncertainty of global climate model simulations (Responsibility: Michel Deque).
Available is:

Hadley Centre: 3 members A2, 1 member B2

Meteo France: 3 members A2 (Hadley Centre SST)
1 member B2 (Hadley Centre SST)
1 member A2 (own SST)
3 members B2 (own SST)

MPI-ECHAM4: 1 member A2 (own SST)
1 member B2 (own SST)

ICTP: 1-2 members A2 (Hadley Centre SST)

Available will be:

MPI-ECHAM5: 1 member A2 (Hadley Centre SST, 19 level)
1 member B2 (Hadley Centre SST, 19 level)

In addition the MPI group thinks about performing an ECHAM5 simulation with own SST and 19 levels.

With these data the influence of both the SST and the model can be investigated. There will be an analysis on a 2-degree-grid. For Europe the CRU data will be used for the validation. In addition there will be a global scale validation using different observations. Also for the climate change there will be an evaluation (scenario minus control simulation) with focus on Europe and on the global scale.

Michel Deque will perform this analysis for all global model simulations. The results will be published. Contributions of other participants are welcome.

Model data and documentation:

Every group has to deliver their data until the 1st of December and half a page of model documentation and half a page about model performance (the most important model deficiencies) until the 1st of January.

Common evaluation strategy:

The problem is that many evaluations have not been done for all RCMs. But this should be done (for example for hydrology (WP3) and extreme events (WP5)). For WP4 this problem is not so relevant - here most of the models are considered already.

Tido Semmler and Christoph Frei are responsible for the calculation of return levels for all models (validation for todays climate and investigation of changes in future climate). Heikki Tuomenvirta is responsible for the application of STARDEX evaluation techniques.

Dave Rowell: Merged deliverables

MD2: Common validation (Responsibility: Jens Christensen). The validation has to be carried out with different data sets. Jens Christensen needs these datasets (from ETH and from the STARDEX project). Extreme events are not part of the deliverable, but they could be an additional part in the report. Deadline for the report: End of this year.

MD3: Uncertainty assessment using RCMs (Responsibility: Dave Rowell). Statical analyses will be carried out in the whole European region by DMI and Meteo France. For the alpine precipitation ETH (Christoph Frei) is responsible. The analysis of the uncertainty of the impact will be done by FMI and UCM. MPI will not look at the Norwegian wintertime precipitation as intended before. KNMI will look at the height dependency of the summer drying. The dependency of precipitation on height will be investigated by Dave Rowell for Europe, by Christoph Frei for the Alpine region for the 50km-simulations and by Tido Semmler for the Alpine region for the 20km-simulations.

MD4: Upper and lower estimates of regional temperature change (Responsibility: Heikki Tuomenvirta). For this evaluation 7 AOGCM simulations and all RCM's will be used. The used emission scenarios are A1F1, A2, B2, B1. The natural variability will be investigated in using a 1000 year Hadley Centre GCM simulation. To present the results it would be possible to divide up the European region into five parts. There are some problems with the model data (some gridpoints missing or set to 0). This issue has to be resolved after the meeting. In addition to pattern scaling and looking at the natural variability a grouping of the results should take place. A very interesting publication would be to apply the Koeppen classification to all models.

MD5: Multi member ensemble of high resolution simulations (Responsibility: Daniela Jacob). For these simulations the deadline is the 1st of July, 2004. GKSS will not perform a high resolution simulation, the UCM simulation will only cover parts of the 50-km simulation domain. The remaining groups performing high resolution simulations are: DLR, DMI, Hadley Centre, ETH, MPI, ICTP. In addition DMI will perform a very high resolution simulation (12 km).

Status of activities in PRUDENCE WP3: Impacts on Hydrology

(Phil Graham, SMHI)

WP3 focuses on the impacts of climate change scenarios on hydrology for the entire Baltic Sea drainage basin, the Lule River basin in Sweden, and the Rhine River basin in Central Europe. SMHI is conducting hydrological modelling in the northern basins, while ETH concentrates on the Rhine. Hydrological studies at MPI are being conducted both in the north and in the Rhine basin. In addition, U. Fribourg has conducted studies on climate change impacts to snow and glaciers in the Alpine region, which are important contributors to runoff generation.

The work at both ETH and at MPI has thus far concentrated on getting the RCM simulations completed for use in the hydrological simulations. The hydrological modelling work performed at these two institutes has up till now used inputs from previous climate model simulations, or ERA fields. SMHI, which had the advantage of having early on completed its simulations, was able to focus more on hydrological simulations already from the start. Unlike the other partners in WP3, U. Fribourg does not perform any hydrological modelling work, but focuses on analysis to specific hydrological variables.

SMHI focuses on performing simple hydrological modelling on as many RCM simulations as possible to get an indication of the range of differences that occur from using different RCMs in impacts assessment. Moreover, diagnostics of the hydrological outputs of the RCMs is also performed, resulting in comparisons of variables such as runoff coefficient over various hydrological basins. Such work has been done for four scenarios using the RCA model simulations. Preliminary results using both HIRHAM and CHRM simulations have also been done.

ETH is investigating questions of scale and how finer horizontal scales in RCMs influence the assessment of impacts on hydrology. Their current hydrological modelling work does not show much sensitivity between the CHRM model on a 56 km grid compared to the CHRM model on a 14 km grid for control and ERA simulations. They are currently investigating why this is so and if they can make modifications to the hydrological modelling that will take into account the finer resolution. Some discussion of this occurred during the breakout sessions.

MPI will use their HD Model to perform flow routing of runoff from RCM simulations. As this model uses different runoff levels to represent fast and slow runoff responses, MPI had expressed interest in getting more detailed results in the form of runoff from different soil layers from the RCMs. This was discussed during the Wengen meeting and the idea was eventually abandoned for both practical and scientific reasons. Scientifically, it is not very likely that runoff from different layers of different RCMs represents something that can be compared. Practically, only total runoff has been delivered to PRUDENCE and generation of additional results fields was not deemed worthwhile, particularly given the low scientific significance of these fields. In place of multiple runoff variables, MPI will instead perform additional analyses to partition total runoff into components that represent fast and slow responses.

U. Fribourg has used climate change scenario results from RCMs to do studies of impacts on snow and glaciers in the Alpine region. They have submitted a scientific article that combines the use of the HIRHAM scenario results with observational analysis and surface energy balance modelling. They have also published a paper that presents an empirical approach for climate impacts studies on the snow pack in the Alps.

In able to insure that we have relevant results to compare, it is important that we fix specific locations on the rivers of interest where we can compare model outputs to each other and to river flow observations. As MPI is performing modelling in both the Baltic Basin and the Rhine, they should provide results from their work that correspond to the points where SMHI and ETH generate results. The details of the points were not discussed in Wengen. However, it was decided that SMHI and ETH should each communicate with MPI about their respective study areas so that it is clear where results are needed for comparison.

Work for SMHI, ETH and MPI during the remaining project year of PRUDENCE will concentrate on evaluating the control and scenario simulations that are available in the project databases. SMHIs work will focus on processing large-scale studies for a large number of simulations, while ETH will focus on looking at only a few simulations in much greater detail. MPI will perform hydrological studies that include both their own RCM simulations and those from SMHI and ETH. U. Fribourg has completed the work that they planned for participation in WP3.

Deliverables for WP3 are on schedule, with the exception of D3A3 (month 24), which is slightly delayed as reported in the last six-month progress report. This delay does not influence any other partners in PRUDENCE. Deliverables D3A1, D3A2 and D3B4 have been met. D3A4, D3B1, D3B2, D3B3 and D3B5 are scheduled for completion month 33.

Status of activities in PRUDENCE WP4: Impacts on agriculture, forestry and ecosystems

(Jørgen E. Olesen, DIAS)

The overall objectives of WP4 are to analyse the impacts of a range of detailed climate change scenarios on agriculture, forestry and ecosystems for selected regions in Southern and Northern Europe, and to evaluate adaptation options and possible effects on mitigation strategies. A list of the deliverables are show at the end of this paper. A meeting of the partners in WP4 was held in April 2004. The presentations here showed that on track compared with the anticipated milestones and deliverables. Impact model calibration and sensitivity analyses have been done for the most part, and WP4 participants are now ready to apply RCM output to the impact models and indices.

Impacts on agriculture in a South European region (ISAg-UPM)

Impact models have been verified for current climate and are now ready for simulation with RCM outputs. Crops and system models (DSSAT and CropSyst) have been linked to the geographical information system for verification with reanalysis data from ERA-15. These models were calibrated with field experiments for different agricultural areas but as complete data sets are not available for all the counties chosen for PRUDENCE, we also used ERA-15 climate inputs. Here we compare the crop models outputs derived from observed and from reanalysis data.

Traditional counties were chosen as our land units to link impact results with demands of information from the Ministry of Agriculture (MAPYA) and with its statistical databases on yields and water use. Soil polygons were built from information from the Soils Map of Spain and detailed profile data from other sources, mainly ETSIA-UPM (see our annual report). When temperature and rainfall gradients are too high within 100 km differences are may be higher than those we could encounter under future climate and distort climate impact analysis.

Impacts on agriculture in a North European region (DIAS)

The DAISY soil-plant-atmosphere model has been used to simulate crop production and changes in soil C and N for range of crop rotations under changing temperature, rainfall and atmospheric CO_2 concentration. The DAISY modelling system has been set up for the crop rotations used in the project. A file system and a database have been designed to store parameter files and simulation results. A sensitivity analysis has been performed with respect to effect of temperature, rainfall and CO_2 on nitrogen cycling in the system. A system has been designed to convert climate model output to data for use by the DAISY model, applying different downscaling methodologies.

Two different parameterisations of the soil organic matter model have used to estimate uncertainty in soil carbon development and in associated effects on nitrogen dynamics. The parameterisation and calibration of the DAISY model with respect to both CO_2 response and with respect to soil organic matter turnover has been more time consuming than originally expected, and the model has only finally been validated and approved for use in August 2003.

The model has applied to three crop rotations typical for arable farming in Denmark on loamy sand soil. Also the model has been used for continuous winter wheat to study effects of crop residue management and effect of change in sowing dates and N fertiliser rates.

The effects of different downscaling techniques are being investigated. This work will be compared with similar work at ISAg-UPM and may form the basis for a paper.

Climate data from 9 stations throughout Europe have been selected, and the model has been run for continuous winter wheat. The resulting data will be used to derive a simple regression-type model for mapping effects of climate change on nitrate leaching throughout Europe (collaboration with SYKE).

During the next 6 months the papers on the sensitivity analyses will be finalised, a simple nitrate leaching model for mapping climate change will be formulated, and the DAISY model will be run for the whole range of climate models at a few sites in Denmark. Also a methodology for spatially linking climate data with soil data and mapping the results for Denmark will be implemented.

The publication plan includes

- Revision of a paper on comparision of methods of parameterisation of soil organic matter model and sensitivity of greenhouse gas emissions to climate change.
- A paper on climate sensitivity of optimum nitrogen application and resultant effects on nitrate leaching.
- A paper on effects of climate change on N cycling in different arable crop rotations
- A paper on scale effects and variability between RCM's on nitrogen cycling in arable crop rotations in Denmark

Impacts on forestry and ecosystems (University of Lund)

The LPJ-GUESS dynamic ecosystem model is being used to simulate current forest composition, biomass NEP, NPP, soil and vegetation carbon in a number of natural and semi-natural forested regions in Europe included in the EUROFLUX project. The model has been validated for 15 flux-sites across Europe. The validation has been performed for CO_2 and water fluxes and shows agreements with measured data for most sites, by also large deviations for some sites. The validation will be finished and after that work on the scenarios will being. LPJ-GUESS model must be run for 200 years from 1901 to 2100. This requires filling the gap from 1991 to 2070 and contact has been made to the Hadley Centre on this issue.

Uncertainties in estimating resource potential under changing climage (FEI)

Analyses of the estimated impacts of climate change on the thermal suitability for cultivation of grain maize, sunflower, and soya in Europe have been performed. A simple temperature-based index, effective temperature sum (ETS) has been computed for observed climate in the 1961-1990 baseline period and projected climate during 2070-2099 based on outputs from a range of GCMs and RCMs. All analyses are conducted on a regular 0.5 x 0.5 degree grid across Europe.

A method requiring information on the standard deviation of daily mean temperature around the monthly mean is being used to estimate ETS from monthly mean temperature data. We have created a new interpolated gridded dataset of standard deviations for Europe based on observed daily station data for the 1961-1990 period. At a later stage, climate model results will used for comparison to that as well as to estimate standard deviation values for the 2080s.

Mapped estimates have been performed of the uncertainty in the future extension of the northern limit of suitability under different model-based scenarios, and also investigate if the risk of harvest failure is likely to be affected by changes in interannual temperature variability.

The model-based analysis was carried out using temperature estimates from 7 GCMs for the SRES A2 and B2 emission scenarios. We have started to enlarge our analysis using the PRUDENCE suite of RCM data; however, no results can be presented yet.

Computer routines to calculate the remaining climate impact indices (heating degree days, cooling degree days, Lieth models of biomass, growing season) have been developed and tested.

The main difficulties encountered were the handling of RCM data, as routines to handle the RCM's native grids and to interpolate these to some common raster have to be developed. This work is more demanding than we first anticipated.

For the next 6 months the main focus will be on the analysis of RCM-based impact indices. Interpolation routines have to be implemented for that. After setting up all climate model data (GCMs and RCMs), an extensive analysis with all promised impact indices will begin. An additional index that estimates the amount of N leaching caused by agricultural activity (will be
suggested by PRUDENCE partner DIAS) will be looked at also.

The publication plans include:

- Paper (possibly two papers, one for observed and one for RCM-based): The variability of daily mean temperatures in Europe (standard deviation work - target submission date early 2004)
- A paper on mapping uncertainties in European resource potential for climate changes simulated by global and regional climate models (general paper discussing the mapping of indices for GCM and RCM projections - target submission date, late 2004)

Uncertainties in modelled predictions of extremes of the Mediterranean Basin (UEA-CRU)

The analyses of uncertainty in the Mediterranean Basin will primarily concentrate on analysis of heat waves and cold spells, and of droughts and high-intensity rainfall. Daily data have been downloaded for the following RCM's: DMI, HadRM3, SMHI, UCM and MF. The variables include daily maximum, minimum and mean temperatures, rainfall and evapotranspiration from a selection of grid points in the RCM, chosen to represent the geographical diversity of Mediterranean environments. The scenarios and ensembles include a common period *a* (1961-1990), *A2a*, and *B2a* (both 2070-2100). These are available for all models. HadRM3 has the additional ensembles *A2b*, and *A2c* that will improve assessment of uncertainty.

The HadRM3 data have been used data to create the following indices of annual precipitation extremes: maximum length of dry spell, maximum running rainfall total over 1, 3, 5, and 7 days, and start and end days of drought. These data have also been used to create the following indices of annual temperature extremes: maximum annual spell > 25° C, number of days/year > 25° C, maximum annual 30-day running mean, number of days > 95th percentile of July temperatures, and degree days > 27° C.

The precipitation and temperature extreme indices were used to provide a preliminary assessment of likely changes in the primary conditions affecting soil water balance between 1961-1990 and 2070-2100 for the A2a and B2a scenarios. Preliminary analysis of seasonal

Mediterranean evapotranspiration (calculated using the modified Blaney & Criddle method) indicates that summer evapotranspiration will increase by about 2.5 to 3.0 mm/day under the A2a scenario.

For the coming period the following activities will be undertaken:
1. Following the discovery of an inconsistency in the current run of HadRM3, the Hadley Centre withdrew the data. Data from the new run of HadRM3 are now available and currently being pre-processed in CRU. The HadRM3 analysis described here will be rerun with the new data within the next two weeks.
2. Create indices and repeat the analysis for DMI, SMHI, UCM, and MF models. The grids are slightly different, so we will do inter-model comparison by interpolating results onto a 0.5° x 0.5° latitude longitude grid.
3. More models have been made available – repeat analysis as appropriate.
4. Since evapotranspiration is a derived variable, we will compare the results from the Blaney & Criddle method (as used above) with versions of the Hargreaves and Priestley-Taylor methods.
5. Uncertainties will be estimated using inter-model variability and, where available, differences between ensembles.

PRUDENCE WP4 Deliverables

No.	Month	Deliverable	Status
A. Agriculture in a South European region			
D4A1	12	Crop-climate model verified for response to adaptive options under current climate	Delivered
D4A2	12	Report on response of crop and biomass production, water use and sustainability indicators for a wide range of climate change scenarios	?
D4A3	30	Report on effectiveness of adaptive management options for a restricted range of climate change scenarios	
D4A3	34	Report on uncertainty in climate model estimation of soil water balance parameters in the Mediterranean region	
B. Agriculture in a North European Region			
D4B1	16	Soil-plant-atmosphere model verified for response to adaptive options under current climate	Delivered
D4B2	30	Report on response of crop production and nitrogen cycling for a wide range of climate change scenarios	
D4B3	34	Report on the effectiveness of adaptive management options and effect on mitigation strategies for a restricted range of climate change scenarios	
C. Impacts on forestry, ecosystems, health, transport, energy, etc.			
D4C1	12	Simulations of present day forest landscapes and ecosystem processes from selected regions under current climate	Delivered
D4C2	18	Validation of model output under current climate against forest inventory data at selected sites	Delivered
D4C3	18	Simulations of ecosystem processes at selected EUROFLUX sites from 1994	Delivered
D4C4	34	Modelled predictions of both vegetation and ecosystem processes for selected forest regions for the period 2071-2100 using the regional climate model outputs and their various SRES scenarios	
D4C5	12	Analysis, interpretation and presentation of present and future	Delivered

		resource potential (simple impact models and indices) in GIS
D4C6	34	Analysis, interpretation and presentation of uncertainties in D4C5 in GIS

PRUDENCE WP4 Milestones

No.	Month	Milestone	Status
A. Agriculture in a South European region			
M4A1	16	Crop-climate model verified under current climate conditions	Achieved
M4A2	30	Analysis of response of crop and biomass production, water use and cropping sustainability for a wide range of climate change scenarios completed	
M4A3	32	Analysis of uncertainty in model estimation of Mediterranean soil water balance parameters completed	
M4A3	36	Analysis of effectiveness of adaptive options completed	
B. Agriculture in a North European Region			
M4B1	16	Soil-plant-atmosphere model model verified for adaptive options under current climate conditions	Achieved
M4B2	30	Analysis of response of crop production and water use for a wide range of climate change scenarios completed	
M4B3	36	Analysis of effectiveness of adaptive management options and impact on mitigation strategies completed	
C. Impacts on forestry, ecosystems, health, transport, energy, etc.			
M4C1	16	Simulations from ecosystem model verified under present climate using inventory data and preparation of GIS environment	Achieved
M4C2	20	Simulation of ecosystem processes verified using EUROFLUX sites	Achieved
M4C3	32	Predictions and analysis of vegetation and ecosystem processes in selected regions using the RCM SRES scenarios and results from impact modelling of resource potential	
M4C4	36	Assessment of the different RCM modelled outputs in terms of the impacts on forest ecosystems and analysis of uncertainties in impact modelling of resource potential	

Summary of WP5 discussions, 31 Sep-2 October 2003

(David Stephenson, UniReading)

Present:

- UREAD: David Stephenson, Chris Ferro
- UFRI: Martin Beniston, Brigitte Koffi, Stephane Goyette
- CRU: Jean Palutikof
- GKSS: Hans Von Storch, Katja Woth
- FMI/SYKE: Kirsti Jylha
- Other: Ole Christensen, Geert Lenderink, Christoph Frei

DS began by setting out the objectives for the meeting: deliverables, obstacles to progress (including data needs), and collaboration within WP5 and with other WPs.

Data issues

OC reported that some of the HadRM3P data would be available by mid-October 2003. KW highlighted the need for 6 hourly wind speed data and that she has special arrangements with 4 of the modelling groups to supply this but still does not have this from the Hadley centre. HVS noted that it would be useful to provide 6 hourly (or even hourly) data from all models for future applications of PRUDENCE data. Ole pointed out the practical problems of doing this.

Choice of models to investigate

There was a discussion about the purpose of WP5: to probe in depth certain RCMs to answer scientific questions OR to assess variation across all RCMs to survey the uncertainty of the results. Since it will not be feasible in the remaining 12 months to go in-depth for all models, a compromise is needed to get a good balance of depth versus breath. Some of the WP5 partners intend to survey (nearly) all of the available RCMs (CRU, FMI/SYKE) whereas other partners will go in to more in-depth on a well-chosen subset of the models. It was proposed that WP5 should consider as many RCMs as feasibly possible, whereas GCM comparisons will be performed in WP2. Furthermore, it was decided that WP5 would concentrate on the more aggressive A2 scenario rather than examining the B2 scenarios. The need for a priority list of RCM runs to investigate was noted and this idea was fed up to the cross-cutting committee for discussion. The selection of models can be done in various ways depending on the scientific questions to be addressed. Christoph Frei explained that he would make use of Michel Deque’s multidimensional scaling technique to select other interesting models to investigate.

Progress with deliverables

The progress of all partners was reviewed. All WP5 partners have now started analysing the available RCM runs. Much progress has been made towards all the WP5 deliverables that are in the form of reports for public dissemination.

Two deliverables are due on due on month 24 (Nov 2003): D5B1 and D5A3 on wind extremes. D5B1 is on target for completion on time but it is likely that D5A3 will be slightly delayed to month 33 due to problems encountered model wind speed data (e.g. low wind speeds over orography in HIRHAM). University of Fribourg will analyse extreme wind events in several RCMs for selected severe events. HVS expressed great interest in the gust-parameterisation scheme developed by SG and so UFRI and GKSS will collaborate on this in order to improve wind speeds over land currently underestimated by the REMO model.

KJ presented work on resource risk performed by FMI/SYKE. Substantial progress has been made at probing a range of RCMs and it is planned to widen this activity to all possible RCMs. FMI/SYKE will focus on extreme indices for cold events rather than heat waves in order to avoid unnecessary replication of work being done by U. Fribourg and CRU. FMI/SYKE started discussions with CRU about extremes indices in the RCM runs.

All other deliverables are on target.

Collaboration

Collaboration between partners was reviewed. Partners in WP5 have developed very good working collaborations. However, it would be beneficial if GKSS and U. Fribourg could liase more closely on wind extremes. FMI/SYKE and CRU will also start to liase more on extremes indices and also on interpolation of data onto CRU grid.

All partners in WP5 plan to collaborate together to write a joint article on risks/extremes (draft deadline: Spring 2004). This can then be included in the special issue volume proposed for PRUDENCE by the cross-cutting committee.

All partners in WP5 found the Spring 2003 WP5 workshop highly beneficial and stimulating and therefore would like to repeat this activity in 2004. A workshop in Chateau d'Oex on 28/29 Feb or 6/7 Mar 2004 was agreed up on. Partners will check their availabilities and travel budgets ASAP to identify any obstacles.

Collaboration with other workpackages was also discussed but no strong working links could be easily identified apart from a link with WP3 with
U. Fribourg on hydropower and statistical advice for WP2 diagnostics to be provided by U. Reading.

Status of PRUDENCE WP6: the role of PRUDENCE on European climate policies

(Kirtsen Halsnæs, URC RISØ)

WP6 Products

1. Economic concepts, examples linked to cc modelling outputs and impact assessment, ***URC***
2. Adaptation, linkages to other EU policies. **URC.**
3. Integrated mapping of climate change impacts and vulnerable sectors:
   - Population
   - Urban areas
   - Agriculture
   - Forestry

   URC contact IIASA to look for datasets. **Hadley** support generation of maps.
4. Decision making framework and the treatment of uncertainties - Climate Change index Approach. Eventually use a standard set of SD indicators to evaluate difference between earlier IPCC impact results and regional Prudence results:
   - Glaciers
   - Biomes, vegetation (coping line)
   - Crops: vineyeards, maize
   - Health (heat comfort index)
   - Tourism (skiing)
   - Water availability
   - Human settlements

   Information source include: UKCIP, approach and data
   Results to be compared with climate change impact costing studies (Richard Tol – IVM working papers, Climatic Change) + case studies with Yohe.
   Cross-cutting dicussion of results including considerations about uncertainties. IPCC impact reporting format.

Cired + Hadley

5. Synthesis paper comparing cc impacts and mitigations costs at regional scale in Europe. ***Cired supported by URC comments.***
6. 2 days workshop with presentation on key impact and mitigation cost information to European policy makers and other stakeholders. Organised by **URC, Cired, Hadley**. Participation could include steering committee, EU Environment Directorate, all member countries, a few NGO's, private companies. Funding is sought for meeting facilities, organisation, and proceedings. Time: medio September.

Timeline

Early February, 2004:

- URC submit drafts of 1 and 2
- URC and Cired meet for one day meeting
- Cired: submit annotated outline of 4 and initial reflections on 5.
- CIRED and URC meet
- Discussion of workshop programme

March to May

- URC do 3.
- Cired draft 4 and 5 (mitigation cost component).

1 May
- Cired sent request for data and calculations for 4. to Hadley (back to CIRED 1. June?)
- Data and calculation requests to LMD France
- Invitations for workshop to be send (Cired)

End of August
- URC and CIRED meet to discuss project results and to plan workshop

Cross-fertilization meeting, 1 October 2003

(Rapporteur Jean Palutikof)

Attendance: Tim Carter, Jens Christensen, Ole Christensen, Richard Jones, Jørgen Olesen, Jean Palutikof, David Stephenson.

Decisions

Model characteristics
More information on model characteristics is needed on the PRUDENCE web pages to guide impacts work. Half a page for each model, written by the modeling group, would be ideal. The gallery pictures, which intercompare spatial patterns in the models, are available on the web page. Jens will let WPs 3, 4 and 5 know this.

A paper setting out the validation of the PRUDENCE model is required, to underpin the work of the impacts groups. Jens will lead on this and there will be a draft by Christmas.

It was recommended that the common diagnostics package developed by the University of Reading group in WP5 would form a useful analysis platform for the validation work.

Impacts people should make interesting characteristics they discover about the models known to the modeling groups. Modellers should have the opportunity to 'moderate' comments of impacts groups.

Model data considerations
The impacts groups require some form of prioritization of the models, since many groups will find that there are simply too many models to analyse all. [*Tim Carter and Ole Christensen produced a draft priority list before the end of the Wengen meeting*.]

A deadline needs to be set, after which new model data arriving on the PRUDENCE web site will not necessarily be analysed by the impacts groups [*This deadline was set as 1st December 2003*.]

It was decided to shave the model data on the PRUDENCE web site, to avoid the impact analysts picking up edge effects. [*This is currently being done*.]

It was decided that Ole would compute the monthly means of climate variables, and make these available on the web site.

Richard Jones has documentation on the Precis model (HadRM3P, which will be used in WP 3, 4 and 5), including information on the sponge zone. This could usefully be provided on the PRUDENCE web site.

Dissemination
Jens is to approach Steve Schneider to discuss the possibility of a Special Issue of Climatic Change devoted to PRUDENCE. Jens would be the Guest Editor for this.

A flagship discussion paper in a journal such as *Bull. Am. Met. Soc*. was proposed, with Jens as first author.

An edited book was suggested, but received much less support.

Meeting between MPS Co-ordinators

Wengen, 3rd October 2002-10-07

Jens, Clare and Jean present

Items:

The planned event for WP6 in September should be coordinated with activities in MICE and STARTDEX. Kirsten Halsnæs is to contact Jean Palutikof for details.

A common MPS meeting during the lifetime of the three projects was discussed. However, it seems unlikely to find time or money for such an event. Therefore another approach needs consideration. Many partners in the three projects will take part in ENSEMBLES and a possibility to arrange a meeting towards the end of 2004/ early 2005 as part of that project should be considered. Jens proposed to contact groups in Latvia and Estonia to see if there was an option for a venue there. The reason is that the price level for a conference could be considerably lower than usual.

The possibility of producing a final MPS brochure was discussed. The question of funding came up. Apparently, there is little help to get support from Brussels. But the budget and the preparedness of support from Brussels needs to be assessed.

The idea of using a common journal for final reporting was discussed again. The idea of approaching Climatic Change was raised. Jens will contact the editor regarding this.

WENGEN-2003 Workshop

ESF Exploratory Workshop

PRUDENCE 3rd Annual Meeting

Regional Climate Change in Europe: Processes and Impacts

Synthesis Report

The Wengen-2003 Workshop took place from September 29 to October 3, 2003, and brought together over 70 climate and impacts scientists from 20 countries. The meeting was in part sponsored by the European Science Foundation, as part of its Exploratory Workshop series. It was also the opportunity to bring together European scientists working within the EU 5th Framework Program "PRUDENCE" project (EVK2-CT-2100-00132), and an opportunity to have invited lectures by leading international specialists in climate-related domains. A first Workshop on regional climate modeling was held in Wengen in 1996, and this year's event was the first opportunity in the context of the "Wengen Workshops on Global Change Research" to revisit some of the issues discussed during Wengen-1996. While there have been significant achievements in high resolution climate modeling, it became apparent at the Wengen-2003 meeting that there is still a need today to focus on regional climate sensitivity for a number of reasons:

- to improve our understanding of the regional response to global climatic change;
- to assess the relations between mean climatic change and climatic extremes;
- to establish a meaningful dialog between climate modelers, impacts modelers and policy-makers, to promote true interdisciplinary research.

In this context, the Wengen-2003 Workshop had the primary objective of addressing these issues in order to:

- exchange views on the scientific and technical issues related to high resolution climate modeling;
- discuss the results of the simulations of regional climate futures in Europe under conditions of enhanced atmospheric greenhouse gas concentrations using a range of Regional Climate Models (RCMs);
- discuss approaches to regional-scale estimates of climate and the sensitivity of different regions to shifts in mean and extreme climates;
- evaluate the needs of the modeling community in terms of observational data for the calibration and validation of climate model results;
- foster discussion between climate modelers and impacts specialists.

The following paragraphs represent a summary of the main sessions of the Workshop, as compiled by the session chair persons.

Session 1: Modeling Activities I

There is a need to assess the confidence of climate-change projections. The sources of uncertainties in climate projections are due to:

- observational limitations (creating multiple means of validation)
- future GHG concentration (SRES emission scenarios affected by societal, demography and technology factors); uncertainties in carbon cycle make it difficult to relate anticipated emissions to ensuing concentrations

- natural variability (30-year climatology is just a convention)
- uncertainty in the response of the climate system (justifying the use a wide range of climate modelling systems)

There is a need for a concerted cross-disciplinary effort to assess the various components of uncertainty.

Some 21 groups participate in PRUDENCE, and a hierarchy of models are used: 3 coupled atmosphere-ocean CGCMs, 4 atmosphere-only AGCMs (including a stetched-grid model), and 8 nested RCM with grid meshes of 50 and 20 km. Some of these models are employed to simulate as many as 3-member ensembles. An important goal of the projects is to analyse the output of these models with respect to climate impact models.

The process of dynamical downscaling from global coupled simulations at 300 km grid mesh down to 50 km (and even to 10 km in some cases) increases the "weather" realism of climate simulations and generates more information; but the question of how to validate these simulations remains. While 50-km meshes appear to be required for realistic weather simulations, there still appears to be some orographic precipitation problem at this resolution. With 25-km meshes, the orographic precipitation problem is lessened, and it almost disappears at 10 km. The question of how to compare model simulations with observations, and at which scales, remains mainly open, in part due to factors of resolution and of observational constraints. It is clear that the computational mesh does not represent the physical resolution of the simulation: once filtered to remove shorter than about 3 or 4 grid-point information, the resulting fields appear to be rather realistic. Similarly a lateral buffer around the perimeter of nested RCM exhibit non-physical behaviour; this zone includes the nesting / sponge zone, plus some (imprecisely defined) extra internal region where fields undergo adjustment.

In summary:

- Uncertainties can and should be addressed using the PRUDENCE data set
- There is a trend towards using even higher resolution; this will allow for more details
- The uncertainties addressed in PRUDENCE are still apparent at higher resolutions

There is a need to identify aspects, where resolution is essential and provides robust results across model formulations etc.

An RCM is a valuable tool for detailed investigations of climate change, providing quite realistic simulations

In any climate-change simulation, it is important to verify how well the control run compares with recent past climate. While this is not a sufficient condition, it seems a necessary one to fulfil for trustworthy climate-change results.

Monthly mean circulation statistics and interannual variability in the PRUDENCE control run in Western Europe have been analysed and compared to available observation statistics for the period 1961-1990. Although 30-yr mean circulation in Western Europe has varied significantly over the past 220 yr, the 1961-1990 climate appears to have been fairly normal. In the control run the simulated circulations falls in general within the range observed over the past 220 yr, although models tend to exhibit too high (low) frequency of westerly flows in winter (spring & summer). The simulated annual temperature cycle is realistic, although there is a warm bias in winter and a somewhat smaller warm bias in summer. Simulated interannual variability of temperature is realistic.

The interannual variability of temperature can be modelled quite accurately using simple predictors such as geostrophic wind and surface wind direction. The circulation bias appears to be responsible for the temperature bias in winter; this bias is not small in comparison with global warming scenarios. This finding reinforces the need for carefully checking the control runs with respect to circulation biases.

A study of uncertainty in the climate-change signal in the PRUDENCE runs for the 2-m temperature and precipitation over Europe in the winter (DJF) and summer (JJA) seasons has been performed. In total some 20 model experiments were compared in order to try to identify the contribution from various sources of uncertainty, relating to 4 aspects of the modelling system: sampling, radiative forcing, GCM boundary conditions, and RCM formulation. Sampling errors are due to natural variability and the finite size of the simulation experiments: ensembles of up to 3 members are used. Radiative forcing uncertainties arise from the various SRES scenarios that are employed: A2 or B2 for PRUDENCE. GCM boundary conditions from various centres used to provide SSTs and to nest the RCMs: Hadley Centre, MPI or CNRM. Finally several models are used: several AGCMs and RCMs. The contributions from different sources of uncertainty can be identified by comparing simulations that use a same set of components for 3 of them and differ in only 1.

The results can be summarised as follows. While there clearly are uncertainties, these are smaller than the average climate-change response. In both seasons 2-m temperature uncertainties are ordered as follows (in decreasing order of importance): SRES scenario, boundary conditions, model, and sampling. For precipitation, uncertainties are ordered as follows (again in decreasing order of importance): boundary conditions, model, SRES scenario, and sampling. Thus the main source of uncertainty is related to radiation forcing (the choice of SRES scenario) for temperature and to boundary conditions (the choice of GCM to provide the boundary conditions) for precipitation. This last finding reinforces the importance of continuing to improve GCMs for climate-change studies.

Climate-change downscaling can be understood by considering that local climate change can be composed of (1) large-scale changes associated with globally changed GHG concentration and (2) regional-scale changes associated with (a) changed large-scale circulation and (b) local forcing such as changed SST, vegetation, soil moisture, etc. Following this decomposition regional-scale climate changes can be studied, using GCM to find changing frequency of large-scale circulation patterns, and RCM to find local/regional anomalies associated with these circulation patterns. Circulation patterns can be identified into a specified number of classes and ranked in frequency. This decomposition has permitted to identify that a significant part of the variance can be explained by orography and land-sea distribution. Such an approach will permit to answer the question to what extent regional changes can be explained by changes in circulation pattern frequency.

The development of fully coupled regional climate systems continues. Such coupling may be necessary to capture regional-scale feedback effects that are present in the climate system.

Session 2: Modeling Activities II

Christoph Schaer (ETH) documented that this year's warm weather in Central Europe was quite exorbitant, if the PDF of the previous period should be taken literally, with a theoretical return period of several million years (a more than 5 sigma event). The PRUDENCE RCM simulations from ETH, DMI, and GKSS show, however, that not only the mean summer temperature but also the interannual variation of this quantity could be growing in the future. Thus, the present warm summer could be an indication that the climate is in transition to a different temperature PDF with a larger variation, possibly due to excessive warming when the soil gets very dry.

Geert Lenderink (KNMI) presented results from a new version of the Dutch RCM RACMO. The most important changes have been a thicker soil (larger water storage) and a new, non-linear relation between evaporative resistance and soil moisture (stress function). The new model shows a reduced bias of European summer temperatures. There has still been problems in the ability of the model to reproduce weather systems of the driving model; in order to investigate this problem a new strict relaxation of winds has been introduced. This improves the situation.

Dave Rowell (HC) talked about the drying of Southern Europe in the future indicated by several PRUDENCE RCMs. Possible causes for this are:

- Spring drying
- Generally increased T
- Changes in the large-scale circulation
- Local feedbacks

Several RCM experiments have been set up to investigate which of these causes is the most important. Changes in large-scale circulation seems to be at least partly the cause. An estimate is that 40% of precipitation change is due to circulation changes and warming, 30% to spring drying, and 30% to local feedbacks (reduced evaporation).

Michel Deque (CNRM) presented a talk by Florence Sevault about the CNRM Mediterranean Sea model driven with PRUDENCE fluxes and without surface salinity relaxation. Surface warmings are about 3K with average water column warmings of 1.1K in the east and 1.4K in the west, 2.7K in the shallow Adriatic. Winter convection may be turned off by climate change.

Tomas Halenka (Charles University) presented the plans of the Czech associated partner to perform simulations with the French RCM Aladin.

Trond Iversen (University of Oslo) and Jan-Erik Haugen (met.no) presented the Norwegian climate research initiative RegCLIM, phase 3. With the Bergen climate model, time-slice simulations have been performed starting from different phases of the Atlantic overturning, which has a characteristic period of about 100 years. These different starting points results in "ECHAM-like" and "HC-like" climate change, respectively. Results of Norwegian HIRHAM runs with ECHAM and HC boundaries were presented, and the effects of combining these two runs through a signal scaling with global temperature change was presented.

Session 3: Modeling Activities III

The session started with a keynote presentation by R. Jones on precipitation and flooding in regional models. The 90th percentile over the Alps of the number of wet days has a good fit with observations. The fit of grid box GEV distribution over UK is also good, which yields some confidence in the model behavior as far as extreme precipitation is concerned. When considering A2 scenario, the 20-year return period precipitation has a frequency multiplied by 7. However using two different driving GCMs produces different responses on the UK.

The following presentation by D. Jacob addresses the problem of scale mismatch between RCM and hydrological basins. Even at 1/6º, the REMO model has problems when defining a catchment line to produce data for hydrologists. A possible solution is to use a river routing model which works at the same resolution as the RCM. With such a coupled model, the Elbe flooding event of summer 2002 was well captured. The discussion about this presentation was rather animated: can we exploit directly grid box hydrologic data from an RCM ?

The presentation by J. Schmidli was a comparison of the PRUDENCE RCMs driven by ERA15 re-analysis data. Taylor diagrams show a considerable variation between models, but no single best model. Erik Kjellstrom showed that, according to the use of the HC SST or MPI SST in the Baltic Sea, summer precipitation increases or decreases over this region in the A2 scenarios. Using a coupled model over the Baltic sea allows to export part of the atmospheric heating in the North Sea and thus reduce the summer warming. The different behavior in the Baltic Sea between the coupled and the HC SST-forced run depends on the NAO index sign.

The following presentation by B. van den Hurk addresses precipitation in the Rhine catchment. A strong daily pattern autocorrelation appears in the RCM as an artifact from the orography. The model is less random in space as observation. In the A2 scenario the precipitation efficiency, dfined as the ratio of total precipitation over water input, decreases. The last presentation of the session, by B. Rockell, was no more focussed on the hydrological cycle, as the preceding talks, but on radiative cycle. The CLM non-hydrostatic model has been used to produce PRUDENCE scenarios. One of the most salient features is the decrease in total cloud cover in summer and increase in winter.

Session 4: Modeling Activities IV

Pier-Luigi Vidale presented analyses of CHRM-simulation for the Alpine region. A comparison to other RCMs shows similarities among all of them. The A2-scenario contains longer dry spells and a stronger annual cycle in soil water content compared to the control run. The maximum of convection during the day is too early. Surprisingly, the daily cycle of precipitation does not change, but the amount of precipitation associated with rainfall events does. This raises the problem that the vegetation in the CHRM is related to today's climate, and there is no dynamical link between vegetation and climate change that may modify the surface-atmosphere feedbacks in a future climate.

Enrique Sanchez summarized analyses of the UCM-simulation for the Mediterranean region. The A2- scenario contains a strong increase of T-Max (up to 8K) compared to the control. The variability of the T-Min is increased, while the B2- Scenario shows similar but attenuated features, and no increase in the variability of T-Min in summer. More differences are observed in the precipitation patterns.

Shimon Krichak provided data analyses of today's climate in the Eastern Mediterranean. During the last decades, the incidence of heavy precipitation is lower in Israel. This is in contrary to the situation that has affected Spain in the same time frame. The reason seems to be trelated to the positive trend in the North Atlantic Oscillation (NAO) Index and the behavior of the East Atlantic/West Russia Oscillation. First sensitivity studies with MM5 show a systematic underestimation of T-Min of between 5 to 10K.

Virginie Lorant investigated the fraction of convective precipitation compared to total precipitation with the Canadian CRCM over the Baltic drainage basin during the PIDCAP period. There seems to be an underestimation of the number of dry days as well as days with extreme precipitation as a result of the very small contribution of convective precipitation (about 10%) to overall rainfall in the region. Sensitivity tests using a prognostic closure instead of the diagnostic closure within the convection scheme show an increase in days without convective precipitation, more convection during the day (afternoon) and a stable boundary layer at night. The results do not appear to be dependent on the chosen resolution or region.

Session 5: Extreme Events and Impacts I

There were six talks during this session by D. B. Stephenson and C. Ferro of the Department of Meteorology, University of Reading (UK), M. Haylock of the Climatic Research Unit (CRU), University of East Anglia (UK), B. Koffi, from the Department of Geosciences, University of Fribourg (Switzerland), O. B. Christensen from the Danish Meteorological Institue (DMI, Copenhagen, Denmark), and S. M. Mendes, Evora Geophysics Center, University of Evora (Portugal). The topics, which in some instances were of an overview nature ranged from statistical methods, to the diagnostics of observed and simulated extreme precipitation and heat waves. While the former has found connectiosn to the large-scale circulation and atmospheric synoptic conditions, the later have been studied in the context of climatic change in the framework of the HIRHAM (1961-1990) and (2071-2100) simulations over the common PRUDENCE extended domain covering the northern North Atlantic and Western Europe.

As pointed out in the very beginning of this session, there is still some uncertainty related to the definition of an "extreme" event, which include the many qualitative and quantitative degrees of perception of the phenomenon. In particular, at the economic end, one should be careful to not always relate extreme loss to the severity of the weather. The key question concerning extremes is the following: how are they currently behaving under today's climate and how are they going to respond to climatic change? To study them, a statistical approach of extremes is indeed required; however, to understand their origin, a meteorological study is also desirable. Some highlights of the talks include winter (December-January-February of DJF) observed extreme rainfall behaviour that has been analysed; results seem to suggest that the principal components of the number of consecutive dry days and those of the number of days above the 1961-90 90^{th} percentile of wet day amounts are correlated to the climate of the North Atlantic, with the North Atlantic Oscillation (NAO) playing a significant role. The analysis of heat waves, as simulated with the HIRHAM4 of the Danish Meteorological Institute at 50-km resolution, presented in terms of heat wave frequency and heat wave duration indices, reveal that the frequency and duration should increase by a factor from 3 to 10 on average, implying that, for example, South-west France or Hungary may experience occurrence of temperature above 30°C as frequently as currently observed in Southern Spain or in Sicily. In addition, the study of extreme precipitation also indicated a drying on average in Central and Southern Europe in late summer coincides with increases in extremes precipitation in a number of regions.

Finally, during this session's discussion, it has been emphasised that more efficient communication between the WPs and the "stat" people is needed in order to ensure a better development of a "stat analysis tool kit", suited for particular needs, concerning particularly the "extremes".

Session 6: Extreme Events and Impacts II

Christoph Frei gave a comprehensive presentation on S*cenarios of European precipitation extremes: An analysis and intercomparison of RCM simulations.* An analysis was presented of precipitation *extremes* and *not-so-extremes* in 3 RCMs: CHRM, HadRM3 (ensemble of 3 runs), and HIRHAM. STARDEX indices were presented and climate change differences tested for statistical significance using non-parametric bootstrap tests. Extreme precipitation events were also modelled using the GEV probability model (maximum likelihood fits). Seasonal maxima were used to do the GEV fits and care was taken to include only non-zero maxima. To get better estimates of the GEV parameters, the geophysical prior approach of Martins and Stedinger (2000) was used. Model results were evaluated by comparison with precipitation data from 6471 Alpine stations aggregated on regional climate model scale. Christoph presented the mean annual cycle of the mean and 90% quantiles over the Alps. The models were able to reproduce the Autumn peak in the 90% quantile although there were some biases. Winter wet day intensity shows enhanced intensity along the Alpine region – all models were able to capture this but there were some important quantitative differences. RCM results and ERA15 forced RCM results were found to be very similar and so were not affected by GCM driving. The biggest differences were found in HadRM3, which is drier when driven by ERA15. RCMs tended to be wetter in Spring and Autumn when driven with RCMs than when driven directly with ERA15. In summary, the RCMs show encouraging skill at reproducing mesoscale patterns of precipitation. Christoph then went on to present differences between the scenario and control runs. Relative change in DJF mean precipitation maps showed decreases to the south of 45N and increases in northern Europe of up to about 30%. Relative changes in wet day frequency were less than changes in the mean but decreases in the south were similar to changes in the mean. All three models showed increases in wet-day intensity in the north with a strange low patch in central Europe in two of the models. Changes in the 5-year extreme 5-day rainfall return level showed a similar picture to precipitation intensity. In northern Europe, rare extreme events became three times more frequent: the 15-year event became a year event in the future scenarios. The 20-year return levels showed less statistically significant changes. A quantitative summary of Scandinavia was presented of the relative change of various statistics. Mean change was equally due to changes in wet day frequency and intensity. Summer mean changes showed similar spatial patterns for different models but magnitudes differed. HIRHAM did not show much drying whereas CHRM showed strongest drying mainly due to changes in wet-day frequency in CHRM. Wet-day intensity changes were less consistent across models. The changes in 1-day 5-year return values were not very statistically significant. Maximum number of consecutive dry days in JJA showed that central Europe spell lengths decreased by 50% with similar patterns between models. In the final summary, Christoph noted that winter magnitudes varied little between RCMs and showed similar behaviour for different quantiles, there was more variation between model changes in JJA, and heavy summer precipitation only increased slightly (over Central Europe).

Tido Semmler gave an interesting presentation on *Modelling extreme events – a climate change simulation over Europe using the regional climate model REMO*. Tido started by presenting a validation of REMO5.1 precipitation extremes for today's climate. Various quantities were investigated: the number of days with precipitation above thresholds of 1mm/day, >10mm/day, >25mm/day and GEV return levels estimated using a local pooling method. Bootstrap techniques were used to assess sampling uncertainty but no attempt was made to take account of spatial dependency between neighbouring grid points. For the validation Tido compared REMO maximum annual precipitation and the number of dry days with aggregated gauge observations over two regions in southern Germany (Bavaria and Badenwurtemburg). REMO slightly underestimated the number of dry days but the number of days with >10mm/day were well represented in REMO with realistic spatial and orographic variation. The 10 and 20-year return levels were well reproduced by REMO. The number of dry days per year showed increases in the scenario runs except over the Baltic warm anomaly. The number of >10mm/day extreme events increased in both northern and southern Europe. The 10-year return levels increased by up to 100% (>50mm/day) all over Europe. The more rare 20-year return level showed large increases over the Baltic, central Europe and Mediterranean. Tido concluded that the REMO model was able to simulate precipitation extremes reliably, and that in the future scenarios there were more dry days and more intense precipitation events.

Hans von Storch gave a thought-provoking presentation on *Recent and future changing coastal climate: storminess and impacts for the North Sea*. Hans started by reviewing the concept of dynamical downscaling using a state-space formalism – he stressed that our dynamical knowledge is encoded in regional model. He explained how spectral nudging was acting on the large-scale states. A plot of variance versus scale was used to show where models were doing fine. There are well-described large-scales plus knowledge encoded in the regional model. Hans then went onto to show results of the REMO regional model with NCEP large-scale forcing. The precipitation simulated by REMO was in good agreement with the NCEP precipitation – even the precipitation maximum off of the southwest coast of Norwegian coast as seen in the observations. However, area means of cloud amount were found to be biased when compared to ISSCP data. The 10m wind speeds at Ekofisk in the North Sea agreed very well the observations (measured on the platform at 80m but scaled down). However, the REMO model wind speeds did deviate from real world at some times. Hans interpreted this to mean that the regional model develops its own dynamics – this is not an error but just that the boundary information is not sufficient to influence the interior. Hans then went on to show the 1st EOF of zonal wind in the German bight and the adjacent coastal zone and concluded that the model cannot discriminate well between different points and so hypothesised that this could be why regional models do so well at simulating extremes locally (as claimed by Richard Jones). Wind speeds at various buoys were compared with REMO results and this showed that the REMO simulation gives improvement (added value). Hans also showed significant wave heights and the wave-height response to hourly REMO winds. Extreme values of winds at platform K13 were well simulated. The 20-year 10m wind speed return value maps of station data and REMO were compared. It was noted that although good over the sea, REMO severely underestimates the wind speed extremes over land. Hans went on to discuss changes in the past 40 years in storm surges and 99-percentiles of geostrophic winds obtained from pressure readings 1881-2002. Storm proxies 1820-2001 from Lund and Stockholm obtained by counting storms from local SLP readings showed no long-term trend in storm numbers. The number of storms in REMO model with Beaufort 8 winds or more in 8-hours were counted and showed downward trends until 1970 and then upward trends from 1970 onwards then things became calmer after 1995. Hans also discussed long-term trends in high waters 1958/9-1997/8 over North Sea. The 90% quantile wave height had trends of about 2cm/year from 1955-1993 (1m over 40 years) in REMO. Hans concluded that the regional model was not that bad over marine and land, that storminess trends has reversed trend in recent years, and that storm surges have shown slight increases in the past 40 years. Hans finished his talk by emphasising the clustering of climatic events such as Alpine floods (as compiled by Pfister since the 1500s) and argued that we should put more attention into understanding the clustering of climate extremes.

Katja Woth gave a clear presentation on *How certain are changes in North Sea storm surges extremes expected at the end of the 21st century?* Katja started by discussing severe extra-tropical storms such as Vivian that produced behind the cold front strong (>30m/s) westerly winds over a large area. Such winds push water towards the coast in the shallow seas around the German bight, Netherlands, and Denmark. Katja then went on to define storm surge as fluctuations in sea-level height due to meteorological events – and explained that wind stress is generally more important than the inverse barometer effect (of around 1cm/hPa). It was explained that storm surges had a big effect on coastal geomorphology, dykes, ocean traffic, and offshore constructions. Katja then presented results from the 10km resolution 1-level TRIM surge model forced by RCM winds. The TRIM runs ignore increases in sea level due to global warming and also ignore surge coming from the Atlantic basin. Katja showed a validation of the model for the 16/17 February 1962 surge event of 3.6m that was well reproduced along the German bight. The TRIM model has been forced with winds from the HIRHAM and RCA control and A2 scenarios. The HIRHAM runs only show a change in wintertime surge percentiles along the continental coast not along the UK coast. In general, there were no obvious changes in the mean but there were large changes in the 99% percentile of up to 0.3m along the coast of the Netherlands. A similar story was obtained with the RCA model but with a slightly weaker yet similar pattern. The 5-year return storm surge values were computed and showed changes of up to 60cm along the northwest coast of Europe. The 50-year return values rose by 1m along the continental coast. However, the 99% percentile wind speed only increased by 0.7m/s and there was no obvious change in the mean. To find out how such a small change in wind speed could lead to such large changes in storm surge, a directional analysis of winds coming from different sectors has been performed. This showed that in certain sectors, there was up to 20% increase in the high percentiles of wind speed. It was concluded that direction of extreme wind speed changes was important for understanding the surge response.

Session 7: Climate Impacts and Climate Change Policies I

This session included four presentations; the first three concerned impacts from climate change and the fourth was a presentation from one of the regional climate models (in place of a scheduled impacts presentation that was cancelled). Kirsten Halsnaes opened her keynote presentation, “The value of improved climate information in relation to investments in the agricultural sector,” with some overall questions to the modelling community. How important are climate change impacts on human welfare and what are the economic impacts of climate change compared to the costs of mitigation? Such issues need to be brought forth to address socio-economic aspects of climate change. Evaluation should be based on sustainability indicators as an alternative to monetary impact assessments. Some focal impact areas are crops, tourism, water availability, human settlements, glaciers and vegetation. Her presentation ended with a general request to other Prudence partners to open a dialogue on how we can best communicate the outcomes of Prudence to policy makers. A workshop with decision makers and a few selected Prudence participants will take place toward the end of 2004.

Jean Palutikoff presented “Predicted impacts of climate change on soil moisture availability in the Mediterranean.” This presentation focused on the question, will there be summer continental drying with increased risk of drought? Using the widely-available modelled climate variables temperature and rainfall, an index of soil moisture was created for Europe south of 50˚N. In addition, other indices including maximum length of dry spell, start of drought, end of drought, and maximum 5-day running sum were investigated. The results indicate that summer drought in the Mediterranean will become much more of a problem according to the modelled future climate.

Pablo Morales presented "LPJ guess: validation and an application of a dynamic ecosystem model using EUROFLUX data and RCM model output." The LPJ-GUESS ecosystem model is being used to assess the responses of different European forests on changing climate using a range of RCM outputs generated within Prudence. It was shown to accurately predict seasonal patterns in net ecosystem exchange (NEE) and actual evapotranspiration (AET) for most EUROFLUX sites, with the exception of Mediterranean and maritime evergreen forest sites. Scenario results from one RCM indicate both changes in species composition of existing forests and changes in their geographic distribution for a future climate.

The final presentation by Jeremy Pal was titled "Variability and extremes in regional climate simulations for the European region: preliminary results." He presented results from the RegCM model control simulation, and the A2 and B2 scenario simulations. Although the control simulation reproduces the main features of observed average and interannual variability of temperature and precipitation, it shows a systematic bias of overestimating interannual variability, particularly in the Mediterranean region. The scenario simulations show that the RegCM tends toward lower temperature increases than the global HadAM3H used for boundary conditions.

Session 8: Climate Impacts and Climate Change Policies II

The first part of the climate impacts session at the workshop was devoted to research activities in workpackages 3 and 4 of the PRUDENCE project. The session did encompass a total of 5 presentations, two of which were keynote presentations.

The theme of the first two presentations was hydrological impacts. In his keynote Phil Graham presented results from offline hydrological modelling (using the HBV model) and a simple flow routing scheme, both forced by output from regional climate models (RCMs). An evaluation of the model chain for several large-scale catchments in the Baltic Basin yields promising results with the seasonal runoff cycle and major inter-catchment differences being adequately represented. But the repartitioning between runoff and evapotranspiration was quite different between different driving RCMs. Also presented were results from the application of regional climate change scenarios (using RCM output with the delta method), which show a general trend of reduced river flow from the south of the Baltic Basin together with increased river flow from the north.

Jan Kleinn presented a related study for the river Rhine in Central Europe. He compared results between RCMs with a high (i.e. 15-km) and a standard (i.e. 50 km) resolution. While the high-resolution RCM depicted more plausible distributions of mean precipitation, the skill in reproducing the observed runoff was very similar between the two model resolutions. Application of the model chain with a surrogate climate change scenario, points towards the remarkable sensitivity of the runoff regime and peak runoff to the intensification of the hydrological cycle and the repartitioning of snow and rainfall expected with future global warming.

The three following presentations were concerned with the modelling of climate change impacts on crops. The keynote by Carlos Diaz-Ambrona focussed on the application of two different crop models in Spain. The crop models employ soil polygons (34 soils with varying depth, layer texture and profile) onto which meteorological output (temperature, precipitation, relative humidity, wind, solar radiation) from RCMs is mapped. The model chain was assessed using RCM integrations with perfect boundary conditions. Good agreement was found with the observed mean yield in areas of northern Spain, whereas in some other areas smaller-scale orography (not resolved by the RCM) appears to be the main challenge to the model chain.

Stefan Fronzek and Timothy Carter developed a statistical model to study the thermal suitability for cultivating various crops across Europe. Their index, an effective temperature sum (ETS) based on monthly mean temperatures and standard deviation of daily temperatures, was computed from observations and from a range of GCM and RCM scenarios for the late 21st century. The results indicate a substantial northward extension of crop suitable areas with climate warming. The magnitude of this extension however varies considerably between different GCMs, and this component of the impact's uncertainty appears to be larger than that from the emission scenarios.

Jørgen Olesen studied crop production using a soil-plant-atmosphere model on crops typical for arable farming in Denmark. The DAISY model simulates crop production as well as changes in soil C and N under changing climate and changing CO_2 concentrations. Modelling experiments indicate that nitrogen turnover and losses from soils were more sensitive to the climatic and atmospheric changes than crop yield itself. The results imply that future climate change may have more significant effects on nitrate leaching than on productivity and this pinpoints to the importance of additional factors (such as yield quality and secondary environmental impacts) for adaptation strategies.

Last-day sessions

The last-day sessions were devoted to five invited talks by internationally-recognized experts, namely René Laprise (University of Quebec at Montreal, Canada) on new techniques to optimize the use of regional climate models when initialized by global model or re-analysis data; Gilles Sommeria, currently at the World Climate Research Program at WMO headquarters in Geneva, who provided an in-depth overview of climate-related programs sponsored by the World Meteorological Organization; Rick Katz (National Center for Atmospheric Research, Boulder, Colorado, USA, currently on sabbatical in Switzerland and Austria), who brought a statistical slant to the meeting, Linda O. Mearns (currently on sabbatical at the Abdus Salaam International Center for Theoretical Physics in Trieste, Italy), one of the pioneering figures of “nested modeling techniques”, who presented a study on the uncertainty of spatial resolution of models when attempting to assess the sensitivity of US agriculture to climatic change. Finally, André Berger (Université Catholique de Louvain, Louvain-la-Neuve, Belgium), gave an honorary lecture on the long-term forcing of climate in the context of the Milankovich cycles and related these to current and future trends in climate.

Document compiled by Martin Beniston on the basis of
chairpersons’ reports prepared by René Laprise, Michel Déqué,
Ole B. Christensen, Daniela Jacob, Stéphane Goyette,
David B. Stephenson, Phil Graham, and Christoph Frei.

Fribourg, Switzerland, October 16, 2003

ESF Exploratory Workshop

WENGEN-2003 Workshop

REGIONAL CLIMATIC CHANGE IN EUROPE: PROCESSES AND IMPACTS

Scientific Programme

Monday, September 29, 2003

	08:15-08:45	Opening remarks: objectives of science and PRUDENCE business Martin Beniston and Jens H. Christensen ESF Sponsorship: A representative of the European Science Foundation
		SESSION 1: MODELING ACTIVITIES
		Chairperson: René Laprise, University of Quebec at Montreal, Canada
1.1	08:45-09:30 Keynote	Assessing uncertainties in climate projections using the PRUDENCE simulations Jens H. Christensen, PRUDENCE Coordinator Danish Meteorological Institute, Copenhagen, Denmark
1.2	09:30-10:00	How representative is the interannual variability of the PRUDENCE control run in Western Europe? Aad P. van Ulden KNMI, De Bilt, The Netherlands
1.3	10:00-10:30	Uncertainties in the temperature and precipitation response of PRUDENCE runs over Europe Michel Déqué Météo-France, CNRM, Toulouse, France
	10:30-11:00	Coffee, tea, refreshments
1.4	11:00-11:30	Evaluation of coupled GCM/RCM runs based on circulation patterns Dietrich Heimann and Maria José Costa Zemsch DLR, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Weßling
1.5	11:30:12:00	Water mass analysis of a regional coupled Mediterranean simulation S. Somot1, K. Haines2, M. Deque1, F. Sevault1 and M. Crepon3 1: Meteo-France, CNRM, France; 2: University of Reading, ESSC, UK; 3: CNRS, IPSL, France
	12:00-14:00	Lunch

Monday, September 29, 2003

		SESSION 1: MODELING ACTIVITIES (Continued)
		Chairperson: Ole Bøssing Christensen, DMI, Copenhagen, Denmark
1.6	14:00:14:4 5 Keynote	Climate change and the water cycle: from processes to scenarios Christoph Schaer Atmospheric and Climate Science ETH, Zürich, Switzerland
1.7	14:45- 15:15	Influence of boundary relaxation schemes on the warm summer bias in RACMO Geert Lenderink KNMI, De Bilt, The Netherlands
1.8	15:15- 15:45	Causes of future summer drying over Central Europe Dave Rowell Hadley Centre for Climate Prediction and Research, Bracknell, UK
	15:45- 16:15	Coffee, tea, refreshments
1.9	16:15-16:45	A simulation of the Mediterranean Sea driven by PRUDENCE fluxes for the 1960-2100 period Florence Sevault METEO-France, CNRM/GMGEC, Toulouse, France
1.10	16:45-17:15	On the development of a regional climate model for Central Europe Tomas Halenka Department of Mathematics and Physics, Charles University, Prague, Czech Republic
	18:30	Icebreaker

Tuesday, September 30, 2003

		SESSION 2: MODELING ACTIVITIES
		Chairperson: Michel Déqué, Météo-France, Toulouse, France
2.1	08:30- 09:15 Keynote	Reasons for changes in precipitation distributions in several RCM simulations and the implications for flooding Richard Jones Hadley Centre, Bracknell, UK
2.2	09:15- 09:45	Scale mismatch in coupling hydrogical and atmospheric models at the catchment scale Daniela Jacob Max-Planck-Institute for Meteorology, Hamburg, Germany
2.3	09:45- 10:15	Interannual precipitation sensitivities in RCMs: An evaluation of ERA-driven RCMs in the Alpine region Juerg Schmidli Atmospheric and Climate Science ETH, Zürich, Switzerland
	10:15- 10:45	Coffee, tea, refreshments
2.4	10:45- 11:15	Future changes in summertime precipitation over the Baltic Erik Kjellström SMHI, Norrköping, Sweden
2.5	11:15- 11:45	Analysis of wind and precipitation changes in the area around the Netherlands, calculated with a regional climate model Bart van den Hurk, Erik van Meijgaard, and Gert Lenderink KNMI, De Bilt, The Netherlands
2.6	11:45- 12:15	Results from simulations with the CLM for PRUDENCE Burkhardt Rockell GKSS Research Center, Geesthacht, Germany
	12:15- 14:00	Lunch

Tuesday, September 30, 2003

		SESSION 2: MODELING ACTIVITIES (Continued)
		Chairperson: Daniela Jacob, Max-Planck-Institute, Hamburg, Germany
2.7	14:00:14:30	Regional climate under a warming scenario: Views from the Alps Pier-Luigi Vidale, Daniel Lüthi, Christoph Frei, and Christoph Schaer Atmospheric and Climate Science ETH, Zürich, Switzerland
2.8	14:30-15:00	Climate change projections in the Mediterranean area with a Regional Climate Model Enrique Sanchez Universidad Complutense, Madrid, Spain
2.9	15:00-15:30	Role of the Eurasian decadal trends in the Eastern Mediterranean climate Simon O. Krichak and Pinhas Alpert Department of Geophysics and Planetary Sciences, Tel Aviv University, Israel
2.10	15:30-16:00	Variation of precipitation intensity: Sensitivity to the treatment of moist convection in a GCM and a RCM Virginie Lorant Canadian Centre for Climate Modeling and Analysis, Victoria, B. C., Canada
	16:00-16:30	Coffee, tea, refreshments
		PRUDENCE BUSINESS MEETING: FIRST SESSION
	16:30-17:30	Plenary Meeting 1: Objectives of breakout group sessions
	17:30-18:30	Breakout group sessions

Wednesday, October 1, 2003

		SESSION 3: EXTREME EVENTS AND IMPACTS
		Chairperson: Martin Beniston, University of Fribourg, Switzerland
3.1	08:30-09:15 Keynote	Statistical methods for diagnosing changes in extreme events David B. Stephenson Department of Meteorology, University of Reading, UK
3.2	09:15-09:45	Extremes in a non-stationary climate: a statistical approach Christopher Ferro Department of Meteorology, University of Reading, UK
3.3	09:45-10:15	Interannual variability of European extreme winter rainfall and lins with large-scale circulation Malcolm Haylock Climatic Research Unit, University of East Anglia, Norwich, United Kingdom
	10:15-10:45	Coffee, tea, refreshments
3.4	10:45-11:15	Heat waves in Europe under climate change Brigitte Koffi Department of Geosciences, University of Fribourg, Switzerland
3.5	11:15-11:45	Extreme precipitation in the DMI PRUDENCE simulations Ole Bøssing Christensen Danish Meteorological Institute, København, Denmark
3.6	11:45-12:15	Heavy precipitation episodes as simulated by the regional climate model HIRHAM4 Susana Margarida Mendes Evora Geophysics Center, University of Evora, Portugal
	12:15-14:00	Lunch

Wednesday, October 1, 2003

		SESSION 3: EXTREME EVENTS AND IMPACTS (Cont.)
		Chairperson: David Stephenson, University of Reading, United Kingdom
3.7	14:00-14:30	Scenarios of European precipitation extremes: An analysis and intercomparison of RCM simulations Christoph Frei, Sophie Fukutome, Jürg Schmidli and Regina Schöll Atmospheric and Climate Science ETH, Zürich, Switzerland
3.8	14:30-15:00	Modelling extreme events - a climate change simulation over Europe using the regional climate model REMO Tido Semmler Max-Planck-Institute for Meteorology, Hamburg, Germany
3.9	15:00-15:45 Keynote	Recent and future changing coastal climate: storminess and impacts for the North Sea Hans von Storch1, Ralf Weisse1, Arnt Pfizenmayer1, Frauke Feser1, Lars Bärring2 and Hans Alexandersson3 1: GKSS Research Center, Geesthacht, Germany; 2: Lund University, Sweden; 3: SMHI, Norrköping, Sweden
3.10	15:45-16:15	How certain are changes in North Sea storm surges extremes expected at the end of the 21st century? Katja Woth GKSS Research Center, Geesthacht, Germany
	16:15-16:45	Coffee, tea, refreshments
		PRUDENCE BUSINESS MEETING: SECOND SESSION
	16:45-18:30	Working Group Breakout Sessions

Thursday, October 2, 2003

		SESSION 4: CLIMATE IMPACTS AND CLIMATE CHANGE POLICIES
		Chairperson: Christoph Frei, ETH-Zurich, Switzerland
4.1	09:00-09:45 Keynote	Runoff in regional climate models – evaluation of simulations and assessment of impacts Phil Graham SMHI, Norrköping, Sweden
4.2	09:45-10:15	Climate change and runoff statistics: A process study for the Rhine Basin using a coupled climate-runoff model Jan Kleinn Institute for Atmospheric and Climate Science ETH, Zurich, Switzerland
4.3	10:15-10:45 Keynote	Assessment of different climate outputs with crop model in Southwestern Europe Carlos G. H. Diaz-Ambrona E. T. S. I. Agonomos, Universidad Politecnica de Madrid, Spain
	10:45-11:15	Coffee, tea, refreshments
4.4	11:15-11:45	Mapping shifts in crop suitability under a range of SRES-based climates Stefan Fronzek and Timothy R. Carter Finnish Environment Institute, Helsinki, Finland
4.5	11:45-12:15	Climate change and CO2 influence crop production and nitrogen cycling in arable cropping systems Jørgen E. Olesen Danish Institute of Agricultural Sciences, Tjele, Denmark
	12:15-14:00	Lunch

Thursday, October 2, 2003

		SESSION 4: CLIMATE IMPACTS AND CLIMATE CHANGE POLICIES (Cont)
		Chairperson: Phil Graham, SMHI, Norrköping, Sweden
4.6	14:00-14:45 Keynote	The value of improved climate information in relation to investments in the agricultural sector Kirsten Halsnaes Risoe Research Centre, Risoe, Denmark
4.7	14:45-15:15	Predicted impacts of climate change on soil moisture availability in the Mediterranean Jean Palutikoff Climatic Research Unit, University of East Anglia, Norwich, UK
4.8	15:15-15:45	LPJ guess: Validation and an application of a dynamic ecosystem model using EUROFLUX data and RCM model output Pablo Morales, Deniz Koca, Martin T. Sykes, and Ben Smith Geobiosphere Science Center, Lund University, Sweden
4.9	15:45-16:15	Extreme weather events and the insurance industry Andreas Tuerk Department of Economics, University of Graz, Austria
	16:15-16:45	Coffee, tea, refreshments

		PRUDENCE BUSINESS MEETING: THIRD SESSION
	16:45-17:45	Working Group Breakout Sessions / Cross Cutting Issues
	17:45-18:30	Plenary Meeting 2: Reports of Working Group Breakout Sessions
	After supper	CLOSED PRUDENCE MEETING: MANAGEMENT BOARD SESSION

Friday, October 3, 2003

		SESSION 5: A VIEW OF SCIENCE FROM OUTSIDE OF PRUDENCE
		Chairperson: Jens H. Christensen, DMI, Copenhagen, Denmark
5.1	09:00-09:45 Keynote	Validation of the downscaling ability of Regional Climate Models using the “Big-Brother” experimental protocol René Laprise University of Quebec at Montreal (UQAM), Montreal, Quebec, Canada
5.2	09:45-10:30 Keynote	Title to be defined Keynote speaker to be defined: perhaps Michel Jarraud, new Secretary-General of WMO ??
	10:30-11:00	Coffee, tea, refreshments
5.3	11:00-11:45 Keynote	The uncertainty due to spatial scale of climate scenarios in integrated assessments: An example from US agriculture Linda Mearns International Center for Theoretical Physics, Trieste, Italy
5.4	11:45-12:30 Keynote	Misconceptions about the use of extreme-value theory in climate change assessments Richard Katz National Center for Atmospheric Research, Boulder, Colorado, USA
	12:30-14:00	Lunch
		SESSION 6: HONORARY LECTURE
		Chairperson: Jean Palutikoff, University of East Anglia, United Kingdom
6.1	14:00-15:00 Honorary Lecture	Honorary Lecture: From the astronomical theory to sustainable development André Berger Université Catholique de Louvain, Louvain-la-Neuve, Belgium

Friday, October 3, 2003

		PRUDENCE BUSINESS MEETING: FOURTH SESSION
	15:00-15:45	Plenary Session 3: Wrap-up of PRUDENCE research in 2002/2003
	15:45-16:15	Coffee, tea, refreshments
	16:15-18:30	Plenary Session 4: Outlook of PRUDENCE research to the end of the program
	18:30	Closing remarks and end of the meeting

Saturday, October 4, 2003

All Day	Optional excursion to the Jungfraujoch High Alpine Research Station

Abstracts of Oral Presentations

(Listed in the order in which they appear in the program,
with the corresponding reference number)

Assessing uncertainties in climate projections using the PRUDENCE simulations

Jens Hesselbjerg Christensen

Danish Meteorological Institute, Copenhagen, Denmark

Simulations of natural climate variability and of human impact on climate are essentially probabilistic in nature, due to uncertainties in the formulation of initial conditions, the representation of physical processes within models, as well as climatic forcing factors such as inherent from emission scenarios of greenhouse gases and atmospheric pollutants. As a consequence reliable estimates of future climatic risk and/or safety can only be made through an ensemble approach using many different integrations of climate models in which these uncertainties are explicitly incorporated. PRUDENCE has provided a milestone in trying for the first time to address this huge challenge with an array of climate models, although still at a relatively modest scale. In contrast to the upcoming project ENSEMBLES, in which a common ensemble climate forecast system will be developed for use across a range of timescales (seasonal, decadal and longer) and spatial scales (global, regional and local). PRUDENCE has focused on a specific time and geographical region for scenario construction. The essence of the project is with a substantial set of regional climate models to probe uncertainty space rather than mapping it entirely. Probability forecasts made with the PRUDENCE models are exploited by linking the outputs of the ensemble predictions to a wide range of applications. In turn, feedbacks from these impact areas back to the climate system will also be assessed and possibly provide valuable information to be included in coming projects such as for example ENSEMBLES. At this stage of the project most of the climate simulations have been finalised and it makes sense to assess the ability to probe various types of uncertainties.

In this paper the role of RCM model formulation, including physical parameterisations and model resolution as a contributor to uncertainty aspects is addressed based on the simulations made available by the PRUDENCE consortium. A first attempt to probe the uncertainties cascading down the chain of models from GCMs to some of the PRUDENCE impacts models will likewise be addressed.

1.2

How representative is the interannual variability of the PRUDENCE control run in Western Europe?

Aad P. van Ulden

KNMI, De Bilt, The Netherlands

A control run with a global climate model cannot be perfect. Such runs may have systematic bias errors, and also errors in the variability of the atmospheric circulation. In addition, a control run of e.g. 30 y is relatively short, and may not represent the full interannual variability. Long observation records are available of pressure patterns and temperatures over Western Europe. The PRUDENCE control run (HADCM) and the RACMO simulation driven by this run are compared with these long observation records, with an emphasis on the interannual variability of monthly and seasonal averages of geostrophic wind and temperature over Western Europe.

1.3

Uncertainties in the temperature and precipitation response of PRUDENCE runs over Europe

Michel J. Déqué

Météo-France, CNRM, Toulouse, France

One of the scopes of the PRUDENCE project is to better document the uncertainties about the climate projections and their sources. To this purpose, various experiments have been conducted using A2 or B2 scenarios, various RCM, and various boundary conditions. By using different simulations in which one parameter varies, the other ones being constant, it is possible to identify to which extent the model response is sensitive to the parameter. Although the uncertainties, measured by the mean absolute error, are not additive, it is instructive to compare them with each other and with the mean climate response.

Four causes of uncertainties are analyzed. The first one is statistical sampling, through the use of ensemble scenarios. The second one is radiative forcing, through the use of A2 and B2 scenarios. The third one is SST forcing, since the CNRM model has been forced with two types of SST anomalies, coming from coupled scenarios with the Hadley Centre model and the CNRM model. The fourth one is the regional model itself, as several RCMs have been used with the same SST and radiative forcing.

1.4

Evaluation of coupled GCM/RCM runs based on circulation patterns

Dietrich Heimann and Maria José Costa Zemsch

DLR, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Weßling, BRD

A multiyear time series of a coupled GCM/RCM run is evaluated with respect to circulation patterns in the RCM domain. The goal of this investigation is to study dependencies between certain large-scale circulations types and regional-scale anomalies. Such correlations can be used to predict regional-scale climatological anomalies from GCM predictions. As an example it is shown that more than 70 percent of the year-to-year variability of temperature and precipitation in Central Europe can be explained by shifts of the frequency of circulation patterns in the Eastern Atlantic - European area.

Water mass analysis of a regional coupled Mediterranean simulation

S. Somot[1], K. Haines[2], M. Deque[1], F. Sevault[1] and M. Crepon[3]

1: Meteo-France, CNRM, France
2: University. of Reading, ESSC, UK
3: CNRS, IPSL, France

A regional coupled ocean-atmosphere model (SAMM for Sea-Atmosphere Mediterranean Model) has been developed to study the climate variability of the Mediterranean basin. This model is based on a variable resolution version of the global spectral AGCM Arpege-Climat (developed by CNRM) and a limited area version of the OGCM OPA (LODyC). The two models are coupled with the OASIS coupler (CERFACS). The AGCM horizontal resolution is about 60 km over the Mediterranean basin and the OPA horizontal resolution is equal to 1/8 (9-12 km). Outside the Mediterranean Sea, the sea surface temperature is prescribed from interannual observed data (Reynolds). A twenty-two years coupled simulation (1977-1998) has been run without relaxation or flux correction.

For the Mediterranean Sea, the balance between surface heat flux and Gibraltar strait heat flux is shown in good agreement with observed data and other modelling studies. This condition is necessary for a realistic thermohaline circulation.

By applying a Walin-type method (Walin, 1982) to this air-sea coupled Mediterranean model, we present a qualitative and quantitative analysis of water mass transformations for the Mediterranean Sea. Walin's method is able to diagnose the relative impact of physical processes such as atmosphere-ocean fluxes and internal mixing (diffusive flux) on the water mass characteristics. The seasonal cycle and the interannual variability in these water mass transformations can also be assessed.

1.6

Climate change and the water cycle: from processes to scenarios

Christoph Schär, Christoph Frei, Martin Hirschi, Jan Kleinn and Sonia Seneviratne

Atmospheric and Climate Science, ETH Zürich, Switzerland

The response of the continental and sub-continental-scale water cycle to global climate change involves a wide range of physical processes. For the construction of climate change scenarios, it is essential to isolate the relevant key processes and appropriately represent the underlying nonlinearities. In this presentation, some of the key processes relating to cold-season orographic precipitation/runoff and to summer draught will be discussed and assessed.

The role of mountains is highly essential for precipitation and runoff formation. The key players affecting orographic precipitation relate to: the synoptic-scale flow impinging upon the mountain range, the associated atmospheric moisture content (that is expected to increase with a warmer climate approximately with the Clausius-Clapeyron relationship), and cloud-microphysical processes (that might experience a shift from cold to warm microphysics). It will be demonstrated that current interannual variations of orographic precipitation are primarily controlled by the variability of the synoptic-scale flow, thus representing at first approximation an essentially linear sensitivity. On the other hand, simple scale analyses demonstrate that climate change might imply a shift in sensitivity towards the non-linearities associated with the atmospheric moisture content and cloud-microphysical processes. Critical non-linearities also affect runoff formation in complex terrain. The key player for cold-season runoff formation is the expected (and observed) increase of the snow line. It is demonstrated how a hypsometric terrain analysis can help to assess the role and importance of this factor. The important role of seasonal terrestrial water storage (mostly in terms of soil moisture) for summer climates derives from the latent heat that is stored over extended periods. Over land, soil moisture entails multi-month memory effects and plays a similarly important role as the surface temperature over sea. Climate change is likely to affect the seasonal cycle of terrestrial water storage and thereby impacts upon the regulation of the surface energy balance. Such changes are difficult to assess, as little is known about the current seasonal evolution of terrestrial water storage, as future climates may imply soil moisture levels that are not or only rarely experienced under current climatic conditions, and as the feedbacks involve convective cloud formation and precipitation processes. It appears that a major effort is needed to better understand these factors and their nonlinear interactions. Recently derived data sets and modeling methodologies may be used to evaluate the ability of climate models to represent these critical processes. The nonlinearities discussed above need to be properly accounted for in order to assess future climates (rather than merely representing current climate variations). This appears particularly difficult in the framework of statistical downscaling methodologies, but it also represents a major challenge to numerical downscaling studies.

1.7

Influence of boundary relaxation schemes on the warm summer bias in RACMO

Geert Lenderink

KNMI, De Bilt, The netherlands

KNMI recently developed a regional climate model based on HIRLAM dynamics and ECMWF (cycle 23r4) physics. With this model, called RACMO, a 15-year run driven by realistic boundaries from the ERA15 re-analysis project has been performed. RACMO turned out to suffer from a significant warm (and dry) bias in summer, in some years up to 8 K in southern and central parts of Europe. Modifications in the ECMWF physics package have resulted in a significant decrease on average of the summer bias. Nevertheless, in some summer months parts of France, Spain and the Benelux are still much warmer (4-8 K) than observed. It turned out the warm bias is related to a tendency of RACMO to overpredict the frequency of blocking situations. In these warm months, RACMO produced biases in the monthly mean sea level pressure of 4-8 hPa. Associated are warm south-easterly winds in western Europe. It turned out that the influence of the lateral boundary relaxation zone is crucial in these months. Different boundary relaxation zones produced significantly different pressure anomaly patterns. With a simple new scheme the pressure bias is reduced to 1-2 hPa, resulting in a strong reduction of the temperature bias. In addition, the new relaxation scheme strongly reduced spurious preciptation near the eastern boundary of the domain.

1.8

Causes of future summer drying over Central Europe

Dave Rowell

Hadley Centre for Climate Prediction and Research, Bracknell, UK

Global circulation models (GCMs) consistently predict that one of the effects of enhanced concentrations of atmospheric greenhouse gases may be a reduction in mean summertime precipitation over much of central and southern Europe. If this becomes a reality, significant stress on water resources and agriculture is likely to result, and thus it is important to assess the reliability of such projections.

The majority of studies to date have suggested that the primary driver of this reduced summertime precipitation is a springtime reduction in soil moisture content, mainly due to enhanced evaporation and reduced snowmelt in a warmer climate. However, two other possibilities which have received less attention are as follows: (1) changes in large-scale circulation driven by climate change in remote regions, and (2) the impact of regional variations in the pattern of local warming and an associated reduction in relative humidity over land.

An analysis of projected climate change for the latter part of the twenty-first century, using a high-resolution atmospheric GCM, HadAM3H, provides evidence that all three of the above ?drivers? may be causing the summer drying. However, in order to assess the reliability of this projected drying, it is necessary to be able to at least roughly quantify the relative importance of these local and remote mechanisms. Yet this cannot be achieved using the same global GCM data.

We have therefore designed a suite of sensitivity experiments which utilise a regional (European) version of HadAM3H. The relative contribution of each potential driver of summer drying is explored by altering the matrix of inputs to this model, so that in any one integration, some inputs are representative of the future climate state, and others are representative of the present climate state. Inputs that are altered in this way are: various components of the lateral boundary forcing, greenhouse gas and aerosol concentrations, SSTs, and soil moisture content. This enables us to assess whether future summer drying over Europe is predominantly caused by: regional variations in the local warming; remote circulation changes (divergence and/or storm track anomalies); or spring soil moisture anomalies. Furthermore, the role of positive feedbacks induced by evaporative anomalies over land is also assessed.

The analysis of these experiments will be presented, and their implications for an assessment of the reliability of projections of future summer drying over central Europe will be discussed.

A simulation of the Mediterranean Sea driven by PRUDENCE fluxes for the 1960-2100 period

Florence Sevault

METEO-France, CNRM/GMGEC, Toulouse, France

The OPAMED model of the Mediterranean sea (10 km resolution) has been forced by the daily surface fluxes of water, momentum and heat calculated in the 140-year AGCM simulation of the CNRM model in the framework of the PRUDENCE project. This global AGCM has a local resolution of 50 km in the Mediterranean sea, which is sufficient to produce a realistic regional forcing. The ocean model undergoes no relaxation nor correction, except the necessary adjustment of heat flux to surface temperature, and a buffer zone in the Atlantic. In particular, the fresh water fluxes come from the Atlantic ocean buffer zone, from the atmospheric hydrologic fluxes and from the river run-off.

The run-off comes from the AGCM simulation. After a 20 year spin-up period, the model is run for 140 years in an A2 simulation. The trends in temperature, current and salinity along the 21st century are analyzed, with a particular focus on the convection areas. Indeed, there is a competition between a salt drift due to the increase in evaporation and decrease in run-off (down to -50% in the Black Sea) and the surface warming drift due to the increase in greenhouse effect. The question of the propagation of the warming into the deep layers and of the difference in response between the eastern and western basins will be addressed.

1.10

On the development of a regional climate model for the Central Europe

Tomas Halenka

Dept. of Meteorology and Environment Protection, Fac. of Math. and Physics, Charles University, Prague, Czech Republic

The project with the aim to develop a regional climate model (RCM) for the territory of central Europe was launched in 2001 in the Czech Republic. The RCM is being developed by modifications of the spectral numerical weather prediction (NWP) model ALADIN, run operationally at the Regional Centre of LACE (Limited-Area Modelling in Central Europe) in Prague. It concentrates on the area of central Europe and is intended in close future to serve as a source of climate change scenarios on a regional and local scales for countries in that region, especially for the Czech Republic. The main feature of this RCM is its very fine horizontal resolution, first tests were done with 12 km, now due to technical reasons in 24 km, still being at the high end of current RCMs.

The ALADIN model proves to be integrable for longer time periods, far beyond its current operational use (up to 48 hours), after only minor modifications of rather a technical nature are implemented as well as the first attempts with modification of physical parameterizations. The presentation will summarize validation of recent experimental runs of the RCM, nested in the operational assimilations by the ARPEGE NWP global model, representing observed conditions, both for monthly experiments in summer and winter seasons and for one year simulations. The influence of a treatment of lower boundary conditions, interpolation at lateral boundaries, the effects of repeated restarts of the RCM as well as some sensitivity tests of parameterization are studied. The validation concerns (i) the upper-air fields, (ii) surface temperature and precipitation at the dense station network in the Czech Republic, as well as against continental-scale gridded climatologies, and (iii) vertical cross-sections.

During the development, supporting tests were completed with the RegCM2 and, finally, RegCM3 concerning the modelling sensitivity to geometry of the model area. Moreover, we use the RegCM to test the methodology for planning and organizing the experiments and for comparison with ALADIN. Finally, to understand the ability of RCM’s to capture the extremes the distribution of precipitation based on longer period experiments with RegCM are compared to real ones.

2.1

Reasons for changes in precipitation distributions in several RCM simulations and the implications for flooding

Richard Jones

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2.2

Scale mismatch in coupling hydrological and atmospheric models at the catchment scale

Daniela Jacob

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The application of coupled atmospheric and hydrological models to investigate climatic changes on catchment scale involves a hierarchy of scales eg. micro scale processes in the soil to meso scale features in the atmosphere.

In addition numerical grid point models of the atmosphere are not accurate on grid point scale due to the numerical schemes involved. However catchments are seperated by a clear 'line', which divides falling precipitation and resulting run-off into one or the other catchment.

An example will be presented to demonstrate the effect of precipitation falling into the wrong grid box along the interface between chatchments eg. falling into the wrong catchment and thus producing wrong run-off results.

A new methodology to overcome this problem will be presented.

Interannual precipitation sensitivities in RCMs: An evaluation of ERA-driven RCMs in the Alpine region

Juerg Schmidli

Atmoshperic and Climate Science ETH, Zuerich, Switzerland

The application of regional climate models (RCMs) for deriving climate change scenarios requires an accurate representation of climate sensitivities. In this study, observed interannual precipitation variations are considered as a manifestation of climate sensitivities due to variations in large-scale circulation and regional processes. These variations are used as a testground for the evaluation of RCMs. Formally the evaluation examines the skill of RCMs in representing the observed interannual variations, when the models are driven by perfect boundary conditions.

The evaluation focuses on the region of the European Alps. Evaluation statistics encompass several diagnostics (taken from the STARDEX list of indices), including mean precipitation, and statistics representative for heavy precipitation and drought spells. The observation reference is an objective analysis of daily precipitation fields covering the entire Alpine region at a resolution compatible with the models. This analysis is based on more than 6000 daily rain-gauge records in the region. Four RCMs are considered: REMO (MPI Hamburg), HIRHAM (DMI Copenhagen), HadRM (The Met. Office Hadley Centre Bracknell), and CHRM (ETH Zürich). All models are driven by the ECMWF reanalysis ERA15; they have a model domain covering all of Europe and a grid spacing of about 50 km. The model skills are visualized in the form of Taylor-diagrams, depicting correlation-, ratio of variance and debiased root-mean-square skills at one glance. Comparison of the model skills to that of ERA15 reveals the added value of the RCMs at the grid-scale of a general circulation model.

Future changes in summertime precipitation over the Baltic

Erik Kjellström

SMHI, Norrköping, Sweden

2.5

Analysis of wind and precipitation changes in the area around The Netherlands calculated with a regional climate model

Bart van den Hurk, Erik van Meijgaard and Geert Lenderink

KNMI, De Bilt, The Netherlands

In the context of PRUDENCE, KNMI has conducted RCM simulations for the HadAM3 control and SRES A2 scenarios. The major emphasis of the analysis of these simulations is on the hydrological cycle over the Rhine catchment and wind regime over the Northsea, as these areas are of most relevance to impact assessment applications in The Netherlands. An analysis of model sensitivities and impact of greenhouse gas scenario is discussed in the light of "impact relevant" parameters. These include probability distributions of P and P-E over the Rhine area for a range of integration periods, cumulative kinetic wind energy over the Northsea, and drought indicators including soil moisture storage on a seasonal time scale. The focus of the presentation is on the methodologies needed to enhance the consistency between various modelling tools in the impact assessment toolkit chain.

Results from simulations with the CLM for PRUDENCE

Burkhardt Rockel

GKSS Research Center, Geesthacht, Germany

The climate version of the non-hydrostatic weather forecasting model "Lokalmodell" of the German Weather Service is used in PRUDENCE for regional climate simulations. Here he model is set-up to run on a 0.5x0.5 degrees rotated grid, driven by boundary conditions provided by the Hadley Centre global model. Results will be presented for the control and SA2 scenario defined in PRUDENCE.

Regional climate under a warming scenario: Views from the Alps

Pier Luigi Vidale, Daniel Lüthi, Christoph Frei and Christoph Schär

Atmospheric and Climate Science -ETH, Zürich, Switzerland

The effects of climate change near elevated terrain still represent a very open research question, since the climate of elevated terrain regions is modulated by the interaction of the atmospheric circulation with orography at several temporal and spatial scales. In Europe, processes over the Alps, for instance, also influence the climate of neighboring regions, which are vulnerable in terms of their water supply.

In this climate change study we address the European regional impacts of precipitation processes by performing multi-year sensitivity experiments, using the CHRM regional climate model. The RCM is forced at the lateral boundaries with data from the HadAM3h GCM, integrated under a full SRES A2 scenario (and its complementary control simulation). By contrasting results from these simulations with those obtained previously from "perfect boundaries" experiments, we are able to assess the soundness of the climate change signal that is produced through the downscaling exercise.

The main results are analyzed in terms of long-term statistics of daily precipitation over the Alpine region, currently an important theater of intense storms, also associated with extreme events at the surface. The variability of processes which modulate the water cycle on the daily and seasonal time scale are also discussed.

Climate change projections in the Mediterranean area with a Regional Climate Model

Enrique Sanchez

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Regional climate modelling results for the last third of 21th century (2070-2100) focused in the Mediterranean area corresponding to two emission scenarios (A2 and B2 SRES) are presented. In this study a Regional Climate Model (PROMES) with 50 km horizontal resolution nested in a AOGCM (HadCM3) has been used. The results correspond to changes in seasonal averages and variances of temperatures, precipitation and other relevant climatic variables. A previous analysis of the RCM accuracy is made by comparing current climate simulation with available climatological grid data.

2.9

Role of the Eurasian decadal trends in the Eastern Mediterranean climate

Simon O. Krichak and Pinhas Alpert

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In addition to the widely investigated positive NAO trend, another, also positive trend of the East Atlantic/ West Russia (EA/WR) oscillation contributed to the Eurasian climate change developments during the last several decades. Joint effect of the two trends also played an important role in the climate processes in Israel during the period. Results of the very-high resolution simulation study of the December 4-5 severe flood in Israel additionally illustrate the climate consequences of the developments in Europe. Hydrodynamic regional climate modeling investigation of the current and future climate trends in Israel is currently being performed under the Joint German-Israeli GLOWA Jordan River Research Program in cooperation with the PRUDENCE. High-resolution regional climate scenarios for the Jordan River catchment and the adjacent regions over the E. Mediterranean (EM) region are to be elaborated using the MM5 based RCM model having horizontal resolution down to 6 km. An optimal modeling system version for the RCM applications over the EM has been designed and tested. Work on the realization of the RCM simulations according to the PRUDENCE program is in progress.

Variability of precipitation intensity : sensitivity to the treatment of moist convection in a GCM and an RCM

Virginie Lorant

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Future climate projections simulated by global and regional climate models suggest that the increase observed in the annual mean of total precipitation over the last 50 years in mid-and high latitude is most likely to continue in the next century. Given the fact that changes in the mean precipitation is often associated with relatively larger changes in heavy and extreme precipitation, it is anticipate that future climate might include more intense and frequent heavy precipitation events which will have profound effects on ecosystems and human activities. However, the shape and especially the upper tail of current climate precipitation distributions remain poorly reproduce by models. Improving precipitation distributions is a necessary step for improving simulation of climate change that offer greater hopes for reliable estimates of changes in heavy precipitation variability.

August to October 1995 simulations run with the Canadian Regional Climate model (CRCM) over the Baltic Sea region have shown that the precipitation distribution is significantly sensitive to the closure of the convection parameterization. The penetrative cumulus convection scheme used in the CRCM as described in Zhang and McFarlane (1995) is a mass flux type scheme with diagnostic closure. Following Pan and Randall (1998) a prognostic closure scheme has been implemented. Studies of sensitivity of the convective precipitation statistics and of the split between large scale and convective precipitation to this alternative closure have been carried out. It has been found that the prognostic closure used with low values of key dimensional parameter, which relates the cumulus kinetic energy to the cloud base convective mass-flux, are characterized by more frequent and stronger convective precipitation and enhanced cooling near the surface. Similar experiments carried out with the CCCma global climate model show that these results are robust and largely independant of the climate model or the specific regional area being modelled. Sensitivity of the near-surface cooling to modifications in land surface and boundary layer parameterizations will also be discussed.

3.1

Statistical methods for diagnosing changes in extreme events

David B. Stephenson

Department of Meteorology, University of Reading, Reading, UK

Extremes in a non-stationary climate: a statistical approach

Christopher Ferro

Department of Meteorology, University of Reading, Reading, UK

We present a statistical model for describing extremes of observed meteorological variables in a non-stationary climate. Fitting the model to observed and simulated data helps to characterise the ability of climate models to simulate extremes, and so informs our interpretation of simulated future climate. We illustrate the approach with data from the PRUDENCE regional climate change project.

Interannual variability of European extreme winter rainfall and links with large-scale circulation

Malcolm Haylock

Climatic Research Unit, University of East Anglia, Norwich, United Kingdom

December-February (DJF) extreme rainfall was analysed at 481 European stations for the period 1958-2000. Two indices of extreme rainfall were examined: the maximum number of consecutive dry days (CDD); and the number of days above the 1961-90 90th percentile of wet day amounts. A principal component analysis of CDD found six components that accounted for 54.5% of the total variance. Five components of DJF R90N were retained that accounted for 38.2% of the total variance. The second component of R90N has a very significant trend and the factor loadings closely resemble the observed linear trend in this index, suggesting that the analysis has isolated the mode of variability causing the trend as a separate component. The principal components of the indices were correlated with the climate over the North Atlantic. The best correlations were generally found to be with sea level pressure observations. A canonical correlation analysis of the two indices with sea level pressure revealed several coupled modes of variability. The NAO was isolated as the first canonical pattern for R90N. For CDD the first two canonical coefficients of CDD were significantly correlated with the NAO index. Generally the canonical coefficients with the highest correlations with the NAO had the most significant trends, suggesting that it is the observed trend in the NAO that has caused the observed trends in the indices. Two other important canonical patterns were isolated: a pattern of anomalous MSLP centred over the North Sea which seems to be related to local SST over this region; and a dipole-like pattern of MSLP with poles over the eastern Mediterranean and south of Greenland causing anomalous southeast airflow over the region.

Heat waves in Europe under climate change

Brigitte Koffi

University of Fribourg, Department of Geosciences, Geography, Fribourg, Switzerland

Changes in the intensity, duration and frequency of heat waves, between the latter 20th and the 21st centuries, for doubled CO2 concentrations are investigated. The daily maximum temperature (t2max) as simulated over Europe by the HIRHAM4 Regional Climate Model is examined for the 1961-1990 and 2071-2100 (scenario A2) periods. Mean changes in the t2max parameter are first investigated: An increase of t2max is observed over the entire European continent, which is higher for the highest temperature values. This increase is shown to be due both to changes in the central position and in the scale of t2max Probability Density Function; the latter one accounting for a larger part of the change in the higher percentiles of the PDF, i.e., in the increase of the highest temperature values. Resultant changes in the occurrence of hot days and heat waves, are then assessed, on the basis of several indices of high temperature: In addition to fixed threshold, exceedence of "site relative" thresholds are analysed, among which the Heat Wave Frequency (HWFI) and Heat Wave Duration (HWDI) Indexes. Results reveal that regions such as South-West France or Hungary may show, in a future climate, an occurrence of temperatures above 30°C as frequent as what was observed in the South of Spain or in Sicily during the 20th century. The mean HWDI and HWFI indices would increase in average by factors 3 and 10, in the latter 21th century with respect to the 1961-1990 period, respectively. Current investigations aim at further quantifying the statistical significance of those changes and analysing their relationships to circulation patterns.

Extreme precipitation in the DMI PRUDENCE simulations

Ole Bøssing Christensen

Danish Meteorological Institute, København, Denmark

Extreme daily precipitation has been analyzed for PRUDENCE simulations with the HIRHAM RCM driven with boundaries from the Hadley Centre.

Results for HIRHAM driven with boundaries from the ECHAM4/OPYC coupled GCM indicate that a drying on average in Central and Southern Europe in late summer coincides with increases in extreme precipitation over large areas.

Climate change signals of precipitation and related fields are investigated for several resolutions and ensemble members, and uncertainties of the results are studied with a bootstrapping method. Also other available simulations are investigated.

3.6

Heavy precipitation episodes as simulated by the regional climate model HIRHAM4

Susana Margarida Mendes

Evora Geophysics Center, Physics Department, Evora University, Evora, Portugal

The purpose of this work is to extend the results and conclusions produced by the analysis of extreme precipitation events simulated by the high-resolution (50 km) regional climate model HIRHAM4, driven by ECHAM4/OPYC output, under IPCC's scenarios A2 and B2. In the present study, HIRHAM4 is driven by the Hadley Centre's atmospheric global climate model HadAM3H, operating in the reference period 1961-90 and the scenario period 2071-2100, under A2 emission scenario. Extreme precipitation events are analysed, as well as the corresponding surface weather conditions, and the associated evaporation and runoff fields. The general results are similar to the previous ones, showing a reduction in the total mean precipitation simulated over Europe, and an increase in the frequency of intense events as well as in the rainfall amounts during their occurrence. Here, the focus on the individual developments responsible for the most extreme events is used to underline the realism of the model performance and to study the cause of the change in the tail of the intensity distribution.

Scenarios of European precipitation extremes: An analysis and intercomparison of RCM simulations

Christoph Frei, Sophie Fukutome, Jürg Schmidli and Regina Schöll

Atmospheric and Climate Science ETH, Zurich, Switzerland

An analysis and intercomparison is presented of changes in extremes of precipitation as simulated by three regional climate models (RCMs). The analysis encompasses a range of indices (taken from the STARDEX list), characteristic for the occurrence of heavy precipitation and long dry spells. Moreover return levels of heavy daily precipitation are estimated by means of Extreme Value Analysis.

Results will be compared between three 50-km RCMs (HadRM, HIRHAM and CHRM), all driven with output from the Hadley Centre Atmospheric GCM (HadAM3H) for two emission scenarios (SRES A2, B2). Where available, ensemble simulations are considered for a more reliable estimate of the extreme indices and return levels. An assessment of the scenarios for sampling uncertainty is undertaken using resampling techniques and extreme value confidence intervals.

Results for an early selection of indices indicate that the scenarios for heavy precipitation are very similar between the models for winter both in magnitude and spatial pattern. The increase of mean precipitation over most of the continent (north of the Mediterranean) is accompanied by a similar relative increase in high quantiles of daily precipitation. In contrast the results for summer vary by a factor of two in mean precipitation and exhibit different sensitivities in the statistics of dry spell lengths.

3.8

Modelling extreme events - a climate change simulation over Europe using the regional climate model REMO

Tido Semmler

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To assess ecological and economic impacts of climate changes in Europe and to develop mitigation and adaptation strategies it is necessary to get regional information on changing probabilities of extreme events. In this study, which is part of the EU project PRUDENCE, a high resolution climate change simulation is performed with REMO for the European region for the years 2071 - 2100 consistent with the SRES A2 emission scenario. Additionally a control simulation for the years 1961 - 1990 is made to compare the future climate with todays climate. REMO is driven by global model output from the Hadley Centre Atmospheric Model HadAM3H at the lateral boundaries. The following questions should be answered during the evaluation of the model results: How will the mean climate state and the climate variability change? Will there be changes in frequency and intensity of extreme events such as heavy storms, excessive droughts or floods? Which European regions are mostly threatened by extreme events? Will areas be affected by extreme events which are not currently affected? Results concerning these questions will be presented.

Recent and future changing coastal climate: storminess and impacts for the North Sea

Hans von Storch[1], Ralf Weisse[1], Arnt Pfizenmayer[1], Frauke Feser[1], Lars Bärring[2] and Hans Alexandersson[3]

1: GKSS Research Center, Geesthacht, Germany
2: Lund University, Sweden
3: SMHI, Norrköping, Sweden

Changing statistics of air pressure and wind speeds over Northern Europe in general and the North Sea in particular are examined, using long instrumental data from meteorological stations and ocean platforms. Also multi-century simulations with regional climate models are analysed with respect to changing storm characteristics. Consistent with previous results of the WASA project, no significant upward or downward trends of relevant storm indicators can be identified, even if significant decadal variability is found so that on time scales of decades and more significant trends prevail. Scenarios for possible future storm climates are prepared by dynamically downscaling global climate change IPCC scenarios. An increase in wind speeds and number of storms is found, which is, however, weak compared to the interdecadal variability of the past decades.

Parallel to changes in wind speed and other storm characteristics, the impact on waves and coastal wave energy is considered.

3.10

How certain are changes in North Sea storm surges extremes expected at the end of the 21st century?

Katja Woth

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The contribution is based on work carried out within the EU Project PRUDENCE as part of the task: An assessment of possible changes in North Sea storm surges in a future climate and of the uncertainty due to the driving model formulation.Possible changes in North Sea storm surge climate are derived by running the "TRIM_GEO" surge model forced by a series of 30-year atmospheric regional simulations under present-day and enhanced greenhousegas conditions. The first model runs will be presented, forced by different regional climate models for the control period 1961 to 1990 as well as for the scenario (2071 to 2100). They will be analyzed and compared with respect to possible changes in extremes of storm surges in the North Sea area and the statistical uncertainty of these estimations. The latter aspect will be discussed not only with respectto statistical significance of the simulated changes in time but also with respect to different model forcings from different RCMs.

4.1

Runoff in regional climate models – evaluation of simulations and assessment of impacts

Phil Graham

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Climate change and runoff statistics: A process study for the Rhine Basin using a coupled climate - runoff model

Jan Kleinn

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The consequences of extreme runoff and extreme water levels are within the most important weather induced natural hazards. The question about the impact of a global climate change on the runoff regime, especially on the frequency of floods, is of utmost importance.

In winter-time, two possible climate effects could influence the runoff statistics of large Central European rivers: the shift from snowfall to rain as a consequence of higher temperatures and the increase of heavy precipitation events due to an intensification of the hydrological cycle. The combined effect on the runoff statistics is examined in this study for the river Rhine. To this end, sensitivity experiments with a model chain including a regional climate model and a distributed runoff model are presented. The experiments are based on an idealized surrogate climate change scenario which stipulates a uniform increase in temperature by 2 Kelvin and an increase in atmospheric specific humidity by 15% (resulting from unchanged relative humidity) in the forcing fields for the regional climate model.

The regional climate model is based on a mesoscale weather prediction model of the German Weather Service (DWD) and has been adapted for climate simulations. The model is used in a nested mode with horizontal resolutions of 56 km and 14 km. The boundary conditions are taken from the original ECMWF reanalysis and from a modified version representing the surrogate scenario. The distributed runoff model WaSiM-ETH is used at a horizontal resolution of 1 km for the whole Rhine basin down to Cologne. The coupling of the models is provided by a downscaling of the climate model fields (precipitation, temperature, radiation, humidity, and wind) to the resolution of the distributed runoff model. The simulations cover the period of September 1987 to January 1994 with a special emphasis on the five winter seasons 1989/90 until 1993/94, each from November until January.

A detailed validation of the control simulation shows a good correspondence of the precipitation fields from the regional climate model with measured fields regarding the distribution of precipitation at the scale of the Rhine basin. Systematic errors are visible at the scale of single subcatchements, in the altitudinal distribution and in the frequency distribution of precipitation. These errors only marginally affect the runoff simulations, which show good correspondence with runoff observations.

The presentation includes results from the scenario simulations for the whole basin as well as for Alpine and lowland subcatchements. The change in the runoff statistics is being analyzed with respect to the changes in snowfall and to the frequency distribution of precipitation.

4.3

Assessment of different climate outputs with crop model in Southwestern Europe

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E.T.S.I. Agronomos, Universidad Politecnica de Madrid, Madrid, Spain

Differences among simulations from climate models are assessed through crop model outputs. These outputs represent clue agronomic parameters that will be used to fingerprint agricultural systems and their sustainability. This work establishes these differences for most of the climate models and for simulations of current climate. Soil polygons are used as basic geographical units and climate data are linked to them.

Mapping shifts in crop suitability under a range of SRES-based climates

Stefan Fronzek and Timothy R. Carter

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We present analyses of the estimated impacts of climate change on the thermal suitability for cultivation of grain maize, sunflower, and soya in Europe. A simple temperature-based index, effective temperature sum (ETS) has been computed for observed climate in the 1961-1990 base-line period and projected climate during 2070-2099 based on outputs from a range of GCMs and RCMs. All analyses are conducted on a regular 0.5 x 0.5 grid across Europe. A method requiring information on the standard deviation of daily mean temperature around the monthly mean is being used to estimate ETS from monthly mean temperature data. We have created a new interpolated gridded dataset of standard deviations for Europe based on observed daily station data for the 1961-1990 period. Climate model results are used for comparison to that as well as to estimate standard deviation values for the 2080s. We present mapped estimates of the uncertainty in the future extension of the northern limit of suitability under different model-based scenarios, and also investigate if the risk of harvest failure is likely to be affected by changes in inter-annual temperature variability.

4.5

Climate change and CO2 influence crop production and nitrogen cycling in arable cropping systems

Jørgen E. Olesen

Danish Institute of Agricultural Sciences, Research Centre Foulum, Tjele, Denmark

The DAISY soil-plant-atmosphere model was used to simulate crop production and changes in soil C and N for range of crop rotations under changing temperature, rainfall and atmospheric CO2 concentration. A revised soil organic matter model was used. The model was applied to three crop rotations typical for arable farming in Denmark on loamy sand soil.

The nitrogen turnover and losses from soils were more sensitive to changes in environmental factors that yield is. Only in a few cases were there significant effects of changes in temperature and CO2 on the grain yield of the crops. In contrast there were significant effects on changes in nitrate leaching, which therefore for Danish conditions seem to be more influenced by climate change than the productivity of the systems.

4.6

The value of improved climate information in relation to investments in the agricultural sector

Kirsten Halsnaes

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Predicted impacts of climate change on soil moisture availability in the Mediterranean

Jean Palutikof

Climatic Research Unit, University of East Anglia, Norwich, UK

Mediterranean water resources are under severe stress. Rainfall amounts barely meet demand, and there is competition between agriculture and tourism in summer, with a high water requirement coinciding with low to zero rainfall amounts. In the face of this marginal situation, there is a need to understand the impact that anthropogenic climate change may have on future water resources in the region.

Information is available from the regional climate model (RCM) simulations performed in the PRUDENCE project for the two periods 1961-90 and 2070-99. Taking data from a number of different simulations performed by different modeling groups, based mainly on the A2 emissions scenario, we examine the effect of climate change on water resources in the Mediterranean region. One measure of water resource availability is soil moisture content, available directly from climate models. However, an alternative and preferable approach is to look at the balance between precipitation (PRN) and potential evapotranspiration (PET), and hence calculate a water resources budget. Evapotranspiration can be calculated from relatively few model outputs using simple formulae such as Priestley and Taylor or Blaney and Criddle. Water resource availability is then expressed as the ratio PRN/PET. Validation can be performed against evapotranspiration and soil moisture status from NCEP reanalysis data. By looking at the water resource predictions from a number of RCMs, we are able to explore the range of uncertainty in the future predictions.

The differences between the two periods 1961-90 and 2070-99 in these three measures PRN, PET and PRN/PET have been mapped. The maps show clearly that the changes in the PRN/PET ratio are large in parts of the Mediterranean, driven as much by enhanced PET due to warmer temperatures as by changes in the precipitation regime.

LPJ-GUESS: validation and an application of a dynamic ecosystem model using EUROFLUX data and RCM model output

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LPJ-GUESS [Smith et al 2001, Sitch et al. 2003] is a dynamic ecosystem model which simulates ecosystem processes and vegetation distributions and dynamics. Within the PRUDENCE project LPJ-GUESS is being used to assess the responses of different European forest ecosystems to changing climate using the range of Regional Climate Model outputs generated within the project and also as a means of comparing different RCM outputs.

Initially the model has been validated using flux measurements collected within the EUROFLUX project (providing at least three years of eddy covariance data) over a wide range of forests types and climatic regions in Europe. Secondly preliminary simulations have been completed with output from one RCM (SWECLIM) to predict potential natural vegetation distributions within Swedish forests.

In the validation exercise with EUROFLUX data, the model was run using present day climatology (and forest management history) for each of 15 sites in Europe to carbon and water fluxes over a three year period. First simulations with an RCM model output was done for 200 years using timeseries data and including as historical climate data the CRU05 (1901-1998) dataset and SWECLIM regional climate model outputs for (2071-2100) based on HadCM3/AM3 & ECHAM4/OPYC3.

In the case of the validation exercise, an analysis of the monthly model outputs and field data shows that, in general, the models accurately predict the seasonal patterns in Net Ecosystem Exchange (NEE) and Actual EvapoTranspiration (AET) for most EUROFLUX sites except for some Mediterranean and Maritime Evergreen forest sites. Using the SWECLIM RCM the ecosystem model predicts changing species composition in existing forests, increasing productivity in Swedish forest ecosystems and therefore increased sequestration of carbon into the future.

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Extreme weather events and the insurance industry

Andreas Tuerk

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Economic losses related to Weather-Extremes, such as floods, storms and droughts, are rising worldwide. Mainly these losses are regarded to result from changes in land-use and the increasing concentration of people and capital in vulnerable areas, but according to the IPCC Third Assessment Report (2001) at least a part of these losses are due to the changing of the climate conditions.

The insurance industry will need to make big changes in its strategies to adopt successfully to climate change. It will need to move from a reactive mode to a more proactive response to climate change. Ignoring the issue will lead to serious problems and even lead to failure, while recognising the challenge could generate entire new profit-streams. Concerning the growing risks of Extreme Weather Events the insurance industry has to incorporate new instruments of risk transfer in order to reduce their chances of insolvency from future catastrophic events. New risk-transfer-options ("Alternative Risk transfer") such as Catastrophic Bonds and weather derivates will be discussed in this paper.

5.1

Validation of the downscaling ability of Regional Climate Models using the Big-Brother experimental protocol

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Nested Regional Climate Models (RCM) have gained rapidly in popularity since the seminal work of Giorgi and collaborators in 1989. High-resolution RCM, nested atmospheric data simulated by lower resolution Global Climate Models (GCM), successfully reproduce several features of observed regional climates. Hence RCM are said to downscale GCM simulations, producing high-resolution results from low-resolution inputs. The actual downscaling ability of RCM is difficult to evaluate for several reasons, including the fact that (1) all models are imperfect representation of the real world -- this is equally true of GCM and RCM, but the latter exhibit additional sensitivities to arbitrary choices of parameters such as computational domain size --, (2) RCM simulations are affected by errors in GCM simulations used to nest them, and (3) high-resolution long-term climatological databases required for model verification are few and are restricted to specific variables and regions of the world. These facts have raised some concerns in the scientific community about the indiscriminate use of RCM; these concerns have been voiced by the Joint Steering Committee (JSC) of the Working Group on Numerical Experimentation (WGNE) in its annual reports over the past several years.

A numerical experimental protocol nicknamed the "Big-Brother Experiment" (BBE) has been designed to address the issue of the downscaling ability of nested RCM. The BBE is specifically designed to address this issue in relation to nesting, but excluding RCM model errors and GCM nesting data errors, and verification climate database. The BBE consists in first establishing a reference climate by performing a large-domain high-resolution RCM simulation, called the Big Brother (BB). The BB simulation will serve as reference for verification for a second, experimental simulation called the Little Brother (LB). The LB model is identical to the BB, but its computational domain is smaller. The LB is nested with simulated data from the BB, but the resolution of this data is first degraded by removing selected fine scales, thus simulating GCM coarse resolution. When the climate statistics of the LB are compared to those of the BB, the differences can be unambiguously attributed to nesting, not to model nor observational limitations.

The BBE has been applied methodically with a 45-km grid version of the Canadian RCM, to two regions of North America (the East and West Coasts where the orographic forcing varies greatly), for winter and summer months when dominant dymanical and / or physical processes vary greatly. The climate statistics are computed in terms of stationary and transient eddies, decomposed by horizontal scales. These results serve to establish the limits of dynamical downscaling ability of RCM, as well as the optimal configuration.

5.2

Title to be defined

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5.3

The uncertainty due to spatial scale of climate scenarios in integrated assessments: An example from US agriculture

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Misconceptions about the use of extreme value theory in climate change assessments

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The PRUDENCE/STARDEX/MICE cooperative cluster on climate change and extreme events lists one objective (under MICE) as "to analyse future changes in climate extremes using a range of statistical techniques including Extreme Value Theory." In this talk, several misconceptions about the role and use of extreme value theory in climate change assessments are identified. These misconceptions include: (1) the application of extreme value theory to climate extremes is new and untested; (2) more conventional statistical methods are adequate, if not superior to extreme value theory; (3) extreme value theory does not hold under a changing climate; (4) extreme value theory does not apply to statistical downscaling; (5) extreme value theory requires that relevant meterological information necessarily be neglected; and (6) extreme value theory is physically unrealistic. An attempt is made to refute each of these misconceptions in turn, in part via presentation of the relevant theory and methods, in part via motivational examples.

Legitimate issues that remain unsolved in applying the statistics of extremes to climate and climate change are outlined as well. These issues include: (1) scaling of extremes (e.g., for comparison of extremes simulated by numerical models with observations); (2) fully spatio-temporal modeling of climate extremes; and (3) devising appropriate concepts for communicating the results of extreme value analyses to impact and policy researchers (e.g., the question of how to extend the concepts of "return level" and "return period" to a changing climate).

Improved treatment of extreme events in future climate change assessments will arise, not only with additional observational data and improved numerical models of the climate system, but if better use is made of existing statistical methodology.

From the astronomical theory to sustainable development

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The future of our climate is a primary concern not only at the human time scale but also at the geological time scale. At both time scales, modeling the climate system, estimating the climatic sensitivity from past climates or researching best analogs in the past are the most usual tools to predict what might be the future climate. Most of the time, paleoclimatologists feel that the last interglacial is a good candidate for our future warm climate. They study its stability and length that they compare to our present interglacial. Limitations to such procedures have been stressed. In particular, a special attention must be care to the forcings of past climates (both insolation and CO2, in particular) because they are important factors which shape the complex latitudinal distribution and seasonal cycle of the world climates. At least from the astronomical point of view the Eemian is not a good choice for the future of the Holocene. Better candidates would be around 400,000 YBP (isotopic stage 11) and even better around 2,000,000 YBP where interglacials lasted longer than during the middle Pleistocene. But first of all, it must be stressed that the orbital forcing for the present and next tens of thousands of years is almost unique, that the predicted CO2 concentration for the next centuries (and already the present ones) are unprecedented and finally that, according to our modeling results, the present Holocene interglacial will, most probably, last exceptionally long, with no counterpart over the last million years. Such a long duration is a very robust feature in our numerical experiments. It seems to be related to the pretty high value of CO2 which lasts already since 10 kyr BP compensating for the declining astronomical forcing. In addition, our results show not only that the Holocene might last particularly long, but also that the sensitivity of our climate system to the greenhouse gas forcing might be exacerbed. As a consequence, there is a threshold in the greenhouse gas concentration of about 700 ppmv beyond which the Greenland ice sheet melts in about 5000 years and does not recover before a few tens of thousands of years.

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